acid prepared by prolonged boiling of 1(+)glutamic acid in sodium hydroxide solution. We found that samples of 1(+)glutamic acid slowly racemized when they were boiled in 8 *N* and 4 *N* sodium hydroxide solutions. However, the yields obtained were very low. Ammonia was evolved continuously during the procedure, and it is evident that a considerable destruction of glutamic acid occurred.

It is our opinion that d,1-glutamic acid can be prepared most conveniently by racemization with heat.[3]

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COCHLEAR POTENTIALS FROM THE BAT

RECENT evidence[1, 2] indicates that bats locate objects in the space through which they are about to fly by hearing echoes of supersonic cries they emit. Normal flying bats produce supersonic cries having a duration of about 20 msec. in which frequencies near 50,000 cycles are most intense, and there is an increase in rate of emission as the animal approaches obstacles which will be successfully avoided. Bats rendered temporarily deaf and bats which are prevented from emitting the cry blunder into obstacles as if with no knowledge whatever of their existence.

These experiments can be explained only if it be assumed that bats hear sounds of 50 kc. In an attempt to test this assumption, cochlear potentials have been recorded from more than 30 bats of 5 different species with the results described below.

The bat cochlea produces electrical oscillations having the same frequency as the incident sound for frequencies up to 98,000 cycles. The 98 kc upper limit represents the limit of the recording apparatus, not of the cochlea. Appropriate checks establish the cochlea itself as the source of the potentials which appear in every respect to be similar to cochlear potentials from other mammals. The author, assisted by Mr. J. E. Hawkins, obtained no responses whatever above 40 kc from the cochlea of a young guinea pig tested in this apparatus.

The experiments were conducted in the laboratory of Dr. G. W. Pierce at Harvard, using a magnetostriction oscillator as the source of pure supersonic tones and a supersonic microvoltmeter to record potentials arising in the cochlea. Similar results can be obtained with a galton whistle or the cry of another bat as the source of supersonic sounds.

Although it is generally agreed that cochlear potentials per se do not necessarily indicate hearing, these experiments are taken to support the theory that bats locate obstacles by hearing echoes of their supersonic cries. Further details of the response of the bat ear will be presented in a report now in preparation.

The author is indebted to Drs. G. W. Pierce, Hallowell Davis and A. C. Redfield for the use of their laboratories and for their generous criticisms and suggestions.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

PHOTOELECTRIC TEMPERATURE CONTROL

A SYSTEM of control for a constant temperature bath employing a thyratron tube has been described by Schmitt and Schmitt.[1] The thyratron is a grid-controlled mercury vapor rectifier of considerable current carrying capacity. In their apparatus the tube served as an on-and-off relay, the grid potential being raised and lowered by the make-and-break of a toluene-mercury thermoregulator. Increased accuracy of temperature control, as compared with the usual electromagnetic relay system, was obtained as a result of the small current flow in the grid circuit and consequent avoidance of fouling of the mercury surface.

In the system which I shall describe, the advantages of the thyratron tube are more fully exploited by employing the phase-shift method of control and by eliminating the make-and-break contact altogether. The method makes possible the construction of a very accurate and reliable constant temperature bath at very modest cost.

A toluene-mercury thermoregulator is used which is so constructed that the column of mercury interrupts a beam of light concentrated to a point by means of a lens. This part of the apparatus is shown diagrammatically in Fig. 1. The light which passes through the capillary above the mercury strikes the cathode of a phototube. Rise or fall of the mercury

[3] L. E. Arnow and J. C. Opsahl, *Jour. Biol. Chem.*, 134: 649, 1940.

[1] D. R. Griffin and R. Galambos, paper read at the American Association for the Advancement of Science meetings in Philadelphia, Pa., January, 1941. Abstract in *Anat. Rec.*, 78: 95. 1940. Supplement.

[2] R. Galambos and D. R. Griffin, paper read at the American Association for the Advancement of Science meetings in Philadelphia, Pa., January, 1941. Abstract in *Anat. Rec.*, 78: 95. 1940. Supplement.

[1] F. O. Schmitt and O. H. A. Schmitt, SCIENCE, 73: 289, 1931.

column decreases or increases the amount of light falling on the phototube, and this in turn, through the electrical circuit described below, controls the amount of current flowing through the heating unit.

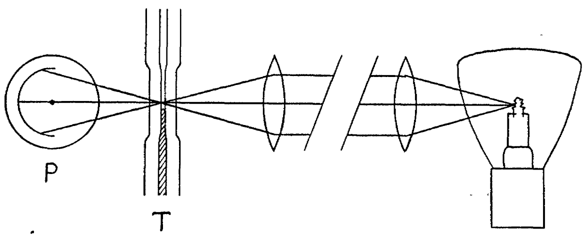

FIG. 1. P—phototube, T—upper part of thermoregulator.

The electrical circuit is shown in Fig. 2. It was taken from Nottingham[2] and is essentially the same as the scheme given by Hull[3] for photoelectric control of a thyratron by the phase-shift method. The circuit was not applied by these authors to temperature control, however. T is the thyratron tube, General Electric Type FG-57, P is the phototube, Type PJ-23,

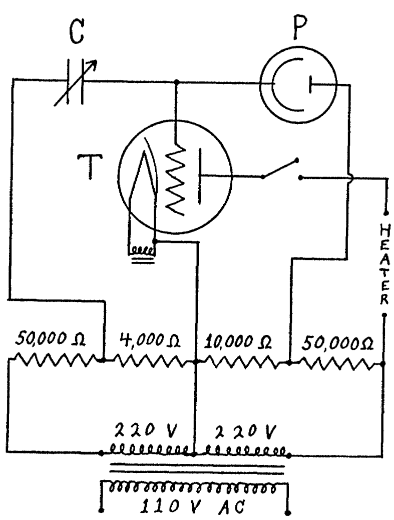

FIG. 2

and C is a variable condenser of 100μμf capacity. It will be seen that alternating voltage is applied to the grid. When this voltage is in phase with the anode voltage the maximum current will flow in the anode circuit. But as the grid voltage is gradually retarded in phase through 180°, the average anode current decreases continuously to zero. This phase shift in the grid voltage is brought about by increase in the resistance of the phototube resulting from decrease in the intensity of light falling upon it.

Thus the heater operates continuously, with very little variation, at a level just sufficient to balance the loss of heat through the walls of the water bath. This continuous control of heat input has the advantage of reducing periodic fluctuations in temperature to an almost infinitesimal value, but it carries with it a potential source of error in that changes in the ambient temperature will be reflected, on a greatly reduced scale, in the bath temperature. However, except perhaps in cases of extreme variation in the room temperature, good insulation of the bath together with adjustments of the system making for maximum sensitivity will keep this variation within very narrow limits. In a laboratory where the room temperature does not vary widely, the bath temperature has been observed to remain constant to ± .001° C for periods of 48 hours and nearly as constant over much longer periods.

A few practical suggestions based on my experience with the apparatus may be added. As a light source a 32 candle power headlight bulb operated from a 6.3 volt transformer has proved satisfactory. The capillary of the thermoregulator (2 mm inside diameter) is compressed so that the cavity becomes a flat oval in cross section, thus minimizing spreading of the light beam as it passes through, and at the same time increasing sensitivity by decreasing the area of cross section of the capillary. The capillary is painted on the outside with black glass-marking ink, except for a slit on each side through which the beam passes. I have had the bulb of the thermoregulator made in the form of a helix, so as to combine large volume with small diameter.

The parts for constructing this apparatus, exclusive of stirrer and heater, can be purchased for about thirty dollars.

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[2] W. B. Nottingham, *Jour. Franklin Inst.*, 211: 271, 1931.

[3] A. W. Hull, *Gen. Elec. Rev.*, 32: 213 and 390, 1929.

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