

failure was peculiar to this litter, further crosses between Golden and *Albus gvestus* were made. These all resulted in the same thing — apparently sterile hybrids. There were two possible causes for this probable sterility: either diet deficiency or genetic characteristic. The dietary phase was checked by changing to a food with large amounts of vitamin K. The animals continued to show sterile traits.

The next problem was to check the hybrids genetically to determine if the males, females, or both were sterile. At this point the *Albus Gvestus* male died of a respiratory disease.

To replace this male, a pair of *Albus Gvestus* animals have been obtained. The female has given birth to a litter of *Albus Gvestus* young. The plan is to cross a hybrid male with a fertile *Albus Gvestus* female, and a hybrid female with an *Albus Gvestus* male. If either of these crosses produce litters, the offspring should be *Albus Gvestus* and hybrid in the ratio of 1/1. If neither of the crosses produce litters, the sterility of the hybrids will be conclusively established. The next step, if the latter is true, will be to rid the *Albus Gvestus* of the black pigmentation in the ears through inbreeding. If this is accomplished, the result should be a totally Albino hamster.

## A STUDY IN SOUND

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The purpose of my project was to study the effects of harmony and discord on humans and dogs. Since I knew nothing about sound before I began, my experimenting involved a general study of sound.

Of course this required more apparatus. A list of materials follows:

1. Three 256 vps tuning forks.
2. One 320 vps tuning fork.
3. Two 384 vps tuning forks.
4. About a half-dozen copper tubes, ranging in length from one to twenty-five centimeters.
5. An apparatus for producing two air jets, consisting of four feet of rubber tubing, a glass "Y" section, and two nozzels.
6. One test tube 10 centimeters in length.
7. One test tube 7 centimeters in length.
8. A piano.
9. One adjustable organ pipe.

A thorough knowledge of the nature of sound is required to understand harmony and discord. First, sound is the effect that sound waves have on the ear. The preceding statement is quite meaningless unless accompanied by an explanation of sound waves and how they are produced. Let us take for example a 256 tuning fork. When struck, it vibrates at the rate of 256 times per second. We say that its rate of vibration is 256 cycles. As the fork moves to the right it compresses the air to the right. Since this compressed air is in no way held, it in turn compresses the air next to it. Meanwhile the fork has moved to the left and the air next to the fork on right expands, or is rarified. As the fork moves back to the right it compresses air to the right, and then to the left, and so on. Thus smooth ripples of alternating compressed air and rarified air reach the ear. As a layer of compressed air strikes the tympanic membrane, it is forced in; as a layer of rarified air reaches the ear, the tympanic membrane is forced out by the greater inside pressure. Therefore the tympanic membrane vibrates at the same rate as the fork. A series of small bones carries the sound to the auditory nerve, which in turn conveys the message to the brain.

If we strike two forks of slightly different frequencies, they alternately interfere with and reinforce each other's waves. When both move to the right at once (and so to the left), we say they are in unison. That is, they are both compressing air at once on any given side. However, the slower fork soon lags behind, and while one fork is compressing air to one side, the other is rarifying the *same* air. The two forces nullify each other resulting in silence. Soon the faster one will get one whole vibration ahead, and they will be in unison again, reinforcing each other. This creates an auditory illusion known as "beats." The number of beats per second is equal to the difference in cycles. The highest number of beats we can count is about six per second. Above that number it sounds as harmony or discord.

Physicists agree that harmony can be produced either by two-note or three-note combination. In a two-note combination the frequencies must be in the ratio of small whole numbers, such as 1:2, 2:3, 3:4, 4:5, 5:6, etc. Three-note combinations must be in the ratio of 4:5:6. All major chords, or triads must be in this ratio.

There is, however, disagreement among physicists regarding how discord is produced. All seem to agree that there is a definite relationship between difference in frequency and discord varying with the heights of frequencies. But none of three books I searched gave a formula to figure maximum discord at any given frequency range, although one book gave three such

examples. Using these examples, I derived a formula which may be stated as follows.

Discord is produced by two sounds when the difference in cycles is approximately twice the square root of the lower frequency. Hence my formula is:

$$F_1 - F_2 = 2 \times \text{square root of } F_2$$

This formula has been checked by the Physics Department at the University of Tennessee and confirmed as correct.

With this essential background knowledge it is now possible to full understand my project. Since it is possible to set up similar vibrations by blowing over a tube, I cut two tubes so that their fundamental frequencies were 2029 and 2118. Therefore, they would produce discord when jets of air are blown over them. Although the resulting sound was not particularly "sour," it produced no pleasing effect. My dog, who appeared restless, seemed to hate me the next morning for exposing her to such an ordeal. Discord on the piano created a similar effect. However, the human voice proved to be a good stand-by, as the dog reacted violently by howling to a note about 650 cycles, or between  $E_1$  and  $F_1$ . A similar reaction occurred when a test tube having a frequency of about 1722.2 cycles was sounded. Apparently the dog actually experienced pain, rather than a mere annoyance.

Next I played "Brahm's Lullabye" on the piano with its full rich chords. The effect was so pleasing to the dog that she almost fell asleep.

By way of conclusion, harmony seems to have a soothing effect on both humans and dogs. Discord has the well-known "sour" sound to humans and makes dogs restless. Certain notes of high volume cause a violent reaction with the dog, who seems to actually feel pain.

## REGENERATION IN EARTHWORMS<sup>1</sup>

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My objective in this project was to study the development of regeneration from various segments of the earthworm (*Lumbricus terrestris*). Every authority that I consulted agreed that if an earthworm lost some of its posterior segments, it could regenerate them, but they were indefinite as to the ability of regeneration in the anterior region of an earthworm.

<sup>1</sup>The project described in this paper was one of the prize-winning projects exhibited at the meetings of the Junior Academy of Science in Murfreesboro, November, 1956.