tissues of a consumptive person (harboring tuberculosis bacilli) would presumably demonstrate a "tuberculosis bacillus-related satellite band" in a CsCl density gradient, normal plastid-containing euglena cells show a "chloroplast satellite band DNA." Similarly, if such a person were cured by an antibiotic more lethal to the bacillus than to himself, DNA isolated from his tissues after therapy would then show a total absence of the bacillus-related satellite band. Analogously, permanently bleached euglena cells lack the chloroplast satellite band DNA. Just as the patient cured of tuberculosis could hardly be called a human "mutant" and his antibiotic medicine a "mutagen," euglena cells whose plastid system has been knocked out by intense visible light (or any other "bleaching agents") should not be thought of as mutants. Simply these euglena cells have been cured of their beneficient photosynthesizing plastids, intracellular symbionts which are more sensitive than the euglena host cells to certain lethal environmental agents.

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References and Notes

1. J. Leff and N. I. Krinsky, *Science* **158**, 1332 (1967).
2. M. Zelle and A. Hollaender, *Radiation Biology*, A. Hollaender, Ed. (McGraw-Hill, New York, 1955), vol. 2.
3. J. A. Schiff and H. T. Epstein, *Reproduction: Molecular, Subcellular and Cellular*, M. Locke, Ed. (Academic Press, New York, 1965).
4. L. Sagan, *J. Theoret. Biol.* **14**, 225 (1967).
5. R. R. McCalla, *J. Protozool.* **14**, 3 (1967).
6. For the alternative example of how a true mutagen (proflavine hydrochloride) acts in a comparable cytoplasmic system (*Chlamydomonas*) see J. Randall, J. R. Warr, J. M. Hopkins, A. McVittie, *Nature* **203**, 912 (1964).
7. A. Gibor and S. Granick, *Science* **145**, 890 (1964).

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Margulis has raised a question that concerned us from the time we made our initial observations that many of the cells which survived an intense visible light irradiation of *Euglena gracilis* were colorless. The concern dealt with whether we had bleached *Euglena gracilis* by inhibiting chloroplast replication at the plastid level or at the host-cell level. As we pointed out in our article (*1*), we do not know the site at which visible light and O_2 exert their action in producing colorless survivors. We, therefore, concluded that the multigenic system consisting of the host cell and plastid had undergone a mutation, that is, a stable heritable change, under the conditions of our experiments. The problem with using this definition of mutation is that in multigenic systems such as *Euglena* and yeast, which contain plastids and mitochondria capable of multiplication and development relatively independent of nuclear control, the site of mutation is not specified.

With respect to the question of whether visible light acts as a mutagen or as a lethal agent, we have made the following observations. When *Euglena gracilis* cells are placed in a resting medium for 2 to 3 days, cell division stops (*2*). If these cells are illuminated aerobically with white light (4.5×10^6 erg cm^{-2} sec^{-1}) for 4 to 9 hours (*1*), the culture bleaches; when viewed under a fluorescent microscope only a few normally red fluorescent cells can be seen, the majority appearing either pink or colorless. These bleached cultures were maintained in resting medium for an additional 2 days under visible light (2750 lumen m^{-2}) during which time the culture became green. Inspection under a fluorescent microscope at this time revealed that almost all the cells had a typical red fluorescence, indicating that the intense visible light had not destroyed the cells' capacity to make chlorophyll. However, if a sample of the culture was transferred to growth medium and plated immediately after the exposure to the bleaching irradiation, a different effect was observed. In this case, 29 percent of the colonies were colorless, a mutation rate similar to those reported in Table 1 of our paper (*1*). However, we found only an 18 to 32 percent decrease in cell number, compared to nonirradiated controls which indicates a very low rate of killing (that is, lethal mutation) when cells are irradiated in a medium which prevents cell division.

The example which Margulis uses of a consumptive person infected with tubercule bacilli is not relevant unless one concludes that a symbiotic (mutually advantageous) relationship exists between man and microbe. This type of relationship apparently does exist in *Euglena gracilis,* and one of the effects of visible light and O_2 is to alter this relationship.

If the question is raised of whether the mutagenic event occurred in the host or the symbiont, our assumption would be that it occurred in the symbiont, but as yet we have no evidence to prove this. If and when experimental conditions are devised to permit "reinfection" of bleached *Euglena gracilis* with plastids this question can be answered, for a host mutation should not be capable of reinfection, whereas a symbiont mutant should be readily reinfected. Until additional evidence is presented it might be more appropriate to refer to the effects of visible light and O_2, as well as other bleaching agents or conditions, as mutagens acting on multigenic systems whose action results in the appearance of stable, heritable changes.

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References and Notes

1. J. Leff and N. I. Krinsky, *Science* **158**, 1332 (1967).
2. A. I. Stern, J. A. Schiff, H. T. Epstein, *Plant Physiol.* **39**, 220 (1964).

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Lunar Interior: Constraint on Basaltic Composition

Gast (*1*) has pointed out that Gault *et al.* (*2*) make an assumption regarding the average lunar composition, in order to conclude that the basaltic composition of its surface implies chemical differentiation. In view of our lack of knowledge of chemical processes in planetary formation, it is certainly justifiable to caution against such assumptions. The purpose of this note is to discuss further the alternative suggestion made by Gast, namely that the composition of the entire moon is similar to the basaltic achondrite meteorites, and, in particular, to the subclass known as eucrites.

It is well known that above pressures of the order of 10 to 20 kb plagioclase feldspar is unstable and transforms to a mixture of garnet and pyroxene. The available data (*3*, *4*) may be used to infer the probable composition and density of a rock of eucritic composition (*5*) at high pressure. In this way it is found that the high-pressure assemblage consists of about 57 percent (by weight) of garnet (28 percent FeO), 32 percent diopsidic pyroxene, and 11 percent quartz. The compositions of these minerals may be matched with those of terrestrial minerals of similar compositions (*6*) to obtain densities of 4.08 and

3.37 for the garnet and pyroxene, respectively. This implies a density of 3.63 for the total rock. The addition of 1 percent metallic iron, if present, would raise the density to 3.67. Above 30 kb, the quartz-coesite transformation may raise the density by an additional 0.05. The effects of compression and thermal expansion are opposite and will approximately cancel each other. For a rock with such a high ratio of Fe to Mg, and such a low Na_2O content, data of Ringwood and Green (*4*) indicate that garnet will appear at about 10 kb at 1100°C, and that the transition to the high-pressure mineral assemblage will be complete by 15 kb.

A model of the moon with a "core" of density of 3.65, a radius of 1388 km, and a "mantle" of eucritic density (3.25) will have a pressure of 15.9 kb at the core-mantle boundary and a central pressure of 69 kb. As discussed above, this core-mantle pressure is sufficient for the transition to the high-pressure mineral assemblage under consideration. The mean density of the moon will then be 3.47 when a radius of 1735 km is used (*7*). This is distinctly higher than the value 3.36 found when a recent value for the lunar mass of 7.3505×10^{25} g (*8*) is used.

As long as the temperature is below the melting point, assumption of higher temperatures in the lunar interior should not greatly affect the result, because dT/dP for the basalt-eclogite transformation is 50° to 100°C kb^{-1} (*4*), whereas the melting point gradient is only 10°C kb^{-1} (*3*). The assumed temperature at the core-mantle boundary of 1100°C is within about 100°C of the melting point, and consequently raising the temperature to the melting point would increase the pressure at the core-mantle boundary only 1 or 2 kb. Of course, if the temperature exceeds the melting point, the density will be lower. Such partial melting of the lunar interior might be expected in this model, since the radioactivity of eucrites (*9*) is sufficiently high. However if such partial melting occurs, it may be expected to have produced a differentiated lunar crust, and again, a lack of correspondence between the surface composition and the mean composition. A lower temperature in the lunar interior will result in an even greater mean density. It therefore appears that it is difficult to obtain a consistent model of a solid moon with a homogeneous eucritic composition, and that correspondences between eucritic densities, the surface density, and the mean density are not necessarily significant.

It is not my purpose to discuss in detail possible lunar models. However, there are possible homogeneous lunar compositions which are consistent with the Surveyor analyses, and which do not become too dense at the pressure of the lunar interior. Lower density is favored by lower FeO content and SiO_2 saturation. A low FeO content results in a less dense garnet and a higher proportion of pyroxene, whereas SiO_2 saturation results in the occurrence of significant quantities of quartz in the high-pressure modification. For example, a quartz tholeiite with about 8 percent FeO would have a high-pressure density of about 3.4 (*4*), and the resulting mean density would be less than that of the moon. Basalts intermediate between this composition and that of the eucrites could match the lunar density. The lunar density could also be matched by the composition of some howardites, but the high ratios of Mg to Ca and Mg to Al of these achondrites have not been found in presently available analyses of lunar surface rocks. Also, a peridotitic moon consisting of magnesium-rich pyroxene and olivine and with a thin basaltic crust would not undergo any significant phase changes at lunar pressures. The basaltic models would be characterized by a large increase in seismic velocity at a depth of about 350 km, whereas the peridotitic models would not. Both types of model could be in agreement with the observational data discussed here, and they indicate that these compositional constraints are not extremely restrictive, but that they nevertheless must be considered in constructing models of the lunar interior.

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References

1. P. W. Gast, *Science* **159**, 897 (1968).
2. D. E. Gault, J. B. Adams, R. J. Collins, J. Green, G. P. Kuiper, H. Mazursky, J. A. O'Keefe, R. A. Phinney, E. M. Shoemaker, *ibid.* **158**, 641 (1967).
3. H. S. Yoder, Jr., and C. E. Tilley, *J. Petrol.* **3**, 342 (1962); L. H. Cohen, K. Ito, G. C. Kennedy, *Amer. J. Sci.* **265**, 475 (1967).
4. D. H. Green and A. E. Ringwood, *Geochim. Cosmochim. Acta* **31**, 767 (1967); A. E. Ringwood and D. H. Green, *Tectonophysics* **3**, 383 (1966).
5. M. B. Duke and L. T. Silver, *Geochim. Cosmochim. Acta* **31**, 1637 (1967); B. Mason, *ibid.*, p. 107.
6. W. A. Deer, R. A. Howie, J. Zussmann, *Rock-Forming Minerals* (Wiley, New York, 1962), vols. 1 and 2.
7. W. L. Sjogren and D. W. Trask, *J. Spacecraft* **2**, 689 (1965).
8. C. G. Vegos and D. W. Trask, *Jet Propulsion Lab. Spec. Progr. Sum.* **3**, 37 (1967).
9. J. W. Morgan and J. F. Lovering, *J. Geophys. Res.* **69**, 1989 (1964); *ibid.* **70**, 2002 (1965); G. Edwards and H. C. Urey, *Geochim. Cosmochim. Acta* **7**, 154 (1955); J. Geiss and D. C. Hess, *Astrophys. J.* **127**, 224 (1958); P. W. Gast, *Geochim. Cosmochim. Acta* **19**, 1 (1960); A. P. Vinogradov, I. K. Sadoroschnii, K. G. Knorre, *Meteoritika* **18**, 92 (1960).

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Urocanic Acid in Sweat: An Artifact of Elution from the Epidermis

Urocanic acid, a product of the reaction of histidine in the presence of histidase, is reported to be a normal constituent of human sweat (*1*), except in patients with histidase deficiency (*2*).

In view of the fact that urocanic acid is present in high concentrations in human stratum corneum (*3*) and that the histidase reaction occurs in animal skin not containing sweat glands (*4*), we examined the hypothesis that urocanic acid is not a true constituent of sweat but is eluted into sweat from the epidermis across a sweat epidermis interface.

Use of the anaerobic technique for collecting sweat minimizes or perhaps eliminates the effects of a sweat epidermis interface. This technique allows sweat to be secreted under mineral oil as discrete droplets emerging from single glands rather than to be layered on the skin.

The concentration of urocanic acid in human sweat (collected by the anaerobic technique) (*4*) from the anterior surface of one arm was compared to its concentration in sweat (collected on filter paper) from the contralateral limb. In this process, both sites were stimulated by pilocarpine iontophoresis, and, after a secretory period of 30 minutes, sweat was collected almost simultaneously from both sites. The urocanic acid was measured spectrophotometrically at 277 nm after sweat was diluted (1:10) in a phosphate buffer, *p*H 7.4.

Figure 1 shows the absorption spectra of the sweat obtained by the two techniques. The spectra are qualitatively similar, but the peak at 277 nm due to sweat collected under oil has only 10 percent of the optical density of sweat collected by conventional means.