exploratory observations have already been made. However, the equipment required for precision, quantitative, solar records must be very large and must be guided on the sun for minutes of time with no error larger than a few tenths of a second of arc. The size of the telescope and its associated equipment are determined by geometrical considerations from which there seems to be no escape.

Radiation detectors at present in use for recording the sun, such as photographic plates, thermocouples, and photoelectric cells, demand that the smallest angular size to be recorded must have a linear scale of at least 25 microns (1/40 mm) in the telescope's focal plane. It follows directly from the geometry of the telescope that if measurements of structures only ½ second of arc in size are sought, the equivalent focal length cannot be less than 10.3 meters and preferably should be three or four times this value, if one makes a reasonable provision for ease of observation. Experiments at the McMath-Hulbert Observatory have demonstrated that focal lengths as long as 1 kilometer can be profitably used for fine structure studies.

The diameter of the telescope objective is fixed by the wave properties of radiation and the angular size of the smallest object to be observed. A telescope capable of forming an image of the sun on a scale of ¼ second of arc per 1/40 millimeter, or 10 seconds of arc per millimeter, using infrared radiation of wavelength 0.0025 millimeter, must have a diameter of 2.5 meters and a minimum focal length of 21 meters. It should be noted that the solar image produced by a telescope with a ratio of focal length to objective diameter equalling 21/2.5, or 8.4, is much "too hot to handle." The focal length must be increased, so that the same amount of energy is spread over a larger area, until instruments in the focal plane are not heated uncontrollably. Simultaneously, the increase in the size of the sun's image makes it easier to study small structures.

Conclusion

These are some of the fundamental reasons why a very large telescope is required for significant progress in the study of fine structure on the sun over a broad wavelength range. A solar telescope with an aperture of a meter, or several meters, and a focal length of the order of 100 meters does seem to be a practical possibility. Accompanied by a properly matched spectroscope of modern design, it would constitute a research tool more nearly adequate than any existing instrument for dealing with the questions raised by the presence of the line details shown in Figs. 3–6, and the completely baffling correlation of these formations with the brightness of the sun.

Indeed, a very large telescope for the study of the sun would not only make possible observations of solar fine structure when the earth's atmosphere is "well-behaved," and good definition is possible; even under unfavorable conditions it would enormously extend the attainable precision and productivity in nearly all fields of solar physics now investigated with smaller instruments.

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Controlled-Climate Facilities for Biologists

Readers are asked to consider the feasibility of constructing what the authors term a "biotron."

S. B. Hendricks and F. W. Went

Knowledge of the effects of the environment on the growth and development of plants and animals has come from two different approaches: (i) observations in the field and (ii) laboratory experiments. Field observations are very difficult to interpret because of the complexity and nonreproducibility of the many climatic variables, whereas in laboratory experiments only a single environmental variable can usually be studied. To bridge this gap, it is necessary to have laboratory facilities in which the whole range of climatic variables may be controlled individually so that the interaction of these variables on the organisms can be assessed.

The first facility for the study of plant growth under a wide range of controlled conditions was constructed at California Institute of Technology in Pasadena, in 1948–49. This facility was dubbed a "phytotron" in a humorous moment, but the term was so appropriate that it has endured. The variables under control are chiefly ranges of temperature, light intensities, and cycles of these variables.

The Pasadena phytotron has been fully described elsewhere (*1*), and the results obtained through its use are in the literature. The phytotron has been generally accepted as an experimental tool, comparable to telescopes, particle accelerators, fossil collections, and other tools of science. Interest in such facilities, although it comes predominantly from plant scientists, has also been expressed by others experimenting with animals; thus the concept of a "biotron" developed.

A question naturally arises with regard to a successful experimental tool: How might it be made more widely available? With regard to a biotron, as well as other experimental tools, this is a complex question, involving enthusiasm, needs, effort and cost, the interest of groups of individuals, and the degree to which the community of biologists can afford to support the tool.

That interest in phytotrons became widespread is shown by the increased number of applications to the National Science Foundation for funds to construct controlled-environment facilities. Because of this interest, the foundation, in 1957, requested the American Institute of Biological Sciences to report on the need among biologists for such controlled-environment laboratories and to advise the foundation about the criteria on which applications should be judged. The findings included the realization that two needs existed: (i) individual growth chambers to create reproducible experimental conditions and to obtain uniform plant material and (ii) large facilities in which the effects on plants of different climatic variables could be studied simultaneously.

Since the report of this committee was not explicit about the most desirable size of a phytotron, or about the specific needs for one or more phytotrons in different regions of the United States, another committee was created to study specifically the feasibility of biotrons, including not only botanical but also zoological needs. This committee, financed by the National Science Foundation under contract with the Botanical Society of America, consisted of S. B. Hendriks, P. J. Kramer, C. S. Pittendrigh, C. L. Prosser, A. J. Riker, and F. W. Went, with Arthur Hess, who was responsible for the mechanical design of the Pasadena phytotron, as a consulting engineer.

The committee, to discharge its first obligation of sensing the level of enthusiasm, encouraging cross-talk, and imparting such information as it had, met early in May 1958 with small groups of biologists in four sections of the United States. Some of the pertinent points and issues raised are presented here, with the intention of informing anyone who might be interested in constructing a facility or in sharing in the effort with others.

Factors To Be Controlled

The factors of environment that were widely considered desirable for bringing under controlled variation were light, temperature, insolation, humidity, and cycles. Other factors that might require attention were the nature of media (composition of air, salinity), pressure (both air and hydrostatic), ionizing radiation, air ionization, and movement, as of air and stream flow. To attain many levels of these variables in the possible combinations was recognized as requiring a large facility. Accordingly, these types, as well as more limited arrangements, were considered.

A first and specific requirement of a phytotron is control and availability of high-intensity light. This necessitates the use of accessory glass houses using solar radiation and of considerable cooling capacity for controlled rooms. Plants generally can be housed together, but in the case of animals separate consideration has to be given to various classes. Animals would chiefly share with plants the requirement of temperature variation in the environment which might be affected by common controls. They might require gradual change, sinusoidal perhaps, instead of the abrupt ones used with plants.

Dormancy problems, for instance, of both plants and animals would have similar temperature and cycling requirements. Ancillary equipment for gas analysis, irradiation in limited spectral regions, production of high humidity, or control of wind velocity, as examples, could often be met in common.

The considerable size of a possible installation, the mechanical and electrical services required, and the use of ancillary equipment forced early consideration of meeting the needs for studies on both plants and animals in one structure, despite some of the obvious drawbacks. General agreement was expressed that some degree of combination would be desirable not only for economic reasons but also for the cooperation and stimulation that results from having botanists and zoologists work together. At one extreme was a single structure with separate parts for environments for plants and animals. At the other extreme were smaller biotrons adapted only to plants or animals and devoted to more limited studies. An intermediate position, which was often stated, was to put major emphasis on either plants or animals, with minor attention to the other.

At these meetings it was obviously impossible to get complete representation of research biologists, but an attempt was made to have at least some representatives of the botanical, zoological, agricultural, phytopathological, and other fields. Whereas the botanists made it clear that controlled conditions are an absolute necessity for the solution of many of their problems, the zoologists seemed to feel less urgency in their needs. However, all the zoologists agreed that they could make use of the facilities if available, and there is little doubt that, once they start, the field will develop as it has in botany.

Problems for Study

Among the problems most generally brought up for study in a biotron were the following: temperature and photoperiod effects, general interaction of environmental factors, rhythmic and cyclic studies, germination, separation of genetic and environmental effects, mechanisms of adaptation, acclimation, evolution, speciation, dormancy, and hibernation. Others such as radiation effects, hormonal control, mitosis and meiosis studies, environmental effects on plant pathology, life-span studies, and some marine problems were also considered.

Design and Location

Many questions of design require consideration. Are the plants and animals to be placed in one compartment for the duration of an experiment and the environment varied as desired within this compartment? This is to be weighed relative to shifting the experimental subject from chamber to chamber as is done, in part, in the Pasadena phytotron. A design for a phytotron in Canberra, Australia, has been drawn up after the first of these patterns, in which about 300 small cabinets are to be used.

The clean-cut distinction was sometimes missed between controlling the environment and study of the effects of its variation. The former is desirable in many cases and is widely used in the growth of plants where interest centers, for instance, on reproducible conditions for nutrition or the effects of herbicides. Many animal colonies are maintained under fixed conditions both for standardization and control of disease. But these types of installations are outside the present consideration because they are more easily attained. When the distinction was realized, a desire was nevertheless expressed to encourage the production of some type of standard chamber.

Types of possible locations were discussed. It was generally agreed that any installation should be on a campus to benefit fully from existing facilities and

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academic associations. The location should be one accessible by travel over short distances from one or more additional universities. This is to encourage use of the facility by groups of individuals during sabbatical years and nonteaching periods. To this end, some residential quarters would be desirable.

Conclusion

To complete the first phase of the work of the Biotron Committee it would be desirable to get further expression of the needs and specific requirements from biologists all over the United States. To this end, the Biotron Committee invites suggestions and ideas pertinent to the planning of national biotron facilities so that no possibilities will be overlooked. The committee is specifically charged with the investigation of large-scale facilities and should not primarily concern itself with individual controlled-environment chambers. Thus far our considerations have been completely independent of actual cost. It is assumed that, provided that the need for biotron facilities is unequivocally demonstrated, funds will be forthcoming.

To assist the National Science Foundation in arriving at realistic cost figures for biotrons, the committee is now drawing up preliminary designs for a large installation in which studies of environmental effects on both plants and animals can be undertaken. It is also intended to design an installation for small nonaquatic animals as a prototype. A modification of the Pasadena phytotron to incorporate the experience gained through its present operation and to permit some studies of animals will be undertaken. In this last case, attention will center on the possible application to ecology since the degree of interest is great. Finally, design of some type of box units will be considered. These designs will be available, in the final report of the committee, to groups that are interested in creating such facilities.

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European Science Museums

A tour shows how they cope with the problems of displaying famous apparatus of the past and present.

Robert P. Multhauf

Among the many treasure houses of Renaissance Florence still to be seen in that city is one easily overlooked by the uninitiated visitor, although to reach it he has but to proceed to the Arno through the court of the Ufizzi Gallery and turn left to the rear of that building. Here is the Palazzo Castellani, once the residence of the Podesta of Florence and now the home of the Museo di Storia della Scienza. Here the visitor can wander through quiet rooms housing the fragile three-century-old glass apparatus familiar from the pages of the *Saggi* of the Accademia del Cimento, the first scientific academy in Europe—a forceful reminder that the *Saggi* and similar publications are not the sole evidences of the work of the busy experimenters of the nascent age of modern science.

The oldest collection of apparatus displayed here is the legacy of the house of Grand Duke Ferdinand II, where these relics of the curious hobby of the illustrious ancestor rested quietly for a century after his death until their first exhibition in 1775. As a result of subsequent accretions in the course of its evolution into the *museo* of today, this is a somewhat motley collection, including, as well as some apparatus illustrated in the *Saggi,* mechanical, electrical, and pneumatic apparatus for the demonstrations dear to the heart of the 18th century scientific enthusiast and the telescopes and microscopes favored by connoisseurs of baroque craftsmanship. Many of these pieces came from other early Italian centers of scientific activity and were acquired in 1929, at the time of the National Exposition of the History of Science. Relics of such distinguished Italian scientists as G. B. Amici, Felice Fontana, and Paolo Mascagni comprise the bulk of these collections.

The fever of enthusiasm for experimental natural philosophy which spread across 17th century Europe has left material traces elsewhere, in museums and, increasingly rarely, in private collections. An air pump of von Guericke can be seen in Munich (at the Deutsches Museum) (*1*). The Boyle-Hooke pumps have been lost, but an early pump modeled after Boyle's first one can be seen in Leiden (at the Netherlands National Museum of the History of Science), and the fashionable designs of the Abbé Nollet and of Senguerd can be seen in many places. The earliest electrical machines seem not to have survived, but many examples remain from the flowering period of electrical experimentation, among the most notable being Hawksbee's (in the collection of the Royal Society of London) and the great machine of van Marum, in Haarlem (at the Teyler museum).

The optical and mechanical preoccupations of the age are similarly represented. The telescopes of Galileo in Florence and the reflector of Newton in London (in the collection of the Royal Society)are only the most famous of the many telescopes preserved. Of the very large instruments, understandably, scarcely anything remains, although the barrel of Herschel's great reflector still exists at the Observatory House, Slough, England. The pre-, or anti-, telescopic observers have also left few relics, although instruments associated with the name of Brahe exist in Kassel, Munich,

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