sisted of control plates. The remaining ten subjects either backed into the stem after emerging one or more times and remained there until the predetermined 3-minute cutoff time for a trial was reached or, after reaching the choice point, backed completely out of the apparatus through the starting end of the stem. In each of these ten instances the subject's prostomium had made contact at least once with a part of the shock plate. The probability that of the 14 subjects that did cross an end arm none would cross the shock side on the basis of chance is less than .001 (binomial test).

The surface on which the substance is secreted does not appear, within some limits at least, to be critical to its effectiveness. We have seen it act effectively on aluminum, stainless steel, paper, and soil, as well as on Plexiglas. However, the substance is most effective when dry, and thus when it is deposited on a dry surface. It is not readily soluble in cold water. A tracked surface immersed in cold water appears to lose little, if any, of its effectiveness after it has been allowed to dry. Also with regard to the persistence of its effects, we have found an undisturbed deposit of the substance apparently as potent more than 3 months after secretion as it was a few hours after secretion and even more potent than when still wet immediately after it had been secreted. This is in marked contrast to the relatively short effective duration of pheromones released by insects in the air or by fishes in water (*2*).

Effects of the alarm pheromone may be responsible for certain features of the data on instrumental learning in earthworms. Strong negative reactions to unidentified stimuli in a T-maze commonly have been observed when electric shock has been used to punish incorrect responses (*3*). Our findings suggest that these may be responses to deposits of the alarm pheromone left in the maze on previous trials and either spread or only partially removed by the procedures used for cleaning the apparatus (*4*). The effect that such deposits would have on choice data would depend upon the cleaning procedure used and upon whether shock was applied on the same side of the maze for all subjects or was varied; even if it was varied, it would depend upon whether the same subject received several trials in a row or was tested in rotation with other subjects. Different combinations of these conditions could lead to either rapid appearance, slow and irregular appearance, or no appearance of data that would be interpreted as evidence of learning.

In any case, our data show that without any opportunity for learning an earthworm can display a tendency to avoid an area where an aversive event previously has occurred. As a result, firm conclusions regarding whether earthworms can learn a maze response, or at the least, what the characteristics of the learning process are, should await a test under conditions in which the effects of the alarm pheromone unequivocally have been eliminated.

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3. A particularly graphic description of these negative responses to unidentified maze stimuli is given by J. S. Robinson [*J. Comp. Physiol. Psychol.* **46**, 262 (1953)]. See also R. M. Yerkes, *J. Anim. Behav.* **2**, 332 (1912); L. Heck, *Lotos* **68**, 168 (1920); H. Schmidt, Jr., *Science* **121**, 341 (1955); D. K. Zellner, *Physiol. Behav.* **1**, 151 (1966).
4. Procedures for cleaning apparatus, when reported, have included rinsing it with water, wiping it with dry cotton wool, changing a paper floor covering between trials (but walls and ceiling were not covered), and wiping the apparatus with a paper floor covering that had been used on the previous trial. Our observations of the relative insolubility of the alarm pheromone and its tendency to adhere to surfaces on which it has been deposited raise considerable doubt about whether any of the cleaning procedures previously described have successfully eliminated the substance from all parts of the apparatus.
5. This research was conducted while S.M.K. was an undergraduate research participant under NSF grant GY-2639.

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Discrimination of the Odor of Stressed Rats

Abstract. *Albino rats can reliably distinguish between the odors of stressed and unstressed rats. Five animals learned to interrupt an ongoing response when air from the cages of stressed rats was introduced into the test compartment, and to continue responding when air from unstressed rats was introduced. The discrimination does not seem to depend on recognition of odors of individual rats.*

Although alarm pheromones have been identified in a number of species (*1*), their presence in mammals is yet to be established. For a substance to serve in intraspecific communication, it must first be capable of discrimination from other similar odors; however, the fact that it is distinguishable in an experimental situation does not imply that it serves any function in the normal life of the organism. Our study was designed to determine if male albino rats will discriminate between air from the vicinities of stressed (S-air) and unstressed rats (U-air) by interrupting an ongoing bar press when S-air is presented.

Six 80-day-old Sprague-Dawley rats were trained to press a bar in an animal compartment (Lehigh Valley) whose normal air intake had been closed. Air (U.S.P. grade) passed at a measured rate of 600 ml/min from a cylinder, over an unstressed rat isolated in a Pyrex desiccator, and then through a delivery tube leading through the bottom of the animal compartment. Whatever might be common to the odor of all rats was thereby part of the compartment atmosphere; whatever differences test air samples introduce would thereby be accentuated. Test samples of air were introduced into the delivery tube from a 50-ml syringe (Fig. 1). A weight-driven device (not shown) emptied the syringe at a flow rate matching that of the air cylinder.

Stimulus air was sampled from the vicinity of animals in individual living cages from which food pellets and water bottles had been removed. Polyethylene sheet, secured by magnets to the sides and back of the cage, sheathed each cage to within 2 cm of the top. Any excrement remained on the sheeting just under the wire-mesh bottom of the cage. Thirty-millimeter samples of air were taken by insertion of a 9-cm needle to its full length through the sheeting into the center front of the cage immediately under the cage bottom. Three different syringes were used in mixed order for sampling U-air obtained from undisturbed rats, and another set of three for sampling S-air, drawn from the cage of a rat which had just received several 1-ma shocks with a probe to the flanks. Emission of two or three typical "alarm cries" (*2*) was the criterion of stress.

Animals for a given session were brought in their living cages from the colony housing room into the training room. To keep stressed and unstressed animals in equivalent locations in the room, we suspended all cages in the

same cage stand. To decrease possible intermingling of their odors, one set of cages was suspended from the top shelf; the other set hung three rows down. For a given bar-pressing rat, positions of the stimulus-rat cages were alternated in successive sessions.

Six animals deprived of food (*3*) were placed on a variable-interval, 1-minute (VI-1) schedule (*4*) for 3-second access to .08 ml of 20 percent sucrose solution. When rates of bar pressing became steady, discriminative punishment training was superimposed on the VI-1 schedule. Under discriminative punishment, every other bar press in the presence of U-air delivered sucrose solution, but every response in S-air produced a 0.3-second shock of 0.25 ma sent through a scrambler to the grid floor. Discrimination should lead to a higher probability of bar pressing in U-air than in S-air.

A standard procedure was followed for introducing all stimulus air samples and measuring response to them. As soon as the animal resumed responding after a reinforcement, an air sample was introduced. Timing of the latency of the next bar press began at the moment delivery of the air sample was complete. Also initiated then was delivery of either sucrose or shock consequences to responses emitted within the following 10-second test period. During this period, the compartment fan was off, and an extra light was on. The change in both light and fan noise was intended to alert the animals to onset and termination of the test period; disconnection of the fan also slowed exhaust of stimulus air from the compartment.

Table 1. Latency (seconds) of bar pressing in presence of unstressed (U) and stressed (S) air during final 20 paired trials.

Rat	Mean		Standard deviation		t*
	U	S	U	S	
Y-5	1.49	8.20	0.25	11.34	2.67
W-5	1.38	11.24	1.73	12.72	3.55
Y-6	1.84	5.26	2.24	6.11	2.38
W-9	1.18	9.51	1.72	11.16	3.39
X-8	2.08	8.22	1.88	8.82	3.02

* All $P < .01$, d.f. $= 19$, t based on correlated data. Binomial probabilities of obtained number of reversals and nonreversals of the predicted order (S-air latency > U-air latency) were .09, .003, .05, .0000009, and .003, respectively.

In discrimination training sessions, 30-ml U-air samples were introduced until the latency of the first response was under 2 seconds and the animal's rate of bar pressing between samples was steady. At this point we made an irrevocable decision to introduce an S-air sample after a specified number of additional U-air samples, either 1 or 2. The criterion of discrimination was the difference between latency of response to S-air and that to the preceding U-air. If we were to avoid bias we needed to schedule S-air trails without foreknowledge of latency on the preceding U-air trial.

Air from stressed rats was introduced under stimulus circumstances identical to those when U-air was introduced. Responses following its introduction, however, produced shock rather than presentation of food. After the 10-second response-contingent punishment period, the system of air-sample delivery was purged with room air. The next S-air sample was not introduced until the latency of response to a U-air sample was again under 2 seconds. An average of five U-air samples followed each S-air sample; a median of seven paired samples of U-air and S-air was presented during each 45-minute session. One rat was discarded early because of apparatus malfunction. The other five animals were given from 68 to 123 (median 82) S-air samples over a period of 8 to 14 days.

Discrimination between the odors was formally tested during the last 20 pairs of U-air and S-air presentations. The latency of the first bar press after introduction of S-air was substracted from the latency to the immediately preceding U-air sample, yielding 20 differences in latency for each animal. Latency was used rather than response rate during the test period because rate was confounded by reinforcement or punishment. The average latency (seconds) in U-air was 1.59; in S-air, 8.49. All animals had longer ($P < .01$) mean latencies after S-air than after U-air (Table 1). The larger standard deviations of the latency after presentation of S-air mainly reflect extremely long latencies (to 54.2 seconds) that occasionally occurred after delivery of S-air and never after U-air. Binomial probabilities computed for each animal corroborate t-test results.

The behavior of the animals during training became progressively more directed toward the odor source. As training proceeded, the rats almost invariably sniffed at the odor source when an air sample was introduced. With S-air they then either stopped responding abruptly, vacillated, or backed away to the far end of the compartment. Such a pattern was not characteristic of response to the identically introduced U-air.

There was no evidence that the discrimination found here was based simply on odors unique to individual rats (*5*). From three to six different stressed animals and from four to eight different unstressed animals served in mixed order as stimulus sources for each of the last 20 trials. In addition, two animals which had just provided U-air,

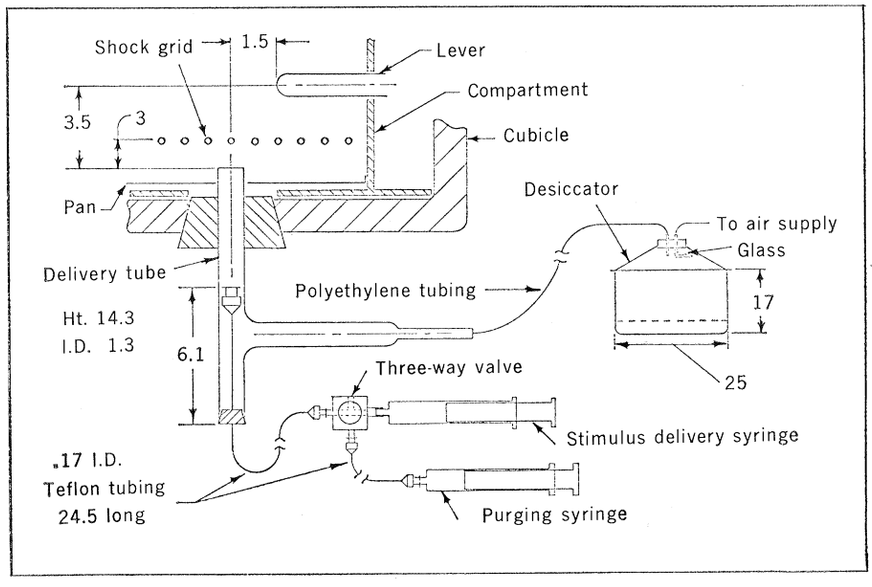

Fig. 1. Experimental arrangement for comparing the effects of odors from unstressed and stressed rats on an ongoing bar-press response. Against a background of pure air passed over a rat confined in the desiccator, odors tested were introduced from the stimulus delivery syringe. All measurements are in centimeters.

were then stressed for the first time. Differences in latency to the air from the same rat when stressed and unstressed were comparable to differences found when one rat was stressed and another unstressed. This observation would also suggest that the discriminable odor did not derive from a chronic stress state, but arose immediately from a given stressing.

Neither can the discrimination be reasonably attributed to greater familiarity with odors of the unstressed rats as a group. Air sampled from unstressed animals not previously used did not produce the long latencies associated with S-air. The possibility that a cue might derive from the living cages from which the stimulus air was sampled, was tested by placing U- and S-stimulus rats in completely new cages for 30 of the 100 test trials. Results were indistinguishable from those obtained when air samples were taken from the living cages.

The major finding of this paper that rats can respond differentially to odors of stressed and unstressed rats suggests the need for instituting experimental controls in those studies in which odor from a stressed animal might affect behavior of nearby animals. Previously such controls were not thought necessary. We are presently seeking to locate the odor source in the animal's body to assist us in determining whether the material has pheromonal activity and in its eventual chemical analysis.

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3. D. G. Davenport and L. R. Goulet, *J. Comp. Physiol. Psychol.* **57**, 237 (1964). Twelve animals were paired on the basis of weight patterns; one from each of the six pairs was randomly assigned to be trained. To provide a base line for normal increments in weight of the still-growing animals, the other member of the pair had continuous access to food and water. Animals being trained averaged about 75 percent of their matched partners' weight.
4. In the VI-1 schedule an average interval of 1 minute separates those bar presses which deliver the filled dipper; intervening bar presses are not followed by operation of the dipper. This reinforcement schedule leads to stable response rates.
5. J. M. Bowers and B. K. Alexander, *Science* **158**, 1208 (1967).
6. Supported in part by PHS research grant 1-RO3-MH 13457-01 and by Rockhurst College Faculty Research Fund. We thank G. E. Edwards and M. Bubb for assistance.

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Surveyor V Landing: the Effect of Slope on Bearing Capacity

Preliminary Surveyor V results (*1*) indicate that the mechanical properties of the lunar surface material at the Surveyor V landing site are generally similar to those determined for the Surveyor I site. The static bearing capacity, however, was reported to be "somewhat lower" than the range of values reported previously. It is to this statement that the authors direct their comments.

An important difference between the Surveyor I and V landings is that the former took place on a virtually flat surface [1.7° ± 0.5° (*2*)], whereas the latter was on a crater slope of approximately 20 degrees. Although there are a number of theories concerning the stability of slopes and foundations embedded in a slope, to our knowledge the bearing strength of a slope loaded over a finite area on the surface has not been treated theoretically. Our theory (*3*) is based on the Prandtl theory of plastic equilibrium. Figure 1 shows the three shear zones which, according to Prandtl's theory, exist at failure in an ideal soil in contact with a smooth footing on a level surface.

The following expression for the ultimate bearing capacity of a level soil loaded over a finite area has been developed from the Prandtl solution by Terzaghi (*4*):

$$q_u = K_1 c N_c + \frac{1}{2} K_2 \gamma_1 b N_\gamma + K_3 \gamma_2 t N_q \quad (1)$$

where q_u is the ultimate bearing strength; K_1, K_2, K_3, the footing geometry coefficients; c, the value of unit

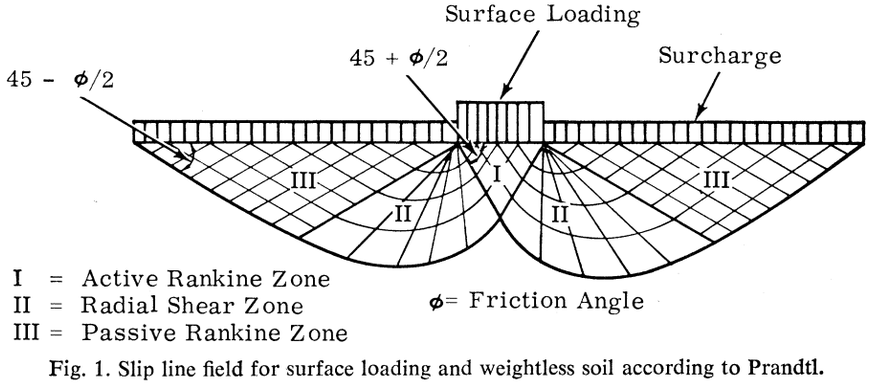

Fig. 1. Slip line field for surface loading and weightless soil according to Prandtl.

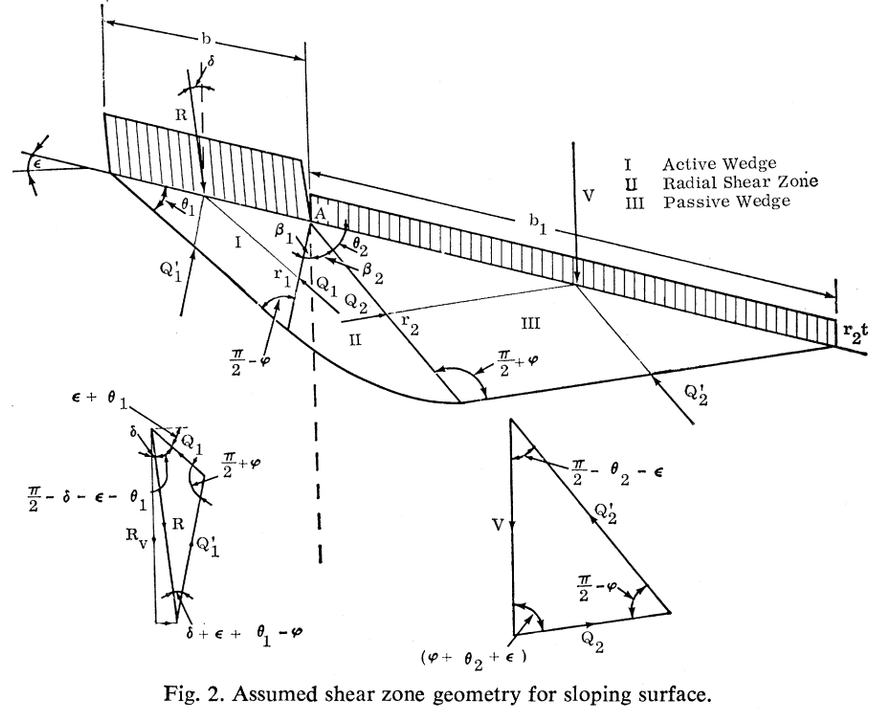

Fig. 2. Assumed shear zone geometry for sloping surface.