The Production of Ultrasonic Sounds by Laboratory Rats and Other Mammals*

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Although it has long been recognized that bats produce ultrasonic sounds and use them for detecting objects at a distance (*1, 2*), little is known of the ability of other animals to produce such sounds. Indeed, insects (*3*) and porpoises (*4*) are the only other animals in which the production of ultrasound has been demonstrated. It is therefore of interest to record some observations on high-frequency sound production by other animals.

Certain audible sounds of wild mammals in the National Zoological Park and of guinea pigs were found to have appreciable components in the ultrasonic frequency range—above 20 kilocycles per second (20 kcy/sec). Laboratory rats, in addition to producing high-frequency components of audible sounds, have the ability to emit pure tones between 20 and 30 kcy/sec-sounds that have no audible component.

For this preliminary survey, a "sonic amplifier" (covering the range from 0 to 80 kcy/sec) similar to that described by Noyes and Pierce (*5*) was employed; its frequency scale was accurate within 1- or 2-kcy/sec, as determined by direct comparison with a Hewlett-Packard oscillator. For a more detailed study of the ultrasonic sounds of the laboratory rat, a condenser microphone, amplifiers, and cathode-ray oscillograph were used, as described by Griffin (*6*).

The audible sounds found to have appreciable ultrasonic or high-frequency components are summarized in Table 1.

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In studying the high-frequency sounds produced by laboratory rats, I first noted that the loud squeals elicited by gently pinching a rat's tail had two prominent overtones, one at 19 and the other at 29 kcy/sec. From time to time, rats in their cages emitted short snuffling sounds with audible components, and these were found to contain overtones over the whole range of the instrument to 80 kcy/sec. In addition to these ultrasonic components of audible sounds, rats that were accustomed to the presence of the apparatus and the observer produced a whole series of sounds, ranging in frequency from 23 to 28 kcy/sec, and 1 to 2 sec in duration, which were not correlated with audible sounds. The frequency of these sounds often shifted rapidly by about 2 kcy/sec.

The ultrasonic sounds were clearly produced by the rats, for they disappeared when the cage of rats was removed from the room and returned when the cage was carried back into the range of the instrument. The prolonged duration of these sounds precludes their being merely ultrasonic components of slight noises associated with the rats' activity. Indeed, the sounds were observed when the animals were standing completely still and could be correlated with the animals' thoracic movements.

Recently these sounds were studied with a system consisting of a Western Electric 640-AA condenser microphone, cathode follower, voltage amplifiers, Spencer Kennedy variable electronic filters, cathode-ray oscillograph, and DuMont type 321 oscillograph record camera. This system was sensitive to frequencies from 10 to 100 kcy/sec, and accurate within 1 or 2 kcy/sec. Direct measurements of the frequency of the rat sounds from the film gave values ranging from 21.5 to 26.5 kcy/sec. The frequency modulation noted with the sonic amplifier was verified by these measurements, and the duration of the sounds was found to vary from about 1/30 sec to 2½ sec.

While the significance of these ultrasonic sounds of laboratory rats cannot be determined from these observations, it should be pointed out that the ability to hear sounds above 20 kcy/sec has been demonstrated

Table 1. Audible sounds with appreciable ultrasonic components.

Common name	Scientific name	Description of audible sound	Ultrasonic or high-frequency components (kcy/sec)
Flying phalanger	*Petaurus norfolcensis*	High "squir"	Up to 33
Squirrel monkey	*Saimiri sciureus*	High, variable	19
Cotton-headed marmoset	*Oedipomidas oedipus**	Squeal	19–23
White-armed marmoset	*Callithrix leucopus**	Long cry	36–39
Lion-headed marmoset	*Leontocebus rosalia*	High squeal; "squir"	10–22; 18–22, 27–28
Kina Balu giant rat	*Rattus infraluteus*	"Squir"	19–22, 33–37
Guinea pig	*Cavia cobaya*	Whistle; squeal	None; 29, 38, 54
Laboratory rat	*Rattus norvegicus*	Squeal; snuffling	19, 29; up to 80

* Individuals of these two species were housed in the same cage, and it was impossible to determine which of the animals were responsible for the cries.

by Gould and Morgan (*7*) for the laboratory rat, and by Schleidt (*8, 9*) for several small, wild rodents. In addition, Kahmann and Ostermann (*10*) have recently shown that hamsters when deprived of their vision can jump to a feeding stand without hesitation. These high-frequency sounds may serve for communication between individual rats; and it is also conceivable, though certainly not yet demonstrated, that rodents use high-frequency sounds for orientation in some manner comparable to the process of echolocation employed by bats.

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The Influence of Hydrocortisone on the Epithelial Phosphatase of Embryonic Intestine *in Vitro**

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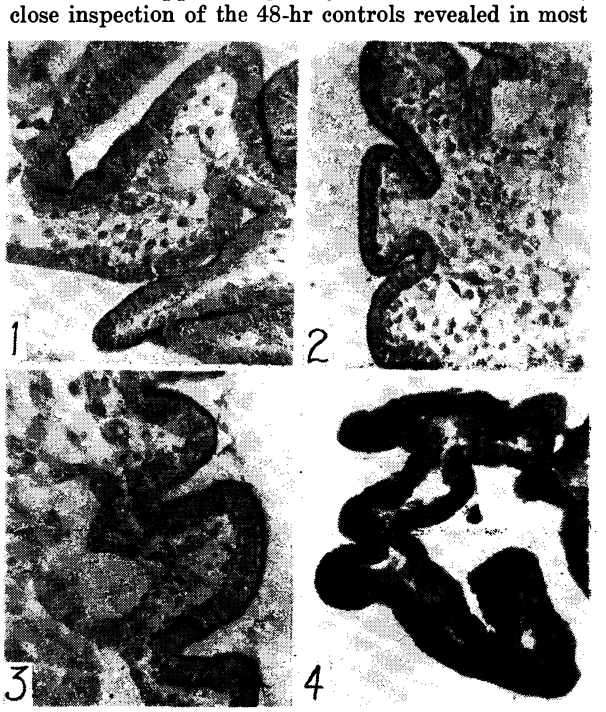
The high concentration of alkaline phosphomonoesterase characteristic of duodenal epithelium is accumulated, in both chick embryos and young mice, in short periods immediately preceding onset or change of digestive function (*1, 2*). In the mouse the accumulative phase is under the control of the pituitary-adrenal axis (*3*), and in the chick embryo *in ovo* duodenal phosphatase can be raised precociously to the hatching level by injection of cortisone (*4*). These studies bring into question the locus of action of the cortisone that was administered: does it affect the intestinal mucosa directly, or does it act indirectly, as for example by interfering with growth (*3, 5*) and thus enlarging the supply of raw material available for specific syntheses?

To determine whether exogenous corticoids can influence intestinal phosphatase concentration without the intermediation of other organs, fragments of the duodenal loop of 16-day chick embryos were raised *in vitro*. Each fragment was supported in a small piece of cellulose sponge (*6*) in a Maximov dish; the medium consisted of a drop of chicken plasma plus chick embryo extract, to which was added a tiny droplet of either saline or solution containing 0.05 gamma of hydrocortisone as free alcohol. The 16-day stage was chosen because it is the time at which the intestine acquires its maximal sensitivity to corticoids (*4*); hydrocortisone has been shown in this laboratory to be just as effective as cortisone in promoting intestinal differentiation. After 24 or 48 hr in culture, the fragments were fixed in iced 85 percent alcohol, embedded in paraffin, and sectioned serially at 7 microns (7 μ). Segments of each ribbon were stained with hematoxylin and eosin, or for phosphatase according to Gomori's current method (*7*).

In the hydrocortisone-treated fragments, the villi present at the time of explanatation were maintained without elongating, during the 48-hr period considered here, whereas in the controls they tended to shorten somewhat. Long, richly branched outgrowths (Figs. 1, 4) consisting of lamina propria covered by columnar epithelium were also produced, and these were more numerous and more elaborate in the experimentals than in the controls. The mucosa in general preserved a quite normal appearance between the muscular layer and the bases of the villi.

The epithelial cells clothing the surfaces of the cultures developed according to the normal pattern, growing progressively longer and narrower and the apical cytoplasm becoming increasingly dense; in both experimentals and controls, these events proceeded slightly faster than *in vivo*. The cut edges of the fragments became covered with an epithelium that sometimes remained squamous but often produced highly differentiated columnar cells. Although the differentiation appeared grossly normal in all series, close inspection of the 48-hr controls revealed in most



Figs. 1 and 2: control (1) and hydrocortisone-treated (2) explants, cultured 24 hr, incubated in phosphate medium 15 sec. Figs. 3 and 4: control (3) and hydrocortisone-treated (4) explants cultured 48 hr, incubated 10 min. (×440)

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