includes both the nitrogen now in the atmosphere and that present in living matter and in sediments; it is probably a good measure of the total amount of nitrogen accumulated by degassing. Such an amount would be released by decomposition of 2×10^{17} tons of ammonium muscovite—a layer 170 m thick at Earth's surface. If one used ammonium feldspar as a basis for these calculations, the layer would be 70 m thick. This is clearly a trivial amount of matter compared with the total mass of Earth. The average natural muscovite contains 60×10^{-6} g of N_2 per gram, or 0.32 percent ammonium muscovite (*2*). Thus a layer of this average muscovite about 50 km thick would have to be degassed to yield the nitrogen present on Earth's surface today. There is no guarantee, however, that this average muscovite has not already lost most of its ammonia.

HANS P. EUGSTER
JAMES MUNOZ
Department of Geology,
Johns Hopkins University,
Baltimore, Maryland

References and Notes

1. W. W. Rubey, *Bull. Geol. Soc. Amer.* **62**, 1111 (1951); H. D. Holland, in *Petrologic Studies: A Volume to Honor A. F. Buddington* (Geol. Soc. Amer., New York, 1962); *Proc. Nat. Acad. Sci. U.S.* **53**, 1173 (1965).
2. F. Wlotzka, *Geochim. Cosmochim. Acta* **24**, 106 (1961).
3. R. C. Erd, D. E. White, J. J. Fahey, D. E. Lee, *Amer. Mineralogist* **49**, 831 (1964).
4. W. Vedder, *Geochim. Cosmochim. Acta* **29**, 221 (1964).
5. D. S. Barker, *Amer. Mineralogist* **49**, 851 (1964).
6. E. Gruner, *ibid.* **24**, 428 (1939); R. M. Barrer and P. J. Denny, *J. Chem. Soc.* **1961**, 971 (1961).
7. H. S. Yoder and H. P. Eugster, *Geochim. Cosmochim. Acta* **8**, 225 (1955).
8. The values for $d(001)$ of synthetic micas are from the following sources: margarite, H. P. Eugster, unpublished data; paragonite, ——— and H. S. Yoder, *Geol. Soc. Amer. Bull.* **65**, 1248 (1954); muscovite, (*7*); celadonite, W. S. Wise and H. P. Eugster, *Amer. Mineralogist* **49**, 1031 (1964); Rb-muscovite, H. P. Eugster and L. Meckel, unpublished data.
9. H. P. Eugster and D. R. Wones, *J. Petrol.* **3**, 82 (1962).
10. B. M. French, in *NASA Report X-641-65-324* (1965).
11. C. W. Burnham, in *Carnegie Inst. Wash. Year Book 1961* (1962), p. 132.
12. For the most recent estimates see K. H. Wedepohl, *Fortschr. Geol. Rheinland Westfalen* **10**, 129 (1963).
13. Supported by a grant from the Petroleum Research Fund of the American Chemical Society. We thank B. M. French for permission to use his data on gas compositions in the system C—H—O.

4 November 1965

Thunderstorm Electrification of Hail and Graupel by Polar Dribble

Abstract. *Hail and graupel falling through rain collect water that selectively dribbles upward from the upper surface of a hailstone. When the hailstones are polarized by nearly vertical electrostatic field these vertically discharged water drops carry away free charge of the same sign as that induced on the upper surfaces. The hail thereby accumulates an equilibrium charge of opposite sign, corresponding to the charges induced on the bottom surfaces. The equilibrium charges are large enough to be important in thunderstorms.*

Large electrification effects are usually observed in thunderstorms whenever hail or graupel is present. An induction process that transfers large free electrical charges to such hailstones or graupel is considered below. The process is somewhat related to the Elster and Geitel mechanism that considers the charges carried away by impinging cloud droplets reflected from raindrops (*1*).

Assume that an insulated but conducting spherical shell is exposed to an impressed electric field E_0 as shown in Fig. 1. This field polarizes the sphere to establish on its surface a field E, in electrostatic units, of magnitude

$$E = 4\pi\sigma = 3 E_0 \cos\varphi \qquad (1)$$

where φ is the angle with respect to the axis of polarization and σ is the free static charge per unit area.

Suppose now that the shell is partly filled with water that is allowed to dribble out a small hole at the pole, P, and fall away. Each drop will carry away charge proportional to the electric field at the point of droplet detachment. In this way, free charge is progressively transferred away from the sphere, which simultaneously builds up an opposite free charge on the shell proper. The transfer of charges continues until the electric field at the point of droplet detachment is reduced to zero. Laboratory tests clearly show that when this equilibrium state is reached, the sphere is charged to the value given by Eq. 2.

Consider an interesting case where

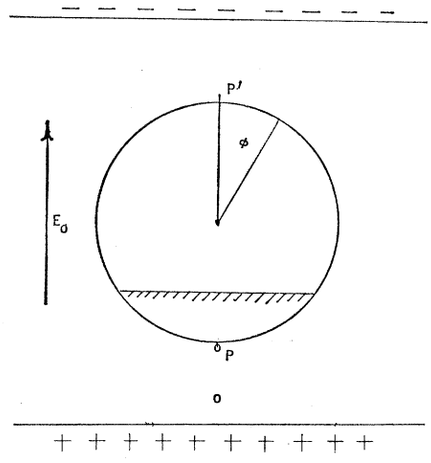

Fig. 1. Diagram of experimental arrangement.

the impressed electric field is vertically upward, as shown in Fig. 1, and the drops are detached at the lower pole, P. The charges induced at the lower pole are negative, so that the water drops carry away negative charges, leaving the shell more positive. The positive charge will increase as drops are lost until the electric field at the bottom pole approaches zero. Since by Eq. 1 the field at the bottom pole was initially inward with a magnitude $3 E_0$, it can be neutralized only by the accumulation of charge on the sphere sufficient to give an outward field of $3 E_0$ at the bottom pole. Thus, the equilibrium charge on the shell of radius a is (in electrostatic units)

$$Q = 3 E_0 a^2 \qquad (2)$$

It is important to notice that if the drops were detached from the top pole, P', by some special mechanism, then the accumulated free charge would be of opposite sign. This is actually what happens when hail or graupel falls through rain clouds. The weakly charged rain swept up by the falling hail wets and accumulates on the surface of the hail or graupel but then dribbles *upward* from the rapidly falling hailstones. This process has been well demonstrated (see *2*, fig. 13). Accordingly, if one adopts the outward-drawn normal as the positive direction for E_0, the free charge, Q, accumulated on falling hail and graupel particles approximates (in electrostatic units)

$$Q = -3 E_0 a^2 \qquad (3)$$

Because of the large size of hailstones and the large measured electric fields usually encountered near the

freezing level of the atmosphere during a thunderstorm, the produced free charges may be very large. Calculations show that the charges are, indeed, more than adequate to describe commonly observed active thunderstorms. Quantitative estimates of the established charge distributions inside active thunderstorms are in preparation.

ROSS GUNN

Physics Department, American University, Washington, D.C.

References and Notes

1. J. Elster and H. Geitel, *Phys. Z.* **14**, 1287 (1913).
2. R. Gunn, *Science* **150**, 695 (1965).
3. Supported by Nonr contract No. 3341(02).

17 November 1965

Mitochondrial DNA in Yeast and Some Mammalian Species

Abstract. *Yeast DNA, in a cesium chloride density gradient, shows a minor or satellite band with a density lower than that of the main nuclear component. The DNA isolated from purified mitochondria of yeasts corresponds in density to this satellite band. In solution, this DNA more easily undergoes renaturation as compared to DNA from cell nuclei. The ease of this renaturation is presumably due to a homogeneity greater than that of nuclear DNA. Mitochondrial DNA isolated from several mammalian species has the same or higher density than nuclear DNA, but differs in its ready renaturability.*

Extranuclear DNA has been found in two kinds of cytoplasmic organelles, the plastids of plants and the mitochondria (*1*). Mitochondrial DNA has been demonstrated in unicellular organisms such as molds (*2*), yeast (*3*), algae (*4*), and protozoa (*5*), as well as in mammalian species (*6*). The evidence for the presence of DNA is based on chemical analysis of isolated and purified mitochondria, electron microscopy, and cesium chloride density-gradient centrifugation. However, although the general occurrence of mitochondrial DNA seems definitely established, many of its properties remain to be described. We now report on the buoyant density and the renaturation properties of mitochondrial DNA from two different species of yeast, as well as from beef and sheep hearts, and from the livers of mouse, guinea pig, rat, and chicken.

Saccharomyces cerevisiae, Harden and Young strain (*7*) and *Saccharomyces carlsbergensis,* strains N.C.Y.C. 74 (*8*) and S-74 (*9*) were grown in an enriched medium (*10*) under aerobic conditions and were harvested at different times during the growth cycle. Yeast protoplasts and mitochondria were prepared essentially as described (*10*). The yeast protoplasts were prepared with helicase or glusulase, commercially available (*11*) digestive enzyme mixtures obtained from the snail *Helix pomatia.*

Mouse, guinea pig, and rat liver mitochondria were isolated essentially as described by Schneider (*12*). Beef-heart mitochondria were prepared by a modification of this method, by first mincing the beef-heart tissue into very small pieces and then dispersing in a glass homogenizer. The crude mitochondrial preparations were highly purified by banding in a discontinuous gradient of Ficoll (Pharmacia, Uppsala, Sweden) (*13*) and carefully isolating the visible mitochondrial regions with a pipette. The integrity of the mitochondrial preparations was ascertained from the respiratory-control index, determined with a Clark electrode for measuring dissolved oxygen. The homogeneity of the mitochondrial preparations was monitored by phase-contrast microscopy.

DNA was isolated from the mitochondria by a modification of the method of Marmur (*14*). Because of the small amount of DNA present in mitochondria, alcohol precipitations were eliminated. After removal of protein, the preparation was treated with T_1 and pancreatic ribonucleases and then dialyzed exhaustively against SSC (0.15*M* NaCl, 0.015*M* sodium citrate, *p*H 7). The DNA was denatured by heating for 10 minutes at 100°C in SSC, followed by rapid cooling in an ice bath; the DNA was renatured by warming denatured DNA (10 μg/ml) at 65°C in double-strength SSC for 5 hours and then slowly cooling to room temperature.

The DNA samples were analyzed by CsCl density-gradient centrifugation at 25°C at 44,770 rev/min in the Spinco model E analytical ultracentrifuge (*15*). The density marker was DNA (density 1.742 g/cm^3) from the virulent *Bacillus subtillis* bacteriophage 2C. The ultraviolet photographs were scanned with a Joyce-Loebl microdensitometer. The densities of the DNA samples were determined (*16*) and are expressed relative to the density of *Escherichia coli* DNA, taken as 1.710 g/cm^3.

The results from the study of DNA are shown in Fig. 1. The DNA isolated from the whole yeast cell, when it is banded in a CsCl gradient, shows a major band of density 1.700 g/cm^3, a shoulder of density 1.704 g/cm^3, and a minor or satellite band at a density of 1.685 g/cm^3 (Fig. 1*A*). The shoulder at 1.704 g/cm^3 is of un-

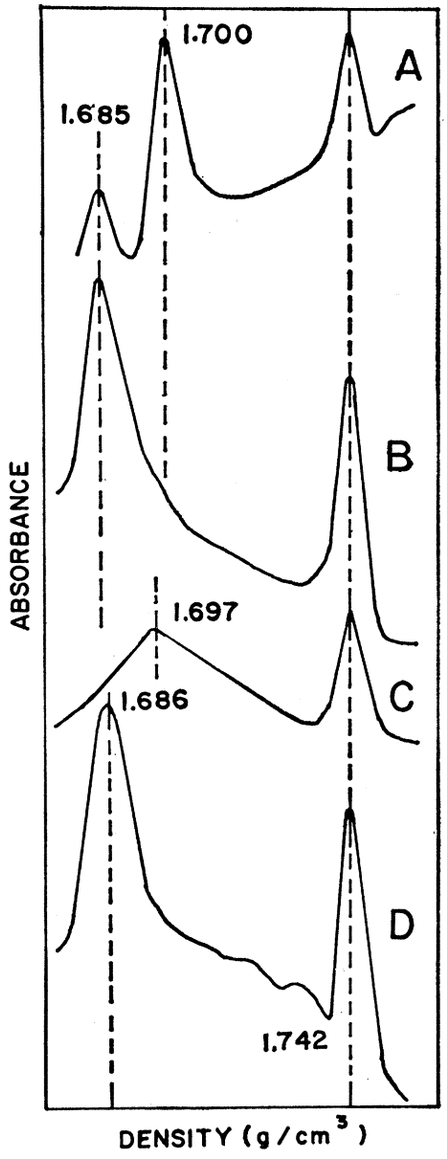

Fig. 1. Microdensitometer tracings of DNA from whole yeast cells (*A*), mitochondrial DNA (*B*), heat-denatured mitochondrial DNA (*C*), and renatured mitochondrial DNA (*D*) centrifuged to equilibrium in a CsCl density gradient. A peak at 1.704 g/cm^3, clearly visible on the exposed film, but not seen in this tracing, appears reproducibly as a shoulder in whole cell DNA from *Saccharomyces carlsbergensis.*