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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References and Notes

1. D. Bindra, *Motivation: A Systematic Reinterpretation* (Ronald Press, New York, 1959); C. N. Cofer and M. H. Appley, *Motivation: Theory and Research* (Wiley, New York, 1964); J. R. Millenson, *Principles of Behavioral Analysis* (Macmillan, New York, 1967); J. Konorski, *Integrative Activity of the Brain* (Univ. of Chicago Press, Chicago, 1967).
2. All basic equipment was purchased from Ralph Gerbrands Co. The pigeon chamber was enclosed within an outer box so that external light and sound were attenuated. A perch was located in the chamber and grit was continuously available. The rat chamber was not enclosed; therefore the rats experienced normal laboratory stimuli. A wood chewing block was continuously available to the rats. The forces necessary to operate pigeon key and rat lever were indirectly measured with a spring-weighing device.
3. Animals will work for some types of visual and auditory stimulation; see G. B. Kish, in *Operant Behavior: Areas of Research and Application*, W. K. Honig, Ed. (Appleton-Century-Crofts, New York, 1966), pp. 109–159.
4. M. H. Marx, *Psychol. Rev.* **57**, 80 (1950).
5. The present phenomenon therefore cannot be explained by "functional autonomy" or an "externalization" of a hunger drive: see G. W. Allport, *Personality: A Psychological Interpretation* (Holt, New York, 1937), pp. 190–212; E. E. Anderson, *J. Genet. Psychol.* **59**, 397 (1941).
6. C. L. Hull, *Principles of Behavior* (Appleton-Century-Crofts, New York, 1943).
7. R. S. Woodworth, *Dynamics of Behavior* (Holt, New York, 1958), pp. 48–133; R. W. White, *Psychol. Rev.* **66**, 297 (1959); D. E. Berlyne, *Conflict, Arousal, and Curiosity* (McGraw-Hill, New York, 1960); P. Marler and W. J. Hamilton III, *Mechanisms of Animal Behavior* (Wiley, New York, 1966), pp. 159–202.
8. C. B. Ferster and B. F. Skinner, *Schedules of Reinforcement* (Appleton-Century-Crofts, New York, 1957); A. J. Neuringer and B. A. Schneider, *J. Exp. Anal. Behav.* **11**, 661 (1968).
9. B. F. Skinner, *J. Exp. Psychol.* **38**, 168 (1948); R. J. Herrnstein, in *Operant Behavior: Areas of Research and Application*, W. K. Honig, Ed. (Appleton-Century-Crofts, New York, 1966), pp. 33–51; A. J. Neuringer, *J. Exp. Anal. Behav.*, in press.
10. Supported by NIMH grants MH-12108 and MH-15495. I thank Dr. Shin-Ho Chung for his collaboration and V. Goldman, M. Mīskella, 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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References

1. Lunar Sample Preliminary Examination Team, *Science* **165**, 1211 (1969).
2. F. Hoyle, *Quart. J. Roy. Astron. Soc.* **1**, 993 (1960).
3. ——— and N. C. Wickramasinghe, *Nature* **217**, 415 (1968).

2 October 1969

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.

Table 2. Oxide composition of Gabbro 1 (of Table 1) recalculated for a plagioclase composition of An 85.

Oxide (% by weight)	Gabbro 1	Lunar surface
SiO_2	42.3	46.4
TiO_2	6.9	7.6
Al_2O_3	14.4	14.4
FeO	15.5	12.1
MnO	0.2	
MgO	6.4	4.4
CaO	12.5	14.5
Na_2O	0.6	0.6
K_2O	.5	
P_2O_5	.2	
CO_2	.3	
	99.8	100.0

date for the rock analyzed in Mare Tranquillitatis is a gabbro or gabbroic anorthosite possibly associated with highly anorthitic anorthosite masses. If this is true, the conclusions of Turkevich *et al.* still hold. Anorthosite is not a common terrestrial rock, and it involves some special geochemical (or petrological) processes, as witness the past controversies involved in accounting for the major anorthosite masses around the world.

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References

1. A. L. Turkevich, E. J. Franzgrote, J. H. Patterson, *Science* **165**, 277 (1969).
2. A. F. Buddington, *Geol. Soc. Amer. Mem.* **7**, 36 (1939).

11 August 1969

Mitochondrial Genetics: A Conjecture

The genetics and phenogenetics of mitochondria have been reviewed (*1*). There may be a major implication for mitochondrial genetics in higher organisms based upon the differences in number of mitochondria contributed by the sperm and the ovum. In the mature egg, the number of mitochondria is very great compared to that in the sperm. It has been estimated that the number of mitochondria in the sea urchin ovum varies from 14,000 to 150,000 depending upon the species (*2*). In *Priapulus* oogenesis, the number of mitochondria increases from 5 to 8 in the oogonia to 40,000 in the mature oocyte (*3*). On the other hand, during maturation of the sperm the number of mitochondria decreases. In the sea urchin a single mitochondria ring is present at the base of the sperm head (*4*). Thus, the number of mitochondria contributed by the sperm is much less than that contributed by the ovum. In instances where the midpiece does not enter the egg, presumably all the mitochondria would be contributed by the ovum.

The large number of mitochondria in the ovum of a sea urchin is reflected in the quantity of extractable DNA having a density different from that of DNA derived from the nucleus. The amount of this DNA corresponds to the number of mitochondria in the egg, if one assumes that the DNA content is the same as in most other mitochondria derived from somatic tissues in other species (*5*).

The above facts would imply that the dosage of strictly mitochondrial genes would be much greater from the mother than from the father. Thus, those proteins directly under mitochondrial control (at transcription) should show a strong maternal characteristic. One assumes that there are indeed such genes in the mitochondria (see *1*, for example). If new mitochondria arise randomly from the existing mitochondria, then there would be no preferential increase in the relative number of mitochondria originally contributed by the sperm. This would imply that the number of such mitochondria would never catch up during development to the number of mitochondria derived from the ovum.

From these facts and assumptions, one can conclude that there should be some properties of the mitochondria which have striking maternal inheritance. If there were a clinically manifested lesion A in the F_1 generation from a mother with A and a normal father, all progeny would have such a lesion. The F_1 daughters would transmit the disease to all progency of the F_2 generation, but the F_1 son would have all normal progeny provided his mate were normal. Because of the lack of information concerning the role of mitochondria in development, the lack of knowledge of the gene loci of the mitochondrial DNA and its relationship to the nuclear gene loci, and the lack of knowledge of the interplay among individual mitochondria, the foregoing comments remain only a conjecture.

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References

1. R. P. Wagner, *Science* **163**, 1026 (1969).
2. B. A. Afzelius, referred to by A. B. Novikoff in *The Cell*, J. Brachet and A. E. Mirsky, Eds. (Academic Press, New York, 1961), p. 299; J. R. Shaver, *Exp. Cell Res.* **11**, 548 (1956).
3. A. Norrenvang, *Int. Rev. Cytol.* **23**, 113 (1968).
4. D. W. Fawcett, *ibid.* **7**, 195 (1958).
5. A. Tyler, in *Control Mechanisms in Development Processes*, M. Locke, Ed. (Academic Press, New York, 1967), p. 170.
6. The author is a recipient of a career development award from the National Institutes of Health.

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Uptake of Actinomycin by Sea Urchin Eggs and Embryos

In experiments with ^{14}C-actinomycin D, uptake and binding were measured in sea urchin eggs and embryos before and after hatching (*1*). Embryos at various stages were exposed to the drug at a concentration of 20 μg per milliliter of seawater for 45 minutes. Biochemical and autoradiographic data showed significant uptake after hatching and little or none before hatching. These findings were discussed in relation to the fact that actinomycin D inhibits protein synthesis in sea urchin embryos beginning 6 to 8 hours after fertilization, but not earlier in development.

We have discussed these experiments and their interpretation, and we agree that the following comment ought to be made: The hypothesis that eggs of sea urchins (and of other forms) contain untranslated ("maternal") messenger RNA depends in part upon experiments with actinomycin (*2*). This proposal is not invalidated by the uptake results (*1*). It is supported by data from experiments done without inhibitors of any kind (*3*). Actinomycin, administered in doses of 20 to 50 μg per milliliter of seawater for appropriate intervals to prehatching embryos, produces characteristic effects upon the polyribosomes (*4*), and it inhibits RNA synthesis under these conditions (*5*). Whatever the penetration rates, therefore, actinomycin exerts the metabolic effects expected of it.

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References

1. M. M. Thaler, M. C. L. Cox, C. A. Villee, *Science* **164**, 832 (1969).
2. P. R. Gross and G. H. Cousineau, *Biochem. Biophys. Res. Commun.* **10**, 321 (1963); *Exp. Cell Res.* **33**, 368 (1964).