Boyce Thompson Institute for Plant Research, Inc.

See Science, *22 September, for details about registration at the meeting.*

Man's propensity for reproduction completely exceeds his capacity to produce essential goods. Most people are slowly becoming aware, and a few of us have become genuinely alarmed, that the demands of an ever increasing population, freed of much of the scourge of war and disease, are beyond our capabilities. Population increases geometrically while the search for raw materials has to be pushed arithmetically farther and farther out into the plains, up into the mountains, deeper into the earth, and out into the sea.

The Boyce Thompson Institute for Plant Research was founded because a man of great foresight saw these elemental facts clearly some 50 years ago, long before the rest of us. Mr. Thompson felt deeply that man's capacity to produce food and fiber had to be increased by scientific investigation. If this was not done, society would degenerate into anarchy and man would sacrifice the fruits of freedom.

This clear thinking proceeded to the idea that an institution should be founded where the basic principles of plant life could be explored. The quickest solution to the principal problems of life is to assign someone to their investigation who is armed with a full understanding of the basic principles; so the urgent need was to resolve the fundamental facts regarding growth, multiplication, nutrition, response to disease agents, influence of foreign chemicals in the environment, interaction of living cells to specially designed molecules conceived by or discarded by man.

The Boyce Thompson Institute has proceeded since 1924 on a course of purposefully oriented basic research. Scientists are assigned a major area of investigation and given great freedom to explore all facets of the interrelationships of the plant, insect, and disease agent in that prescribed area. These scientists from the earliest days set out to explore the physical and chemical forces operating against or within the living subject so they would understand the nature of the reactions going on before their eyes. Certainly neither Mr. Thompson nor the early management had any clear concept of investigating cell physiology and molecular biology as we know them today but intuitively they were orienting the Institute toward these areas in seeking a better understanding of life forces.

A group of about 40 senior scientists (Ph.D. level) supported by a body of research associates, research assistants, and laboratory aides work in modern facilities at the principal laboratories located in northwest Yonkers, New York, on the northerly outskirts of New York City overlooking the Hudson River to the west. Behind this group of about 100 laboratory operators is a strong supporting staff in clerical, mechanical, greenhouse, gardening, photographic, library, and business administration services.

From the earliest day these services have been designed to relieve the scientists and their staffs of every inconvenience or diversion of effort possible. Periodic reorientation of research programs calls for remodelling and reequipping of laboratories by the engineering staff and the design of new equipment. The illustration division drafts all graphs and prepares all illustrations according to approved standards from rough copy. A complete editorial and publication service is provided, including the publishing of the quarterly journal *Contributions from Boyce Thompson Institute*. The basic philosophy of management is that research is not completed until published; this journal is maintained so papers can be released in the best possible form within 2 to 3 months after they are written. The library staff checks every citation back to the original to eliminate errors. The editorial staff goes over them for grammar after they have been approved by a committee of the author's colleagues.

The Institute adheres to a policy that research never operates strictly according to professional disciplines. The solution of a disease problem, for example, may call for the services of a plant pathologist, a plant physiologist, and a chemist. Therefore, research is organized into a number of programs of a flexible nature which may be modified from time to time. The programs in force at present and their program directors are: Plant Chemistry, Leonard H. Weinstein; Physiology of Parasitism, Richard C. Staples; Insect Physiology and Virology, Karl Maramorosch; Plant Pathology and Special Projects, George L. McNew; Bioregulant Chemicals, Dewayne C. Torgeson; Biocidal Chemicals, Larry E. Limpel; and Forest Entomology, J. P. Vité. Administrative coordination is provided by George L. McNew, managing director, and S. E. A. McCallan, secretary of the corporation.

The Plant Chemistry program is primarily concerned with the environmental health of plants and the regulation of plant growth by synthetic and natural chemicals. A careful study has been made of the physiological and biochemical effects on plant life of air pollution by various types of fluorides. Tolerance of about 100 different species of plants has been determined and the threshold concentration of dosage × duration has been determined for many of the annual and perennial crops at different stages of development. A number of studies on the biochemical responses of plants to atmospheric fluorides have been carried out. Current research is being pushed on the mediating effects of environment such as atmospheric conditions and soil fertility on response to air pollutants and the interaction of various combinations of pollutants.

The Physiology of Parasitism program is oriented strongly toward the study of obligate parasitism in the rust fungi and other classes of obligate para-

sites. The basic biochemistry of these organisms with particular attention to protein synthesis, turnover in nitrogen metabolic pool, differences in nucleic acid metabolism of the parasite, and changes in the sugar metabolism of the host are under investigation. Other lines are concerned with the biochemistry of resistance of soybeans to nematodes and of strawberries to the red stele fungus. The effects of parasites on cell growth and differentiation of self-limiting and sustained gall development are being explored.

The Plant Pathology and Special Projects program is concerned with the nature of virus diseases, a study of the biochemical and biophysical attributes of fungicidal molecules such as the hydroxyquinoline series, the mechanism of fungicidal action, the processes of protein metabolism and nucleic acid activity during the breaking of dormancy in seeds and buds, and the pathways of synthesizing amino acids and nucleotides.

The Insect Physiology and Virology program stresses the effects of plant viruses on their insect vectors. A careful study has been made by physiological and electron microscope examination of leaf hoppers and other insects from the time they acquire viruses until they are capable of transmitting them to determine the sites of multiplication, possible migration, and eventual effects of the virus on the vector which is, in substance, not only an alternate host but probably a primary host of the virus. These investigations have been extended in recent months to a study of nematode vectors and the finer structure of plant nemas. Other investigations in this program are concerned with pathology of insects induced by viruses and by fungi. In the latter area, study is being concentrated on the nature of toxins produced by *Metarrhizium anisoplae*.

The response of free-flying bark beetles to pheromones (produced in logs, extracted from the beetles, or produced synthetically) is determined by olfactometers in the Institute's experimental forest at Grass Valley, California.

The program in Bioregulant Chemicals is concerned with the design of biologically active molecules of potential interest—insecticides, fungicides, herbicides, nematocides, bactericides, and plant regulants. The ultimate purpose is to develop new concepts regarding the relationship of structure to activity and to determine the factors responsible for selective toxicity in a wide assortment of chemical classes. Since it is beyond the financial resources of the Institute to design and synthesize the thousands of chemicals required for this research, collaborative arrangements have been made with industrial organizations which are strong in organic chemistry but receptive to assistance from biologists who have wide experience and even wider viewpoints in this area. One of the projects is oriented strictly toward a study of biological degradation of herbicidal molecules by soil microorganisms.

The Biocidal Chemicals program also is oriented toward developing biologically active molecules on a cooperative basis with the Diamond Alkali Company. The research has been strongly oriented toward a study of chlorinated benzonitriles and their effect on plant growth and pests. The program provides funds for basic studies on mechanism of action of the outstanding new compounds coming from this investigation to determine the mechanism of plant penetration and other factors. An organic chemist collaborates with the Institute biologists in developing new concepts on mode of action of fungicides. They are establishing statistical analyses for predicting the effect of different substituents and nucleophilic changes on selective activity based on cell permeation and kinetics of reaction with cell constituents.

The Forest Entomology program is concerned primarily with the attack of bark beetles on different species of pines. Research was initiated 11 years ago by establishing a laboratory in a 700-acre forest on the outskirts of Grass Valley, California, some 60 miles from Sacramento on the western slope of the Sierra Nevada Mountains. The research of Institute entomologists attracted the attention of forestry interests in east Texas and Idaho who requested similar laboratories be established in their areas. Through cooperation and financial assistance of these people an experimental forest was acquired 8 miles west of Beaumont, Texas. A small, fully equipped, air-conditioned laboratory was constructed with full-time entomologists in residence. A summer field station is operated at Headquarters, Idaho, by the California staff.

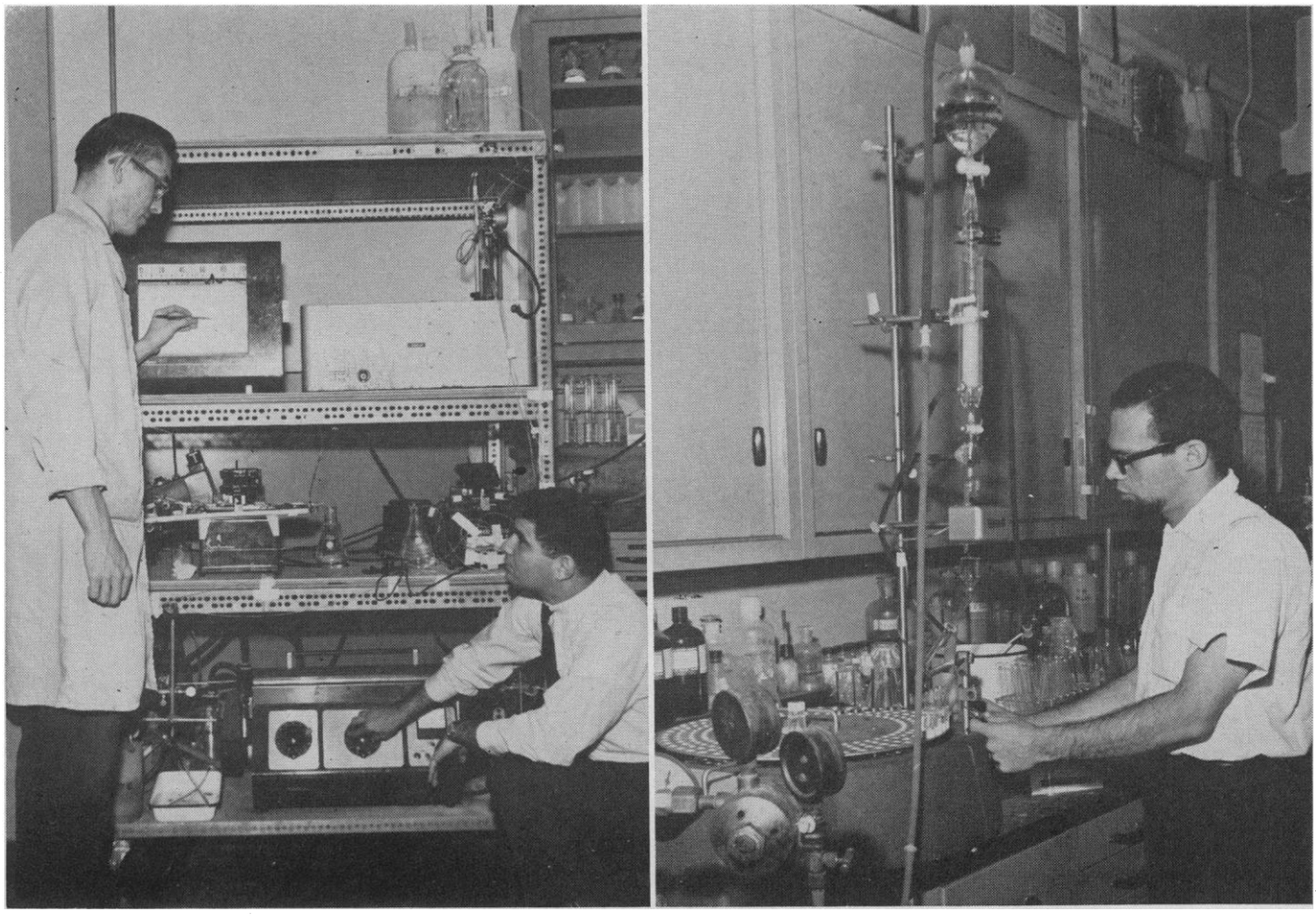
These three installations have led to a coordinated program in which cooperative research is being done on *Dendroctonus brevicomis* on *Pinus ponderosa* in California, *D. frontalis* on *P. taeda* and other species in Texas, and *D. ponderosae* on *P. monticolae* in Idaho, and their several associated species of *Ips* in the three localities. In 1961 the California staff demonstrated conclusively that the two major species of their area (*Ips confusus* and *D. brevicomis*) produced volatile pheromones. The two pheromones were differentially selective for the two species up to distances of approximately half a mile. Research also showed that these two attractive forces were produced in the posterior third of the hindgut but only after the insect had fed on phloem tissue. It has since been shown that the other two species of *Dendroctonus* produce a pheromone and the three pheromones are cross-attractive among the three species. Within the past few months full proof has been secured that the major component in this attractive substance is transverbenol but it requires supplementary essences from the invaded tree to exercise its full power. A beetle-invaded log that has lost its attractiveness will attract thousands of beetles once it is treated with synthetic transverbenol. For some reason which is not clear, only the female beetle produces the attractant based on transverbenol. The male produces the analogous, more highly oxidized structure of verbenone which is not attractive. The interesting fact revealed to date is that male *Ips confusus* also produces a ten-carbon terpene alcohol (molecular weight, 154) with a branched chain. However, the female *D. frontalis* produces a bicyclic, ten-carbon terpene alcohol (molecular weight, 152); the male *D. frontalis* produces a bicyclic, ten-carbon ketone (molecular weight, 150). Research is proceeding with characterization of secondary components of these pheromone mixtures and the relationship of tree physiology to their generation.

Field trial on the effects of air pollution by fluorides on photosynthesis and respiration of sorghum. Portable, plastic-covered houses are placed over the plants at the desired stage of growth and supplied with metered amounts of fluorine. The air in each house is automatically sampled for carbon dioxide content every hour through aluminum tubes running to the infrared analyzer in the shed.

To implement the kind of research the Institute is now pursuing, it has been necessary to equip a variety of laboratories and expand the specialized research services. Analytical services under an experienced chemist have been developed to support the biologists. The facilities include an assortment of gas chromatographs, infrared, and recording ultraviolet spectrophotometers, mass spectrophotometer, preparative and analytical ultracentrifuges, and other equipment. Two electron microscope laboratories have been set up to supplement each other, the last of which was activated this summer. The individual laboratories have been equipped with radiometry devices including scintillation counters and refrigerated ultracentrifuges for handling macromolecules. Automated preparative and analytical devices have been installed for amino acids, nucleotides, and fluorine analysis. Several of these are based on new methods and procedures developed at the Institute. Complete systems are available for automated analysis of phosphorus and nitrogen metabolism where tracer elements are being used. The mass of data coming from these highly instrumental laboratories have necessitated the establishment of a computer and statistical consultant service for the staff.

The Institute operates as a privately endowed, tax-exempt organization. The endowment has a current value of about $25 million and the current annual budget is in the order of $2 million. The Institute owns and operates a 27-acre experimental farm in Yonkers, a 450-acre farm and recreation area for the staff in Dutchess County some 75 miles north of the laboratories, a 700-acre forest in California, and a 200-acre southern pine forest in Texas.

Policies of the Institute are established by a board of 12 directors which include two staff members, the managing director, and secretary. Decision as to program development and operational procedures is vested in the managing director and the program directors which he appoints. The Board of Directors is appointed annually by a self-perpetuating board of Members of the Corpora-



(Left) Semiautomated method developed at the Institute for analyzing tissues for fluorine. (Right) Methods of analyzing plant tissues for organic fluorides are being perfected by Peter Preuss who will use the results in a doctoral thesis on the unique synthesis of monofluoracetic acid by *Acacia georgianae*.

tion. These board members also serve as trustees of the foundation for the State of New York.

One of the unusual managerial and management features of the Institute is an annual review of research progress and management practices by a Committee of Scientific Advisors. A group of distinguished scientists and administrators from other institutions, under the chairmanship of one of the scientists on the Board of Directors, meets at the Institute for 2 days each spring after reviewing the annual summary of progress on each research project and the annual report of the managing director to the Board. They receive verbal reports and confer with the scientists and management, discuss with management the basic philosophy and policies of the program, and submit a report to the Board of Directors. The advisory committee is chosen to usually include a representative of a land-grant college, a liberal arts university, the U.S. Department of Agriculture, and an industrial or independent institute research. An effort is made to choose these men so that they will have had significant research experience in the several areas of the Institute's activities such as plant pathology, virology and nucleic acid metabolism, entomology, and pesticides. Present members are James H. Jensen (president of Oregon State University), Max Lauffer (Mellon Distinguished Professor of Biophysical Chemistry of the University of Pittsburgh), Edward F. Knipling (director of Entomological Research Division, ARS, U.S. Department of Agriculture), and Edward R. Weidlein (director emeritus of the Mellon Institute).

The strong emphasis in the several programs today is oriented toward biochemical mechanisms and ecology. The Institute staff does not consider any practical problem to be beneath its dignity and is willing to explore the needs of research in any area. But the management and trustees feel the greater contribution will still come from doing basic research provided it is properly conceived and oriented. There is a strong feeling throughout the Institute that we live in a golden age of biological science where we have been given unbelievably good tools for research and we have freedom to make use of this opportunity such as few men have had or now have. The scientists are not restricted to any subject-matter area, any economic crop, or any class of chemicals. They can go where the action is—that is, where the problem leads them and use whatever devices and skills as may be needed in solving their problems. The achievements of the past 46 years reflect the wisdom of these policies and philosophies and set the stage for a progressive and successful future.

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