establish a possible dose-response relationship. Unfiltered 136 kv x-rays were administered to dormant spores at the rate of 1000 r/min for total doses of 2000, 4000, 8000, and 16,000 r, with an unirradiated control. The total numbers of recognizable tumors of all sizes were counted after a 6-week culture period. The frequency of tumors per million spores of the inocula for the various doses is shown in Fig. 1. Approximately 28,000,000 spores were analyzed for the five points shown.

There is as yet no definitive evidence concerning the nature of the basic cellular alteration which occurs in the spores and is eventually expressed as a tumor. It would therefore be premature to attempt to conclude beyond our present data. However, for the sake of a working hypothesis we are inclined to consider this a mutation, or possibly a group of similar mutations. Dormant spores of *Pteridium* are quite radio-resistant, the survival curve extending beyond the limits of the present data by approximately a factor of 10 (*4*). Considering that this is a haploid organism, the type of linearity shown in the dose-response curve (Fig. 1) might be expected of a mutation in this dosage range. Also, at this relatively low frequency of occurrence, an exponential response can be linear (*8*). That dormant spores can be irradiated, kept in continued dormancy for at least another year, and still produce tumors would indicate that the causal event is not transient. It might be said, then, that although there is no evidence which points directly to this being a mutation, neither does any of the evidence at hand contradict this hypothesis. In any case this system and the present approach do present rather unique opportunities for the quantitative analysis of a tumorization process at the cellular level.

The limits of the present experiments were determined by the practical limits of the equipment at hand. Current work is being directed, among other things, toward an extension of these data through the entire viability range to determine both the tumor frequency and the complete survival curve.

CARL R. PARTANEN
Children's Cancer Research Foundation, Children's Medical Center, Boston, Massachusetts, and *Biological Laboratories, Harvard University, Cambridge, Massachusetts*

References and Notes

1. T. A. Steeves *et al.*, *Am. J. Botany* 42, 232 (1955).
2. C. R. Partanen *et al.*, *ibid.* 42, 245 (1955).
3. C. R. Partanen, *Cancer Research* 16, 300 (1956).
4. C. R. Partanen and T. A. Steeves, *Proc. Natl. Acad. Sci. U.S.* 42, 906 (1956).
5. This investigation was supported in part by a grant (No. CY3335) from the National Institutes of Health, U.S. Public Health Service. Part of this investigation was initiated while I was working under an American Cancer Society grant (BO16H) made to Prof. R. H. Wetmore and Prof. T. A. Steeves, Harvard University. I wish to thank the Harvard Biological Laboratories for the use of their facilities during these studies. The technical assistance of Miss Jane Nelson is gratefully acknowledged.
6. I am especially indebted to G. Stinson Lord, Weymouth, Mass., for making all of the spore collections used in these experiments.
7. A commercial product containing 70 percent calcium hypochlorite, manufactured by the Columbia-Southern Chemical Corp., Pittsburgh, Pa.
8. U. Fano, in *Radiation Biology*, A. Hollaender, Ed. (McGraw-Hill, New York, 1954), p. 126.

25 July 1958

An Olfactometer for the Rat

This report describes an apparatus and operant conditioning procedure (*1*) for studying olfactory discrimination in the rat (*2*). A bar-pressing apparatus and dipper mechanism to provide water reinforcement is mounted in a cylindrical glass "wind tunnel." A stream of deodorized air flows continuously through the tunnel at a known velocity. This can be odorized by the addition of known volumes and concentrations of odorized air. The animal is trained to face into the air stream when pressing the bar so that all body odor or odorant adsorbed on the animal's fur is blown out to the rear of the response chamber. The injection of the odorized air is the signal to stop bar-pressing.

The apparatus shown schematically in Fig. 1 shows the response chamber (*b*), containing the bar-press apparatus (*i*) in the cylindrical "wind tunnel" (*j*, *k*), 4 in. in diameter and 12 in. in length. A rotary-vane laboratory pump forces a continuous stream of air through a calcium chloride drying agent and the charcoal and silica gel deodorizing column at a rate of approximately 40 lit. per minute, as monitored by flowmeter *a*. This is the main air stream to the response chamber (*b*).

A small fraction of the air is diverted at *c* through the flowmeter (*d*), via the manifold and stopcocks, to one of four odor bottles (e_1, e_2, e_3, e_4). The odor stream passes over the surface of odorant *f* and returns to the main air stream just in front of the response chamber. Two stationary stainless-steel vanes (*h*) mix the odorized and pure air streams. The

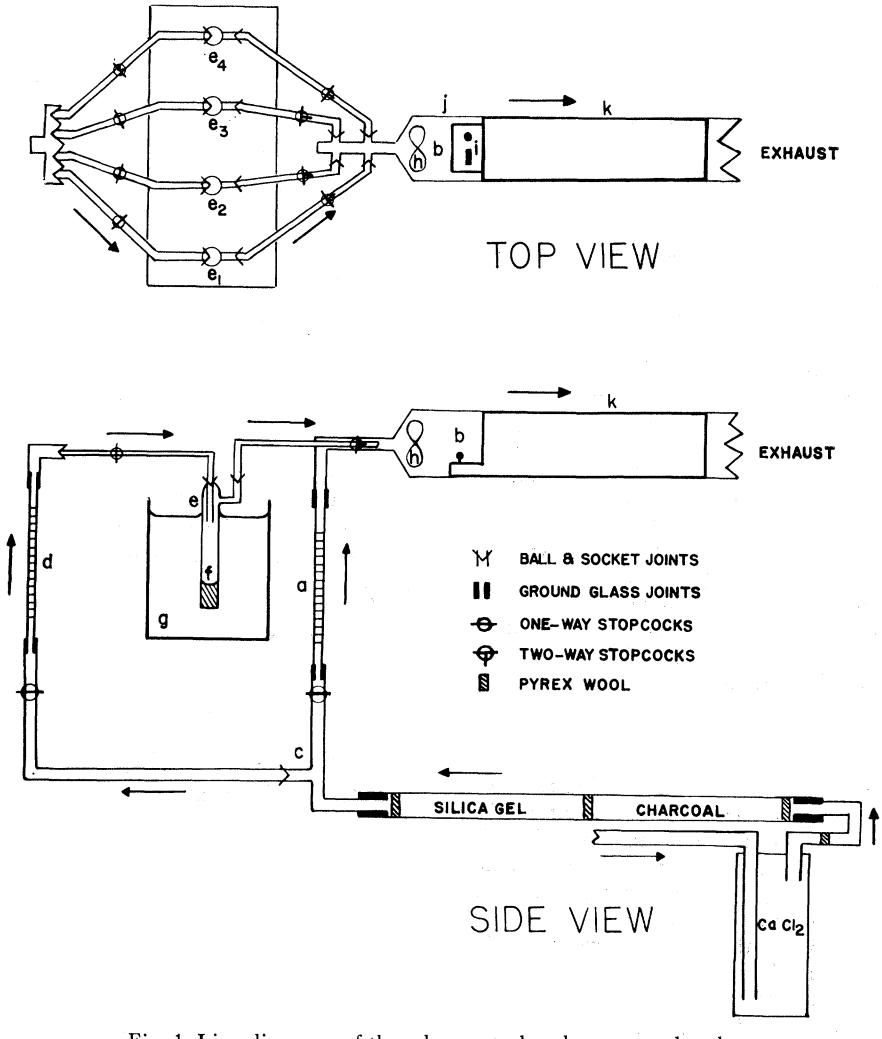

Fig. 1. Line diagrams of the odor control and response chamber.

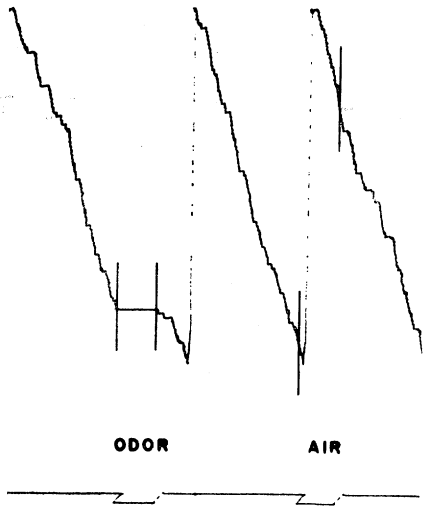

Fig. 2. Sample record of odor discrimination (cumulative response record of bar pressing). The pen moves from the top to the bottom of the record and resets automatically. Note that there is complete cessation of response during the introduction of odor but no diminution of response during the introduction of air from an empty control channel. The pairs of vertical lines on the record were drawn in to show the onset and duration of stimulation indicated by the signal marker.

odor bottles are maintained at a constant temperature by water bath *g*. The outflow from each odor bottle is controlled by a three-way stopcock so that the odor can be added to the main stream or shunted through a bypass (not shown) to an exhaust. This provides a continuous flow of air through the odor bottle when the input stopcock to the odorant bottle is opened, to insure equilibrium when the odor is added to the main stream. The concentration of odorant in the odor stream is a function of the rate of air flow over the odorant surface, the height of the odorant in the odor flask, and the vapor pressure of the odorant. The concentrations of odorant can be computed from the weight of odorant lost for given durations and flow rates. The final concentration of odor can be computed from the relative flow rates of pure and odorized air and may be specified in milligrams per liter, moles per liter, or number of molecules.

All parts of the olfactometer are made of Pyrex glass, including the first 5 in. of the "wind tunnel" section (*j*). The liberal use of ground glass joints makes the entire system easily demountable for cleaning. Section *k* is made of brass tubing 4 in. in diameter and contains the bar-pressing platform and dipper mechanism, which projects 3 in. into the glass part (*b*) of the response chamber. The platform, bar, and dipper and the anterior two-thirds of the animal are visible to the experimenter. A new model of the apparatus has been built (*3*) in which the response chamber is made entirely of glass and in which the bar and drinking font project into the chamber from below, through small ports.

The training procedure is typical of operant discrimination training in which responses are occasionally reinforced in the absence of odor (S^D) but never during the presence of odor (S^Δ). The onset of odor signals the "no-reinforcement" condition. A control training procedure is employed in which clean air from an empty odor bottle is presented, *with reinforcement,* to insure that discrimination is learned on the basis of odor and not of other cues incidental to turning stopcocks, to changes of air pressure, and so on. Odor training (S^Δ) and control training are interspersed randomly. After discrimination has been established, test trials consisting of a 10-second period during which odorized air is introduced and a 10-second odorless control situation are presented, without reinforcement.

In the early experiments we employed a discrimination criterion of fewer than six responses during the 10-second odor test with no diminution in response rate during the 10-second odorless-air control procedure. In order to maintain discrimination at this level, discrimination training trials were continued and interspersed among test trials. Training trials usually consisted of 30 seconds or more of odor (S^Δ) or of odorless control procedure. Responses during the 10-second control test numbered approximately 30 (mode), with a range of from 20 to 40, depending on the animal. A well-trained animal usually stopped bar-pressing immediately in response to a suprathreshold odor, with a negligible latency after the odor stopcock was turned (see Fig. 2). The time before resumption of bar-pressing after the odor is turned off may be variable, but this was not important in the present testing procedure. This method has proved useful for studies of threshold in normal animals after ablation of the olfactory bulbs and in experiments on animals with altered endocrine balance.

CARL PFAFFMANN
Brown University,
Providence, Rhode Island
WILLIAM R. GOFF
University of Virginia, Charlottesville
JOHN K. BARE
College of William and Mary,
Williamsburg, Virginia

References and Notes

1. B. F. Skinner, *Behavior of Organisms* (Appleton-Century-Crofts, New York, 1938).
2. This study was carried out in the psychology laboratory of Brown University, under a grant from the National Science Foundation.
3. Victor Bartosewitz of the Brown University chemistry department constructed the glass components of this olfactometer.

29 July 1958

Chromatography of Molten Salts on a Glass Powder Column

The physicochemical similarity of glasses with zeolithes and with the noncrystalline oxides (silica, alumina) used in chromatography induced us to test the ion-exchange and adsorptive properties of glass under conditions in which these properties might be expected to be of practical use. As a medium, molten salts were selected.

A Pyrex column of inner diameter 8 mm and length 20 cm was filled with Pyrex glass powder (100 to 140 mesh); the column could be slowly charged with the melt. As stopcocks, connecting tubes of length 10 cm and inner diameter 2.5 mm were used. The tubes were placed in sections of the (vertical) oven that could be cooled.

In order to avoid chemical attack on the glass, only salts melting below 400°C were used, such as alkali nitrates and mixtures of alkali halides (preferentially the eutectic mixture of lithium and potassium chlorides, which melts at 352°C).

To this mixture, from 0.1 to 1 percent of chlorides of heavy metals, such as Cr^{III}, Cu^{I}, Ni^{II}, Co^{II}, and Mn^{II}, were added. Separation in zones was observed, which compared in sharpness favorably with those obtained by chromatography in aqueous solution. With the above column and the eutectic mixture used, the adsorption of the heavy metals at 400°C decreased in the above order.

Elution (with pure molten salt) is as easy as in the chromatography from aqueous solutions.

When a small particle of the eutectic mixture of lithium and potassium chlorides, containing one or more heavy metals, is slowly heated to the melting point on a porous Pyrex filter plate, concentric colored circles, showing the differential adsorption of the heavy metals, are observed.

MICHAEL M. BENARIE
Scientific Department,
Ministry of Defense, Tel-Aviv, Israel

7 April 1958

Nonpolar Transport of Gibberellin through Pea Stem and a Method for Its Determination

Gibberellin was found to differ from auxin in many physiological effects (*1*). Hence, it is of interest to see whether the transport of gibberellin through the stem is polar or not. As to gibberellin transport, it is only known that gibberellin is transported lengthwise twice as rapidly as transversely (*2*).

A method of determining gibberellins is needed for transport experiments, as