Awards: The Tyler Ecology Award: Banquet Speech, Nairobi, Kenya, May, 1982

On the occasion of the

Governing Council session of a special character
commemorating the Tenth Anniversary of the Stockholm Conference

The President of the Council
and
The Executive Director of the
United Nations Environment Programme

request the pleasure of the company of

Mr. & Mrs. C. Wilson

at a reception on Wednesday 12 May 1982
from 7 to 9 p.m. at the Hilton Hotel

Please bring
this card with you

For the Tyler Prize Committee

The Ambassador of the United States of America

and Mrs. Harrop

request the pleasure of the company of

Dr. and Mrs. Wilson

at luncheon

on Thursday, May 13th

at twelve-thirty *o'clock*

~~*R. S. V. P.*~~
p.m.

No. 93 Muthaiga Road
Muthaiga

Mostafa K. Tolba
Executive Director
United Nations Environment Programme

and

Alice C. Tyler
Tyler Ecology-Energy Prize

request the honor of the presence of

Mr. & Mrs. C. Wilson

at the
Special Environment Awards Banquet

to be held in the
Grand Ballroom,
Intercontinental Hotel
Nairobi
on Friday evening, the fourteenth of May,
nineteen hundred and eighty-two
at [redacted] seven o'clock

RSVP on the enclosed card

Dark suit or traditional dress

John and Alice Tyler Ecology · Energy Fund

Since 1973, the Tyler Prize has been the largest achievement award presented by an American institution, and it has become the largest ecology energy prize in the world. Eleven environmental laureates have received honors for their outstanding achievements benefiting mankind.Prizes have totaled over $1 million, ranging from $150,000 to $200,000 annually.

In 1980 selection criteria were broadened to encompass energy as well as ecology. The further development and improvement of known sources of energy and the discovery of new sources of energy are inseparably linked to the protection, maintenance, improvement, and understanding of the environment. Pursuit of energy for progress needs to be conditioned by sensitivity to environmental preservation. The Tyler Prize seeks to honor those who contribute new knowledge or critical leadership to that relationship.

Former winners have been honored for pioneering water purification and water quality standards, for discovery of the chemical nature of smog, for landmark work in understanding animal ecology, for new perspectives on the interaction between the environment and the human organism, and for world leadership in respect to the human environment and wildlife protection.

Past honorees include Arie Jan Haagen-Smit, G. Evelyn Hutchinson, Maurice Strong, Ruth Patrick, Abel Wolman, Charles S. Elton, Rene Dubos, Eugene P. Odum, Russell E. Train, Carroll L. Wilson, and the Southern California Edison Company.

Endorsed by The United Nations Environment Programme

Tyler Prize

Eligibility

Citizens of all nations are invited to nominate individuals or institutions of any nation who have benefited humanity in the fields of ecology or energy.

Persons eligible to make nominations include, but are not limited to :

Scientists in fields related to ecology and energy;

National academies of science, engineering or their equivalent, and their members;

Research institutions, and their members;

Nominees can be associated with any field of science. Nominated institutions can be universities, foundations, corporations, or other types of organizations. Awards to non-exempt corporations pursuant to U.S. tax laws, will be used for student scholarships to benefit universities as chosen by such non-exempt honored corporations.

Selection Criteria

Prizes are awarded for any one of the following:

(a) the protection, maintenance, improvement and understanding of ecological and environmental conditions anywhere in the world; or

(b) the discovery, further development, improvement, or understanding of known and new sources of energy (including, but not limited to, oil, coal, solar, hydroelectric, geothermal, wind, oil shale, nuclear, and tar sands).

Deadline For Nominations

Nominations for the 1983 Tyler Prize must be postmarked no later than *November 15, 1982*. Related credentials and letters of recommendation should be mailed by that date, also. The Prize(s) will be announced in March, 1983.

Nomination Procedures

Nominations must be submitted in a letter, in the English language, and must include the following information:

1. *Identification of Nominee*
   Include a person's name, professional or home mailing address, present occupational title, and institutional affiliation. Enclose a vita or resume.
   If an institution or corporation is nominated, identify the administrative officer of the organization or subgroup responsible for the accomplishments cited.

2. *Summary of Accomplishment*
   Provide a brief statement of the individual's or institution's discovery or improvement in one or both fields for which the award is proposed. Be clear and succinct.

3. *Detailed Description of Contribution*
   Provide a detailed explanation of the contribution and explain why it is unique. Describe how it was accomplished. Mention any significant involvement of others. Enclose publications or other evidence of the contribution.

4. *References*
   Provide three letters of recommendation from individuals who can assess the nominee's contribution. Identify three to five additional referees who might be contacted by the Tyler Fund.

Length Of Candidacy

Nominations will be considered for two years, beginning with this round. Renomination will be required after two years.

Mail Nomination To

Executive Director
John and Alice Tyler Energy/Ecology Fund
University of Southern California
Administration 101
Los Angeles, California 90007, USA

Inviting Nominations For The

Tyler Prize

The World Prize
in Ecology and Energy

1982

Tyler Award Recipients

Dr. Arie Jan Haagen-Smit

Dr. G. Evelyn Hutchinson

Maurice Strong

Dr. Ruth Patrick

Dr. Abel Wolman

Dr. Charles S. Elton

Dr. Rene Dubos

Dr. Eugene P. Odum

Russell E. Train

Carroll L. Wilson

Southern California Edison Company

Your E. (1) {the President ~~Moi~~ (3) Your Excellencies
(2) Mr. Stewart (4) Ladies & Gentlemen

Remarks by Carroll L. Wilson

John and Alice Tyler Ecology-Energy Prize Laureate

Nairobi, Kenya

14 May 1982

Text of Acceptance Speech

Climate Change

It is a great honor to receive the prestigious Tyler Prize. It is a source of regret to all of us that Alice Tyler could not be with us on this memorable occasion. I know that she is with us in spirit and I hope that the photographic record of events this week will convey a vivid message.

Growing awareness of environmental changes and risks first began in the 1970's. Much credit for this is due to the influence of the U.N. Conference on the Human Environment in Stockholm in 1972 and the initiatives of the United Nations Environment Programme based here in Nairobi. Many people from many countries are meeting here now to assess the state of the global environment and implications for the future.

I will discuss one feature of the global environment - climate - and some changes which may lie ahead but first I'll comment on this decade of change. Twelve years ago scarcely anyone discussed climate change - especially changes which might be caused by man's activities. Very few atmospheric scientists were interested in climate so there were very few articles or students.

Today there is a large amount of research and many articles. There are major national and multinational programs of climate measurement, modelling and research. Almost everybody has heard about the greenhouse effect which causes warming of the global atmosphere due to the build-up of Carbon Dioxide - CO_2 from combustion of fossil fuels. Rising concern about the effects of such a warming in changing the location of crop production - especially cereals for export - adds to global anxieties.

Some impetus for this growing awareness of climate change and the research relating to it was probably given by a unique study held in July 1970 which brought together for an intensive month of work forty people from many disciplines. The subject was Critical Global Environmental Problems and the purpose was to determine what we knew about the environmental condition of the oceans, the atmosphere and terrestrial systems; what we did not know; and the kinds of research which should be undertaken to fill in the gaps in our knowledge. A report was published in October 1970. I gave a copy to Maurice Strong upon his designation as Secretary General of the U.N. Conference explaining that we had done some homework for his conference which might prove useful.

The most lively discussion which followed that report centered on possible climate changes. Thus in the summer of 1971, encouraged by Maurice Strong, we brought together in Stockholm 35 atmospheric scientists from 15 countries to probe more deeply into our knowledge and our ignorance about climate and to lay out a program of action aimed at reducing our ignorance. A report entitled Inadvertent Climate Modification - Report of the Study of Man's Impact on Climate was published in September 1971 and was delivered to the Preparatory Committee for the U.N. Conference which was held in June 1972.

I will give you my impressions of the state of our knowledge and our ignorance eleven years later. Questions lie in three areas: Firstly, how likely is a global warming from CO_2 build-up and what effects might it have? Secondly, how soon might this occur? And thirdly, if there is such a warming how might we reduce damaging impacts?

As to the first question, we know by measurement that the level of CO_2 in the atmosphere is increasing and that much of this CO_2 comes from fossil fuel combustion. There is wide agreement that higher CO_2 levels can cause a greenhouse effect which would warm the atmosphere. Although there is no agreement that warming has actually begun, it is estimated that a doubling of the CO_2 level would raise average global temperatures by 2 to 3° C with larger increases in high latitudes. It is believed that such temperature increases would change regional rainfall and temperature patterns and affect growing seasons. Some changes would be beneficial, others might alter the location of some of the world's principal cereal production areas with large social and political consequences. The global atmosphere is a very complex system and the projections I have given are based on the behavior of global circulation models which still do not include important variables. Nonetheless, despite many uncertainties, there are now enough warning lights flashing to make us ask how soon might we feel such changes if indeed they come.

Most of the projections based on such global circulation models assume a rate of increase of fossil fuel combustion of 4% per annum which was the rate of increase for many years. But that rate has now dropped in half to less than 2% largely because of greater efficiency in energy use. This means it will take twice as long for the CO_2 level to double. This stretches the time for taking avoiding action to about 2060 instead of 2025. This helps, but the problem does not disappear and significant effects may be felt long before the CO_2 doubles.

So what can we do to reduce the impacts of a global warming if it happens? What about capturing the CO_2 before it enters the atmosphere? Prospects of such a technical fix are very, very poor.

What about replacing fossil fuels by nuclear power and renewable sources such as hydroelectric, solar, wind and bio-mass? This route is not very hopeful either. Renewable sources are likely to grow larger but they have many problems of cost and intermittency and cannot be expected to contribute greatly to the world's energy needs for many decades. As to nuclear power, the first nuclear power age seems to me to be about over for many reasons and in any case nuclear energy is only useful to produce electricity in very large power stations which are unsuitable for most of the countries of the world.

What about restricting the use of coal, gas, oil and wood? Global control would be necessary because CO_2 produced anywhere circulates everywhere in the global atmosphere. In a world of sovereign nation states a world government with such authority is not now conceivable even if there were unanimous agreement among scientists (a) that a warming will occur, and (b) what its effects would be and where and when.

Is there not something we can do to mitigate the effects of a global warming if it occurs? Yes, indeed there are some things we can do and if we do them there will be benefits whether the global warming does or does not occur. The best plan I have heard proposed is to adopt strategies that increase the resilience of agricultural systems to environmental stresses including climate change. We should make genetic improvements in the climate resilience of our main food crops and develop other species which have better resilience to drought, salinity and changed growing seasons. And, of course, we should intensify actions to protect arable soil and improve water management.

Natural climate variability is one of the most severe disturbances to stable agricultural production. For example, the heat wave and drought of 1974 and again in 1980 in the USA reduced the crop by 20-25%. This was a natural climate variation. If we can develop crops and agricultural practices which are less affected by climate variability, not only can we mitigate the effects of a possible global warming but we can enjoy gains all the way along which will reduce the risks farmers face in coping with seasonal climate changes.

Much work has of course been done to develop higher crop yields, disease resistance, higher protein in corn, more suitability for arid conditions, etc. But relatively little has been done to improve climate resilience in the main cereal crops of the world and in the regions which are main sources of food exports. Expanding knowledge and techniques of genetic engineering should facilitate the design and development of crop varieties with the characteristics we want.

The climate resilience I am stressing is focussed on plant tolerance to variability of rainfall, temperatures, frost limits on the growing season and other stresses in the plant environment which are caused by climate changes. A concerted pursuit of such goals over the coming decades seems to me the best course to follow in order to mitigate the effects of a global warming if it occurs.

In conclusion I believe that the chances of global warming due to CO_2 build-up are great enough to justify vigorous action to mitigate the effects of such a warming. It is well within what we know how to do and what we can afford to develop more climate-resilient crops and agricultural practices. Such a program of action is particularly suitable for international cooperation of the kind which is so well illustrated by this convocation under the auspices of the United Nations Environment Programme which itself has already taken important initiatives, such as the establishment of the Global Environment Monitoring System.

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Tyler Prize Speech

Frontiers in Crop Production: Chemical Research Objectives

Hans Geissbühler, Paul Brenneisen
Hans-Peter Fischer

The science of chemistry and chemicals has been an essential element in achieving the remarkable increases in agricultural productivity which have been observed during the last half century in the industrialized and also, to some extent, in developing economies (*1*). Chemicals will continue to be an integral part of agricultural and food processing technologies in the global efforts that will be required to cope with the challenging objectives, problems, and opportunities of providing sufficient food for the burgeoning world population. However, when one is assessing and defining the future role of chemistry it is essential to refrain from making simple linear projections of current inputs and to consider the following three imperatives.

Summary. The science of chemistry and chemicals will continue to be an integral part of future crop production technologies. In assessing and defining the future role of chemistry three imperatives must be considered: (i) the necessity to preserve natural resources, (ii) the complementary solutions offered by the rapidly advancing biological sciences, and (iii) the specific requirements of developing regions where increasing crop productivity is most important. Chemical research objectives for improving crop protection and crop growth must take into account the perceivable and potential changes in crop production techniques, which, in turn, are dictated by a number of accentuating constraints.

1) The worldwide potential of (eco-)-biological systems to provide resources—such as energy, land, water, and air—continues to be eroded. These resources must be conserved by reducing environmental stress and by improving resource management (*2*).

2) The current and forecasted extraordinary advances in the biological sciences appear to offer complementary or alternative technical solutions to a number of agricultural problems (*3*, *4*). Therefore, chemistry must be closely integrated with or adapted to biological approaches in order to achieve optimum effects and efficiency.

3) In order to meet the exacting future food requirements, scientific and technical efforts must be focused on increasing agricultural productivity in the developing countries. This means that the use of chemicals must be adapted to the particular environmental, economic, social, and institutional conditions prevailing in these areas.

The coming IUPAC/IRRI-CHEMRAWN II International Conference on "Chemistry and World Food Supplies—The New Frontiers" will attempt to place these imperatives into proper perspective and to generate recommendations concerning the required research objectives and priorities (*5*). In this article we focus on a number of scientific and technical trends and opportunities in crop production.

Development in Crop Production Technology

The chemical research objectives we describe herein cannot be defined properly without taking into account the perceivable and potential changes in crop production technology, which, in turn, are dictated by a number of accentuating external constraints. The results of properly selected research objectives can contribute to alleviating some of these constraints and thus facilitate or permit the introduction or extension of different crop production techniques.

The major current and anticipated constraints of crop production and some of the extending or emerging technologies are summarized in Table 1. In order of priority, soil erosion (deterioration), increasingly erratic water supplies, rising energy costs, and progressive contamination of the environment (water, air, and soil pollution) are the commonly noticed and rapidly accentuating major constraints of present and future crop production (*6*). Techniques to counteract or overcome one or more of these constraints include conservation tillage, different modes and practices of mixed cropping, modified irrigation procedures, and improved pest management systems.

The vulnerability of crops to adverse climatic and meteorological conditions not only causes frequent crop failure and harvest losses but also prevents a significant extension of the global surface of arable land and a shift of more productive crops to new areas. Techniques that can help to overcome climatic vulnerability are proper irrigation and, provided they can be economically and scientifically improved, "greenhouse" cropping (including foil coverage of sensitive crop stages), hydroponics, and nutrient film techniques (*7*).

Optimization of inputs into crop production and modeling of input/output ratios will be greatly facilitated by systematic exploitation of the rapidly advancing electronic data evaluation and processing techniques. If accompanied by improved sensoring and monitoring of environmental parameters and conditions, this will allow a gradual sophistication and extension of "systems" agriculture (*8*, *9*).

Rising agricultural production and increased mingling of agriculture with densely populated nonagricultural areas will accentuate problems of agricultural wastes. These problems must be overcome through technical and economic progress in agricultural recycling procedures (*10*).

It is evident from the above comments that now, even more than in the past, chemical research objectives in crop production must be closely correlated with changes and advances in agronomic practices and techniques.

The authors are head of research and development, senior staff specialist, and research fellow, respectively, Agricultural Division, CIBA-GEIGY Ltd., CH-4002 Basle, Switzerland. This article was prepared on behalf of the Organizing Committee of the forthcoming IUPAC/IRRI-CHEMRAWN II International Conference on "Chemistry and World Food Supplies—The New Frontiers," to be held in Manila, Philippines, 6 to 10 December 1982.

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Crop Protection

Crop losses due to insects, plant diseases, weeds, nematodes, and rodents continue to be a major threat to the productivity of many important world crops, especially those grown in developing countries (*11*). Because of their efficiency and economy, synthetic pesticides will continue to be an essential factor in future pest management strategies.

During the recent past, the properties of synthetic pesticides have been significantly improved, so that they can now be applied in reduced quantities, they are more selective with regard to nontarget organisms, and their behavior in the environment has been ameliorated. However, reliance on chemicals as a single line of defense also has created problems of pesticide resistance, suppression of natural pest enemies, and outbreaks of secondary pests. In order to avoid perceived and potential contamination of the environment and adverse health effects, synthetic pesticides have been subjected to increasingly stringent regulatory constraints (*12*).

For future efficient and judicious employment of chemicals in pest control, it is imperative to improve their inherent biological properties, their formulations, the way in which they are applied, and the tactics of their use. This last form of improvement includes finding methods of combining pesticides with appropriate supplementary and alternative control methods. The main research objectives resulting from these integrated approaches are summarized in Table 2.

Insect control. The search for substances that induce pest-specific biochemical lesions or that regulate natural control mechanisms is most advanced in the area of insect control. The discovery of diflubenzuron [1-(4-chlorophenyl)-3-(2,6-difluorobenzoyl)urea], an insecticide that acts by interfering with the synthesis and depositing of chitin, a major constituent of the insect exoskeleton, has spurred intensive synthesis programs. New derivatives of this compound and related structures are likely not only to be nontoxic to certain beneficial pest predators and parasites, but also to have spectra of activities that cover additional pest species of economic importance (*13*).

Although research on endogenous insect juvenile hormones and their synthetic mimics (juvenoids) has not, thus far, led to extensive practical applications, it appears that their potential, especially when they are used in combination with other insect control methods, has not been fully explored. However, as their activity is confined to a short and specific period of insect development, their utility in controlling mixed populations under field conditions is likely to remain limited. Therefore, attention has turned to insect antijuvenile hormones (hormone antagonists, antiallatotropins). These compounds, of which the precocenes are but one example, cause precocious metamorphosis and sterilization and appear to be more versatile in their use than juvenoids (*14*).

Research on the chemistry and biology of insect pheromones, that is, natural and synthetic chemicals which, as attractants, repellents, or "disruptants" affect insect behavior, continues at a high rate. Innumerable compounds have been isolated or synthesized, and examination of their biological effects has revealed a bewildering and complex pattern of insect communication systems. Although practical applications have thus far been limited to surveying and forecasting pest infestations and to the localized control of some insect species in forests, fruit crops, and public hygiene, more extended uses can be envisaged, especially where the physical problems of targeting, release, and timing are resolved (*15*).

From among the countless entomopathogenic (insect-destroying) fungi, bacteria, and viruses, some have already been developed into selective, commercial insecticides. The search for additional preparations of this kind is likely to reveal products with improved efficiency and more useful spectra of activity. Modern biotechnology and genetic engineering methods appear to be excellent tools for substantial technical and economic improvements in microbial insecticides (*16*).

Further areas that seem to open new avenues in insect control, but that have not yet been sufficiently explored with regard to their practicability, are natural antifeedants from insect-resistant plants, insect-specific neurotransmitter agonists or antagonists, and insecticidal antibiotics and antibodies (*17, 18*).

Plant fungal diseases. The control of fungal diseases is at present dominated

Table 1. Perceivable and potential development in crop production technologies as dictated by accentuating environmental constraints.

Constraint	Crop production technique
Soil erosion, soil degradation (sedimentation, desertification, salinization, for example)	Conservation tillage (reduced or no tillage)
	Mixed cropping, including inter-, cover-, and avenue-cropping
Water shortage	Minimum irrigation: for example, drip or trickle irrigation and "chemigation"
Energy costs (shortage)	Energy farming, including silviculture
	Integrated pest management, including increased biological control
Environment contamination	"Greenhouse" cropping
	Hydroponics, nutrient film technique
Climatic vulnerability	"Systems" agriculture, including electronic monitoring, data evaluation, and input control
Agricultural wastes	Recycling

Table 2. Major research objectives for maintaining and improving the future use of chemicals in crop protection (pests here include diseases and weeds).

Continue and accelerate search for selective, biodegradable compounds that rely on pest-specific biochemical lesions or natural pest-controlling (pest-inhibiting) mechanisms

Attempt to delay or eliminate induction and appearance of resistance to pesticides by appropriate use-tactics or by systematic interference with resistance mechanisms

Improve application technology for pesticides by more specific placement, timing, and targeting

Extend and ameliorate integrated pest management systems by
- a) Research on the biology of pest development, pest-population dynamics, pest-host relationships, and interactions among pests
- b) Development of appropriate forecasting techniques by determining economic thresholds and designing monitoring methods and devices
- c) Combining synthetic pesticides or growth regulators with suitable cultural, biological, physical, pest-genetical and plant-breeding methods
- d) Modeling of area-specific or crop-specific pest-management strategies by systems analysis and programming, including use of electronic data evaluation and processing devices

by chemicals that either destroy the pathogen itself or are converted into toxic derivatives by the pathogen or host plant tissues. The recent discovery of a number of highly efficient, selective, and systemic fungicides, such as the triazoles and acylalanines, has set new standards among these chemicals and their range is likely to be expanded further. However, research has started to turn to areas that are likely to offer alternative chemical approaches to disease control. Essentially these endeavors attempt to elucidate and exploit the numerous existing natural biochemical interactions between pathogenic (or nonpathogenic) organisms and their host plants. Such reactions, which determine expression (or suppression) of disease phenomena, are being investigated along the following lines.

1) The interference with components of pathogenic processes (enzymes or toxins, for example) that are involved in breaching external and internal defenses of host plants.

2) The induction (activation) of phytoalexin formation, that is, the mobilization of the plant's own localized cellular defense system both by biotic and abiotic "elicitors."

3) The induction of systemic host plant resistance by inoculation with or exposure to pathogenic and nonpathogenic organisms or their extracellular metabolite fractions.

Although these approaches reflect the different defense or resistance mechanisms that seem to occur in plants, it is possible that they represent interlinked components of a more general phytoimmunological system against diseases and pests that might be manipulable both by chemical and genetical means (*19*).

Weed control. In most crops and under most cultural conditions, weeds include mixed populations of a variety of annual and perennial broad-leaved plants and grasses. Though the present armament of pre- and postemergent herbicides is already impressive, it is in the process of being further extended and improved by the addition of new compounds that are active at significantly lower rates of application. This trend is best exemplified by the recent discovery of the sulfonyl ureas (*20*). The ongoing systematic search for herbicide "antidotes," "safeners," and "synergists" has started to yield results and can be expected to provide an increasing number of chemicals that increase the selectivity and efficiency of conventional herbicides and permit lower rates of application (*21*). In order to delay soil erosion, it is envisaged that, under certain agro-

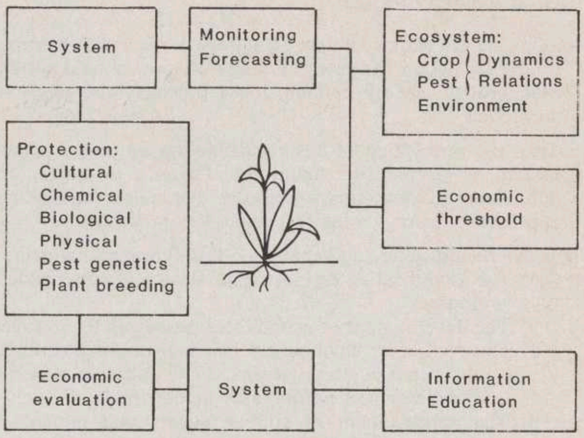

Fig. 1. The major components of an integrated pest management system and their sequential interlinkage. Recognized features of the defined crop ecosystem, such as crop-pest relations, allow the determination of an economic threshold (pest or disease level above which a loss will occur that is greater than the cost of a particular control action). These components are essential for proper monitoring and forecasting and for timely protection. Systems modeling can be performed at different stages of the integrated pest management procedures (*25*).

nomic conditions, weed canopies will no longer be completely destroyed by herbicides but controlled by appropriate plant growth regulators. The possibilities of exploiting or copying natural defense systems against weed growth, such as allelopathy (release of growth-inhibiting substances from higher plants) or biological agents (plant-killing microorganisms) appear to be limited to particular weed populations or habitats where it suffices to eliminate one or a few closely related weed species (*22*).

Resistance. Attempts to delay or prevent resistance of insects and crop pathogens to synthetic pesticides have, in practice, not been very successful. However, research in the physiology and biochemistry of resistance mechanisms has accelerated and should allow more rational approaches to controlling resistance phenomena. The tactics initiated or envisaged include the mixed or alternating application of compounds with distinctly different modes of action, the addition of chemicals that antagonize the induction of resistance, and the deliberate search for control agents that affect the proliferation of insects and pathogens at growth stages that are less inducive to the formation of resistance (*23*).

Application technology. Although application technology for pesticides has been continuously improved, the currently available formulations and delivery systems are still somewhat inefficient. This can be demonstrated by comparing the amounts that are normally applied with the small quantities that eventually reach the envisaged target organisms. More efficient targeting is to be expected from improving controlled release formulations and devices, from more sophisticated coating or encapsulation of seed, and from improving spray equipment physics (*24*).

Integrated pest management. Recognition of the shortcomings mentioned in the unilateral use of chemicals in crop protection has accelerated the conception and implementation of integrated pest management (IPM) (also referred to as integrated pest control). This "systems" approach to crop protection combines, in an organized manner, all forecasting and control components that can efficiently and economically contribute to crop protection in a particular and defined crop or agro-ecosystem. Figure 1 depicts the essential elements of IPM and their interactions. Further extension of IPM in terms of acreage and crops will proceed stepwise and will depend heavily on the generation of additional biological and agronomic research data that are not now available. These data will also assist in improving the timing and targeting of chemical IPM components and in the identification or design of new and more selective compounds (*25*).

Crop Growth

The required gains in overall crop productivity (that is, increasing average crop yields per unit area) can only be achieved through improved control of crop growth and development. The extension and perfection of currently used principles and methods, and the design and introduction of new agronomic, biological, engineering, and chemical concepts and tools are needed to secure more, and especially more efficient, inputs of solar energy, carbon, nitrogen, and minerals, for example, and more efficient utilization of available water and land resources. Some of the research objectives to improve and extend contributions by chemistry to crop growth and development are summarized in Table 3.

Plant growth regulators. Basic and applied research in plant growth regula-

Table 3. Major research objectives for improving crop growth and development by chemicals or chemistry-based concepts.

Rationalize the search for new plant growth regulators by acquiring additional basic knowledge on the regulation and interactions of phytohormonal systems at different stages of (natural) crop growth and by defining more precisely the physiological target mechanisms to be controlled
Extend the acquisition of basic information on photosynthetic carbon assimilation to those factors or mechanisms that limit efficiency in major crop plants under natural growth conditions. Exploit this knowledge for more rational chemical, genetical, and cultural approaches for regulating respective key processes
Improve the efficiency and economy of different components of the nitrogen cycle by a) The identification or biorational design of new catalysts for nitrogen fertilizer production b) The development of economical processes for nitrogen recycling from wastes c) The control of biochemical mechanisms that regulate photosynthetic energy flow to nitrogen-fixation processes, the distribution of protein components in plants, and the mobilization of nutrients by mycorrhizae d) The improvement of control agents that inhibit wasteful nitrogen transformation processes in soil
Accelerate the acquisition of basic knowledge on the terrestrial biosphere, especially the crop "rhizosphere," to improve the efficiency of nutrient and trace element additions
Adapt the delivery of chemicals to conservation irrigation systems

tors has been slow in producing tangible practical contributions toward increased productivity of economically important crops. The intensive efforts to exploit chemical and physiological features of naturally occurring phytohormones (auxins, cytokinins, gibberellins, abscisic acid, and ethylene, for example) and empirical screening procedures have resulted in a number of chemicals that are used for a variety of horticultural and agricultural purposes. The physiological effects obtained include rooting, flowering, fruit setting and abscission, ripening, bud and sprout inhibition, dwarfing, and defoliation. These effects, which are based mainly on controlling inhibitory plant growth mechanisms, contribute only indirectly to increased crop productivity. However, it is accepted by most experts that they represent only a small portion of the potential for chemical growth regulators in crop production. The main reasons for the slow progress in this area appear to be the following: (i) a continuing lack of basic knowledge on how phytohormones interact and how crop growth is actually regulated at different stages of development, (ii) imprecise definitions of the goals, that is, the physiological mechanisms to be controlled, and (iii) genetic and environmental variability of target crops (*26*). To reach demanding objectives such as yield enhancement, growth promotion under stress conditions, and control of senescence, both basic and applied research must be accelerated and also concentrated on the following essential aspects:

1) Identification of natural growth regulator mechanisms (phytohormones) in addition to those already described; and the interactions of these mechanisms at different stages of crop growth and development.

2) Determination of rate-limiting regulatory mechanisms or interactions in major crops under representative agronomic (field) conditions.

3) Precise definition of physiological target mechanisms to be controlled and translation into appropriate screening or modeling procedures.

4) Improvement of coherence between laboratory or greenhouse and field testing.

It may be assumed that many industrial laboratories are already involved in tackling some of the described phenomena, but this does not reduce the need for extended parallel contributions by universities and government laboratories which are indispensable.

Photosynthetic carbon assimilation. The central role of photosynthetic carbon assimilation in crop production is demonstrated by the fact that carbon input provides 90 to 95 percent of the dry weight of crop plants. The photosynthetic electron transport mechanisms and carbon assimilation reactions involved have been elaborated in impressive detail. However, attempts to improve carbon input efficiency under agronomic conditions by manipulation via chemical or biological means have not been very successful. Rationalization of future approaches and the design of appropriate testing models requires the acquisition of additional basic knowledge (*27*). These efforts must concentrate on a detailed characterization of the particular features of photosynthetic assimilation systems of major crop plants and on those factors or mechanisms that limit or control the efficiency of these systems under natural growth conditions. As this basic knowledge becomes available, more rational approaches can be taken for regulating by chemical, genetical, or cultural means key processes such as light conversion, carboxylation reactions, dark and light (photo-) respiration, photosynthate partitioning and transport, and leaf senescence (*28*).

Nitrogen. The input of nitrogen as a fertilizer has been essential to achieving the current levels of crop productivity. Future agricultural needs will require substantial increases in the production of this major nutrient. However, there are serious constraints (energy costs, capital requirements, environmental impact) which call for significant improvements in the efficiency and economy of nitrogen production and utilization and also for the extension and improvement of alternative nitrogen input techniques (*29*).

Chemical research objectives to ameliorate the efficiency of the various components of the nitrogen cycle include the following:

1) The identification or biorational design of catalysts that permit the production of fertilizer (fixation of dinitrogen) at reduced temperatures and pressures.

2) The improvement of existing processes and the development of new low-cost processes to recover nitrogen from agricultural wastes.

3) The regulation of the biochemical mechanisms involved in providing photosynthetic energy from leguminous crop plants to symbiotic or associated nitrogen-fixing microorganisms.

4) The extension or improvement of control agents that inhibit wasteful soil nitrogen transformation processes, such as microbial nitrification or denitrification and soil urease activity.

5) The design and development of low-cost controlled-release fertilizers.

6) The control of the biochemical mechanisms that regulate the transport of protein components to edible crop parts.

Exploitation of new or improved chemical tools or processes for nitrogen utilization requires integration with novel agronomic and biological techniques.

Other nutrients. The input of nutrients other than fixed nitrogen must be extended and improved under the same constraining conditions as described above. Much more basic knowledge in the terrestrial biosphere and on the microenvironment of the crop "rhizosphere" is required before more efficient use of such major nutrients as phosphorus and potassium can be made and before the addition of trace elements can be optimized (*30*).

In exploiting this knowledge, attention should not only be directed toward optimum soil conditions, but even more so to the widespread arid and semiarid areas, where soil improvement by massive additions of fertilizer is not only uneconomical but also of questionable value. The alternative strategy of adapting crop growth to adverse soil conditions (for example, drought and salinity) on the basis of chemical concepts must be pursued further (*31*).

Water. A shortage or an excess of water is the most common limiting factor in world crop production. The extended and improved management of water resources will depend mainly on operations and engineering technology. Potential contributions by chemistry are indirect or secondary. Thus, chemistry will continue to be involved in seawater desalination projects and can also contribute to the prevention of soil salinization and reclamation of saline or sodic soils. Sophisticated water management techniques are likely to offer new opportunities in modifying and economizing on the application or delivery of chemicals to crop plants and soils (*32*).

Biotechnology, Including Genetic Engineering

Recent advances in gene manipulation have opened new avenues in agricultural research and have added a new dimension to the future of crop production (*3*, *33*). Though the developing genetic technologies are considered to be a part of the biological sciences, chemistry is involved in or affected by these activities in several ways:

1) Chemistry is an indispensable tool for acquiring or extending the necessary basic knowledge and for perfecting methodology.

2) Gene manipulation techniques have the potential of ameliorating microbial or other single-cell fermentation processes for the manufacturing of biologically active agricultural chemicals and products.

3) Biotechnology offers opportunities and eventually solutions that can complement conventional chemical means and approaches in agriculture.

For these reasons, biotechnology has been included in the agenda of the forthcoming CHEMRAWN II conference and is briefly discussed herein. The following areas of biotechnology appear to be relevant in order to increase or improve crop production: (i) genetic improvement of crop plants; (ii) genetic improvement of microbial crop associates including symbionts and pathogen antagonists; and (iii) genetic improvement of fermentative processes for the production of crop protectants and growth regulators, for example. A summary of pertinent research objectives is given in Table 4. These objectives emphasize the complementary nature of biological and chemical approaches.

Table 4. Major research objectives for improving crop growth and development by modern biotechnology (including genetic engineering).

Elaborate or improve the scientific and methodological components of crop plant biotechnology, for example, gene transcription, transfer, and expression mechanisms, protoplast fusion and foreign vector transfer, and regeneration of plants from single cells
Modify current species or design new crop species by gene manipulation in order to improve growth features, nutritional quality, and resistance to plant pests and diseases
Use gene manipulation techniques for improving the efficiency of microbial crop symbionts or associates and for extending the range of useful organisms
Improve fermentation processes for the production of biologically active agricultural products or organisms, including, for example, microbial pest and disease control agents

Genetic improvement of crop plants. For the genetic improvement of crop plants the new cell- and gene-manipulating techniques are suited to the expansion and complementing of conventional breeding methods. They allow circumvention of the classical barriers of genetic incompatibility and acceleration and perfection of the process of genetic refinement and propagation. However, before useful results on important crop plants can be expected, the following scientific and technical components must either be elaborated or improved: (i) identification and mapping of genes and characterization of their transcription and transfer mechanisms; (ii) protoplast fusion or foreign vector (plasmid, virus) transfer of DNA sequences into plant cells; and (iii) regeneration of whole, genetically stable plants from individual cells. Modified or even new crop species obtained by gene manipulation may be designed to exhibit improved growth features, such as more efficient photosynthesis, nitrogen-fixing capability, and tolerance to stress conditions; improved nutritional quality; and (multiple-gene) resistance to plant pests and diseases.

Genetic improvement of microbial crop associates. Recombining DNA among microbes is less complicated and more advanced. This technique may therefore be exploited for the genetic improvement of microbial crop symbionts or associates, such as bacteria, cyanobacteria, actinomycetes and fungi, which live in, on, or in the vicinity of plant roots and which are able to supply the crop in situ with desirable nutrients, such as fixed nitrogen and phosphorus. In addition, microbial antagonists might secure vigorous growth of roots by protecting them against pathogens (*30*, *34*).

Genetic improvement of fermentation processes. The future use and genetic improvement of industrial fermentation processes for the production of biologically active agricultural chemicals will depend on a number of external stimuli, including the scarcity of classical supply sources, the availability of potentially useful and cheap raw material, and the discovery or design of new biologically active and selective entities that cannot be economically produced by conventional means. Examples of products that can be envisaged to meet these criteria are microbial and antibiotic crop protectants (insect and disease control agents) and plant growth regulators (*16*).

Objectives for Developing Regions

Political, socioeconomic, institutional, and educational factors will be the main influences on the extension and introduction of chemistry and chemicals for improving crop productivity in the developing regions. In the technical area, the enlargement of local research capacities, extension services, and training facilities will be essential (*35*, *36*). The activities of these institutions must concentrate on problems and opportunities related to native crop species and to local cultural and growth conditions, as well as pest and disease phenomena.

The small farmer. While the transfer and adaptation of current and future industrialized agricultural technology is indicated for plantation and estate crops, it appears that a distinctly different scientific and technical approach will be required for improving and stabilizing the productivity of the small farmer, who is and must continue to be the central figure in cultivating staple and subsistence crops. The so-called "intermediate" techniques to be further developed and perfected for this purpose must be low in cost and energy, simple, safe to health and environment, and nondestructive to natural resources (*37*). The key elements of these techniques are genetically adapted high-yielding seed materials, appropriate cropping practices (for example, mixed, inter-, relay-, or avenue cropping, including the use of leguminous vegetables and tree crops) and conservation, tillage, and irrigation procedures. Chemicals, as fertilizers, trace elements, herbicides, insecticides, and growth regulators, will have to be exploited in a complementary or incremental manner to achieve defined beneficial effects. The tools and methods used for their application must be simple, reliable, and independent of logistical constraints (*38*).

Conclusions

We have attempted to describe and define chemical research opportunities, which, if explored and pursued systematically, can be expected to contribute further to the improvement and stabilization of future crop production. Technical solutions can already be identified for some of the objectives mentioned, whereas for others, further progress in basic research is essential in order to define more precisely those avenues to be followed toward ultimate practical success. This emphasizes the need for unbiased, straightforward, and close cooperation between academic, governmental, and industrial scientists and institutions from numerous countries. It is hoped that the coming CHEMRAWN II conference will be able to maintain and improve this cooperative spirit through its efforts to define objectives and priorities for the judicious use of chemicals to ensure adequate world food supplies.

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June 26, 1982

Dr. Omar Fareed, President
The Carr Foundation
10350 Wyton Drive
Los Angeles, CA 90024

Dear Omar:

Thanks for your note of June 11th.

We have just had the first meeting of the Steering Group of the European Security Study near Frankfurt and got off to an excellent start. Enclosed is a description of that project.

It was fun to do things with you in Nairobi and Mary and I enjoyed it very much. I will certainly bear in mind your gracious invitation to visit you as and when I am in the vicinity of Los Angeles.

With best regards.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

THE CARR FOUNDATION
Non-Profit Corporation
10350 WYTON DRIVE
LOS ANGELES, CALIFORNIA, U.S.A., 90024
(213) 276-2676

OMAR JOHN FAREED, M.D.
President

June 11, 1982

Mr. Carroll Wilson
130 Jabob Street
Seekonk, MA 02771

Dear Carroll:

Many thanks for your letter dated May 24, 1982. It was indeed a pleasure to have been with Mary and you in Nairobi, Kenya. The Tyler Ecology/Energy Prize presentation event was most successful and should evoke international attention.

I appreciated the visit with you to the International Centre for Insect Physiology and Ecology and to the National Park with Mary and Walter Rosenblith.

Should you visit Los Angeles in the future, it would be an honor to entertain you in my home. Kindly telephone (213) 271-5377 or (213) 272-1540.

Sincerely yours,

Omar

Dr. Omar Fareed

OJF/dn

June 26, 1982

Dr. Jerome B. Walker
Assistant Vice President for
Academic Affairs
University of Southern California
Adm 101, University Park
Los Angeles, CA 90007

Dear Jerry:

Thank you for your note of the 3rd and the check for reimbursement of my expenses which I received.

I am glad to have Jimmy's remarks and also his biography and the phenomenal list of the 75 films in which he had acted.

We had the first meeting of the Steering Group of the European Security Study in Germany last week and got off to a very good start. Enclosed is a somewhat revised and up-to-date description of the project which is heading for a series of intensive five-day workshops on the topics under Phases I and II over the next nine months which should give us the ingredients for developing the alternative options in Phase III.

With best regards to you and Lora.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

June 26, 1982

Mr. James Stewart
918 North Roxbury Drive
Beverly Hills, CA 90210

Dear Jimmy:

En route back from Nairobi I stopped in Paris to explore the possible participation of the French in the European Security Study. Fortunately I finished my work by lunch time and at two o'clock was entering the small movie theater on the rue des Ecoles to see "Indiscretion" and with French subtitles here was that wonderful "Philadelphia Story" with you and Cary Grant and Katherine Hepburn. It had been playing for some weeks in Paris and was well attended even at two o'clock in the afternoon.

Jerry Walker has sent me a memo concerning your career and a list of your 75 or more films which is a most impressive contribution to our period of history.

I am sure that you gave the Princeton graduates of the Army ROTC a good send-off as they received their commissions at the time of the Commencement for which you were present because of your 50th reunion.

We had the first meeting of the Steering Group of the European Security Study in Germany last week and got off to an excellent start. Most of the members of the Steering Group from the U.S., U.K. and Germany were present and this was the first time we had all gathered together. These are always a gamble as to whether the personal chemistry goes well and it did in this case. A series of intensive workshops lie ahead over the next nine months to explore the topics we will be studying which are listed in the enclosure.

Mary and I greatly enjoyed becoming acquainted with you and Gloria and Kelly and having that delightful day at Lake Naivasha.

With best regards.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

Tyler Prize

John and Alice Tyler Ecology · Energy Fund
University of Southern California, University Park, Los Angeles, CA 90007

June 3, 1982

Mr. Carroll L. Wilson
130 Jacob Street
Seekonk, MA 02771

Dear Carroll:

Alice Tyler is in Palm Springs for a week so I took the liberty of reading your letter to her over the telephone. Today we are forwarding it to her Los Angeles home.

I am scouting for my copy of Jimmy Stewart's introduction at the banquet. I think I have it at home and will enclose it with the letter. I thought you would be interested in what we prepared for him to say at the Los Angeles news conference and I have enclosed a copy. Also enclosed is a brief biography of Mr. Stewart which indicates that his nickname is spelled with a "y". His home address is 918 North Roxbury Drive, Beverly Hills, California 90210.

Of course I am delighted that you and Mary enjoyed yourselves during those hectic days in Nairobi and that you had a chance to relax at Lake Naivasha. The Tyler group went to the Masai Mara game reserve and everyone was ecstacic about the fine weather and the numerous animals we were able to view. Lora and I took a few extra days afterward to see the lake country, enjoying Lake Borengo particularly. Our last morning was spent at Lake Naivasha lunching on the front lawn of the local Block hotel. Next time I go to Kenya I have determined to stay there for at least a week and to bring my fishing rod.

I am particularly anxious to see your latest multinational study on European security succeed. I wish you as much success on this effort as you have had on so many previous ones.

Warm personal regards,

Jerry

Jerome B. Walker

JBW/tz
Enclosures

REMARKS BY JAMES STEWART

NAIROBI BANQUET

MAY 14, 1982

GLORIA AND I HAVE COME TO KENYA FREQUENTLY IN THE PAST TO WORK WITH THE AFRICAN WILDLIFE LEADERSHIP FOUNDATION AND TO SEE OUR DAUGHTER, KELLY, AND OUR SON-IN-LAW, ALEXANDER HARCOURT, WHO ARE WORKING AT THE KARISOLI RESEARCH CENTER IN RWANDA STUDYING THE MOUNTAIN GORILLA.

THIS TIME WE HAVE COME TO AFRICA BECAUSE YOU, THE INTERNATIONAL COMMUNITY, HAVE GATHERED TO RENEW THE COMMITMENT MADE IN STOCKHOLM 10 YEARS AGO "TO SAFEGUARD AND ENHANCE THE ENVIRONMENT FOR PRESENT AND FUTURE GENERATIONS." THAT SAME YEAR, JOHN AND ALICE TYLER OF LOS ANGELES DECIDED TO ESTABLISH A MAJOR INTERNATIONAL AWARD IN THE SPIRIT OF STOCKHOLM, TO HONOR CONTRIBUTIONS TO THE PROTECTION, MAINTENANCE, IMPROVEMENT AND UNDERSTANDING OF THE ENVIRONMENT.

GOVERNMENT APPROVALS DELAYED THE INAUGURATION OF THE TYLER PRIZE UNTIL 1973, THE YEAR UNEP WAS INAUGURATED. UNEP AND THE TYLER PRIZE HAVE A VERY IMPORTANT PURPOSE IN COMMON--BOTH ARE DEDICATED TO RAISING PUBLIC AWARENESS ON ENVIRONMENTAL ISSUES. UNEP ACTS AS A CATALYST FOR GLOBAL ACTION, AND THE TYLER PRIZE HONORS GLOBAL ACHIEVEMENT.

IN PAST YEARS, THE TYLER PRIZE HAS BEEN AWARDED FOR PIONEERING RESEARCH IN WATER AND AIR POLLUTION, AND FOR CRITICAL LEADERSHIP IN PRESERVING WILDLIFE AND IMPROVING THE ENVIRONMENT FOR HUMANS.

MAURICE STRONG SHARED THE FIRST TYLER PRIZE IN 1973 WHILE HE WAS UNEP'S EXECUTIVE DIRECTOR. RENE DUBOS, WHOSE MEMORY WE HAVE HONORED THIS EVENING, SHARED THE THIRD TYLER PRIZE IN 1975.

RUSSELL TRAIN RECEIVED THE 5TH TYLER PRIZE FOR HIS GUIDANCE OF THE WORLD WILDLIFE FUND, THE AFRICAN WILDLIFE LEADERSHIP FOUNDATION, AND THE U.S. COUNCIL ON ENVIRONMENTAL QUALITY.

TONIGHT WE HONOR TWO NEW TYLER PRIZE LAUREATES, CARROLL L. WILSON AND THE SOUTHERN CALIFORNIA EDISON COMPANY, REPRESENTED BY WILLIAM R. GOULD, BOARD CHAIRMAN AND CHIEF EXECUTIVE OFFICER OF THE EDISON COMPANY. WILL MR. WILSON PLEASE JOIN ME AT THE PODIUM...

CARROLL WILSON, PROFESSOR EMERITUS FROM MIT, IS BEING HONORED FOR DEVOTING HIS LIFETIME TO THE ENVIRONMENT. MANAGER, TECHNOLOGIST, SCHOLAR AND INDUSTRIALIST, CARROLL WILSON HAS SPANNED THE BOUNDARIES OF THE CORPORATE AND ENVIRONMENTAL COMMUNITIES. PROFESSOR WILSON HAS BEEN INSTRUMENTAL IN THE DEVELOPMENT OF GLOBAL ENERGY ASSESSMENTS, INTERNATIONAL ATOMIC ENERGY CONTROL, BIODEGRADABLE PESTICIDES, THE FIRST UN CONFERENCE ON THE HUMAN ENVIRONMENT, AND RESEARCH FOCUSING ON FUTURE WORLDWIDE ENERGY PROSPECTS. IN 1969 HE HELPED ESTABLISH THE INTERNATIONAL CENTER FOR INSECT PHYSIOLOGY AND ECOLOGY HERE IN NAIROBI. PROFESSOR WILSON HAS DEVELOPED A UNIQUE PROCESS FOR INVOLVING LEADERS OF INDUSTRY AND GOVERNMENT IN GLOBAL ENERGY ASSESSMENTS.

CARROLL WILSON, FOR YOUR CONTRIBUTIONS BENEFITING HUMANKIND, THE TYLER PRIZE FUND IS PLEASED TO PRESENT A $100,000 CASH AWARD AND THIS COMMEMORATIVE GOLD MEDAL. (APPLAUSE) CONGRATULATIONS.

MR. GOULD, PLEASE STEP FORWARD.... FOR THE FIRST TIME SINCE THE TYLER PRIZE WAS ESTABLISHED A CORPORATION IS THE HONOREE. IT TURNS OUT TO BE ONE OF THE GREAT CORPORATE CITIZENS OF MY STATE, THE SOUTHERN CALIFORNIA EDISON COMPANY. THEY HAVE A DISTINGUISHED RECORD OF WORKING TO PROTECT THE ENVIRONMENT IN A STATE THAT TREASURES ITS NATURAL RESOURCES. IN 1980 THE SOUTHERN CALIFORNIA

EDISON COMPANY BECAME THE FIRST ELECTRIC UTILITY IN THE UNITED STATES TO MAKE A COMMITMENT TO ACCELERATE DEVELOPMENT OF ELECTRICAL POWER SOURCES THAT ARE RENEWABLE RATHER THAN FINITE. ABOUT ONE-THIRD OF THEIR ADDITIONAL GENERATING CAPACITY NEEDED FOR THIS DECADE WILL COME FROM WIND, GEOTHERMAL, SOLAR, SMALL HYDROELECTRIC, AND FUEL CELL SOURCES. WITH THE START OF OPERATION LAST MONTH OF "SOLAR ONE," THE WORLD'S LARGEST CENTRAL RECEIVER SOLAR ELECTRIC POWER PLANT, SCE NOW UTILIZES EIGHT PRIMARY ENERGY RESOURCES TO GENERATE ELECTRICITY-- MORE THAN ANY OTHER ELECTRIC UTILITY IN THE WORLD.

WILLIAM GOULD, FOR YOUR COMPANY'S CONTRIBUTIONS BENEFITING HUMANKIND, THE TYLER PRIZE FUND IS PLEASED TO PRESENT THIS COMMEM- ORATIVE GOLD MEDAL AND TWO CHECKS FOR $50,000 EACH, MADE OUT AS YOU HAVE INSTRUCTED TO TWO DISTINGUISHED UNIVERSITIES IN CALIFORNIA TO BE USED FOR STUDENT SCHOLARSHIPS IN THE FIELDS OF ECOLOGY AND ENERGY...(APPLAUSE)

REMARKS BY JIMMY STEWART
TYLER PRIZE NEWS CONFERENCE
LOS ANGELES, MAY 6, 1982

I'D LIKE TO WELCOME YOU ALL TO THIS NEWS CONFERENCE, WHICH HAS BEEN CALLED TO ACQUAINT YOU WITH THE WINNERS OF THE 1982 JOHN AND ALICE TYLER ECOLOGY-ENERGY PRIZE.

TO GIVE YOU A BIT OF BACKGROUND: THE TYLER PRIZE, RANGING UP TO $200,000, IS THE LARGEST ECOLOGY-ENERGY PRIZE IN THE WORLD, AND ALSO THE LARGEST ACHIEVEMENT AWARD PRESENTED BY AN AMERICAN INSTITUTION. IT WAS ESTABLISHED IN 1973 BY THE LATE JOHN C. TYLER, FOUNDER AND FORMER CHAIRMAN OF THE FARMERS INSURANCE GROUP, AND HIS WIFE ALICE C. TYLER.

I HAVE BEEN GIVEN THE HONOR OF PRESENTING THE PRIZE THIS YEAR, AT THE INTERNATIONAL MEETING OF THE UNITED NATIONS ENVIRONMENT PROGRAMME. THIS MEETING WILL TAKE PLACE IN NAIROBI, KENYA, A WEEK FROM THIS FRIDAY, MAY 14.

I'M ESPECIALLY PROUD TO BE PRESENTING THE TYLER PRIZE, BECAUSE NOT ONLY IS IT AN IMPORTANT RECOGNITION FOR SOME WORTHY PEOPLE, BUT IT GIVES ME A CHANCE TO TRY AND CATCH UP WITH MY FAMULY. MY DEAR WIFE, GLORIA HAS LONG BEEN DEEPLY INVOLVED IN THE AFRICAN WILDLIFE LEADERSHIP FOUNDATION.

-MORE-

My daughter Kelly Stewart Harcourt is another one who has increased my own awareness. She has her PhD in Zoology and is now working with her husband in the Rwanda Preserve, Karisoli Research Center in Rwanda, Central Africa studying the Mountain gorilla.

My family has taught me how absolutely necessary it is for us to preserve and protect our invaluable natural heritage. I hope by my having even the small role of presenting this Prize, they'll see that the old man has learned his lessons well.

In past years, the Prize has been awarded for pioneering research and critical leadership in areas of water and air pollution, and in preserving and improving a healthy environment for both humans and wildlife.

Although the Tyler Prize has had a relatively short history, it has been a distinguished one, and this year is no exception. This year's Tyler Prize laureates are Professor Carroll Wilson of the Massachusetts Institute of Technology, and Southern California Edison Company. Dr. Wilson has been honored for his leadership in the fields of ecology and world energy supplies. And Southern California Edison has been named the first corporate honoree in the Prize's history, for the company's efforts at energy and environmental conservation, and for development of renewable and alternative energy sources.

-MORE-

Dr. Wilson is in London and thus couldn't be with us today. His photograph is in your press packets, however, and let me take a few moments to mention some of his many accomplishments.

Professor Wilson has had a busy career seeking solutions to global energy and environmental problems. As early as 1946, he served as secretary of a group which developed the first plan for the international control of atomic energy, and this became the basis of the United States' proposals to the United Nations Atomic Energy Commission.

He joined the Massachusetts Instutute of Technology as a professor in the Sloan School of Management in 1959. Beginning in 1969, he helped establish and operate the International Center for Insect Physiology and Ecology in Nairobi, a laboratory dedicated to basic research aimed at producing species-specific, biodegradable pesticides. As the U.S. delegate and chairman of an international committee on Research Cooperation, he helped launch a number of projects attacking environmental problems, such as toxic chemical trade and packaging, acid rain, and air and water pollution.

Among his many other accomplishments, Professor Wilson presented a lecture in 1973 on "A Plan for Energy Independence for the United States," which included a plan for increasing the production of coal and nuclear energy and the development

-MORE-

OF SYNTHETIC FUELS.

PROFESSOR WILSON CONCEIVED AND ORGANIZED TWO INTERNATIONAL ASSESSMENTS RELATING TO ENERGY MATTERS, THE WORLD COAL STUDY, WHICH ISSUED ITS REPORT IN 1980, AND THE WORKSHOP ON ALTERNATIVE ENERGY STRATEGIES, WHOSE REPORT WAS ISSUED IN 1978.

SOUTHERN CALIFORNIA EDISON COMPANY WON THE COVETED AWARD FOR ITS DISTINGUISHED RECORD OF WORKING TO PROTECT THE ENVIRONMENT, AND ITS RECENT COMMITMENT TO AGGRESSIVELY DEVELOP RENEWABLE AND ALTERNATIVE ENERGY SOURCES.

AS AN EXAMPLE, ON OCTOBER 17, 1980, EDISON ANNOUNCED A MAJOR CHANGE IN CORPORATE POLICY REGARDING DEVELOPMENT OF ABOUT ONE-THIRD OF ITS ADDITIONAL GENERATING RESOURCES NEEDED FOR THE DECADE FROM SOURCES WHICH ARE RENEWABLE RATHER THAN FINITE. EDISON'S DRAMATIC CHANGE IN DIRECTION WAS LAUDED BY CUSTOMERS, INSTITUTIONAL AND INDIVIDUAL SHAREHOLDERS, FINANCIAL RATING AGENCIES, REGULATORY AGENCIES, PUBLIC OFFICIALS AND THE NEWS MEDIA. ENVIRONMENTALISTS ALSO PRAISED THE COMPANY'S DECISION, AND THE NATIONAL WILDLIFE FEDERATION PRESENTED THE COMPANY ITS "SPECIAL CONSERVATION AWARD" ON MARCH 28, 1981.

AND NOW MAY I PRESENT MR. WILLIAM R. GOULD, CHAIRMAN OF THE BOARD AND CHIEF EXECUTIVE OFFICER OF SOUTHERN CALIFORNIA EDISON COMPANY.

-MORE-

Tyler Prize

University of Southern California, University Park, Los Angeles, CA 90007

Contact: John Strauss (213-655-8970) TP4/6

Biography

JAMES STEWART

His film career spans nearly half a century.

Actor James Stewart made his first motion picture in 1935, appearing with Spencer Tracy in "The Murder Man."

Since then, he has appeared in more than 75 films (see appended list). He has been nominated for five Academy Awards and has received an Oscar for best actor of the year, two New York Film Critics best actor awards, and the American Film Institute's Life Achievement Award.

James Maitland Stewart was born in 1908 at Indiana, Pennsylvania. He attended Princeton University, majoring in architecture and acting in Princeton Triangle Club shows.

He earned a bachelor's degree in 1932 and planned to attend graduate school. But Joshua Logan, another Princetonian, asked him to work in the University Players -- a stock company in Falmouth, Massachusetts -- and Stewart decided to pursue an acting career.

He made his professional debut in the University Players' production of "Goodbye Again" and stayed with the play when it moved to Broadway.

After appearing in a series of New York plays ("Yellow Jack," "Divided by Three," "Page Miss Glory" and "Journey at Night"), Stewart signed a film contract and headed for Hollywood.

Starting with "The Murder Man," he appeared in 24 films in five years. He was nominated for an Oscar in 1939 for

(more)

his performance in "Mr. Smith Goes to Washington." The following year, he won the Academy Award as best actor of the year for his performance in "The Philadelphia Story."

In World War II, Stewart was one of the first top stars to volunteer for service. He enlisted in the Army Air Force on March 22, 1941, nine months before Pearl Harbor. After a year of training, he became a bomber pilot and squadron commander.

He participated in 20 missions, including raids on Bremen, Frankfurt and Berlin, and was decorated many times. For his leadership of a wing of bombers during a raid on aircraft factories at Brunswick, Germany, Stewart was awarded the Distinguished Flying Cross with two Oak Leaf Clusters.

For his outstanding military performance, Stewart was made a group commander and promoted to the rank of colonel before his discharge from the service in 1945.

He then served in the U.S. Air Force Reserve and rose to the rank of brigadier general prior to his retirement in 1968. He is one of two officers in the history of the Air Force Reserve to have received the Distinguished Service Medal for "exceptionally meritorious service to the United States."

Stewart's first picture after his return to Hollywood was "It's a Wonderful Life" (1946), for which he received another Academy Award nomination.

He received his fourth Oscar nomination, in 1950, for his portrayal of Elwood P. Dowd in "Harvey," and his fifth nomination, in 1959, for his performance in "Anatomy of a Murder."

Stewart has starred in two television series -- "The Jimmy Stewart Show" (1971-72) and "Hawkins" (1973-74).

Stewart and his wife, Gloria, live in Beverly Hills.

J. Lytle -USC- April 29, 1982

JAMES STEWART FILMS

Murder Man
Rose Marie
Wife versus Secretary
Small Town Girl
Next Time We Love

Speed
Gorgeous Hussy
Born to Dance
After the Thin Man
Seventh Heaven

Last Gangster
Navy, Blue and Gold
Of Human Hearts
You Can't Take It with You
Vivacious Lady

Shopworn Angel
Made for Each Other
Ice Follies
It's a Wonderful World
Mr. Smith Goes to Washington

Destry Rides Again
Shop around the Corner
Mortal Storm
No Time for Comedy
Philadelphia Story

Come Live with Me
Zeigfield Girl
Pot of Gold
It's a Wonderful Life
Magic Town

Miracles Can Happen
Call Northside 777
Rope
You Gotta Stay Happy
Stratton Story

Malaya
Broken Arrow
Winchester 73
Harvey

Jackpot
No Highway in the Sky
Greatest Show on Earth
Bend of the River
Carbine Williams

Naked Spur
Thunder Bay
Glenn Miller Story
Far Country
Rear Window

Strategic Air Command
Man From Laramie
Man Who Knew Too Much
Spirit of St. Louis
Night Passage

Vertigo
Bell, Book and Candle
FBI Story
Anatomy of a Murder
Mountain Road

Two Rode Together
How the West Was Won
Man Who Shot Liberty Valance
Mr. Hobbs Takes a Vacation
Take Her, She's Mine

Cheyenne Autumn
Dear Brigitte
Shenandoah
Rare Breed
Flight of the Phoenix

Firecreek
Bandolero
Cheyenne Social Club
Fool's Parade
Shootist

Airport '77
Big Sleep
Magic of Lassie
Tale of Africa

ROOM E51-232
CAMBRIDGE, MASSACHUSETTS 02139

WALTER A. ROSENBLITH

TEL: (617) 253-1990

June 7, 1982

Professor Carroll L. Wilson
130 Jacob Street
Seekonk, MA 02771

Dear Carroll:

It was a great pleasure being with you and Mary in Nairobi at that most pleasant occasion, and I benefitted a great deal from your personally guided tour of ICIPE. I see that you have taken further steps in that direction, and I look forward to hearing from you if I can be helpful in any way.

The conventional arms issue is certainly bubbling up, and I trust that your project will benefit from this newly developed insight on the part of others.

Sincerely,

Walter

Walter A. Rosenblith
Institute Professor

WAR/je

Dr. Frederick N. Andrews
Vice President Emeritus
Purdue University

Dr. Vernon Blackman
President & Chairman of the Board
S-Cubed

Professor Frank Bowerman
Environmental Engineering
University of Southern California

Mr. Frank W. Clark, Jr.
Partner
Parker, Milliken, Clark & O'Hara

Omar Fareed, M.D. (Chairman)
President
The Carr Foundation

Dr. Owen T. Lind
Proffesor of Biology & Environmental Studies
Baylor University

Professor Ralph Mitchell
Gordon McKay Professor of Applied Biology
Harvard University

Dr. William A. Nierenberg
Director
Scripps Institute of Oceanography

Dr. Walter A. Rosenblith
Institute Professor
Massachusetts Institute of Technology

Dr. Robert P. Sullivan
Director and Executive Vice President
JAYCOR

✓ = People at Nairobi
May 1982

THE INTERNATIONAL CENTRE OF
INSECT PHYSIOLOGY AND ECOLOGY
P.O. BOX 30772 NAIROBI, KENYA

ICIPE

Director:
Professor Thomas R. Odhiambo

REF: S7/DIROFF/51/6750

20th May 1982

Professor Carroll L. Wilson
Director,
European Security Study
Norton's Woods
136 Irving Street
CAMBRIDGE, MA 02138
U.S.A.

Dear Carroll,

VISIT TO NAIROBI AND ICIPE

I wish to convey our warmest appreciation for your visit to the Centre last week and the extremely exciting discussions we had during your sojourn.

I very much hope that we will find these encouraging ideas useful in the very near future.

With kindest personal regards,

Yours sincerely

+Mojal

for THOMAS R. ODHIAMBO
Director, ICIPE

TRO/mmo

CABLE: ICIPE NAIROBI TELEX: 22053 PHONE: NAIROBI 43049/43081/43235/43719

INTERNATIONAL
Herald Tribune
Published With The New York Times and The Washington Post

* **R PARIS, TUESDAY, MAY 18, 1982

Big Loser in Argentina's Propaganda War

nta's Attempts to Manipulate Opinion Sow Confusion

keptical journalists, are d that the Hermes is dis-

conflicting reports are natic of the confusion that

The propaganda may be discouraging a peaceful settlement of the war. "The military is manipulating public opinion," said a journalist for a prominent Argentine magazine.

winning. "Argentina to win!" radio announcers repeatedly shout, as they harangue the public with patriotic exhortations and martial music. The cover of a leading mag-

Gainza, editor of the prominent daily La Prensa. "No independent news organization has correspondents on the islands. The government news agency, Telam, sends trash. At least Goebbels called his operation the Ministry of Propaganda."

* * *

Actor **James Stewart** announced that a Massachusetts professor and a California power company are the 1982 winners of a major U.S. environmental award. Stewart, at a press conference during a United Nations symposium on the environment in Nairobi, named this year's winners as **Prof. Carroll L. Wilson** of the Massachusetts Institute of Technology, and the Southern California Edison Co. The prize has been awarded annually since 1973 by a fund set up at the University of Southern California by **John Tyler,** founder and former chairman of the Fireman's Fund insurance group. Wilson, an ecologist and expert in world energy supplies, was commended for enlisting government and industrial leaders from around the world in studies of global energy prospects to the year 2000. Southern California Edison, the first corporate winner of the prize, was praised for its "distinguished record of working to protect the environment and the company's recent commitment to aggressively develop renewable and alternative energy sources." The John and Alice C. Tyler Ecology-Energy Prize, the full name of the award, is the largest achievement award presented by an American institution, Stewart said. Cash awards range from $150,000 to $200,000 a year, a foundation spokesman said. . . . Spanish writer **Jorge Guillen** has won Mexico's Ollin Yoliztli prize for the promotion of Spanish-language literature. The International Cervantes Festival in Guanajuato, Mexico, announced the five-member jury's decision. The award is worth 1.75 million pesos, about $37,500. Previous winners are **Octavio Paz** of Mexico and **Jorge Luis Borges** of Argentina.

the road.

Bossy, the leading goal scorer in the playoffs with 17 in 19 games, paced the four-game rout and earned the Conn Smythe Trophy as the postseason's most valuable player. His seven goals in a cup-final series tied the record set in 1956 by Montreal's Jean Beliveau (who scored his seven in five games).

Bossy's offensive effort complemented another superb goal-tend-

NHL PLAYOFFS

ing effort by Bill Smith, who allowed 10 goals in the four games. Smith also won his 15th game of the 1981-82 playoffs, breaking his own mark of 14 set last spring.

It was the New York power play that was the difference in Game 4, both of Bossy's goals following foolish fouls by Vancouver. The Islanders, No. 1 in the NHL on extra-man plays during the regular season, scored on eight of 20 opportunities during the playoffs.

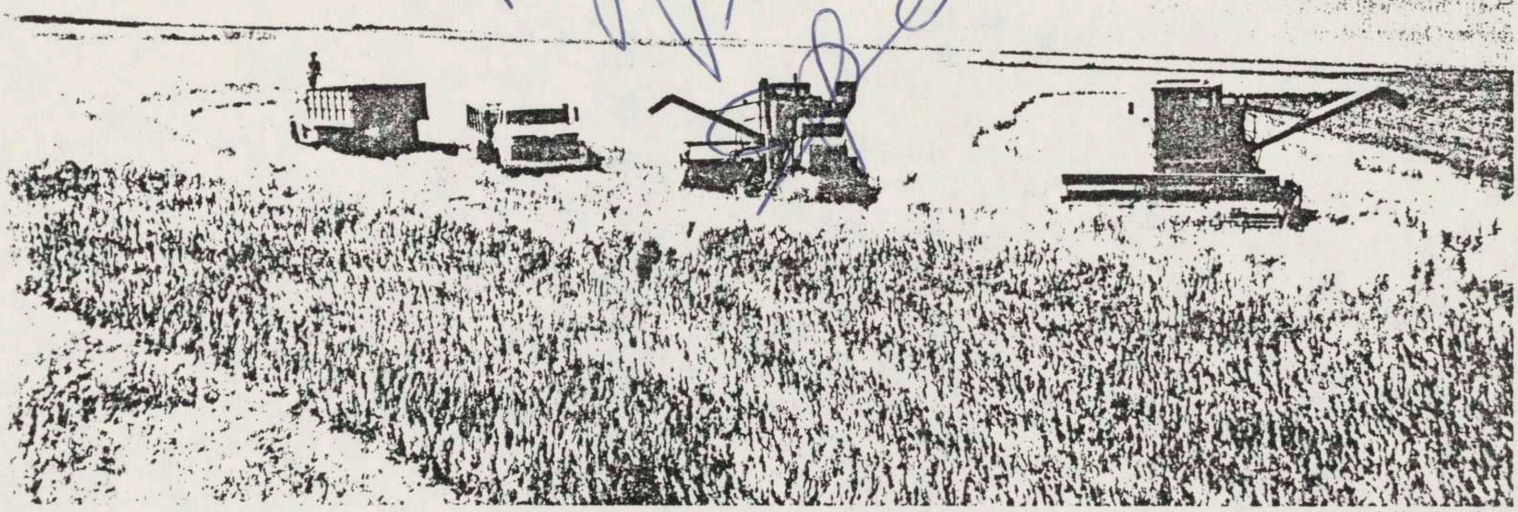
At 5:00 of the second period, just as a cross-checking penalty to Darcy Rota was expiring, Bossy broke a 1-1 tie by poking a rebound past goalie Richard Brodeur. It was the fourth shot in a rapid-fire sequence that ended with Canucks Gerry Minor and Harold Snepsts playing without sticks.

Precisely three minutes later — after Stan Smyl had put his stick in Stefan Persson's face and was sent off for high sticking — hockey's most potent right wing got his second goal of the night. Brian Trottier raced down the left side, took Persson's pass with one skate on the blue line and passed cross-ice to Bossy, who loosed a blistering 30-footer.

Trottier wound up the playoffs with 27 points, leading all scorers.

Journal of Soil and Water Conservation
May-June 1980, Volume 35, No. 3
pp. 116-120.

File Tyler Prize Speech



Wheat harvest in Kansas

Vernon L. Hamilton photo

Carbon dioxide and climatic change: An agricultural perspective

By Sylvan H. Wittwer

Climatologists warn of adverse impacts on agriculture from rising levels of carbon dioxide in the atmosphere, but mounting evidence indicates these higher concentrations of carbon dioxide may also have beneficial effects on crop yields

CONSIDERABLY more is known about the nonclimatic or biological effects of a carbon dioxide-enriched atmosphere on crop productivity than is known about the climatic effects. Biological effects are immediate, easy to observe, and may be potentially as important.

Since 1948, there has been an annual 4 percent increase in the rate of carbon dioxide released into the atmosphere. About half the amount released has remained airborne. Between 1860 and 1979, the volume of carbon dioxide in the atmosphere increased from 290 parts per million to 335 parts per million, about 13 percent. There were 314 parts per million in 1958. Annual increases in carbon dioxide have grown from 0.7 part per million per year in the 1960s to 1.5 parts per million per year in the 1970s (*24*).

Sensitivity studies using mathematical

Sylvan H. Wittwer is director of the Agricultural Experiment Station, Michigan State University, East Lansing, 48824. *This article is an edited version of a paper presented at the American Association for Advancement of Science meeting in San Francisco, California, on January 5, 1980. Michigan Agricultural Experiment Station Publication No. 9270.*

models of the global climate indicate that the increase in atmospheric carbon dioxide will result in global climatic change (*5*, *13*, *14*, *17*, *18*, *24*). All predictive models show that a doubling of atmospheric carbon dioxide will eventually produce significant temperature increases and other climatic changes. The primary prediction is a warming of the lower atmosphere. Increases in surface air temperatures will vary by region and seasons. Changes will occur in the hydrologic cycle.

Just how much warming takes place will depend on the extent of carbon dioxide accumulation or its increase in concentration in the atmosphere. If the present concentration of carbon dioxide doubles, world climate models predict the average global warming will be between 2°C and 3.5°C. The range shown by models is from 1.6°C to 4.5°C, with 2.4°C estimated as the likely value. Warming at the poles would be greater by a factor of three to four. It would be less in the tropics. However, the rapidity, magnitude, and impact of such a warming are uncertain. Nor is there any agreement on the degree of warming predicted by the various models.

From most all reports emanating thus far from the multitude of conferences and studies of the presumed carbon dioxide problem there are dire predictions of massive dislocations in agricultural production caused by warming trends and shifts in precipitation patterns. The real world, however, has not yet confirmed the climatic changes suggested by these predictive models even though substantial increases in carbon dioxide have already occurred. Any heating of the earth between 1880 to 1970 was 0.4°C or less. It has also been projected that the continued exponential increase in the carbon dioxide content of the atmosphere may warm the earth by an additional 0.3°C to 0.4°C by the year 2000 (*10*).

What are the possible effects of presumed climatic changes from rising levels of atmospheric carbon dioxide on agricultural, range, and forest productivity? What will be the direct biological effects of rising levels of atmospheric carbon dioxide on renewable resource productivity?

Effects of induced climatic change

The prospects of climate change from increasing atmospheric levels of carbon dioxide do not frighten agriculturists and foresters in the United States. The predictive scope of any climatic change relating to the carbon dioxide issue is international.

Seasonal and interannual variabilities in climate have always made agriculture uncertain. The purchase of a farm, acquisition of machinery, choice of a fertilizer formula and seed variety, and development of markets all depend upon next year's weather resembling last year's.

All projections of increased atmospheric carbon dioxide for the coming era speak of rising temperatures. These may be as beneficial as they are bad (*8*, *28*). Water may become the most limiting resource for American and world agriculture. Projected temperature changes may have their greatest impact on the length of the growing season. Seasonal and interannual variabilities in rainfall or snow cover, length of the growing season, as well as the thermal variability in growing degree days (heat sums), are the climatic concerns of agriculture. Stability or dependability of production is as important as production itself.

Fortunately, the past century provides evidence that U.S. agriculture and its research establishment can cope with and even improve during climatic change. Over the past 100 years, for example, the High Plains became the wheat belt during a moist period, then the Dust Bowl during a dry period. Agriculture, through migration and technology, was able to adapt.

Examining the course of yields for the major food crops in the United States during the past century, one never sees a downward trend through the yearly fluctuations. Conversely, during the last century, one sees only upward trends attributed to new technology applied during both warm and cold and wet and dry periods.

Extracting confidence from the past requires a comparison of changes in the past century with those forecast for the coming century as a function of the rising carbon dioxide level. Climatic change can be viewed as a year-to-year variation, rate of a trend, range of a trend, and the correlation of changes from place to place. During the past century, American farmers coped with year-to-year standard deviations of 30 millimeters in eastern Kansas rainfall and two weeks in Minnesota growing seasons. From 1915 to 1945, Indiana farmers experienced a +0.1°C per year trend in temperatures and a total change of +2°C during the past century. American agriculture already has demonstrated that it can adapt to a trend of +0.1°C per year, assuming no change in interannual fluctuations.

Apprehension about a more prolonged trend in the future and a greater change can be balanced by the expectation that research, perhaps spurred by the opportunity of more carbon dioxide for photosynthesis and a reduced water requirement, can continue to increase crop yields. For the past 60 years the variation in weather as reflected in the wheat fields of six nations has allowed nations with good weather to supply wheat to nations with bad weather. Global warming would likely make available for crop production substantial areas in the USSR where successful harvests are now marginal or impossible (*8*). The USSR is the world's largest wheat producer. While foreseeable domestic demands on agriculture and forestry can be met most years, climatic shifts detrimental to agriculture, range, and forestry in other nations could cause greater demands on, and challenges for, American agriculture, forestry, and range resources.

The adaptability of agriculture can also be measured by observed rates of change. Hybrid corn production in Iowa increased from 5 percent to 95 percent of the total corn acreage between 1935 and 1940 (*19*). The average of high-yielding wheat varieties in India went from nothing to 82 percent of the total acreage between 1967 and 1977. Eighty percent of the cultivated land in the Philippines is now planted to high-yielding varieties.

Through the use of short-season, early-planted, single-cross maize hybrids, commercial production of corn in the United States has moved 500 miles further north during the past 50 years. The U.S. winter wheat zone could be moved 200 miles northward using a new level of winter hardiness now genetically available.

Crops can be made more "climate-proof" by genetic improvement and appropriate soil, water, and pest management (*16*). The half-life of a new disease-resistant cereal variety is regularly less than a decade. Mechanization changes rapidly as shown by the nearly complete shift from horses to tractors between 1930 and 1950. The rapidity with which marketing and agricultural trade in oil crops can change within a decade is shown by the large rise in the production of soybeans in Brazil, sunflowers in the Red River Valley of North Dakota and Minnesota, and the production of African oil palm in the tropics.

Reassurance of the resiliency of agriculture and forestry to climate in the United States can be drawn from the present geographical range of crops. Wheat, barley, and potatoes can be grown throughout the United States, including Alaska. Soybeans are produced in almost every state east of the Rockies, and sunflowers can be grown from Texas to Minnesota. Important trees, such as aspen, red maple, Douglas fir, and ponderosa pine, over the latitudinal range, are found from Canada to Mexico. Making the Minnesota climate that of Texas, therefore, would not eliminate many important crops.

It is projected that a warming trend will likely occur with more (or less) amounts and decreased (or increased) variability of precipitation. While these changes may exceed past interannual variations, the unknowns outweigh the knowns. One option involves a prudent course of preparing for the worst. There could be some unpleasant surprises.

The responsiveness of the agricultural research establishment nationally, regionally, and at the state level is an important ingedient. Entering an era of uncertainty, one plans for the ability to change rather than how to respond to a specific change. If the future is uncertain, the agricultural scientist does not develop a crop variety for warmer weather. Instead, he develops a system for promptly developing varieties for any reasonable and conceivable change.

While there is some assurance that U.S. agriculture can cope with the moderate climatic change projected, such a change will add one more problem that agriculture must handle during the coming decades. Other problems facing agriculture include increasing shortages of water, arable land, and fossil energy. Yet another problem is the need to maintain dependable production at high levels. The addition of a projected climatic change makes comprehensive agricultural research even more critical if the nation is to deal effectively with that change. A specific research initiative would be to mount immediately a major effort through genetic improvement, chemical treatments, and management practices to alleviate environmental stresses on renewable resource productivity.

Biological effects of carbon dioxide

In most documents published on the carbon dioxide issue, climatic issues are dealt with in isolation. There is little reference to the possible beneficial biological effects of elevated atmospheric levels of carbon dioxide. This reflects a decided lack of balance, first, in failure to approach the carbon dioxide phenomenon objectively and in its entirety and, second, as a serious lack of balance in research investment relative to the carbon dioxide issue. All previous efforts relate to climatic implications or effects with no attention to biological or nonclimatic impacts. Furthermore, the failure to examine adequately the role of the biosphere in the carbon cycle and as an input into the three dimensional models that project a warming trend lead to many uncertainties (*18*).

The rising level of atmospheric carbon dioxide is variously referred to by climatologists and ecologists as a menace, threat, problem, risk, or catastrophe. Reference is made to inescapable agricultural impacts and dislocations (*12*). The consequences for wheat growing areas, for example, are declared as nothing short of catastrophic (*3*). National energy policy relative to synthetic fuel production rests, in part, on the current debate about the presumed undesirable effects of a rising level of atmospheric carbon dioxide on climatic change. There is little reference to possible beneficial biological effects (*24*).

Photosynthetic efficiency and crop productivity. Carbon dioxide in the atmosphere is a resource for crop production. The low carbon dioxide concentrations ambient to plant foliage remain the single most important rate determinant for further increases in photosynthesis and crop production. In other words, the currently low level of atmospheric carbon dioxide may well be the most limiting factor in overall global agricultural productivity.

The potential for carbon dioxide stimulation of plant growth as revealed by greenhouse and other controlled-environment studies has been referred to as "an abandoned gold mine" (*30*). No exception has been reported to the observed improvement in growth as a response to moderate enhancement of atmospheric levels of carbon dioxide. It is no longer necessary to design and conduct experiments to establish the efficacy of carbon dioxide enrichment on commercially grown greenhouse crops (*27*). All respond with generally higher yields and enhancement of quality, especially during the early seedling stages (*26*). The magnitude of the response is light-dependent, even though beneficial effects are derived over a wide spectrum of light intensities—either daylight or artificial.

A comprehensive review (*22*) of plant responses to global carbon dioxide enrichment discovered over 500 studies reporting increases in yield, growth, and photosynthetic rates and reduced water requirements. Thirty-one plant responses to carbon dioxide enrichment are reported, most all favorable.

A summary of experiments on effects of elevated levels of atmospheric carbon dioxide for plants grown in greenhouses and growth chambers, in tunnels, those separated by vertical barriers, under shade cloth, in the open field, and from plant growth-yield models reconfirmed that most all crops would benefit from a doubling of the carbon dioxide level in the atmosphere (cereal grains, legumes, potatoes, cotton, woody plants).

A study of responses of greenhouse-grown crops to elevated atmospheric levels of carbon dioxide produced yield increases of at least 20 percent, with some as high as 600 percent (*1*). Greenhouse-grown vegetable crops respond especially well, particularly lettuce (*30*).

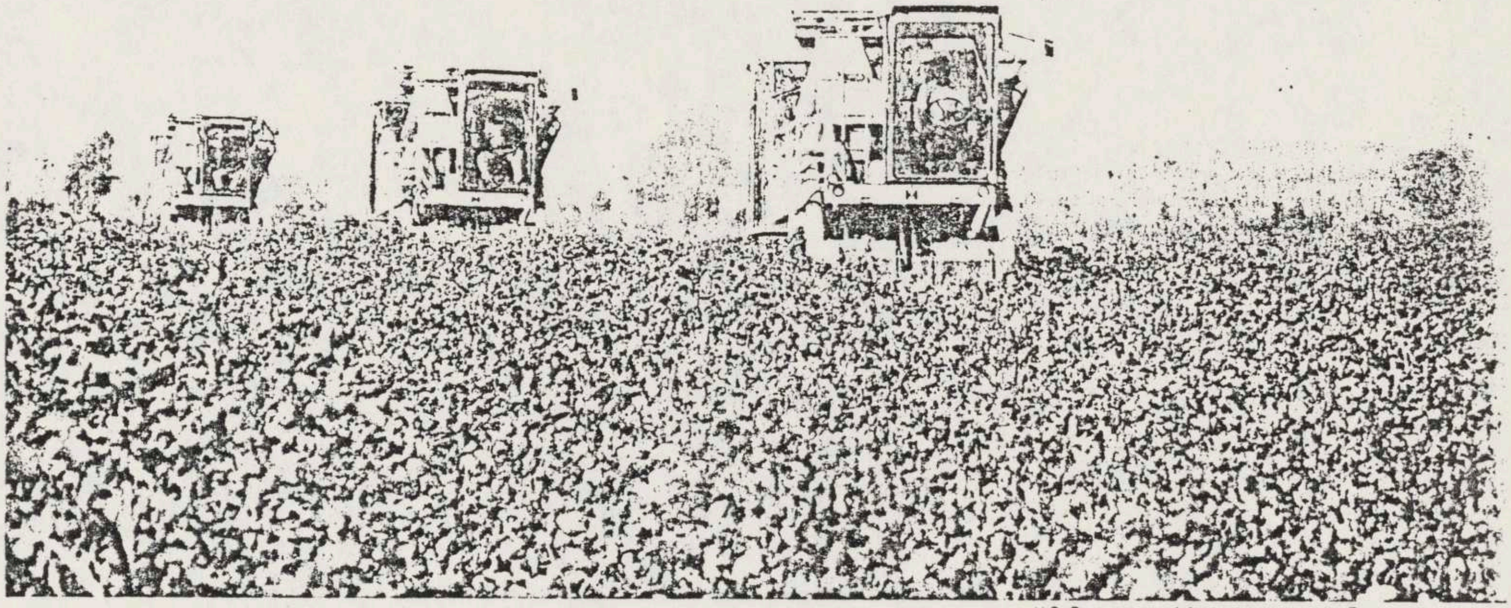
Yield responses peak at 1,000 to 1,200 parts per million of atmospheric carbon dioxide. Adverse effects often occur at higher carbon dioxide levels. The potential for increased photosynthesis is about 0.5 percent for each 1 percent increase in the concentration of atmospheric carbon dioxide in the range of 100 to 300 parts per million above ambient.

Increased photosynthetic rates and accelerated growth and yield responses are genetically dependent. Photosynthetic responses to increased ambient carbon dioxide varies from species to species. Increases in photosynthesis induced by elevated levels of atmospheric carbon dioxide have not yet been effectively introgressed with yields for major agricultural crops or forestry. Moreover, almost no studies of whole plant responses that could be used to predict crop behavior to long-term increasing concentrations of carbon dioxide have been conducted.

There is also an inadvertent potential for increasing crop production from the current global increase of atmospheric carbon dioxide. The higher levels of carbon dioxide now in the earth's atmosphere may already be making a significant contribution to the productivity of agriculture and other renewable resources. A further increase of carbon dioxide in the atmosphere to 400 parts per million (the level projected by some for the year 2020) would probably result in a 20 percent increase in photosynthetic rates for some plants, provided other growth factors were not limited (*1*).

Controlled-environment agriculture and future plant science research. The issue of rising atmospheric levels of carbon dioxide relates directly to controlled-environment agriculture and plant science research conducted in greenhouses and growth chambers. There currently are about 250,000 hectares in controlled-environment agriculture globally. Included are extensive plantings in western Europe, eastern Europe, the USSR, Scandinavia, the Peoples' Republic of China, Japan, Korea, Israel, Turkey, the Arabian Gulf, United States, Canada, Australia, New Zealand, and South Africa.

The majority of these greenhouses in which flowers, vegetables, and fruits are produced are carbon dioxide enriched. Growth, earliness, and production increases attributed to the added carbon dioxide range from 10 to 40 percent. Such observa-



U.S. Department of Agriculture photo by Rana

A variety of greenhouse experiments and field observations and tests indicate that yields of cotton and most other agricultural crops could rise as a result of higher concentrations of carbon dioxide in the atmosphere.

tions are not new. They have been reproduced commercially for 25 years (*6, 11, 29, 30*). Aquatic plants, such as the water hyacinth, will produce in excess of 200 dry tons per hectare per year when grown in greenhouses at an elevated level (800 ppm) of atmospheric carbon dioxide; this is 40 percent more than production at a level of 400 parts per million.[1] Expanding use of the nutrient film technique (*21*) in greenhouse culture offers new opportunities for carbon dioxide enrichment where both root and top environments are under control. Possibilities for increasing crop production through more controlled photosynthesis, including elevated levels of atmospheric carbon dioxide, have been outlined (*4*).

Water use efficiency. Studies relating water use efficiency to atmospheric levels of carbon dioxide have been minimal. Stomated closure occurs on plants following exposure to elevated levels of atmospheric carbon dioxide. There is also a decrease in stomatal conductance.

Reports on increased water use efficiency or decreased water requirements could be important. In one test (*7*), sunflowers, soybeans, and maize were exposed to atmospheric levels of 300, 600, and 1,200 parts per million of carbon dioxide. Rates of growth and photosynthesis increased with increased carbon dioxide for both sunflowers and soybeans, but not for maize. Transpiration declined with increasing carbon dioxide for all three plants. Water requirement per unit of biomass dropped 52 percent for each doubling of carbon dioxide. This work confirmed earlier reports of a substantial decrease in transpiration as the concentration of carbon dioxide in the air increased.

Root and tuber growth responses. Elevated levels of atmospheric carbon dioxide reduce top/root ratios, increase the relative growth rates and net assimilation, but reduce the leaf area index. This may be particularly beneficial for increasing drought resistance and for yields of certain root and tuber crops (*22, 23*).

Potato plants are particularly suited to carbon dioxide enrichment. In one study, significant growth responses were recorded, and roots tolerated a high level of carbon dioxide without damage (*2*). Root zones were aerated for varying time intervals with a gas stream that was 45 percent carbon dioxide, 21 percent oxygen, and 34 percent nitrogen. Stolons and tubers were suspended above the aerated solution, with the carbon dioxide enrichment confined to an airtight root zone. The shoots only were exposed to light.

Twelve-hour carbon dioxide treatments showed striking results from the standpoint of increased dry matter and tuberization. There were significant increases in tuber weights (twofold) and highly significant increases (sevenfold) in the number of tubers per plant. Total plant dry weights increased progressively, indicative of remarkable increases in photosynthesis or a decrease in photorespiration. The researchers (*2*) concluded, first, that there was a significant increase in photosynthesis and, second, that underground carbon dioxide enrichment might be a means of increasing productivity of this important world food crop.

Biological nitrogen fixation. The most important industrial input into agricultural productivity is nitrogen fertilizer. Rising levels of atmospheric carbon dioxide will not promote optimum crop productivity if nitrogen is limiting. Crops having nitrogen-fixing associations with *Rhizobium* (legumes), *Azolla Anabaena* (rice, taro), *Spirillum lipoferum* (tropical and range grasses), and *Actinomycetes* (angiosperms or other endophytes) may not experience this limitation. They may even relieve the nitrogen needs of other crops.

Little is now known about how biological nitrogen fixation will respond to the projected increases in atmospheric carbon dioxide. Indications are that the results would be favorable. Limited studies have been conducted under controlled environments. These have been only for short time periods and only with the *Rhizobium*-legume associations (*15, 20, 25*).

Only one study (*9*) has been conducted in the field for most of a growing season. Here it was dramatically demonstrated that photosynthates are a major limiting

[1]Personal communication with M. R. Fontes, Environmental Research Laboratories, University of Arizona.

factor in biological nitrogen fixation. A threefold carbon dioxide enrichment (1,000 parts per million) of leaf atmospheres resulted in a six-fold increase in atmospheric nitrogen reduction to ammonia by the *Rhizobium japonicum*-soybean association and a doubling in the yield of pods. Favorable results have also been obtained with other legumes (peas, peanuts).

Meanwhile, little is known of the responses of other nitrogen-fixing associations to elevated levels of atmospheric carbon dioxide. This is one of the potentially most fruitful and important areas for biological research relating to rising levels of atmospheric carbon dioxide. The processes of nitrogen fixation and photosynthesis, though physically separated in food, feed, range, and forest crops, are in chemical communication and most likely modulate each other.

Conclusions

There are two effects of rising levels of atmospheric carbon dioxide on agriculture. First are the projected climatic changes that reports thus far suggest will dramatically alter agricultural production areas, growing seasons, and precipitation patterns. The reports refer to inescapable agricultural impacts and dislocation affects on food, feed, and fiber production. Second, almost all reports heretofore published on the carbon dioxide issue deal only with climatic change. Little reference is made to possible beneficial biological effects. Increases in photosynthetic efficiency, reduced water requirements, accelerated growth, increased productivity and positive impacts on other biological processes may be of greater significance for agriculture than climatic effects.

Issue is taken, first, concerning the presumed, impending calamitous events that will climatically overtake agriculture as a result of the rising atmospheric level of carbon dioxide. Seasonal and interannual variabilities in climate have always made agriculture uncertain. U.S. agriculture and its research establishment can cope with and perhaps even improve during climate change. History demonstrates agriculture's resilience to change, and rapidity of agricultural change is well documented. The surety of climatic change should, however, force a major research initiative using genetic resources, chemical treatments, and management practices to alleviate climatic stresses on renewable resource productivity.

Second, we should conduct assessments of the effects of elevated levels of atmospheric carbon dioxide on photosynthetic efficiency, productivity, and growth of economically important crops. Genetic differences in response to high levels of carbon dioxide should be noted and agricultural diversity encouraged. Tuber and root crops should be included in the assessment of carbon dioxide effects as well as cereal grains, legumes, and forest and range species.

Differences in water requirements and water use efficiencies at varying levels of atmospheric carbon dioxide should be studied as well as the effects on other biological processes controlling crop productivity. The growing interest and expansion of controlled-environment agriculture and the use therein of elevated levels of atmospheric carbon dioxide to enhance crop yield and quality strongly suggests that "carbon dioxide pollution" may be good. The positive biological effects on production agriculture need to be carefully weighed against the projected negative climatic impacts.

Finally, climate change itself should not be viewed exclusively in a negative context. There may be some favorable agricultural outputs.

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CARBON DIOXIDE AND CROP PRODUCTIVITY[1]

by

Sylvan H. Wittwer[2]

The greatest challenge facing the people of the world between now and the 21st century will be to produce adequate food to meet the demands for improved diets, rising affluency of nations, an expanding global population, and to increase food availability for hungry people. Dependable production is just as important as the magnitude of output. In fact, less uncertainty of crop yields, which provide directly or indirectly over 95 percent of the food people consume on this earth, could be the most sought after goal of mankind. This uncertainty is primarily a result of climate variability. Two phenomena -- total agricultural output and dependability of production, both primarily crop-dependent, are thus identified critical to the future of all people of the earth. Both total crop output and dependability of crop production may be affected by the currently rising level of atmospheric carbon dioxide (1.3 to 1.8 ppm/year). Primarily it is 20 crops that stand between man and starvation.[3]

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[1]Paper presented at a conference, "The Potential Effects of Carbon Dioxide Induced Climate Change in Alaska," University of Alaska, Fairbanks, Alaska, April 8, 1982.

[2]Director, Agricultural Experiment Station; Associate Dean, College of Agriculture and Natural Resources, and Professor of Horticulture, Michigan State University, East Lansing, Michigan.

[3]Wittwer, S.H. 1981. The 20 Crops that Stand Between Man and Starvation. Farm Chemicals 144(9): 17, 18, 23, 26, 28. The author has, herein, extracted some thoughts from his earlier papers: Agricultural Adaptation to the Rising Level of Atmospheric Carbon Dioxide. Carbon Dioxide Reviews (in press), 1982. Oakridge National Laboratory, Oakridge, Tennessee; Carbon Dioxide and Climate Change: An Agricultural Perspective. Journal of Soil and Water Conservation 35(2): 116-120, 1980; and Wittwer, S. H. and W. Robb. 1964. Carbon Dioxide Enrichment of Greenhouse Atmospheres for Food Crop Production, Econ. Bot. 18: 34-56.

Five of them (wheat, barley, oats, potatoes, sugar beets) can be grown in Alaska.

The practices that result in rising levels of CO_2 are global issues. Combustion of fossil fuels -- particularly oil, gas, and coal -- deforestation, overgrazing, and the cultivation of agricultural lands contribute to global atmospheric CO_2. In the future, the contributions of the United States, the Soviet Union, and China to the pool of atmospheric CO_2 with be particularly significant since these three countries have 90 percent of the coal reserves of the world. While the per capita consumption of energy in China is now about 1/20 that of the United States, China has four times as many people, and the country is rapidly becoming industrialized. Soil erosion, deforestation and overgrazing are problems worldwide, and all contribute to the rising level of atmospheric CO_2. Conversely, there may now be a significantly greater CO_2 uptake by plants, as reflected by an increase in the intensity of the metabolic cycle, from atmospheric enrichment itself. This could be resulting now in a stimulation of photosynthesis, and improving water use efficiency.

The progressive increase in the concentration of atmospheric carbon dioxide (314 ppm in 1958 to over 340 ppm in 1982) amounts to a long-term global experiment for which there is no certain climate or biological model, and the outcome is fraught with uncertainties (Figure 1).

Since 1975, hundreds of studies have been conducted, papers prepared, national and international conferences convened with proceedings published, committees and workshops organized and numerous scientific, popular and semipopular articles have appeared -- all addressing what is generally referred to as a presumptive "CO_2 problem." Almost without exception the focus has been on climate change and with a doomsday perspective of distorted agricultural

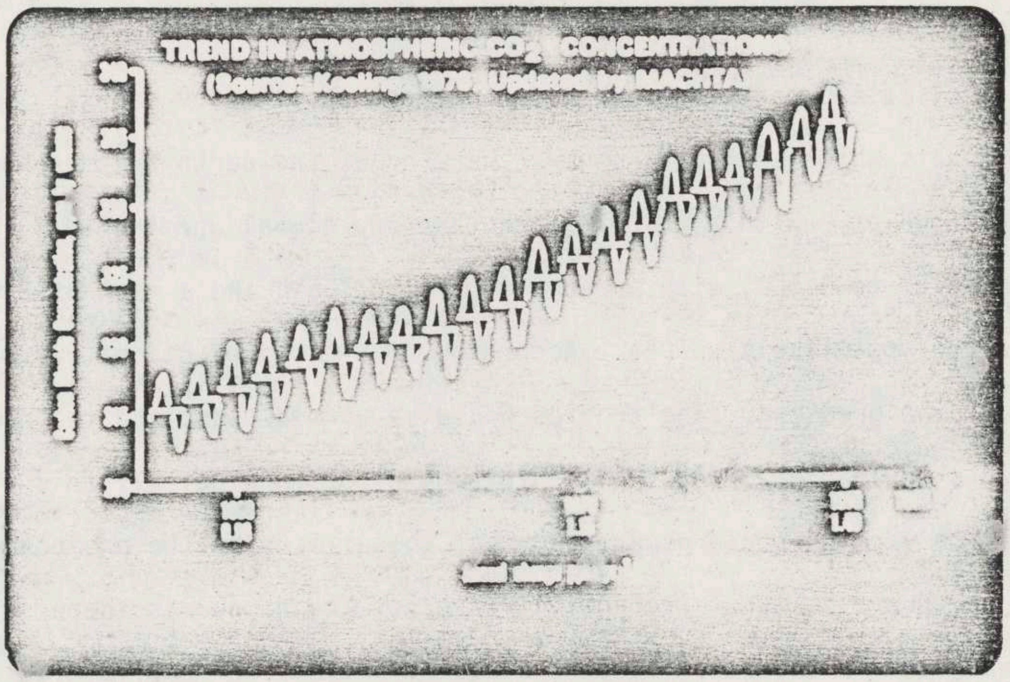

Figure 1. Trend in Atmospheric Carbon Dioxide Concentration from 1958 - 1980.

patterns and dislocations and flooded coastal cities from rising sea levels caused by melting polar ice caps.

Climate Effects

Most all climate projections are based on data provided by general circulation models which predict a general warming of the earth's atmosphere if the CO_2 level doubles. With a doubling, the average global warming is projected to be 2° to 3.5°C, with a range of 1.6 to 4.5°C and a mean of 2.4°C estimated as the most likely values. According to these projections, warming at the poles would be greatest. The tropics would be warmed least and the now temperate zones would experience intermediate warming. How quickly this would happen, how much warming would occur, and what the effects of the projected trend would be on agricultural productivity are not known: nor is there agreement among the "authorities." If the models project correctly, Alaska will be influenced more by a CO_2-induced climate change than any other part of the United States.[4] A real climatic warming could enhance the prospects for success in Alaska's new agricultural and forestry development projects both as to yields and number of crops that could be grown and harvested. Hawaii would be the least affected. Recent analysis of both sector and global models suggests a CO_2 induced dryness (reduction in zonal soil moisture) during the summer season at middle and high latitudes by an atmospheric concentration of CO_2 four times the normal.[5]

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[4]Juday, G. 1982. Climatic Trends in the Interior of Alaska. Moving Toward a high CO_2 World? Agroboreales, pp. 10-15, Alaska Agricultural Experiment Station, Fairbanks, Alaska, January, 1982.

[5]Manabe, S., R. T. Wetherald and R. J. Stouffer. 1981. Climate Change 3: 347-386, D. Reidel Publishing Co., Dordrecht, Holland and Boston, USA.

Almost all reports emanating thus far from the multitude of conferences, workshops and studies addressing the presumed CO_2 problem and climate change, which have been given national and international visibility, warn of massive dislocations in agriculture and food production caused by warming trends and shifts in precipitation patterns. Visionary generalizations are the mode. No one has identified specifically what or where the climate changes would be that would disrupt agricultural productivity. Nor is it now possible to do so. The same evidence used to predict disruptive effects on agriculture, supports equally well the theory that the benefits would be as great as, or greater than, the disadvantages. Furthermore, the climatic changes suggested by the predictive general circulation models have not yet been confirmed by real world phenomena, though substantial increases in carbon dioxide already have occurred. No verifiable "first detection" of climate change has been reported despite extensive efforts that are under way to do so (U.S. Department of Energy Workshop on First Detection, Harpers Ferry, Virginia, June 3-5, 1981). In fact, the "first detection" of an effect of the rising level of atmospheric carbon dioxide might be biological rather than climatic, as will be emphasized later in this report.

In any event, one positive effect of rising levels of CO_2 on agricultural productivity could be an increase in the length of the growing season. While no great advantage might be anticipated for the arctic because of inherently low productivity, temperate zone agriculture, from which most of the surplus grain is produced for international markets, might benefit. This zone would include the United States with Alaska, Canada, vast areas in the Soviet Union, Northern and Western Europe, China, and in the Southern Hemisphere, Australia, New Zealand and Argentina. For example, it has been estimated that in the United States, for each 1°C temperature rise, the corn belt would move 175 kilometers further northeast.[6] For many regions involving agricultural crops, forest tree and range species, the length of the frost-free growing season or the period with temperatures above some minimum are as important as seasonal mean temperatures.

The predicted effects on climate change induced by rising levels of atmospheric CO_2 point to a great gap in current agricultural research. Climate now, and historically, determines more about agricultural productivity than any other single factor. Yet, little agricultural research focuses on the alleviation of climate stresses on crops and livestock and the instability those stresses cause in food supplies, even though high priority has been given to such research by several national and international studies. An example of this instability was observed in the United States with the heat wave and drought in 1980. This weather or climate combination reduced national agricultural productivity by 20 percent, compared with 1979 and 1981. Local deviations from the norms, in the summer of 1980, in both temperature and rainfall have been comparable to any projected for a doubling of CO_2 in the earth's atmosphere. Season to season or interannual variations are compelling worldwide influences on both the magnitude and stability of agricultural production.

If such environmental constraints are to be overcome, either the environment for crops must be changed through protected cultivation or crops must be adapted to environmental limitations. The potential for environmental control of agricultural crops through protected cultivation is limited, because controlled-environment agriculture is capital, resource, and management intensive.

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[6] Newman, J. E. 1980. Climate Change Impacts on the Growing Season of the North American "Corn Belt." Biometerology 7, Part 2: 128-142.

Nevertheless, the current revolution in the use of plastic covers and mulches for crop protection in Japan, Korea, Taiwan, China, Israel, France, Italy, the USSR, and many other nations indicate this is not a technology to be ignored.

Another approach is to adapt crops to their environments. This will dictate a significantly greater research investment in studies that investigate how climate stresses in crop production might best be alleviated. Greater resistance to environmental stresses has been identified by several United States National Research Council/National Academy of Science reports and an international conference on Crop Productivity -- Research Imperatives (Boyne Highlands, Michigan, Oct. 24-29, 1975).[7] Such research should be done first -- and most importantly -- because of the highly significant interannual variations in both termperature and rainfall that already exist in all major agricultural production areas of the earth including the United States. Secondly, the projected CO_2-induced climate changes should be anticipated more precisely. One should not have to wait for first-detection effects of climate change from a rising atmospheric level of carbon dioxide to be impelled to action.

Biological Effects

Photosynthesis -- Biological effects of elevated levels of atmospheric CO_2 are well known. Long established commercial practice, in controlled environment agriculture, has demonstrated that CO_2 enrichment (double and

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[7]World Food and Nutrition Study -- Contributions of Research. National Academy of Sciences, National Research Council, 1977, Washington, D.C.; Crop Productivity-Research Imperatives, 1976. Michigan Agricultural Experiment Station, East Lansing, Michigan, and Charles F. Kettering Foundation Research Laboratories, Yellow Springs, Ohio; and Wittwer, S. H. 1978. The Next Generation of Agricultural Research, Science 199:4327.

triple the current level of 340 ppm) increases the productivity of winter grown greenhouse vegetable (Figure 2) and flower crops even under conditions of severe light limitations. Such CO_2 enrichment practices are based on experiments under practical commercial growing conditions that were not short-term studies but investigations conducted through entire life cycles of plants in many locations in the United Kingdom, Western Europe, United States, Canada, and Japan. Similar results with wheat in Australia have been obtained under highly controlled conditions (Figure 3). The increased intercellular CO_2 pressure from the higher atmospheric levels is offered as the explanation. Such deficiences of light occur not only in greenhouses in winter time, but with lower leaves in most canopies in the field during the summer. Elevated levels of atmospheric CO_2 also lower the light compensation point. According to recent results from Australian scientists this extends the duration of the net carbon gain and possibly the longevity of the lower leaves in a crop canopy.[8]

Water use efficiency. It now appears that the most significant influence of elevated levels of atmospheric CO_2 on crop productivity may be an increase in water use efficiency. This has now been demonstrated in numerous controlled experiments of long duration in Australia and elsewhere with plants grown in full sunlight for cultivated crops such as cotton -- a C_3 plant, and maize --

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[8]Downton, W. J. S., O. Bjorkman and C. S. Pike. 1980. Consequences of Increased Atmospheric Concentrations of Carbon Dioxide for Growth and Photosynthesis of Higher Plants. In: Carbon Dioxide and Climate: Australian Research, pp. 143-151. Australian Academy of Science, Canberra City; Gifford, R. M. 1977. Growth Pattern, Carbon Dioxide Exchange and Dry Weight Distribution in Wheat Growing Under Different Photosynthetic Environments. Aust. Jour. Pl. Physiology 4: 99-110; and Gifford, R. M. 1979. Carbon Dioxide and Plant Growth Under Water and Light Stress. Implications for Balancing the Global Carbon Budget, Search 10(9): 316-318.

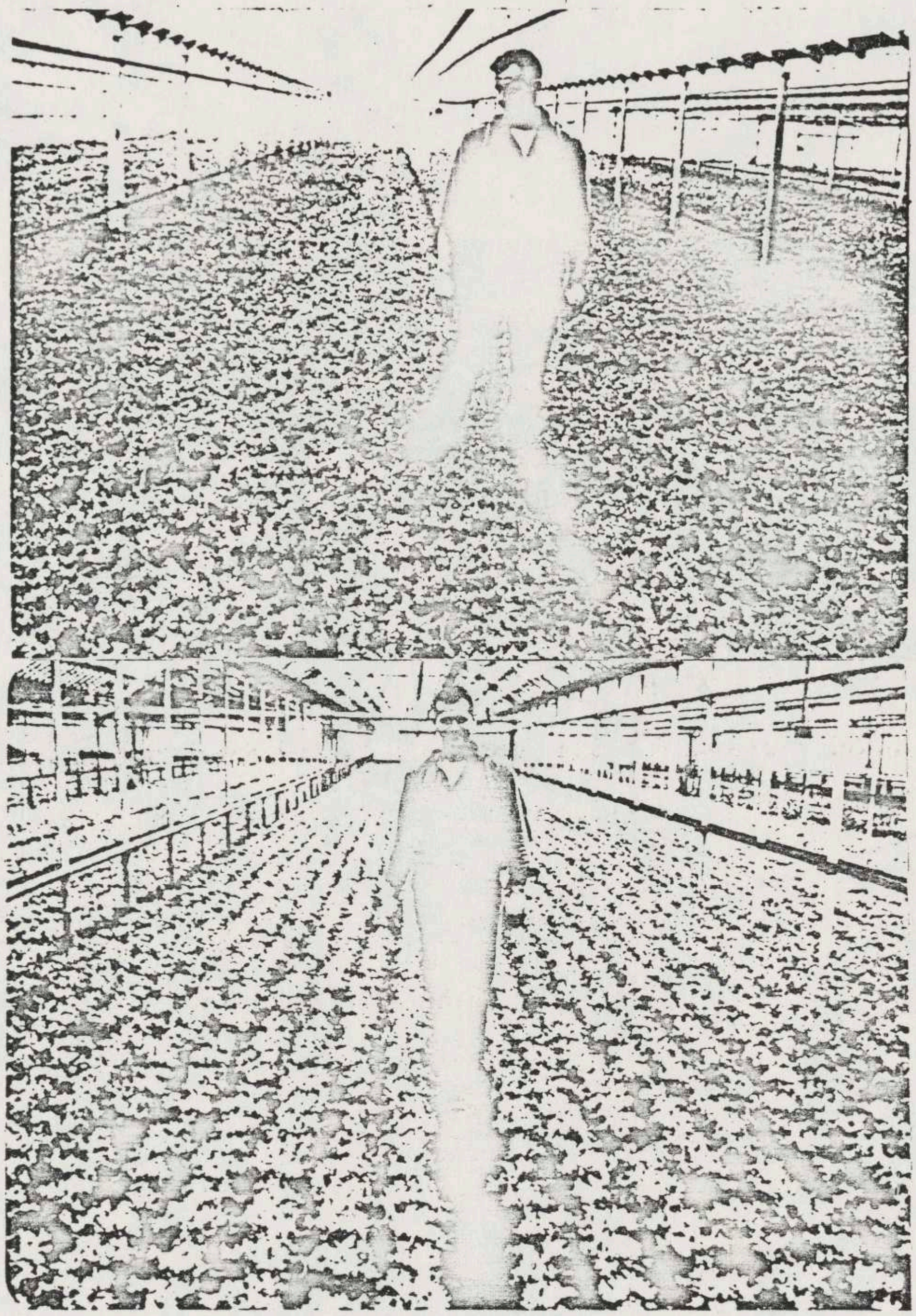

Figure 2. Effects of Elevated Levels of Atmospheric Carbon Dioxide on the Growth of Greenhouse Lettuce. (Top: 1,000 ppm; bottom: normal level of 335 ppm)

Photo taken at Holwerda Greenhouses in Grand Rapids, Michigan

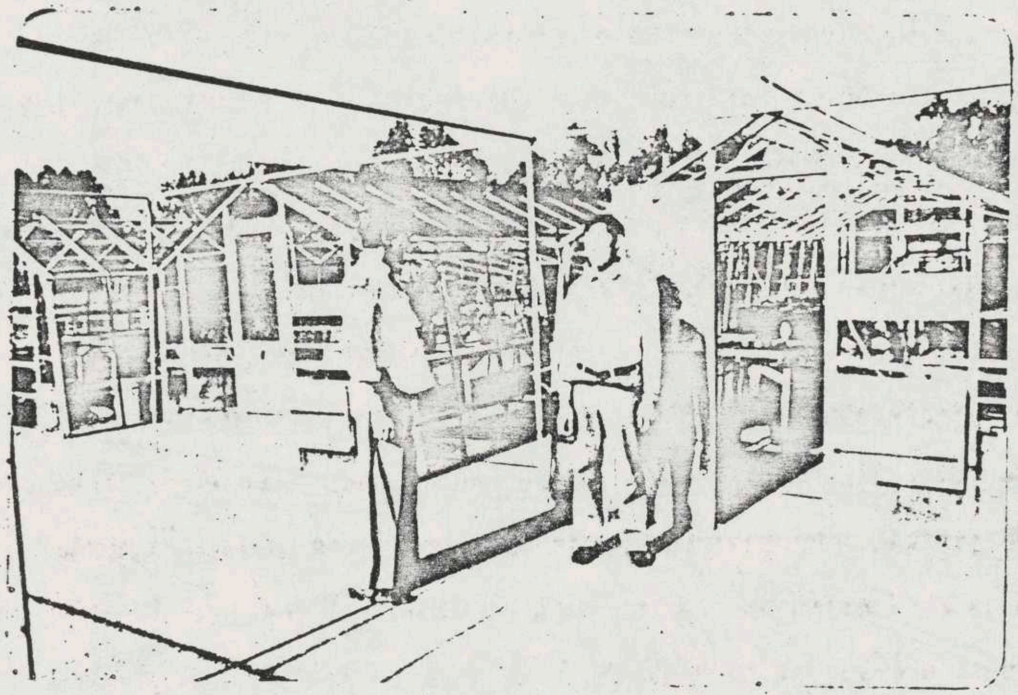

Figure 3. Small Greenhouse Units for Containment of Elevated Levels of Atmoshperic Carbon Dioxide

Photo taken at Commonwealth Scientific and Industrial Research Organization (CSIRO), Canberra, Australia a C_4 plant and for wheat, and for several native shrubs of both C_3 and C_4 metabolism.[9] Whereas the greatest enhancement in rate of CO_2-assimilation was in cotton, a C_3 plant, the greatest reduction in transpiration was in maize, a C_4 plant. These data and other supporting reports strongly suggest that -- contrary to popular reports -- the global area available for agriculture could increase in the future because of the currently rising level of atmospheric CO_2. This would result from increases in water use efficiencies, greater CO_2 assimilation rates, an upward shifting of temperature optimums -- a projected climate change which would result from higher atmospheric CO_2 levels -- and improved CO_2 uptake and crop production, even where light and moisture are limited. Furthermore, under some extremes of environmental stress, there could be a significant crop production capability at some locations under CO_2 enrichment, whereas at current CO_2 levels no productivity would be possible.

The primary conclusion from all evidence is that the present level of atmospheric level of carbon dioxide is suboptimal -- and the O_2 level is supraoptimal, for photosynthesis and primary productivity for the great majority of plants and food crops of the earth. This has been postulated repeatedly by the author and is confirmed in large part by further evidence recently cited by C. B. Osmund, O. Bjorkman, and D. J. Anderson of the Commonwealth Scientific and

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[9]Downton, et. al., op. cit.; Gifford, R. M. Growth and Yield of CO_2-Enriched Wheat Under Water Limited Conditions. Aust. Jour. Pl. Physiol. 6: 367-378; Wong, S. C. 1979. Elevated Atmospheric Partial Pressure of CO_2 and Plant Growth. Oecologia 44: 68-74; and Wong, S. C. 1980. Effects of Elevated Partial Pressure of CO_2 on Rate of CO_2 Assimilation and Water Use Efficiency in Plants. In: Carbon Dioxide and Climate. Australian Research, pp. 159-166. Australian Academy of Science, Canberra City.

and Industrial Organization (CSIRO) of Australia.[10] The position taken by P. J. Kramer[11] that responses to elevated levels of atmospheric CO_2 are beneficial for crop productivity only in the absence of other environmental stresses (adequate sunlight, moisture, optimal temperatures, soil nutrient levels) is not supported by current experimental evidence.

Biological nitrogen fixation. Other biological effects of elevated levels of atmospheric CO_2 should be further examined, particularly the microbiological. The classical reports of Hardy and Havelka of E. I. DuPont de Nemours established that with field-grown soybeans a sixfold increase in biological nitrogen fixation occurred from symbioses with *Rhizobium*.[12] This was accompanied by a doubling of pod yield. Confirmatory results were obtained with other food legumes. There are other microbiological nitrogen-fixing associations with crops related to enhancement of productivity. These include not only the vast legume family and *Rhizobium* species, but the *Azolla-Anabaena* for rice and taro, *Spirillum* for tropical and range grasses, and *Actinomycetes* for a variety of angiosperm species in forests. All evidence now indicates a rising level of atmospheric carbon dioxide would have a very positive effect on enhancement of nitrogen fixation for most all biological systems, but the critical experiments have not been conducted.

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[10] Osmund, C. B., O. Bjorkman and D. J. Anderson. 1980. Physiological Processes in Plant Ecology: Towards a Synthesis with Atriplex, pp. 419-425, Ecological Studies 36, Springer-Verlag, New York, Heidelberg.

[11] Kramer, P. J. 1981. Carbon Dioxide Concentration, Photosynthesis, and Dry Matter Production. BioScience 31(1); 29-33.

[12] Hardy, R. W. F. and U. D. Havelka. 1975. Photosynthesis as a Major Factor Limiting Nitrogen Fixation by Field-Grown Legumes with Emphasis on Soybeans. *In*: P. S. Nutman (ed.), Symbiotic Nitrogen Fixation in Plants. Cambridge University Press, London, pp. 421-439.

Plant competition. There are other biological and biological-climate effects on crop productivity, some which may be anticipated and others not (Figure 4). Some may be direct, others indirect. CO_2-induced climate alterations may influence indirectly the comparative productivity of crops and weeds. Atmospheric levels of CO_2 that exceed present levels may directly change the balance that now allows some crops to dominate some weeds or the reverse. Species of weeds that use the C_3 pathway for photosynthesis could, at higher levels of atmospheric CO_2, become more competitive with C_4 food crops such as corn and sorghum. Conversely, other crops such as cotton, soybean and potatoes -- all C_3 plants -- now plagued by weeds, may become better competitors in a CO_2-enriched world.[13]

A significant and possible deleterious effect of CO_2 enrichment might be repressed synthesis of ribulose diphosphate carboxylase in the leaf.[14] This may have important implications for future protein quality since this enzyme constitutes up to 50 percent of the leaf protein in C_3 plants. Rising CO_2 levels in the atmosphere, however, may counter decreases in the affinity of the enzyme for CO_2 as temperature rises and shift the temperature optimum for photosynthesis upward.

Conclusions and Projections

There are many unknowns as to both the possible climate and biological effects of higher than now levels of atmospheric carbon dioxide on crop produc-

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[13]Patterson, P. T. and E. P. Flint. 1980. Potential Effects of Global Atmospheric CO_2 Enrichment on the Growth and Competitiveness of C_3 and C_4 Weed and Crop Plants. Weed Science 28: 71-75.

[14]Downton, et. al., op. cit.

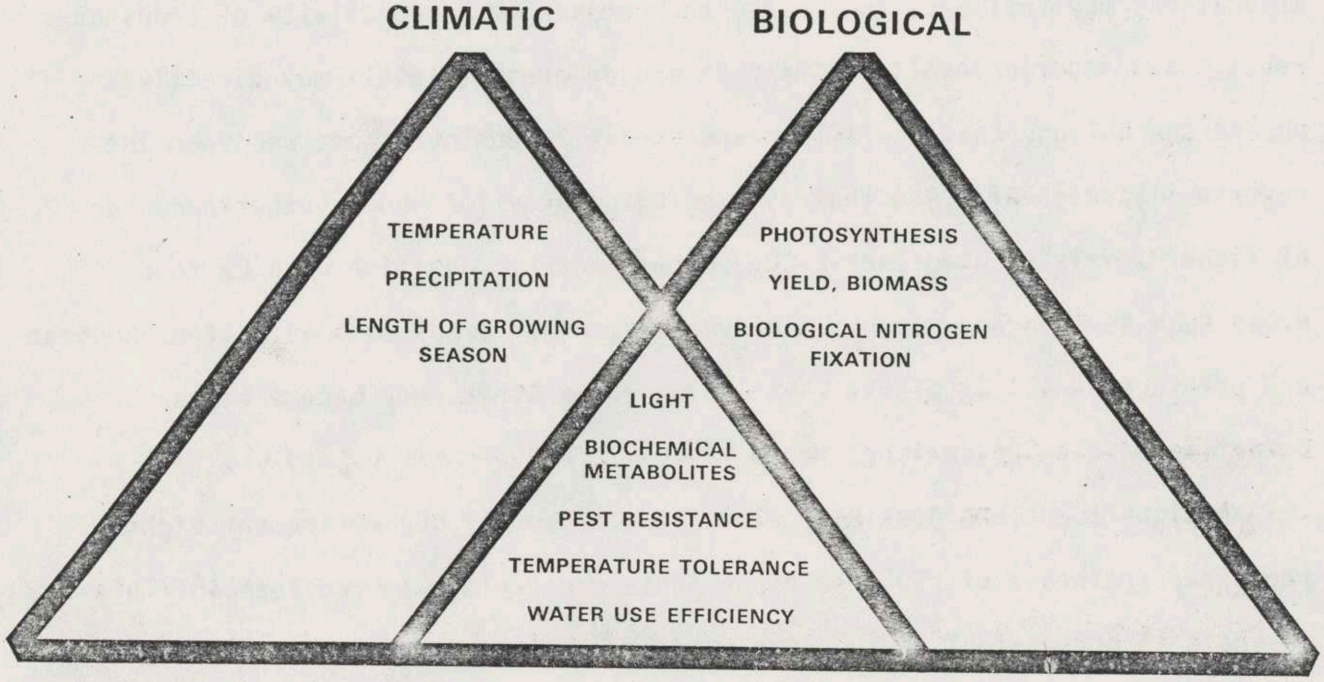

Figure 4. Climate, Biological, and Biological-Climate Effects of Elevated Levels of Atmospheric Carbon Dioxide on Plants.

tivity. There is an urgent need for a research agenda. This is the driving force behind a forthcoming international conference on Rising Atmospheric Carbon Dioxide and Plant Productivity at the Russell Agricultural Research Center in Athens, Georgia, May 23-28, 1982. Federal Agency and organizational inputs include the American Association for the Advancement of Science, the Department of Energy, the Department of Agriculture, the Environmental Protection Agency and the National Science Foundation. Conference panels will include: carbon metabolism, environmental physiology, whole plant growth and development, fresh water aquatic systems, microbiological effects, and plant communities. There is convincing evidence that crop productivity will likely increase with increasing global CO_2 concentrations.[15] Up to a certain atmospheric CO_2 level, crop productivity increases from favorable effects on biological processes (photosynthesis, nitrogen fixation, water-use efficiency) may be more important to the well-being of people on the earth than the presumed negative effects of rising levels of CO_2 on climate. Even with climate change, the beneficial effects might outweight the negative -- plant breeders have for decades strived, with considerable success, to extend the northern boundaries for successful corn and winter wheat production. Most plant biological effects would likely be beneficial and would be clearly manifest even if a CO_2-induced climate change did not occur. We don't know the atmospheric level of CO_2 that will give maximal benefit or harm. Critical now is to determine the impact of small incremental levels of atmospheric CO_2 (10 to 100 parts per million) that are just above the current ambient that will likely be encountered during the next

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[15]Allen, L. H. 1979. Potentials for Carbon Dioxide Enrichment. In: B. J. Barfield and J. F. Gerber (eds.), Modification of the Aerial Environment of Crops, pp. 500-519. American Society of Agricultural Engineering, St. Joseph, Michigan.

two decades, on a variety of biological responses and species. Particular attention should be given to increments of 10 to 20 ppm, which will likely occur in the next five to ten years. We should also seek an answer to the question as to whether current levels of atmospheric CO_2, which are significantly higher than those of 1958, and likely much higher than those of a century ago, have already added to the plant productivity of the earth through increased water use efficiency, greater photosynthesis efficiency, improved biological nitrogen fixation, and partial alleviation of sunlight deficiencies. In other words, are we already "hooked" with high CO_2 levels that are now contributing to crop productivity? We should determine if the metabolic cycle of plants on earth has increased during the past several decades as a result of rising levels of atmospheric CO_2. Has the amplitude of the seasonal cycle in temperate zones actually increased?

Finally, we should take advantage of the several vast geologic depots of relatively pure CO_2 which exist in the Southern and Western United States and in the vicinity of Shanghai in China. In proximity to such areas, major crops and plant communities already exist and could be exposed to elevated outdoor concentrations of CO_2 over prolonged periods with a minimal of cost and hardware to contain the CO_2. This would require close collaboration of oil and gas engineers, meteorologists and plant scientists, but results would be enlightening as to both biological and climate effects and future global crop productivity.

AGRICULTURAL ADAPTATION TO THE RISING LEVEL OF ATMOSPHERIC CARBON DIOXIDE*

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Considerable visibility has been given to the rising level of atmospheric carbon dioxide (1.3 - 1.8 ppm/year) because of its presumed deleterious effects on agricultural production. Further, recent research in this area has emphasized modeling climate change. Projected is a general warming of the earth's atmosphere, marked by an increase in temperature that will be three to four times greater at the poles than in the tropics. These are guesses only.

Neither the magnitude nor the impact of such warming is certain. There is still little, if any, evidence of any climatic signal that can be identified, even though appreciable increases in the level of atmospheric CO_2 have already occurred (Wittwer, 1981). It could be argued that the positive effects of climate change could outweigh the negative (Wittwer, 1980). One effect might be an increase in the length of the growing season. While no great benefit might be anticipated for the artic (Cooper, 1982), an area of far greater significance could be in temperate zone agriculture where most of the surplus grain is now produced for international markets. It has been estimated that in the United

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*Submitted December 1, 1981 to the Institute for Energy Analysis, Oak Ridge Associated Universities, Oak Ridge, Tenn., for publication in Carbon Dioxide Review, Vol. 1, Spring, 1982.

States for each 1°C temperature rise, the corn belt would move 175 kilometers further northeast (Newman, 1980). For many regions involving both agricultural crops, forest tree species and range, the length of the frost-free growing season or the period with temperatures above some minimum are at least as important as the seasonal mean temperature. Hence, this respondent chooses to emphasize the importance of direct biological rather than various projected and uncertain climatic influences on agriculture and food production.

The impact of potential climate change induced by altered levels of atmospheric CO_2 points up a gap in current agricultural research. Climate now determines more about agricultural productivity than any other single factor, yet there is currently little agricultural research to support the alleviation of climatic stresses that make food supplies unstable. This instability -- and the climatic stresses that cause it -- can be observed in the heat wave and drought of 1980, which reduced national agricultural productivity by 20 percent this year, compared with 1979 and 1981. Season to season or interannual variations are important influences on both the magnitude and stability of agricultural production. Thus, a significantly greater investment should be made in research on both crops and livestock and how to best alleviate climatic stresses. Such programs would lessen the possible impact of a CO_2 induced climate change and the current interannual variations in both temperature and rainfall. One should not have to wait for climate change to be impelled to action.

The biological effects of a rising atmospheric level of CO_2 on agricultural crop production must also be considered. The position taken by Cooper (1982) and supported by Kramer (1981) that responses to elevated levels of atmospheric CO_2 are beneficial for crop productivity only in the absence of other environmental stresses (adequate sunlight, moisture, optimal temperatures, soil nutrient levels) is not fully supported by current experimental evidence (Table 1).

Long established commercial practice has demonstrated that CO_2 enrichment is a benefit to productivity of winter grown greenhouse vegetable and flower crops even under conditions of severe light limitations. These practices are based on tests that were not short-term studies but investigations conducted through entire life cycles of plants (Wittwer and Robb, 1964). Similar results have been obtained under more controlled conditions with wheat (Gifford, 1977) and more recently with leaf chambers on forest trees in their natural settings (Gates, 1981). The increased intercellular CO_2 pressure from the higher atmospheric levels is offered as the explanation. Such deficiencies of light occur not only in greenhouses in winter time, but with lower leaves in most canopies in the field. Elevated levels of atmospheric CO_2 also lower the light compensation point. This extends the duration of the net carbon gain and possibly the longevity of the lower leaves in a crop canopy (Downton, Bjorkman and Pike, 1980).

It now appears that the most significant influence of elevated levels of atmospheric CO_2 on plant productivity is an increase in water use efficiency (Wong, 1979, 1980). This has now been demonstrated in long-term experiments with plants grown in full sunlight for cultivated crops such as cotton -- a C_3 plant, and maize -- a C_4 plant (Wong, 1979), for wheat (Gifford, 1979a, 1979b), and for several native shrubs of both C_3 and C_4 metabolism (Downton, Bjorkman and Pike, 1980). Confirming results for wheat have been obtained by Sionit, Hellmers and Strain (1980) and for potted carnation plants by Enoch and Hurd (1979). Whereas the greatest enhancement in rate of CO_2 assimilation was in cotton, a C_3 plant, the greatest reduction in transpiration was in maize, a

Table 1. The Effects of Elevated Levels of Atmospheric Carbon Dioxide in the Presence of Various Environmental Constraints on Plant Growth

Environmental Constraint	Effects of Elevated Atmospheric Levels of Carbon Dioxide	References
Moisture Deficiency or Drought	Decreased transpiration and improved water use efficiency for both C_3 and C_4 plants. The greater the water stress imposed, the greater the relative increased growth response to CO_2 enrichment.	Gifford (1979); Downton, Björkman and Pike (1980); Sionit, Hellmers and Strain (1980)
Low Light Intensity	Growth response greatest at low light intensity. The dimmer the light the greater the yield increase.	Gifford (1977, 1980); Wittwer and Robb (1964)
High Temperature	Temperature optimal for plants may be shifted upward.	Downton, Björkman and Pike (1980)
Mineral Deficiency	Assimilation rate of cotton increased 1.5 fold at high levels of nitrogen with lesser increases at low levels. With maize a 1.2 fold increase at high levels of nitrogen, but a reverse at low levels of nitrogen.	Wong (1979)
Air Pollution	Presumed to be less because of partial closure of stomata.	Cooper (1982)

C_4 plant. Downton, Björkman and Pike (1980), Gifford (1980), and Wong (1980) suggest that as a result of increased water use efficiency, greater CO_2 assimilation rates, an upward shifting of temperature optimums, and improved CO_2 uptake and production -- even where light is limiting -- the global area available for agriculture could increase in the future because of the currently rising atmospheric level of CO_2. Under extremes of stress, the response may be infinite relative to enhancement of yield from higher atmospheric CO_2 levels. This is because some productivity may occur under CO_2 enrichment, whereas without enrichment, no productivity would be possible.

The primary conclusion from all the above evidence is that the present level of atmospheric carbon dioxide is suboptional -- and the O_2 level is supraoptional -- for photosynthesis and primary productivity for the great majority of plants. This has been postulated repeatedly by the author and is confirmed in large part by the evidence cited above and more recently by Osmund, Björkman and Anderson (1980).

Some interrelationships of the two major effects -- climate and biological -- likely to occur from a rising level of atmospheric CO_2 are illustrated by Figure 1. The projected climate changes are increases in temperature and length of the growing season and changes in precipitation patterns. Known biological effects are increases in photosynthesis, yield, biomass, and biological nitrogen fixation. There are, in turn, marked biological, interactive effects on water use efficiencies, temperature tolerances, the effectiveness of light, and modification in biochemical metabolites, and on pest resistance; but the latter are also related to, influenced by, or maybe a part of, the climate complex. It now seems likely that adverse climatic effects -- low light intensities, high temperaures, and moisture deficits -- may be compensated for, at least in part, by the biological effects of elevated atmospheirc levels of carbon dioxide.

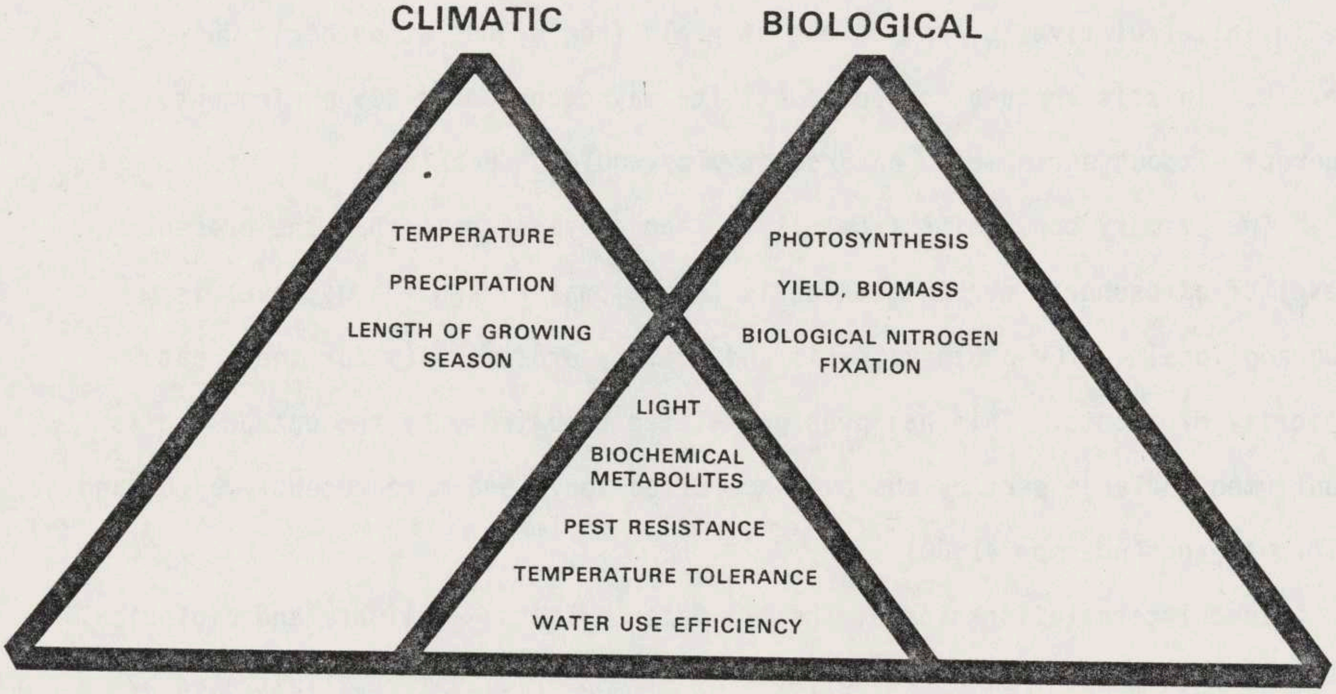

FIGURE 1. EFFECTS OF A RISING LEVEL OF ATMOSPHERIC CO_2 ON PLANTS

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May 31, 1982

Dr. Jerome Walker
Assistant Vice President for
Academic Affairs
University of Southern California
Adm 101, University Park
Los Angeles, CA 90007

Dear Jerry:

Enclosed is a memorandum of the expenses of myself and Mrs. Wilson for our journey to Boston-Nairobi-Boston for the Tyler Prize events.

The safari to the Nairobi Game Park on which Walter Rosenblith and Omar Fareed joined it was suggested by Omar Fareed might be an appropriate charge on the hotel bill. I had already paid it through American Express but you will see it listed here with the voucher.

It was a great experience and we were delighted to have this opportunity. On Saturday of that week, when happily you were off on safari, Maurice and Hanne Strong and the Stewarts and Mary and myself went up to Tubby Block's place on Lake Nairasha. We got some great pictures that day.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

May 31, 1982

Memorandum of Expenses May 5-18

Mr. and Mrs. Carroll Wilson
Boston-Nairobi-Boston

(Prepaid tickets supplied by Gibson travel)

Kenya visas	$ 20.00	
Cholera and gamma globulin inj.	40.00	
Aralan - anti-malarial	27.66	
May 5 - Taxi to station	10.00	
Bus return ticket PRO-BOS 2 X $14	28.00	
Refreshments	7.50	$133.16

Nairobi - 10.40 Sh. = $1.00

May 11 - Taxi	Sh	185	
Tip		8	
Taxi		25	218
May 12 - Taxi		25	
Taxi		35	
Miscellaneous		25	80
May 13 - Miscellaneous		10	
"		16	
"		20	46
May 14 - Safari U.T. Co. (Fareed, Rosenblith Wilsons - Nairobi Game Park)		530	
Tip		100	
Miscellaneous		10	
Taxi		30	670

Memorandum of Expenses May 5-18
Page 2

Brought forward		Sh 1014	$133.16
May 15 - Tips	200		
Taxi	100		
Airport tax (2)	160		
Porters	20		
Tip	20	500	

(Hotel Norfolk paid)

Sh 1514	=	$145.57
		$278.73

($\frac{1514}{10.40}$ = $145.57)

Cardmember Account Number
3718 330485 61000

Cardmember Name
10/81 THRU 09/83 73 AX
CARROLL L WILSON 3785

Approval Code

Check or Bill No.

Service Establishment

Date of Charge

Any delayed charges are entered below:

UNITED TOURING
NAIROBI KENYA
970 260 0016

Merchandise/Services
K 4470.00

Type of Delayed Chg.

Amt. of Delayed Chg.

Tips/Misc.

Revised Total

Establishment agrees to transmit to American Express Company (Amexco) or Authorized Representative for payment. Merchandise and/or service purchased on this card shall not be resold or returned for cash refund.

Cardmember Signature
X

Total
K 4470.00

Amexco Use Only

Number
823807

American Express Card

Please Print Firmly

Record of Charges

Cardmember Copy

ROC FORM 42-03-00-790-0-R PRINTED IN U.K.

UTC

CASH SALE No. 55965

UNITED TOURING COMPANY LIMITED

TRAVEL HOUSE MUINDI MBINGU STREET NAIROBI KENYA

P.O. BOX 42196, TELEPHONE: 331960 TELEGRAMS: "OVERTOURCO", TELEX: 22228

M MR. Wilson x 4
c/o Norfolk Hotel

MOVEMENT ORDER NO.	S. D. C. No.	VEHICLE NO.	DATE
			14/5/1982

FOREIGN CURRENCY RECEIVED			SHS.	CTS.
		Amexco NO: 3718-330485-61000		-
US$	R Kamau	Tour KP. 105	50	00
£STG		4 @ 1307 additional		
DM		payment - the rest paid		
F.FR		by Amexco		
		Shillings fifty only	50	00

SERIAL NUMBERS OF TRAVELLERS CHEQUES TO BE SHOWN

№ 139918

The Norfolk Hotel
Box40064 Nairobi.
Tel335422 Telex22559

The Lord Delamere
Bar&Terrace Restaurant

CUST	2
PBAL	.00
"NK"	918
"NK"	3
20	7.15
METRIC	14.30
POST	14.30

17:57 #0662A100
15/05/82 228-8

PBAL	14.30
WCHP.	7.15
SUBT	7.15
POST	21.45

18:00 #0672H100
15/05/82 228-8

PBAL.	21.45
CASH TEND	21.45

18:23 #0710A100
15/05/82

Signature ____________________

Name ____________________

Room No. ____________________

FM#025-18-1413-A
Medix 3-#8539975-A

DOB: 9/21/10

336-8615

STATEMENT

RICHARD KEY MEAD, M.D.

INTERNAL MEDICINE

PHYSICIAN'S OFFICE BUILDING
110 LOCKWOOD STREET
PROVIDENCE, RHODE ISLAND 02903

TELEPHONE: 331-3580

Mr. Carroll Wilson
130 Jacob Street
Seekonk,Massachusetts 02771

DATE	DESCRIPTION	CHARGE		PAYMENT		CURRENT BALANCE	
4/10/80	CME,EKG,UR & SB	84	00			84	00
5/8/80	ROA			84	00		
8/12/81	CME,EKG,UR & SB	92	00			92	00
10/6/81	ROA			92	00		
12/9/81	Flu Inj.	10	00			10	00
1/8/82	ROA			10	00		
2/9/82	OV	27	00			27	00
3/3/82	ROA			27	00		
4/29/82	INJ's (2)	20	00			20	00

Cholera
& Gamma G

PLEASE PAY LAST AMOUNT IN THIS COLUMN

CME—Complete Medical Examination
OV—Office Visit
EKG—Electrocardiogram
UR—Urinalysis
HCT—Hermatocrit
INJ—Injection (s)

MPE—Modified Physical Exam
HV—House Visit
NH—Nursing Home Visit
CON—Consultation
ER—Emergency Room Care
HC—Hospital Care
NC—No Charge

ANT—Anticoagulation Regulation
ROA—Received on Account
BS—Blue Shield
INS—Insurance
FM—Federal Medicare
SM—State Medicare
SB—Stool for Blood

THIS IS A COPY OF YOUR ACCOUNT AS IT APPEARS ON YOUR LEDGER CARD.

FM# 025-18-1413-B
BS#002292121 (Mass)

DOB: 10/5/13

336-8615

STATEMENT

RICHARD KEY MEAD, M.D.

INTERNAL MEDICINE

PHYSICIAN'S OFFICE BUILDING
110 LOCKWOOD STREET
PROVIDENCE, RHODE ISLAND 02903

TELEPHONE: 331-3580

Mrs. Mary Wilson
130 Jacob Street
Seekonk, Massachusetts 02771

DATE	DESCRIPTION	CHARGE		PAYMENT		CURRENT BALANCE	
2/28/80	CME, EKG & UR	81	00			81	00
4/9/80	ROA			81	00		
5/4/81	OV	25	00			25	00
6/16/81	ROA			25	00		
11/18/81	CME, EKG, UR, SB & Flu Inj.	102	00			102	00
12/4/81	ROA			102	00		
4/29/82	INJ's (2)	20	00			20	00

Cholera
& Gamma G

PLEASE PAY LAST AMOUNT IN THIS COLUMN

CME—Complete Medical Examination
OV—Office Visit
EKG—Electrocardiogram
UR—Urinalysis
HCT—Hermatocrit
INJ—Injection (s)

MPE—Modified Physical Exam
HV—House Visit
NH—Nursing Home Visit
CON—Consultation
ER—Emergency Room Care
HC—Hospital Care
NC—No Charge

ANT—Anticoagulation Regulation
ROA—Received on Account
BS—Blue Shield
INS—Insurance
FM—Federal Medicare
SM—State Medicare
SB—Stool for Blood

THIS IS A COPY OF YOUR ACCOUNT AS IT APPEARS ON YOUR LEDGER CARD.

Exp - UK - Nam - Pan
Bas

2 - Cholera &
7 Glob

- Amalan & — 27.66
anti diarrh

- Visas — 20.

~~Swt~~ — 14.95

Rfr — 7,50

1.85

7 Lu — 21.50

7 Maneg — 3.

8 Hotel

8 Pet.nal — 6,85

9 Rimon — 14.

10 Taxi — 2.40

" — 1.50

" — 1.60

" — 1,50

" 10 — 1,10

Memorandum of Expenses May 5-18

Mr & Mrs Carroll Wilson (Prepaid Tickets supplied by Gibson Travel)
Boston - Nairobi - Boston

~~5~~ Kenya Visas $20,
Cholera & Gamma Globulin Inj $40
Aralan - anti malarial 27.66

5 - Taxi to Sta $10.
Bus rett Tick Pro-BOS 2X14 $/$ 28.

+ Refreshments $ 7.50

10 - Nairobi $0.40 Sh = $1.00
Taxi 185
Tips 8
Taxi 25 218

12 -	Taxi	25	
	"	30	
	Misc	25	80
13.	Misc	10	
	"	16	
	"	20	46
14 -	Safari		
	UT Co		
	(Fareed, Rasoubtelle	530	
	Wilsons - Nairobi		
	Game Park		
	Tips	100.	
	Misc	10	
	Taxi	30	670
15 -	Tips	200	
	Taxi	100	
	Amp TX 2×80	160	
	Porters	20	
	Tip	20	500

(Hotel at Norfolk paid)

Sh 1514

$= \$\frac{1514}{10.4} = \$145.57$

May 24, 1982

Dr. Jerome Walker
Assistant Vice President for
Academic Affairs
University of Southern California
Adm 101, University Park
Los Angeles, CA 90007

Dear Jerry:

I am sending two letters via you, one to Mrs. Tyler and one to Omar Fareed.

I would like to obtain a copy of the remarks of Jimmy Stewart when he presented the medal to me. That was essentially the citation and I would like to have the text.

I'd also like to know how Jimmy Stewart spells his name Jimmy. Is it with a Y or an IE because I want to write to him.

It was a great occasion and Mary and I greatly enjoyed meeting you and Laura and taking part in those interesting events that week. We went on Saturday out to Tubby Block's place on the shores of Lake Nairasha with Maurice and Hanne Strong and the Stewarts.

I hope your safari went well and that you saw lots of animals and got lots of good pictures.

Enclosed is a copy of the memo I sent to Mrs. Tyler concerning my activities for the next few years.

With best regards.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

May 24, 1982

Mrs. Alice Tyler
c/o Dr. Jerome Walker
Assistant Vice President for
Academic Affairs
University of Southern California
Adm 101, University Park
Los Angeles, CA 90007

Dear Mrs. Tyler:

You were in the minds and hearts of all of us that evening in Nairobi when you and the Executive Director of UNEP co-hosted a wonderful banquet and series of prize awards.

Enclosed is a copy of my remarks in acceptance of the Tyler prize which Jimmy Stewart presented to me on your behalf.

It was a special pleasure for Mrs. Wilson and myself to become acquainted with Jimmy, Gloria, and their interesting daughter Kelly as well as other members of the Executive Committee.

It had been eight years since I had visited the International Centre for Insect Physiology and Ecology in Nairobi which I took part in founding in 1969 and served as Chairman until 1974. It was exciting to find that the quality of scientific work has remained very high and that important advances have been made in understanding the physiology of such things as tsetse flies which are the basis for moving towards means of more effective control. Walter Rosenblith accompanied me for a full day of visits to the ICIPE laboratories and Omar Fareed went with me again the next day.

It was a very good decision that the awards be made in that very international setting with its focus on how the world looks ten years after Stockholm.

It was also very nice that UNEP awarded one of its three gold medals to Maurice Strong with whom I have been working closely for the last twelve years and whose receipt of the first Tyler prize I observed at that first award ceremony in 1973.

I have shifted my attention to another set of problems which seem to me very large in the decade or two ahead and which are illustrated by the enclosed description of the European Security Study which I began to organize about a year ago and which will hold its first Steering Group meeting in Germany next month.

When my travels take me westward instead of across the Atlantic as is the usual case I hope I shall find myself in Los Angeles and have the pleasure of meeting you personally and thanking you for your vision and generosity in creating this exceptional prize.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosures

May 24, 1982

Dr. Omar Fareed
c/o Dr. Jerome Walker
Assistant Vice President for
Academic Affairs
University of Southern California
Adm 101, University Park
Los Angeles, CA 90007

Dear Omar:

Enclosed is a copy of my letter to Mrs. Tyler. It is a pity that she couldn't be there on that exciting evening. I thought you handled the subject of Mungai with great skill and sensitivity and it could be that your action and invitation which brought him there could help to heal some of the breach with Moi.

Mary and I enjoyed very much our discussions together and the opportunity to become acquainted with you.

With best regards.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

May 24, 1982

Professor Walter A. Rosenblith
Room 3-240
Massachusetts Institute of Technology
Cambridge, MA 02139

Dear Walter:

Enclosed is a copy of my letter to Mrs. Tyler. It was a great occasion and I enjoyed it enormously.

Soon I will talk with Harvey Brooks, who is now on the ICIPE Board, and John Voss about their potential interest in the very good idea you had in Nairobi about the traveling symposium. As the next step on his end Tom is preparing a draft of what might be such a traveling program with two stops in Europe, let's say, and three in the United States. Meantime we'll see what interest there is in the ICIPE Foundation or otherwise to provide the base for this enterprise.

I think the vision you have of the molecular biologist having extremely effective tools but looking for problems and the ICIPE basic work reaching up to the frontiers but having no tools of the kind molecular biologists have developed offers a fascinating opportunity for communication between communities which would not otherwise meet.

I'll be in touch with you soon about what I am able to start here.

With best regards.

Sincerely,

Carroll L. Wilson

CLW:F

Enclosure

Itinerary - Carroll and Mary Wilson
Wednesday, May 5 - Tuesday, May 18, 1982
London/Nairobi/Paris

Wed, May 5/82 - Boston/London BA 274 8:00 p.m. - 8:10 a.m.

Thurs, May 6/82 - Godfrey Davis Car Rental

Christopher Stewart-Smiths
West Wycombe - tel: 024024-3009

Fri, May 7/82 - Sir Hugh Beach, St. George's House, Windsor Castle
tel: (home) Windsor 64842

Montague Arms, Beaulieu

Sat, May 8/82 - Edmund deRothschild, Exbury
tel: 893-145

Sun, May 9/82 - Lord Carver, Wickham (Wood End House)
tel: Wickham 83 21 43

Mrs. Amanda Robinson, Parsons Green, London
tel: 736-7175

Mon, May 10/82 -Sir Alasdair Steedman, 67 Portland Place, London
tel: 01-580 8343 (office)

London/Nairobi BA 55 9:40 p.m. - 8:00 a.m.

Tues, May 11-
Sat, May 15 Norfolk Hotel, Nairobi
tel: 335-422
telex: 22550
cable: Norfolk

ICIPE-Tom Odhiambo
tel: 43235
telex: 22053

Sun, May 16 Nairobi/London BA 54 12:30 a.m. - 7:05 a.m.
Mary- London/Boston BA 275 12:10 p.m.- 2:20 p.m.
Carroll - London/Paris AF 809 9:30a- 11:30a

Stanislaws - 27bis Quai Anatole France
tel: (01) 551-3944

Mon, May 17 12?
Ambassador Francois deRose
5, rue Faubourg St. Honoré,
tel: (01) 265-7060

Tues, May 18 Paris/London AF 810 10:30a - 10:30a
London/Boston BA 275 12:10p - 2:20 p

Inviting Nominations For The

Tyler Prize

The World Prize
in Ecology and Energy

1982

John and Alice Tyler Ecology · Energy Fund

Since 1973, the Tyler Prize has been the largest achievement award presented by an American institution, and it has become the largest ecology energy prize in the world. Eleven environmental laureates have received honors for their outstanding achievements benefiting mankind.Prizes have totaled over $1 million, ranging from $150,000 to $200,000 annually.

In 1980 selection criteria were broadened to encompass energy as well as ecology. The further development and improvement of known sources of energy and the discovery of new sources of energy are inseparably linked to the protection, maintenance, improvement, and understanding of the environment. Pursuit of energy for progress needs to be conditioned by sensitivity to environmental preservation. The Tyler Prize seeks to honor those who contribute new knowledge or critical leadership to that relationship.

Former winners have been honored for pioneering water purification and water quality standards, for discovery of the chemical nature of smog, for landmark work in understanding animal ecology, for new perspectives on the interaction between the environment and the human organism, and for world leadership in respect to the human environment and wildlife protection.

Past honorees include Arie Jan Haagen-Smit, G. Evelyn Hutchinson, Maurice Strong, Ruth Patrick, Abel Wolman, Charles S. Elton, Rene Dubos, Eugene P. Odum, Russell E. Train, Carroll L. Wilson, and the Southern California Edison Company.

Endorsed by The United Nations Environment Programme

Tyler Prize

Eligibility

Citizens of all nations are invited to nominate individuals or institutions of any nation who have benefited humanity in the fields of ecology or energy.

Persons eligible to make nominations include, but are not limited to :

Scientists in fields related to ecology and energy;

National academies of science, engineering or their equivalent, and their members;

Research institutions, and their members;

Nominees can be associated with any field of science. Nominated institutions can be universities, foundations, corporations, or other types of organizations. Awards to non-exempt corporations pursuant to U.S. tax laws, will be used for student scholarships to benefit universities as chosen by such non-exempt honored corporations.

Selection Criteria

Prizes are awarded for any one of the following:

(a) the protection, maintenance, improvement and understanding of ecological and environmental conditions anywhere in the world; or

(b) the discovery, further development, improvement, or understanding of known and new sources of energy (including, but not limited to, oil, coal, solar, hydroelectric, geothermal, wind, oil shale, nuclear, and tar sands).

Deadline For Nominations

Nominations for the 1983 Tyler Prize must be postmarked no later than *November 15, 1982*. Related credentials and letters of recommendation should be mailed by that date, also. The Prize(s) will be announced in March, 1983.

Nomination Procedures

Nominations must be submitted in a letter, in the English language, and must include the following information:

1. *Identification of Nominee*
   Include a person's name, professional or home mailing address, present occupational title, and institutional affiliation. Enclose a vita or resume.
   If an institution or corporation is nominated, identify the administrative officer of the organization or subgroup responsible for the accomplishments cited.

2. *Summary of Accomplishment*
   Provide a brief statement of the individual's or institution's discovery or improvement in one or both fields for which the award is proposed. Be clear and succinct.

3. *Detailed Description of Contribution*
   Provide a detailed explanation of the contribution and explain why it is unique. Describe how it was accomplished. Mention any significant involvement of others. Enclose publications or other evidence of the contribution.

4. *References*
   Provide three letters of recommendation from individuals who can assess the nominee's contribution. Identify three to five additional referees who might be contacted by the Tyler Fund.

Length Of Candidacy

Nominations will be considered for two years, beginning with this round. Renomination will be required after two years.

Mail Nomination To

Executive Director
John and Alice Tyler Energy/Ecology Fund
University of Southern California
Administration 101
Los Angeles, California 90007, USA

Tyler Award Recipients

Dr. Arie Jan Haagen-Smit

Dr. G. Evelyn Hutchinson

Maurice Strong

Dr. Ruth Patrick

Dr. Abel Wolman

Dr. Charles S. Elton

Dr. Rene Dubos

Dr. Eugene P. Odum

Russell E. Train

Carroll L. Wilson

Southern California Edison Company

7 May 1982, Volume 216, Number 4546

SCIENCE

Ten Years After Stockholm

In 1972 the Stockholm Conference on the Human Environment marked a peak of public concern for the maintenance of environmental quality. One of its outcomes, the United Nations Environment Programme (UNEP), is celebrating the 10th anniversary of the conference with a "session of special character" on 10 to 18 May in Nairobi, where national and nongovernmental representatives will review events of the decade and lessons to be drawn from them. What can be said of significance for the scientific community?

It is relatively easy to rack up the scores on the legal and administrative measures taken in response to the Stockholm Conference recommendations. UNEP provides a succinct account of treaties ratified or not ratified, agencies established, programs initiated, and meetings convened in large number.

It is extremely hard to appraise what, in fact, has happened to the principal components of the environment—the atmosphere, marine environment, inland waters, lithosphere, terrestrial biota, and people. The evidence as reported by UNEP is ragged. The trends that can be discerned with confidence show good news and bad news, and I note a few of each.

Compared with the situation in 1972, the rate of annual population growth in 1980 was diminishing on all continents except Africa. The quality of air in many high-income cities was improving. Likewise, contaminant loads in the inland waters of industrialized countries were generally decreasing. Significant advances were made in reclamation of surface-mined lands and in establishing reserves for the preservation of terrestrial biota.

On the negative side, urban air quality in low-income countries continued to decline. The pollution of certain sectors of coastal waters increased, although the marine production in large sectors grew slightly or leveled off. Deterioration of many semiarid lands and of some irrigated soils expanded. Moist tropical forests were being reduced, but there was a wide divergence among the estimates concerning rates and extent. The implications of increasingly massive alterations in the global cycling of carbon, sulfur, and nitrogen were only beginning to receive integrated analysis.

The assembled data on these and numerous other trends not mentioned here should be critically appraised. While they will no doubt be interpreted in different ways, at least three observations deserve the immediate attention of the scientific community.

First, as revealed by the difficulty in measuring changes, a more coherent effort needs to be made to monitor key parameters. The expectations of many at Stockholm that an efficient global earthwatch program would soon be put into place proved sanguine. The present deliberate effort should be streamlined and its pace should be accelerated.

Second, it is becoming evident that appraisals of all but a few basic changes such as those in atmospheric carbon dioxide or ozone are most meaningful on a regional basis, where the intertwining of biological, physical, and social factors can be examined in context. Promising advances, for example, have been made in looking at regional seas rather than at the oceans as a whole.

Third, the scientific grounds for measures to correct much of the degradation in soil, water, biota, and air are well known, but there needs to be more systematic analysis of ways of overcoming social and political obstacles to undertaking them. While speculation runs high on questions of long-term climate change, the quiet degradation of biotic and soil resources proceeds.

The decade after Stockholm has shown that environmental improvement can be achieved, that the pace is slow in many areas, and that scientific inquiry can help speed it up.—Gilbert F. White, *Gustavson Professor Emeritus of Geography, Institute of Behavioral Science, University of Colorado, Boulder 80309*

From the News Office
Massachusetts Institute of Technology
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M.I.T. Professor Urges Development of Climate-Resilient Crops as Best Defense Against 'Greenhouse Effect'

FOR USE AFTER NOON
FRIDAY, MAY 14, 1982
NAIROBI TIME

NAIROBI, Kenya, May 14--Developing crops that can better withstand drastic temperature changes is the world's best defense against the greenhouse effect--the global warming that may occur because of the burning of fossil fuels--a Massachusetts Institute of Technology professor said in Nairobi today (May 14) as he accepted the 1982 John and Alice Tyler Ecology/Energy Prize.

Professor Carroll L. Wilson, a renowned technologist and manager in the fields of ecology and energy supplies, said that scientists throughout the world should mount "a concerted pursuit" of climate-resilient crops. Such crops, he said, would be very useful even if the feared global warming does not occur. The greenhouse effect may warm the global atmosphere because of the build-up of carbon dioxide from burning fossil fuels--coal, gas, oil and wood. Doubling the current carbon dioxide level might raise average global temperatures by 2-3 degrees Centigrade, change regional rainfall and temperature patterns and affect growing seasons.

The Tyler Prize, considered the world's most prestigious ecology/energy award, was presented to Professor Wilson by James Stewart, the actor, on behalf of Mrs. Tyler. Mrs. Tyler and her late husband established the prize in 1973. Mr. Tyler was founder

-more-

and chairman of the Farmers Insurance Group. The Southern California Edison Co. also won a Tyler Prize.

The presentation coincided with a meeting in Nairobi of the United Nations Environment Program which is re-examining the state of the world's life-support systems and planning future action on crucial environmental problems.

Professor Wilson, recognized internationally for organizing and directing a number of global studies involving energy and ecology, says he believes that the chances of a global warming "are great enough to justify vigorous action to mitigate the effects of such a warming."

He is calling for an all-out effort to develop more resilient crops, he said, because prospects for a "technical fix" to capture CO_2 as fuels are burned are "very, very poor," because there is little hope that renewable energy sources can be substituted for fossil fuels within the time frame that global warming may occur, and because restricting the use of fossil fuels is not possible on a global scale.

"In a world of sovereign states a world government with such authority is not now conceivable, even if there were unanimous agreement among scientists (a) that a warming will occur, and (b) what its effects would be and where and when."

On the other hand, Professor Wilson pointed out, developing more climate-resilient crops and agricultural practices "is well within

-more-

what we know how to do and what we can afford...."

In addition, he said, recent increases in the efficiency with which fossil fuels are burned has lowered the rate of increase of carbon dioxide buil -up from 4 percent a year to 2 percent a year.

"This stretches the time for taking avoiding action to about 2060 instead of 2025. This helps but the problem does not disappear and significant effects may be felt long before the CO_2 doubles."

Professor Wilson said his proposed action "should give us benefits whether the warming does or does not occur."

"The principal thing we should do is to adopt strategies that increase the resilience of agricultural systems to environmental stresses including climate changes. We should make genetic improvements in the climate resilience of our main food crops and develop other species which have better resilience to drought, salinity and changed growing seasons. And, of course, we should intensify actions to protect arable soil and improve water management.

"Natural climate variability is one of the most severe constraints on stable agricultural production," Professor Wilson continued. "For example, the heat wave and drought of 1974 and again in 1980 in the United States of America reduced the crop by 20-25 percent....If we can develop crops and agricultural practices which are less affected by climate variability, not only can we mitigate the effects of a possible global warming but we can enjoy gains all the way along which will reduce the risks farmers face in coping

-more-

with seasonal climate changes."

Much work has been done to develop higher corn yields but relatively little has been done to improve climate resilience in the main cereal crops of the world and in the regions which are main sources of food exports, Professor Wilson said.

"The climate resilience I am stressing is focused on plant tolerance to variability of rainfall, temperatures, frost limits on the growing season and other stresses in the plant environment which are caused by climate changes....Such a program of action is particularly suitable for international cooperation of the kind which is so well illustrated by this convention under the auspices of the United Nations Environment Program which has already taken important initiatives such as the establishment of the Global Environment Monitoring System," Professor Wilson said.

LUNCHEON

THURSDAY, MAY 13, 1982
12:30 P.M.

AMBASSADOR'S RESIDENCE

HOST & HOSTESS: Ambassador and Mrs. William C. Harrop

GUESTS:

Honorable Peter Oloo-Aringo, E.G.H., M.P., Minister of Environment and Natural Resources, and Mrs. Oloo-Aringo
Honorable Philip Leakey, M.P., Assistant Minister of Environment and Natural Resources, and Mrs. Leakey
Mr. and Mrs. James Stewart, who will present the 1982 John and Alice Tyler Ecology-Energy Awards
Mrs. Anne M. Gorsuch, Administrator, Environmental Protection Agency
Mr. A. Alan Hill, Chairman, Council on Environmental Quality
Dr. and Mrs. Carroll L. Wilson, Professor Emeritus of Massachusetts Institute of Technology School of Engineering (recipient of Tyler Award)
Mr. and Mrs. William R. Gould, Chairman of the Board and Chief Executive Officer, Southern California Edison Company (company recipient of Tyler Award)
Dr. Omar John Fareed, President, The Carr Foundation; Chairman, Tyler Prize Executive Committee
Mr. Russell Train, President, World Wildlife Fund
Mr. and Mrs. M. Rupert Cutler, Senior Vice President, Audubon Society
Mr. Archibald E. Hanson, Jr., Hanson Enterprises, Paso Robles, CA.
Mr. and Mrs. Michael B. Pearson, Nairobi
Dr. Kelly Stewart Harcourt, Karisohi Research Station, Ruhengiri, Rwanda
Mr. and Mrs. Jack Block, Chairman of Kulia Investments
Mr. E.R. (Tubby) Block, Deputy Chairman of Kulia Investments and Chairman of Block Hotels
Dr. and Mrs. Vernon Blackman, President and Chairman of the Board, "S-Cubed" Corp.; Member, Tyler Prize Executive Committee
Dr. and Mrs. Owen T. Lind, Professor of Biological and Environmental Studies, Baylor University; Member, Tyler Prize Executive Committee
Dr. Walter A. Rosenblith, Institute Professor of Massachusetts Institute of Technology
Dr. and Mrs. Robert P. Sullivan, Director and Executive Vice President, Jaycor; Member, Tyler Prize Executive Committee
Dr. and Mrs. Jerome Walker, Assistant Vice President for Academic Affairs, University of Southern California; Director of Tyler Fund at USC
Mr. Leonard Lefkow, Public Affairs Officer, American Embassy
Mr. Coleman Nee, UNEP Permanent Representative, American Embassy

Tyler Prize

John and Alice Tyler Ecology · Energy Fund
University of Southern California, University Park, Los Angeles, CA 90007

April 26, 1982

Tyler Prize Nairobi Delegation

Dear Friends:

Since departure time for Kenya is rapidly approaching for Tyler Prize Executive Committee members, Tyler Prize recipients, and guests, let me explain the arrangements in Nairobi for the Tyler delegation. All members of our group have confirmed reservations at the Norfolk Hotel. It is a very popular old-style establishment in a garden setting 1 km from the city center. We hope you will be comfortable.

Our group will consist of Mr./Mrs. Carroll Wilson and Mr./Mrs. William Gould, this year's co-honorees; Mr./Mrs. Jimmy Stewart, this year's presenter at the awards banquet; and Messrs. Fareed, Rosenblith, Blackman, Lind, and Sullivan from the Executive Committee. I will be representing USC. The latter four of us also will be accompanied by our wives.

The group's schedule in Nairobi includes five gatherings. Members of the Executive Committee will have an advisory meeting at 4:00 p.m. Thursday, May 13 in the Norfolk Hotel. The Wilsons, Goulds, Stewarts and Committee members' spouses are invited to join us for cocktails and dinner at 6:00 p.m. so everyone can get acquainted.

The Tyler Prize press conference will be held at noon on May 14, in the Kenyatta International Conference Center auditorium. Messrs. Stewart, Wilson, Gould, Fareed and Walker will be seated at the table for the formalities, but all members of the Executive Committee are requested to be present. The conference will be followed by a buffet lunch for the press corps, and you all are needed to mingle and answer questions informally.

The Special Environmental Awards Banquet is being co-hosted by Alice Tyler and Mostafa K. Tolba, Executive Director of UNEP. The dinner is scheduled for 7:30 p.m. in the Intercontinental Hotel's ballroom on Friday, May 14. Four hundred guests are expected, including the heads of national delegations, the Secretary General of the U.N., and the President of Kenya. The program will include the presentation of three UNEP medals for service to UNEP in its first decade, and the presentation of the two Tyler Prize Commemorative Gold Medals by Jimmy Stewart. Messrs. Gould and Wilson will each have fifteen minutes for acceptance speeches. The evening will be covered by two film crews and 10-20 members of the world press. It promises to be a marvelous occasion.

Over the weekend, from Saturday morning until Monday afternoon, you are invited to take a safari. Reservations have been made for the entire group in the Masai Mara Game Reserve at the Keekorok Lodge, and further efforts are being made to get us all into Governor's Camp. Departure for the Mara is scheduled for 8:30 a.m. on Saturday, May 15. Anyone preferring the Kilaguni Lodge in the Tsavo National Park (West) or the Mt. Kenya Safari Club should notify me by phone by April 28, and we will request reservations for you.

Finally, there will be an introduction to the U.N. Environment Program's headquarters and activities on Thursday or Friday, May 13 or 14. A time will be announced in Nairobi.

Enclosed are two items from the Kenyan Consulate in Los Angeles, a map and a booklet which has a rough map of Nairobi. Hope they are helpful.

Bon Voyage,

Jerry

Jerome B. Walker
Assistant Vice President for Academic Affairs
Univeristy of Southern California

JBW/tz
Enclosures

ESECS **EUROPEAN SECURITY STUDY**

Carroll L. Wilson, Director

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136 Irving Street
Cambridge, MA 02138

Telephone: (617) 492-8033
Cable: AMCAD
Telex: 92-1473 MITCAM

April 30, 1982

Mr. T. Odhiambo
ICIPE
P.O. Box 30772
Nairobi, Kenya

Dear Tom:

The Tyler Prize people want to make a movie of various events in Nairobi. They would like to send a camera crew with us when Walter Rosenblith and I come to visit ICIPE on May 12th and 13th. I do not expect that we can keep a crew busy all that time but I am sure you will have ideas as to scenes they should shoot.

We'll be staying at the Norfolk and Mrs. Wilson will be accompanying me.

It will be a great pleasure to see you and Ojal again and to observe the great progress made since my last departure about eight years ago.

Sincerely,

Carroll

Carroll L. Wilson

CLW/sml

(Dictated by CLW,
signed in his absence)

THE INTERNATIONAL CENTRE OF
INSECT PHYSIOLOGY AND ECOLOGY
P.O. BOX 30772 NAIROBI, KENYA

ICIPE

Director:
Professor Thomas R. Odhiambo

REF: S7/DIROFF/51/6743

10th May 1982

Professor Carroll L. Wilson
C/O Norfolk Hotel
NAIROBI

Dear Carroll

VISIT TO NAIROBI AND ICIPE, MAY 1982

I have just received your letter dated 26th April 1982, and wish to confirm that we have now reconfirmed your hotel reservations at the Norfolk Hotel and cancelled the Silver Springs Hotel. I also appreciate your informing us about the changes in your programme for the week of the visit, and we will try to arrange the visit along the lines I suggested in my letter dated 5th April 1982.

My colleagues, and other staff that you have met before, will welcome you to the ICIPE and show you what we have been doing at the ICIPE. I myself, will be in Addis Ababa at the beginning of your visit on matters concerning the ICIPE as well as the United Nations University. I will be back on 12th May 1982 and hope to see you on the following day.

We look forward to your visit with pleasure, and hope that you will enjoy your encounter with the ICIPE again.

With best wishes

Yours sincerely

T R Odhiambo

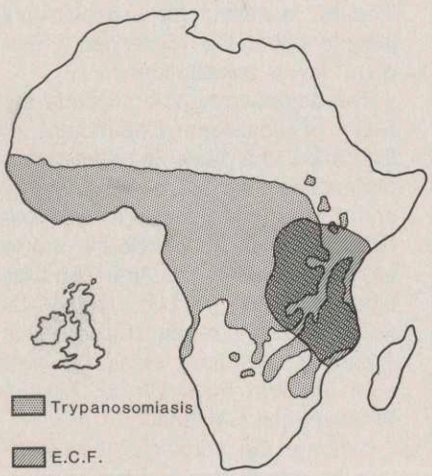
THOMAS R. ODHIAMBO
Director, ICIPE

TRO/mua

Nairobi Laboratory Fights More Than Disease

With a mandate to tackle two major animal diseases, an internationally funded laboratory has established a fine scientific reputation, but still has problems

Africa supports about 160 million cattle and 286 million sheep and goats; some of these are reared on large commercial ranches, but the majority provide the principal livelihood to subsistence farmers and pastoralists. Productivity—the lowest in the world—could be doubled, except for the prevalence of two widespread parasitic diseases, trypanosomiasis and a form of theileriosis called East Coast fever. Other forms of these two diseases are also important in large areas of Asia and South America. The International Laboratory for Research in Animal Diseases (ILRAD) was established in Nairobi, Kenya, in the early 1970's with the aim of succeeding with novel methods to control trypanosomiasis and theileriosis where traditional approaches had failed.



Cattle diseases in Africa

The map shows the geographical scope of trypanosomiasis and East Coast fever, with the United Kingdom as scale reference.

ILRAD's founders focused the laboratory's research on immunological control, for a long time the method of choice for bacterial or viral infections but still in its infancy in dealing with parasitic diseases. In the 7 years since the project began, ILRAD has encountered two major barriers to achieving its goal. The first is the work of nature, the second of man. ILRAD has yet to come to terms with either of them.

The first problem concerns the parasites themselves. Although the chances of immunological intervention with one of the diseases (East Coast fever) may now be promising, for the other they appear to be diminishing. The trypanosome is turning out to be so complex a piece of molecular machinery that conventional methods of immunization might well be impracticable. Intellectually, the challenge is ever more stimulating, but at a time when ILRAD's international backers are under increasing pressure to husband their budgets, the lack of imminent practical results could become embarrassing.

The second problem stems from ILRAD's status as an international research center in a Third World country. ILRAD is one of 13 centers that are embraced by the Consultative Group on International Agricultural Research (CGIAR), which has its secretariat at the World Bank in Washington. Like the other 12 centers, ILRAD has an international (mainly European and North American) team of researchers established in affluent surroundings in a relatively poor host country. A degree of envy of superior facilities and life-style is inevitable.

In addition, ILRAD is alone in the group of 13 centers in being mandated to do basic research only. The work of the laboratory does not involve the kind of technology transfer that, for instance, has given the International Maize and Wheat Improvement Center (CIMMYT), in Mexico, and the International Rice Research Center (IRRI), in the Philippines, such immediate and positive impact. As a consequence ILRAD is isolated from the activities of many national organizations and is perceived to be inward-looking and aloof. (The laboratory is now taking steps to overcome this problem.) Real affluence and apparent aloofness exacerbate each other in the onlooker's mind, and such an image does not make for political popularity in the international community.

Trypanosomiasis and East Coast fever are caused by blood-borne parasites that are transmitted to mammalian hosts by blood-sucking vectors, the tsetse fly in the case of trypanosomiasis and the tick in East Coast fever. Parasites travel from vector to mammal in saliva and from mammal to vector in ingested blood. Both diseases induce anemia and reduced productivity in infected mammals, and both frequently cause death.

The methods now available to combat these two diseases are inadequate in many situations. East Coast fever can be controlled by twice weekly dips in acaricides, which kill the tick vectors. This is expensive and impracticable for many African livestock producers, and the resistance of ticks to acaricides is an increasingly serious problem. Methods to control trypanosomiasis include regular drug treatment against the parasite and widespread spraying with insecticides to kill tsetse flies. Both approaches are expensive and neither is completely effective in areas of heavy infestation. Further drawbacks include increasing drug resistance and the possibility of environmental disturbance. "Assiduously carried out, such techniques can be successful," says Ross Gray, director general of ILRAD, "but in many cases the required standards of veterinary supervision and environmental control are simply unattainable." The great goal of an immunological approach is that a single inexpensive vaccination might give lifetime protection.

"The reason ILRAD was given its special mandate, and the reason we continue to hope for practical results, is that under certain conditions cattle acquire natural immunity to trypanosomiasis and theileriosis in the wild," says Gray. "Immunity is clearly possible, and our job is to find out if it can be carried out effectively, safely, and cheaply."

In its mammalian host, the parasite that causes East Coast fever, *Theileria parva*, passes first into white blood cells and then into red blood cells. Infected red blood cells reach the gut of the tick, a sexual stage is passed through, and eventually the parasite reaches the insect's salivary gland where tremendous multiplication occurs. One thoroughly infected tick contains enough parasites to kill 100 cattle.

Each year, half a million cattle are killed by East Coast fever in Africa, and yet it is already possible to immunize against infection. Cattle given an oxytetracycline-controlled infection of parasites develop a good solid immunity.

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sion on this point, the authors suggested in their briefing that the loose tubes probably did the damage that triggered the accident.

Aside from the problem with metal debris, the NRC inspectors noticed few mechanical failures during this accident. There were some foul-ups, however. The main process computer shut down for 16 minutes during the crisis, for unknown reasons. Two valves stuck open. Recorders that indicate whether valves are open or closed failed to operate.

The report also noted some nonmechanical failures. The chief of these was that the specified procedures for dealing with a leak of this type did not explain how to cope with the bubble that developed in the top of the reactor vessel. In fact, the procedures gave unhelpful instructions. Being clever, the operators at Ginna quickly grasped what was wrong and improvised their own solutions, or as the report puts it, their "deviations from procedures." Thus they brought the plant under control within 4 hours of the first sign of a leak.

The small amount of radioactive steam that escaped at the peak of the crisis presented almost no risk to the general public, the NRC report concluded. The worst exposure a person outside the plant might have received was about 15 millirems. For comparison, a medical x-ray gives the average adult patient about 103 millirems.—***Eliot Marshall***

Scrap NSF, Slash NIH, Conservatives Urge

A coalition of right-wing groups has proposed an alternative budget that, among other things, would eliminate the National Science Foundation (NSF) and cut support for the National Institutes of Health (NIH) by 50 percent. The proposal is an attempt to keep the Reagan Administration, which the groups helped elect, to a hard-line conservative economic agenda. The alternative budget would cut domestic spending by 30 percent and boost defense spending by 20 percent.

The proposals for NSF and NIH were not spelled out in detail, but an official of the National Conservative Political Action Committee, one of the leaders of the coalition, said that "a lot of this research, if it really is beneficial, should be done in the private sector." He added: "Federal tax dollars are just keeping professors employed."—***Colin Norman***

GAO Ignores Flaw in Concept of Space War

The General Accounting Office (GAO) in a secret report* to Congress has urged the Pentagon to speed the development of laser battle stations. There is just one problem. The authors of the report did not address the question of whether a nuclear blast in space might knock the battle stations out of action.

The much-publicized report, an unclassified digest of which has been made public, told Congress that "a constellation of laser battle stations in space has the potential to provide a credible air and ballistic missile defense system for the United States." To implement the goal, it suggested the armed services establish an Aerospace or Space Force.

Not mentioned in the report, according to GAO officials, was the issue of nuclear survivability. Nevertheless, a single nuclear blast in outer space would instantly set up an electric pulse of up to a million volts per meter in hundreds of satellites and battle stations, zapping their solid-state circuits and ending their ability to wage war. The mechanism behind the threat is simple. In space, radiations from a nuclear blast travel unimpeded over vast distances at the speed of light. When radiations strike a metal object, they knock out electrons and create a strong electric pulse (*Science*, 12 March, p. 1372).

"We did not go into the issue of nuclear effects too much," says Bernard D. Easton, the GAO official who headed the report team. "We looked at survivability to some extent, but not much in the nuclear area." In particular, Easton said the group did not address the survivability issue raised by the electric pulse from nuclear radiations. Asked why, he said, "I really can't say any more. You are getting into areas that are classified."

Perhaps Easton was taking his lead from President Reagan, who on 2 April signed an Executive Order that for the first time makes the "vulnerabilities" of systems, installations, projects, or plans relating to the national security candidates for the classification category of Top Secret.

—***William J. Broad***

**DOD's Space-Based Laser Program: Potential, Progress, and Problems* (C-MASAD-82-10, General Accounting Office, Washington, D.C., 26 February 1982).

Trial Set for Louisiana's Creationist Law

The trial of the nation's second creationist law has at last been scheduled for 26 July in Baton Rouge, Louisiana. If the law is judged to be unconstitutional, as in the recent decision in Arkansas, future legislative initiatives by creationists are likely to be brought to a complete halt.

A long list of plaintiffs, including legislators, educators, and religious leaders, is asking for a declaratory judgment that the "Balanced Treatment" law is constitutional.

The defendants, which include the State of Louisiana Department of Education, the State Superintendent of Education, the Board of Elementary and Secondary Education, and the Orleans Parish School Board, are to be represented by the American Civil Liberties Union (ACLU). The ACLU will be hoping to repeat its success in Arkansas, this time aided by New York law firm Paul, Weiss, Rifkind, Wharton, and Garrison.

Although the wording of the Louisiana law differs from that in Arkansas, the ground covered in the trial is likely to be very similar to the case heard in Little Rock. Meanwhile, it is still possible that the Louisiana case will never reach the court. "We will move for summary judgment," says Jack Novik, lead counsel for the ACLU, "and the judge may be able to come to a decision based on written material, and this of course includes the Arkansas decision."

A tangle of lawsuits and motions by both sides makes the Louisiana situation far more complicated than the one in Arkansas, and it could well be that the trial will not begin as scheduled in July.—***Roger Lewin***

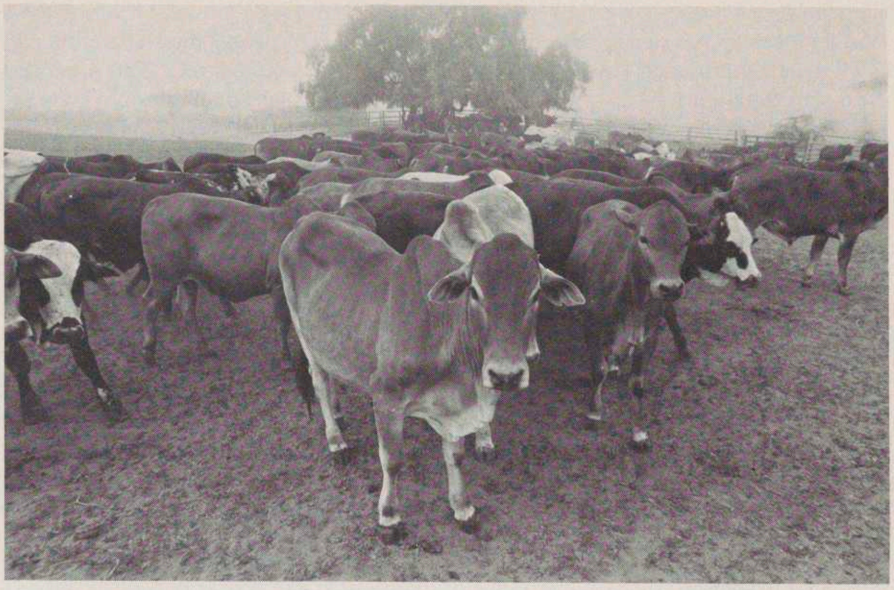
"There are a couple of difficulties with this approach," says Gray. "The first is a real danger of setting up a carrier state in immunized animals. And the second is that, inevitably, we are dealing with more than one strain of parasite, and as yet we don't know how many there are." This type of immunization requires close veterinary supervision, according to Gray, and is therefore too expensive for widespread application.

A second approach is to inject cattle with white blood cells that are infected with parasite at the macroschizont stage. Again, the induced immunity is very good, but there are problems. Immunity can be established with as few as 100 cells, but only if the injected blood is the animal's own. If the blood of another animal is used, then the dose has to be at least 10 million cells. Neither path is practical for routine immunization.

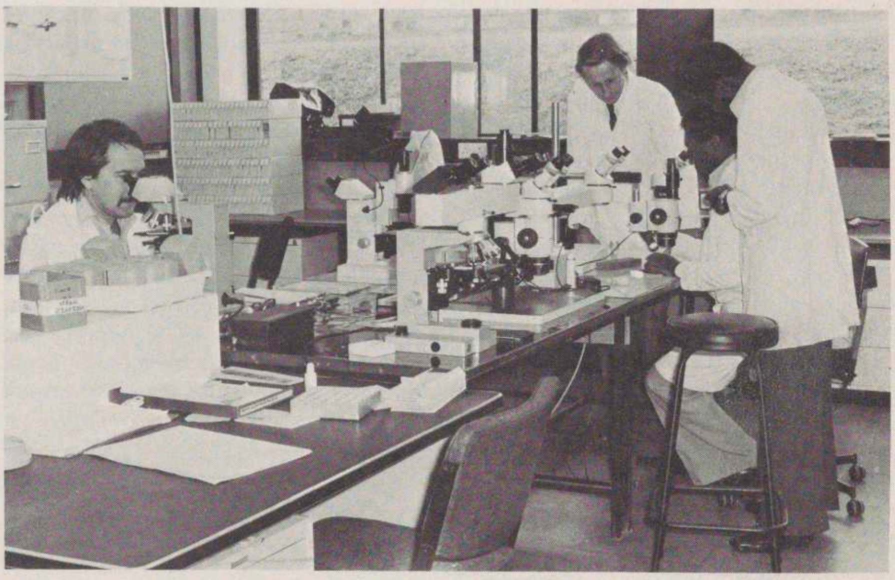
The more general issue with East Coast fever is determining more precisely the nature of the immune response. Antibodies are apparently involved in the sporozoite challenge, but to which antigens is not clear. Parasite-infected white blood cells provoke a cell-mediated response, apparently to a combined parasite and host antigen, the identity of which remains elusive.

"If we could only identify an effective antigen," says Gray, "we could perhaps shift some of the molecular biology emphasis from trypanosomiasis to East Coast fever." Through cloning the individual genes for important antigens it would be possible to manufacture large quantities of antigen for use in safe immunization. Gray is reluctant to "put a date on significant progress," but the first quinquennial review of ILRAD, reported at the end of 1981, anticipates a major breakthrough "within the next five years."

By contrast with East Coast fever, trypanosomiasis is more thoroughly understood and yet less accessible to immunological intervention. At its most basic, the problem is one of numbers. There are three species of cattle-infective trypanosomes, *Trypanosoma brucei*, *T. congolense*, and *T. vivax*, each of which has an unknown number of strains, although probably of the order of 20. Prospects for effective immunization decrease as such numbers increase. As if this were not bad enough, the trypanosome changes its antigenic coat at frequent intervals, thus evading a sustained host-immune response and making prospects for a vaccine yet dimmer. Each strain has a set of at least 100 coat antigens, and in some cases it may be as high as 1000. The order in which new



Cattle productivity is reduced by East Coast fever and trypanosomiasis



ILRAD is the best equipped laboratory in Africa

Part of ILRAD's elegant environs

coat antigens appear during infection follows a pattern for each strain, but is by no means invariant.

The means by which the parasite changes its clothes so neatly is yet to be elucidated, but some clues are emerging. Each parasite has a full complement of antigen genes, some of which are arranged in tandem. Expression of some of the antigens involves DNA rearrangement, including the production of a temporary extra copy. Rearrangements sometimes involve modification of part of the gene's structure. Scope for variation is large, but what imposes some degree of order on the sequence of gene expression is not yet known. What is known, however, is that the host's immune response does not induce the switch to a new coat; this appears to be a built-in property of the trypanosome.

"There's clearly no real hope of producing vaccines to all these variable antigens," concedes Gray, "but the one glimmer of hope we do have is that the metacyclic stage, in which they are transmitted by tsetse flies, has only a limited repertoire of antigens." When the parasites of any given strain enter the insect host, they emerge with just one of perhaps 10 to 15 possible metacyclic antigens. "It might be possible to produce a vaccine cocktail to this number of antigens," Gray suggests, "but you have to remember that even in one geographical area there are likely to be several strains of trypanosome." Overall, the problems are immense. "The prospects of conventional immunoprophylaxis are very slim indeed," Gray concludes.

Research facilities at ILRAD must be the best in Africa and rival those in any European or North American country. Molecular biology, biochemistry, and cell biology are bringing tremendous technical pressure to bear on the recalcitrant problems of trypanosomiasis and East Coast fever. "What sustains us," says Gray, "is that the technology is changing and so we no longer have to think in terms only of the traditional type of vaccine. We can think about making antigens and even manipulating the immune response to be more effective."

A combination of circumstances has conspired to make ILRAD's history somewhat turbulent. For a start, Gray is the laboratory's fourth director general in 7 years. The first, E. Sadun, died before he assumed office. Sadun's successor, James Henson, resigned during his second 2-year term. The third, Anthony Allison, was asked to resign after less than 2 years.

Compounding the inevitable practical problems involved in setting up a new laboratory in a Third World country, there have been accusations of administrative incompetence, racism, scientific poaching, and lack of leadership. ILRAD's beautifully manicured lawns were the site of more than one protest demonstration during Allison's directorship, for example.

Opinions differ, but the consensus in the laboratory is that Allison inherited an administrative quagmire in which no director could have survived, even one lacking Allison's strong and demanding personality. There is no doubt, however, that in spite of his curtailed directorship, Allison substantially enhanced the scientific standing of the laboratory.

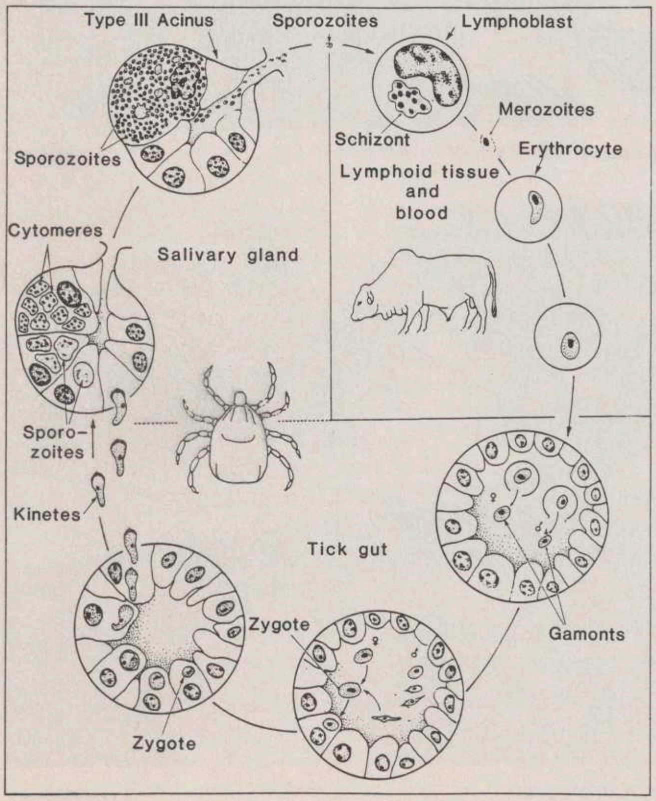
By the time Allison left ILRAD at the end of 1980, both the director of administration and the financial controller had also been asked to look for jobs elsewhere. Roger Rowe brought his extensive experience at another CGIAR center to the vacated position of director of administration, and some degree of order and stability began to settle on the beleaguered laboratory. Ross Gray, who had been a runner-up to Allison in the 1978 selection, took over as director general in November 1981.

Remarkably, throughout all the upheavals, the laboratory continued to produce good science and consolidated its growing international reputation. For instance, the work there has made it possible to cultivate two species of trypanosomes through their full life cycles. Four genes for trypanosome variable antigens have been cloned and the protein for one of them expressed. Unusual aspects of trypanosome surface antigen biochemistry have been discovered. The immune response to East Coast fever has been partially elucidated. Elegant electron microscopy has revealed important details of the *Theileria* life cycle. By any standards the list of achievements is long and impressive.

Gray describes ILRAD as "the trypanosomiasis and theileriosis university of Africa." That may well be so, but his appointment, particularly combined with Rowe's, is certain to shift the future direction of the laboratory, a shift that is probably crucial to ILRAD's long-term survival.

Gray says his first objective is to get his researchers to be more aware of the diseases they are supposed to be addressing. "The molecular biologists and biochemists are tremendous scientists," he says, "but they are not as familiar with the real field situation out there as I am." He is not suggesting they put on big boots and go tramping around cattle. "People can work at whatever level they like, as long as it is in some way related to producing an immunological solution. If people remember that just once a week it will be a start."

Although ILRAD's focus has been on



Life cycle of the tick

basic research, the laboratory is not as distant from the practical world as most research institutions are. There are not many facilities that have a P3 containment laboratory within hailing distance of 300 head of cattle. "This is one of the great strengths of the laboratory," says Max Murray, a senior ILRAD scientist. "We can go from the gene to the sick animal on the same site."

Nevertheless, Gray worries that most researchers' lack of contact with the field means that they have not concentrated their efforts in the right direction. "For instance, there's a great emphasis of work on *Trypanosoma brucei* as compared with the other species," says Gray, "and this happens to be the least important of the three in terms of disease." The researchers counter this by insisting that as *T. brucei* is the easiest to work with it provides a model from which to move on to the more difficult and more important species. Gray acknowledges the logic, but still finds it exasperating.

Gray plans to extend ILRAD's reach into the field in epidemiology and in the study of cattle that are naturally tolerant to trypanosomiasis. A small epidemiology project had already been planned when Gray arrived and was designed to try out some field tests that will help in identifying trypanosome strains. "We are doing this on a very carefully managed dairy ranch in the coastal region of Kilifi," says Murray, "where the density of tsetse flies is low and the number of strains of trypanosomiasis is probably limited."

Murray sees the ranch's relative freedom from disease as an advantage, as it simplifies the experimental procedure, whereas Gray sees the same attributes as a drawback. "I can understand their reason for doing it this way," says Gray, "but I would have preferred an area that had all the components of the trypanosomiasis complex, even though it is more difficult to analyze." There is clearly some tension between director and research staff, but no obvious sign of antagonism.

Researchers and herders have known for a long time that certain breeds of cattle are able to survive in tsetse areas where others cannot. One good example of these so-called trypanotolerant cattle is the West African N'Dama. Gray says that ILRAD will have to start looking at trypanotolerance much more seriously than hitherto and that existing collaboration with the International Livestock Center for Africa (ICLA) will have to be developed further. No one knows why N'Damas and other trypanotolerant animals are able to combat the trypanosome; their immune defenses might be better attuned to the parasite, or they might have a more general physiological resistance to the effects of infection. Clearly, a thorough understanding of the mechanism of tolerance might provide some important insights in combating the disease in susceptible animals.

"Alternatively," suggests Gray, "perhaps we should simply work out ways of screening for resistance and then carry out some good breeding programs." Gray knows that this would not be a completely satisfactory solution because no cattle are fully resistant to the disease. "It would, however, bring immediate results," he says, thus making the point that practical results are just as much the business of ILRAD as is understanding the fundamentals of the diseases.

Before joining ILRAD, Rowe spent several years at the International Potato Center in Lima, Peru. "Although we were based in Peru," says Rowe, "we had seven regional centers throughout the world. Our whole mode of operation was to look outward and to learn from people in the field." ILRAD does not work like this because of its mandate to do basic research. The laboratory is therefore much more isolated from its host country than is the case with other centers. If it is maintained, this insularity could endanger the laboratory's future, says Rowe.

Most CGIAR centers devote a good deal of effort to technical training so that the work of the center is disseminated to the countries that need it. "Centers should not be solving a host country's problems," says Rowe. "They should be helping a country get into a position to solve its own problems." Again, ILRAD is a little different because of the nature of its research. "Yes, we should be training people," says Luciana Rovis, one of ILRAD's founding scientists, "but we should be training the country's professors, not people who will treat sick animals." As things stand at the moment, Rovis is right. ILRAD is more attuned to turning out professors than people skilled in animal husbandry. But, contends Rowe, ILRAD must seriously contemplate extending its activities beyond the iron gates of its elegant research compound.

The recent quinquennial report noted the laboratory's minimal commitment to training. And at a meeting of centers and donors at the end of last year in Washington, ILRAD's training efforts were described as "pitiful." Gray says that he is conscious of the problem. "At the very least," says Rowe, "we should have a good working relationship with the people who would be responsible for deploying a vaccine, supposing we were to come up with one." To this end, Tony Irving, one of ILRAD's researchers, helped to establish last year a group known as the Nairobi Cluster, a collection of a dozen or so Kenyan institutions involved in work on trypanosomiasis and East Coast fever. "It's a start," says Rowe, "but there is a long way to go."

"I hope they continue to do excellent work. But what my ministry is interested in is something practical—and fast."

Until now the 13 centers supported through the CGIAR have not suffered financially, but the current downturn in the world economy is beginning to make donor countries and organizations measure their priorities. Progress and budgets will be considered at a meeting of center personnel and donors to be held in Paris at the end of May, and final pledges for the next financial year will be made at "Centers Week," to be held in Washington in the fall. A serious squeeze will be felt for the first time; ultimately funding for one or more of the centers may end. There would be a political outcry if, for instance, CIMMYT or IRRI were to be axed, but what about ILRAD? With so uncertain an impact on the world's problems, the laboratory might find few political supporters.

Ishmael Muriithi, a director in the Kenyan Ministry of Livestock Development, sums up ILRAD's achievement and predicament. Muriithi, a former board member of ILRAD, told *Science*: "I hope they continue to do excellent work. But what my ministry is interested in is something practical—and fast." Clearly, the emphasis on basic research written into the ILRAD mandate in 1973 could bring serious problems to the laboratory in these times of great economic stringency.—Roger Lewin

Portraits of a Parasite

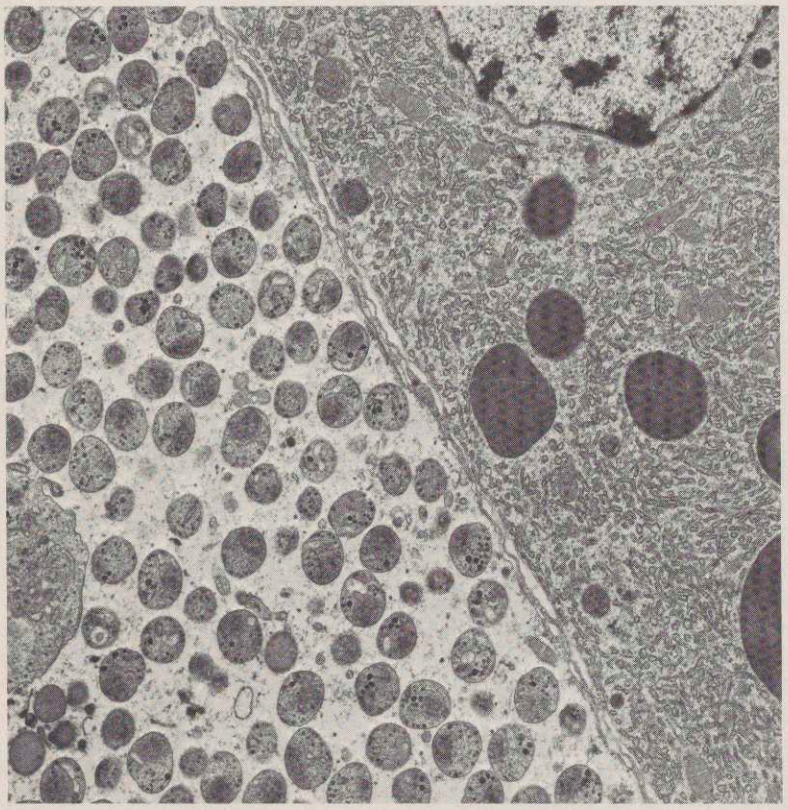
Don Fawcett, former chairman of Harvard's Anatomy Department, has been coaxing some excellent images from ILRAD's new electron microscope facility. With the help of Stephen Doxsey, and in collaboration with the Kenya Agricultural Research Institute, he has clarified some of the key events in the life cycle of *Theileria parva*, the causative agent in East Coast fever.

A crucial episode in the infection of cattle by *Theileria* is the entry of sporozoites into the mammalian host's white blood cells, a process that has been visualized only dimly in light microscopy and which was thought to have taken several hours. Fawcett's electron microscopy has revealed that the interaction of parasite and blood cell is highly specific, and probably involves the binding of ligand to cell receptor, with entry being complete in about 5 minutes (see photographs at right).

The infected white blood cells are unable to destroy the sporozoites because, by the time defensive lysosomes have formed in the cell, the invaders have rid themselves of the envelope of host cell membrane that is necessary for lysosome attack.

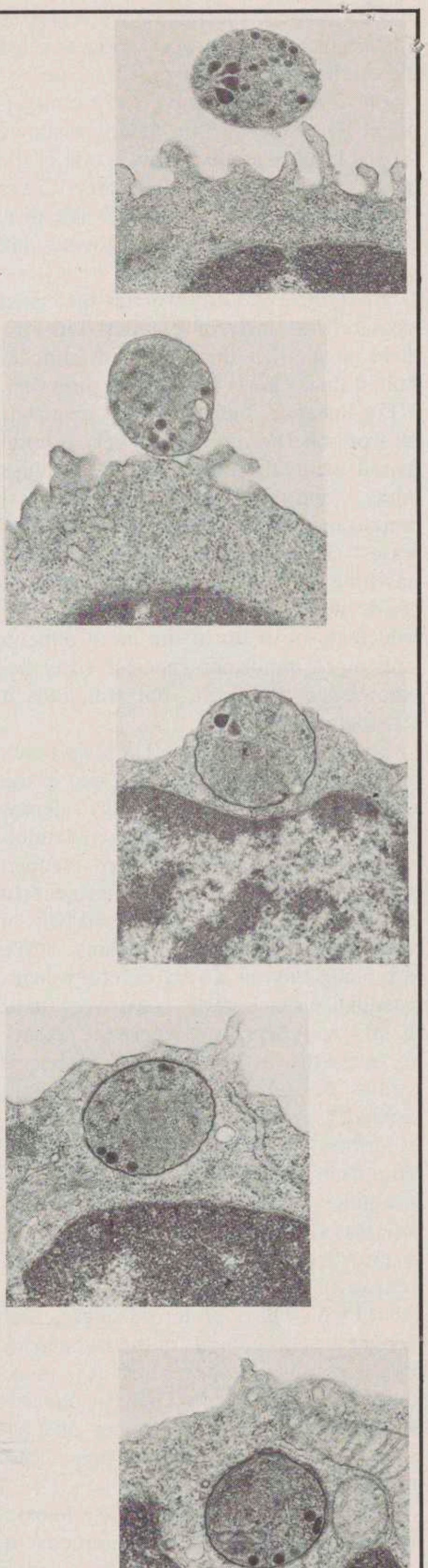
The parasite's odyssey through the tick vector takes it from the gut to the salivary gland, where sporozoites develop. Fawcett has shown that the parasite colonizes just one specific cell type in just one of three different groups of cells (acini) that make up the tick's salivary gland. Once invaded by a single parasite, the salivary gland undergoes what Fawcett describes as "one of the most dramatic transformations in cell biology."

The cell enlarges as the parasite forms a huge ramifying multinucleate bag; the metabolism is switched to serve the needs of the proliferating parasite, specifically in laying down massive stores of energy-rich glycogen; and eventually its cytoplasm is all but obliterated as upward of 50,000 sporozoites are formed by fission.—ROGER LEWIN



Parts of a normal cell (right) and a parasitized cell (left)

The extensive endoplasmic reticulum has disappeared in the parasitized salivary gland cell, which eventually will contain up to 50,000 sporozoites.



Sporozoite enters lymphocyte

The sporozoite binds tightly with the lymphocyte membrane and enters the host cell in about 5 minutes, a process that is not slowed significantly in the cold (sporozoite diameter: 1.5 micrometers).

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OMAR JOHN FAREED, M.D.
President

April 29, 1982

Mr. Carroll L. Wilson
130 Jacob Street
Seekonk, Massachusetts 02771

Dear Carroll Wilson:

Ambassador W. Harrop^{x} has most cordially extended his kind invitation for you and Mrs. Wilson to be his honored guests for luncheon at his home in Nairobi, Kenya on Thursday, May 13th.

We shall welcome you to Kenya for the Tyler Ecology-Energy Prize.

Kindly contact me at the Norfolk Hotel upon arrival.

Sincerely yours,

Omar

Dr. Omar Fareed

OJF/dn

x US Ambassador to Kenya.

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Massachusetts
Institute
of Technology

TECH TALK

C.L. Wilson To Receive Tyler Prize

By ROBERT C. Di IORIO
Staff Writer

Professor Carroll L. Wilson, a enowned technologist and manger in the fields of ecology and orld energy supplies, and Southrn California Edison Co. have won ıe 1981 John and Alice Tyler Ecoloy/Energy Prize. Each will receive 100,000.

The Tyler Prize was established in 973 by the late John C. Tyler, coounder and chairman of the 'armers Insurance Group, and his 'ife, Alice Tyler. The recipients are ominated and selected by a panel f educators, scientists of international reputation and professional ersons.

Mrs. Tyler will present the 1981 wards to Professor Wilson and epresentatives of Southern Califoria Edison later this year in Los ıngeles.

Professor Wilson, who developed unique process for involving leadrs in industry and government

Professor Wilson

from a dozen or more countries in global assessments, has spent much of his career seeking solutions to world energy and environmental problems. In 1946, Professor Wilson served as secretary of a group that developed the first plan for international control of atomic energy. The plan became the basis of the US proposals to the United Nations Atomic Energy Commission. As the first general manager of the US Atomic Energy Commission (1947-1950), Professor Wilson took a leading part in establishing a civilian-managed program including atomic power for submarines and civilian electricity, development of improved weapons and the use of radioactive isotopes for scientific and medical uses.

Following an industrial career that included uranium mining and the manufacture of nuclear fuel for submarines, he came to MIT in 1959 as professor in the Sloan School of Management.

Beginning in 1969, Professor Wilson helped establish and operate the International Centre for Insect Physiology and Ecology in Nairobi, Kenya. This laboratory is dedicated to basic research aimed at producing species-specific, biodegradable pesticides. As the US delegate and chairman of the Committee on Research Cooperation of OECD (the Organization for Economic Cooperation and Development comprised of 23 industrial Western nations), he helped launch a number of projects attacking environmental problems, such as toxic chemical trade and packaging, acid rain, and air and water pollution. As a member of the UN Advisory Committee on the Application of Science and Technology for Development, he helped to formulate the basic plan for the first UN Conference on Human Environment, held in Stockholm in 1972.

Professor Wilson organized a study group of 40 people from many disciplines which met for a month in 1970 in Williamstown to consider critical global environmental problems. Their report was published in October 1970 as "Man's Impact on the Global Environment: Report of the Study of Critical Environmental Problems." The following year he brought together 35 atomospheric scientists from 15 countries at Stockholm. Their assessment was published in September 1971 as "Inadvertent Climate Modification: Report of the Study of Man's Impact on Climate."

These two landmark studies summarized existing knowledge, identified critical gaps in that knowledge, and set priorities for work to be done. These research agenda have influenced priorities in many countries during the past decade.

In 1973 Professor Wilson delivered the Elihu Root lectures at the Council on Foreign Relations and described a plan for energy independence for the United States, proposing a quadrupling of coal output, conversion of a billion tons a year to gas, and expanding nuclear to 10 percent of energy supply, but putting all new plants underground. He also proposed a synfuels corporation and a special RFC-type of financing mechanism, both to be dissolved after 10 years. He also described the process he had conceived for making global assessments–one which would engage industrial and governmental leaders from a dozen or more countries.

To demonstrate that process, Professor Wilson enlisted 35 leaders from 15 countries to study global energy prospects to the year 2000. In May 1977, after nearly three years of work, the Workshop on Alternative Energy Strategies (WAES) released its report, "Energy: Global Prospects 1985-2000."

WAES was followed by the World Coal Study (WOCOL), which Professor Wilson organized in 1978. The WOCOL report, "Coal: Bridge to the Future," published in May 1980, found that coal could be mined, moved and used in ways that would meet the most stringent environmental standards of any country and still cost only half as much as oil.

"The projects which led to this award were the results of dedicated efforts by many people from many countries. I thank them for their superb support. An essential element for success was the unwavering support of MIT and its leaders, especially its chairman, Howard W. Johnson. I am pleased to have this occasion to thank all of my collaborators."

William R. Gould, SCE board chairman and chief executive officer, says the company is "humbly grateful" to be the first corporate winner of a Tyler Prize. All previous recipients have been distinguished individuals, including the late Dr. Arie J. Haagen-Smit, the Caltech professor credited with discovering the chemical nature of photochemical smog, and Dr. Rene Dubos, whose pioneering research in the 1930s led to the development of antibiotics.

The utility company was recognized as a "corporation vitally concerned and active in energy conservation programs and alternative energy sources." The announcement said the company won the prize "for its distinguished record of working to protect the environment and the company's recent commitment to aggressively develop renewable and alternative energy sources."

The $100,000 that SCE will receive with its prize will be divided and presented to USC and the California Institute of Technology, Gould has announced.