Further confirmation of the location of the double bond in both the isolated and synthesized acids was obtained by (i) cleavage of the unsaturated acids with alkaline permanganate to give 2-pentanone and by (ii) cleavage of the corresponding ozonides of the unsaturated acids with toluenesulfonic acid in ethanol to give diethyl oxalate.

Because the odorous substance is acidic, and because the only detectable difference in composition between the samples from schizophrenic patients and controls is the presence of *trans*-3-methyl-2-hexenoic acid, this acid is presumed to be responsible for the peculiar odor in the "sweat" of schizophrenic patients.

Crystals of this synthetic acid were added to "normal sweat" and a panel of four trained observers agreed that the odor produced was identical with the peculiar odor characteristic of the sweat of schizophrenic patients. This work represents a first step in an attempt to identify the metabolic disorder responsible for nuclear schizophrenia.

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4. The method of collecting sweat specimens is described in (*1*). The term "sweat" as used in this article refers to skin secretions. The chemical substance is thought to be of sebaceous gland origin rather than eccrine or apocrine in origin.
5. R. L. Shriner, R. C. Fuson, D. Y. Curtin, in *The Systematic Identification of Organic Compounds* (Wiley, New York, 1956), p. 63.
6. All the gas chromatography was carried out on columns containing 10 percent diethylene glycol adipate and 2 percent phosphoric acid (85 percent) on acid-washed Chromosorb-W.
7. Mass spectra were obtained on a Consolidated Electrodynamics mass spectrometer (model 21-104) equipped with an F and M (model 810) gas chromatograph.
8. Ethyl-3-hydroxy-3-methylhexanoate, prepared by the Reformatsky reaction of ethyl bromoacetate with 2-pentanone, was dehydrated with phosphorus oxychloride according to the method of L. Canonica, E. Fedeli, A. Castelnuovo [*Gazz. Chim. Ital.* **87**, 998 (1957)].
9. The NMR spectrum of the isolated acid was obtained with a Varian HA-100 spectrometer equipped with a C-1024 time-averaged computer (tetramethylsilane, internal standard). The sample was examined with two successive accumulations of spectra, each totaling 137 scans.
10. Spectrum No. 114, NMR Spectra Catalog, Varian Associates, Palo Alto, California.
11. We thank R. Frederickson and P. Kingslan for help with the experimental work, the Monsanto Chemical Company for determining the mass spectra, and Varian Associates for determining the nuclear magnetic resonance spectra. Supported by grants MH 05415, MH 5938, and MH 5804 from the National Institutes of Health.

9 December 1968; revised 10 July 1969 ■

Animals Respond for Food in the Presence of Free Food

Abstract. *Pigeons pecked a response disk to gain access to grain rewards while identical grain was freely available from a cup within the experimental chamber. Similarly, rats pressed a lever for food pellets while free pellets were present. It is not necessary, therefore, to deprive an animal of food before it will engage in instrumental responding for food. Such responding can serve as its own motivation and reward.*

An animal will perform instrumental responses for food after being deprived of food but will not respond after eating a large meal. This common observation suggests that responding to obtain food is primarily motivated by hunger or, more exactly, by food deprivation. But is it true that the animal must be deprived in order to work reliably for food? The answer to this question is usually yes (*1*). However, this study shows that pigeons and rats respond for food when they are not deprived of food and when a cup filled with identical food is continuously available.

Two male White Carneaux pigeons with no previous experimental training were used for the basic study. Each bird lived alone in an operant-conditioning chamber (48 cm long, 28 cm wide, and 31 cm high), the front wall of which contained a continuously lighted response disk (1.9 cm in diameter) and a feeder mechanism (*2*). A peck by the pigeon of at least 0.15 newton force on the disk gave the bird 5 seconds of access to mixed grain in the feeder. A 7-watt bulb illuminated the feeder while grain was presented. Cups (8.9 cm high and 7.6 cm in diameter) were secured in the rear corners of the chamber: one cup always contained water; the other sometimes contained mixed grain identical to that in the feeder and sometimes was empty. The pigeon lived in the chamber throughout the experiment except for approximately ½ hour each day while the chamber was cleaned and resupplied.

Each pigeon was deprived of food and taught to peck the disk for grain reward. The free-food cup was empty (so that the pigeon had to peck the disk to get food) and was kept empty for 7 days while the feeder was operated by pecking. One pigeon responded about 270 times per day during the last 3 days of this base-line condition (Fig. 1), and the second pigeon responded about 1100 times (a difference that is attributable to pigeon 2 eating for a relatively short time after each response).

The free-food cup was then filled with grain for 15 days. Since responses continued to produce access to feeder grain, there were now two sources of identical food, free and response-produced; yet both pigeons continued to peck the disk at relatively high frequencies (Fig. 1). Pigeon 1 responded only 33 times during the first day of this condition, but increased its responding over the next few days; pigeon 2 responded at high frequency throughout. Gross measures indicated that (i) grain was taken from both feeder and cup, (ii) more grain was eaten from feeder than from cup, and (iii) both birds occasionally responded but did not eat from the feeder.

In the first of four control studies, responding depended on access to feeder grain rather than merely on the sound of the feeder operating or the sight of grain (*3*). Pigeon 1 remained in the chamber for 13 days during which the feeder was empty; pigeon 2 was in the chamber for 10 days while a transparent shield covered the feeder, thereby permitting the bird to see the grain but not to reach it. As before, each response operated the feeder, and free grain was available from the cup; but under this condition, frequencies of responding decreased to low levels (Fig. 1). When responses again produced access to grain (for 11 days), frequencies of responding again increased (Fig. 1).

To explore the generality of the above findings, two female albino rats with no previous experimental experience were studied under similar conditions. The rats were individually housed in an operant-conditioning chamber containing two metal levers (*2*). A response of at least 0.32 newton force on the left lever caused one 45-mg Noyes pellet to appear in a recessed food tray (the right lever was not operative throughout this experiment). A metal food cup (9.4 cm high and 6.5 cm in diameter) was located in the rear right corner of the chamber. Water was always available from an overhead spout.

The procedures were similar to those described above, although the order of presentation differed. The rats were deprived of food and taught to press the left lever to get food pellets. (i) Each rat then lived in the chamber for 15 days while each response produced a pellet. The free-food cup was filled with Noyes pellets throughout this time. (ii) Responses were then made ineffective (they produced only auditory feedback) for 10 days while food pellets remained in the free-food cup. (iii) The experimental condition (i above) was reinstated for 6 days. (iv) Finally, the free-food cup was emptied for 7 days and food could be obtained only by responding on the lever. Both rats responded for food pellets while identical pellets were otherwise freely available; the frequencies of responding decreased when bar-pressing did not produce pellets; and the frequencies increased when pellets were again produced [Fig. 1 (bottom)]. Almost all pellets produced by responding were immediately eaten, an indication that the rats were not hoarding (*4*). Pellets were also eaten from the free-food cup. The behavior of the rats differed from that of the pigeons in one respect: the rats made fewer responses when free pellets were in the cup than when the cup was empty. The pigeons, however, responded perhaps slightly more in the presence of free food than in its absence. While this difference should be explored further, the basic finding was replicated: rats responded for food while a cup filled with identical food was continuously available.

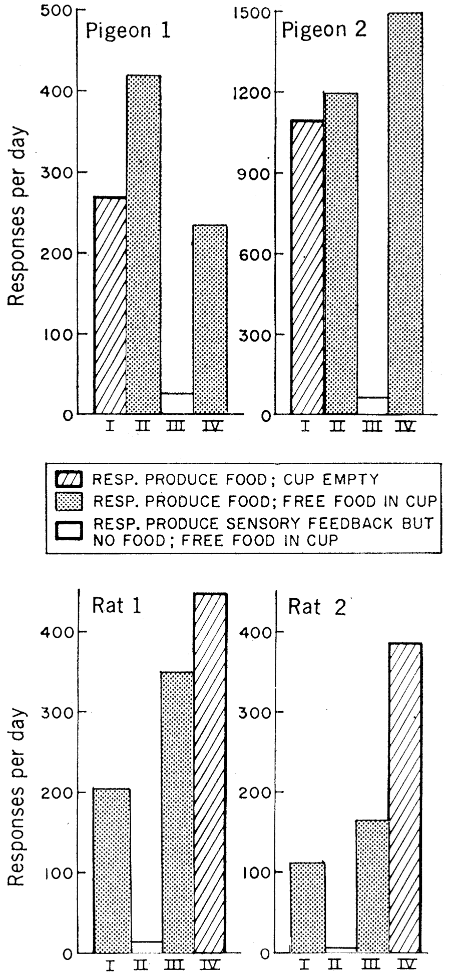

Fig. 1. Average number of responses per day over the last 3 days of each experimental condition. The subjects experienced the conditions in the order shown, from left to right.

The final study indicated that the responding was not simply a "carry-over" of a previously learned habit. One experimentally naive pigeon lived in the operant chamber for 20 days. From the start, the free-food cup was filled with grain, and each peck at the response disk resulted in 5 seconds of access to feeder grain. The pigeon was not deprived of food nor trained in any way (that is, the bird was not trained to eat from the feeder or to peck the response disk). As a control for special properties of the peck response, a second experimentally naive pigeon was placed in the same situation with one difference: the response disk was removed and a microswitch was secured behind the front panel. The arm of the microswitch was approximately 2 cm above the floor of the cage and protruded into the cage about 1.5 cm to form a response lever. Depressing the lever activated the feeder for 5 seconds. Both pigeons learned, in the presence of a cup filled with grain, to respond for grain (peck a disk or press a lever) (Fig. 2). After 20 days, a transparent shield was placed over the feeder opening (as with pigeon 2 above) for about 5 days so that grain produced by responding could be seen but not eaten. Frequencies of responding decreased rapidly (Fig. 2). When the cover was removed, responding again increased. Thus pigeons learned arbitrary new responses for food while free food was present (*5*).

Under what conditions will an animal engage in instrumental responding? Hullian theory suggests that the motivation for all instrumental behavior is derived from a threat to life (*6*). One must deprive an animal of a biologically necessary substance, such as water, food, or oxygen, or present it with a predator or other life-threatening object in order to motivate responses that lessen, avoid, or abolish the threat; when there is no threat, there is no instrumental activity. According to an alternative view of behavior, many instrumental acts occur in the absence of a threat to life and moreover without the animal being deprived of any stimulus, biologically necessary or otherwise (*7*). For example, animals continually explore, play, manipulate, seek novel stimuli, make novel responses, and so forth. Since these activities are not dependent upon any motivating operation, they have been called characteristic of waking behavior and therefore natural. My findings support and extend the latter view. Even arbitrary instrumental responses for food can be acquired and maintained when the subject is not deprived or threatened. Responding for food, like playing and exploring, appears to be a natural part of the behavior of animals and does not necessarily depend upon any prior motivating operation. Further evidence for this view is found in the operant-conditioning literature. First, animals often do not minimize their instru-

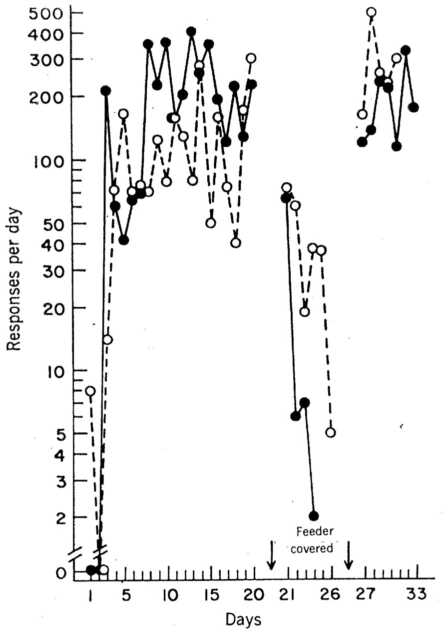

Fig. 2. Number of responses made each day by two pigeons that had not previously learned to respond. One bird (black circles) pecked a response disk to obtain grain and the other (open circles) pressed a lever for grain. During days 21 through 26, grain produced by responding could be seen but not eaten. The free-food cup was filled with grain throughout the 33 days.

mental output: under a variety of reinforcement schedules, enormous numbers of unnecessary responses are made (*8*). Second, even when rewards are freely presented without regard to specific responses, the rewarded animal nevertheless acts as if it were producing the reward: behavior is vigorous, consistent, and stereotyped—that is, superstitious (*9*). These and the present findings suggest that animals often emit instrumental responses which reduce no biological need and abolish no threat. To make an animal press a lever for food, one need not first deprive or otherwise motivate the animal. The act of producing food can serve as its own motivation and, therefore, as its own reward.

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10. Supported by NIMH grants MH-12108 and MH-15495. I thank Dr. Shin-Ho Chung for his collaboration and V. Goldman, M. Miskella, D. Ramsay, and A. Schein for their assistance.

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Planetary Formation and Lunar Material

The indications (*1*) that "igneous" lunar rocks are old, perhaps as old as the meteorites, may lead to the suggestion that the moon experienced a period of intense volcanic activity early in its history. I point out here that there is no need for volcanoes to have occurred *in situ* on the moon. Considerations of angular momentum (*2*) show that planetary material probably separated from the sun when the radius of the latter was considerably greater than its present value. Current work on stellar structure requires that the effective surface temperature of the solar condensation be substantially constant at 3500° to 4000°K during this phase, independent of radius. Hence, for comparatively large radii the luminosity would have been very much greater than the present-day value, so that primitive planetary material could well have been considerably hotter than would be estimated for material at corresponding distances from the present-day sun.

Quantitative consideration of the angular momentum problem suggests that the planetary material separated from the sun when the radius was $\sim 2 \times 10^{12}$ cm. Such material driven out to the terrestrial distance of $\sim 1.5 \times 10^{13}$ cm would be expected to experience temperatures of $\sim 3500 \times (7.5)^{-\frac{1}{2}}$°K, which is not much different from the temperature in volcanoes. Thermochemical details relating to this situation have been reported elsewhere (*3*). Here I simply remark that melting and chemical segregation could have taken place within the primitive planetary material, even though this hot phase was short-lived, $\sim 10^4$ to 10^5 years. It will be of great interest to see if the recently acquired samples of lunar material establish the existence of such a hot phase, and, if so, to discover if any features of terrestrial geochemistry, which have hitherto been attributed to igneous activities on the earth itself, really belong to the initial primitive phase of the solar system.

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2 October 1969

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Pyroxene Gabbro (Anorthosite Association): Similarity to Surveyor V Lunar Analysis

The data from the alpha-scattering experiment of Surveyor V in Mare Tranquillitatis (*1*) resemble data from average oceanic basalts with, however, several major exceptions, principally Ti. Turkevich *et al.* (*1*) concluded that no common earth material provided a match for these revised lunar data and that perhaps special geochemical processes were required to produce the lunar material.

One terrestrial rock type, however, does bear a striking resemblance to these refined data. Pyroxene gabbros, late differentiates of major anorthosite masses, are almost always titaniferous, containing major amounts of sphene or ilmenite, or both. Two typical analyses from the Adirondack Mountains (Table 1) are close to the Surveyor data for all oxides except Na_2O. The observed plagioclase compositions in these gabbros range from An 42 to An 50 (*2*). Better agreement for Na_2O results if one simply postulates that the lunar gabbros bear a more anorthite-rich plagioclase. If we assume an An content of about 85 for the lunar sample, then the analysis can be recomputed (Table 2) with closer agreement.

Thus, it appears that a better candi-

Table 1. Oxide compositions of lunar surface (*1*) and of two pyroxene gabbros from anorthosite masses in Adirondack Mountains (*2*). Gabbro 1 is pyroxene gabbro facies of gabbroic anorthosite from near Brown Pt., N.Y. Gabbro 2 is sphene gabbro pegmatite from Wilmington, N.Y. Water and sulfur not included here for either gabbro.

Oxide (% by weight)	Lunar surface	Gabbro 1	Gabbro 2
SiO_2	46.4	45.2	44.3
TiO_2	7.6	6.9	9.6
Al_2O_3	14.1	11.8	13.2
FeO	12.1	15.5*	6.6†
MnO		0.2	0.1
MgO	4.4	6.4	2.0
CaO	14.5	10.2	18.4
Na_2O	0.6	2.1	2.8
K_2O		0.5	0.4
P_2O_5		.2	1.2
CO_2		.3	0.5
	100.0	99.3	99.1

* Contains 1.6 percent Fe_2O_3 recalculated to FeO. † Contains 1.4 percent Fe_2O_3 recalculated to FeO.