be required to maintain mitochondrial structure so that the bound Ca^{++} can be retained.

These considerations permit us to postulate that Ca^{++} accumulation can also be supported by an intermediate such as that proposed in Fig. 2 for Mg^{++} accumulation. Again in Ca^{++} accumulation as in the Mg^{++} reaction, the ATP-supported reaction may involve a reversal of the enzymatic mechanism for ATP production by way of oxidative phosphorylation, but other oligomycin-sensitive energy transfer mechanisms appear to be more likely. One piece of evidence against a simple reversal of oxidative phosphorylation is provided by the observation that aged mitochondria which cannot bind Ca^{++} in the absence of substrate retain rather high P/O ratios.

Although the accumulation of Mg^{++} and Ca^{++} has many features in common, it is not yet clear whether these ions are accumulated in the mitochondrion by the same system, or whether several mechanisms for accumulation exist. It should also be made clear that more than one high-energy intermediate may be involved. The only criterion which must be met by such a compound is its location with respect to the site of oligomycin inhibition.

It is also not yet clear whether participation of high-energy compounds other than ATP is a feature of ion-transport systems in general or is unique in mitochondrial reaction such as those described (*11*).

G. P. BRIERLEY
E. MURER
D. E. GREEN

Institute for Enzyme Research, University of Wisconsin, Madison 6

References and Notes

1. A. L. Lehninger, *Physiol. Rev.* **42**, 467 (1962).
2. F. Huijing and E. C. Slater, *J. Biochem. Tokyo* **49**, 493 (1961).
3. G. P. Brierley, E. Bachmann, D. E. Green, *Proc. Natl. Acad. Sci. U.S.* **48**, 1928 (1962); G. P. Brierley, E. Bachmann, E. Murer, D. E. Green, in preparation.
4. B. Chance, in *Biological Structure and Function*, T. W. Goodwin and O. Lindberg, Eds. (Academic Press, New York, 1961), p. 119.
5. H. F. DeLuca and G. W. Engstrom, *Proc. Natl. Acad. Sci. U.S.* **47**, 1744 (1961).
6. F. D. Vasington and J. V. Murphy, *J. Biol. Chem.* **237**, 2670 (1962).
7. D. B. Slautterback and G. P. Brierley, unpublished. Electron-microscope studies have not yet located Mg phosphate in mitochondria, but this salt is readily removed by conditions similar to those used in fixing the samples for electron microscopy.
8. The accumulation of Ca^{++} is a very rapid reaction; in an incubation medium similar to that of Vasington and Murphy (*6*) heart mitochondria take up about 75 percent of the available Ca^{++} (3.3 m*M*) in 5 minutes. For this reason we have evaluated the effect of inhibitors and uncouplers on the initial rate of Ca^{++} uptake and not on net accumulation. At low Ca^{++} concentrations (*5*) the rate must be determined in the first 30 to 40 seconds of reaction to be meaningful.
9. Endogenous respiration is inhibited to a large extent by the concentrations of Ca^{++} used.
10. E. C. Slater and K. W. Cleland, *Biochem. J.* **55**, 566 (1953).
11. Supported by National Heart Institute grant HE-00458 (USPH) and by Atomic Energy Commission contract AT (11-1)-909. We thank Oscar Mayer and Co., Madison, for meat by-products, D. G. Hadley for technical assistance, Dr. H. F. DeLuca for many discussions, and Dr. E. Bachmann for ATPase determinations.

10 January 1963

Superconducting Indium Antimonide

Indium antimonide transforms from a semiconducting to a metallic state at 22.5 kb at room temperature (*1*). X-ray powder photographs taken at high pressures show that the metallic phase has the white-tin structure with a random distribution of the In and Sb atoms (*2*). As In and Sb are virtually indistinguishable by ordinary x-ray techniques, no information about possible ordering of the atoms has been reported.

At atmospheric pressure the lattice constant of zinc-blende type InSb is nearly the same as that of gray tin, and it appeared probable that if the metallic phase of InSb could be obtained in a metastable state at 1 atmosphere the volume of the unit cell would be very nearly that of white tin. On considering especially the importance of the volume (*3*) and the lesser importance of the electron-atom ratio, we thought that the metallic form of InSb would be a superconductor with a transition temperature near that of white tin.

The high pressure transition in InSb is reported to be very sluggish, especially if a single crystal is compressed hydrostatically (*4*). Our attempts to recover the metallic form by the use of a Teflon cell and a 40-centistoke silicone oil as the pressure cell and transmitting medium respectively, in a piston-cylinder apparatus designed by Boyd and England (*5*) and Kennedy (*6*) failed.

Work done at the University of California, Los Angeles (*7*), indicated that the metallic form of InSb could be recovered at liquid-nitrogen temperatures. Accordingly, we made an opposed-anvil apparatus from hardened tool steel. The sample cell was similar to the Bridgman (*8*) design. This cell has a retaining ring of isomica (*9*) that is 0.016 inch thick and has an outside diameter of ½ inch and an inside diameter of 3/16 inch. The sample cell has a silver chloride disk 0.012 inch thick by 3/16 inch in diameter. The InSb sample itself is 0.012 inch thick by 3/32 or 3/16 inch in diameter. The anvil assembly was placed in a stainless-steel beaker with a Styrofoam jacket and was partially insulated from the press by insulating blocks composed of alternating sheets of stainless steel and mica.

The resistivity was monitored by measuring the drop in voltage across the anvils per unit of applied current. As the transition on a single crystal sample is sluggish under quasi-hydrostatic conditions, the samples were kept above the transition pressure for 3 to 4 days. Then liquid nitrogen was added to the beaker and the pressure was released.

Three consecutive experiments were performed in this apparatus: (i) the nitrogen was evaporated and the resistivity was monitored as the sample warmed to room temperature, which proved that the metallic form had been stabilized at the temperature of liquid N_2 and even higher; (ii) an attempt was made to take an x-ray powder photograph at low temperatures to verify the volume and structure of the metallic form, but as a result of the difficulty of loading the camera at low temperatures the experiment failed; (iii) the sample was transferred to a helium-3 cryostat and was tested for superconductivity by the alternating-current method of Schawlow and Devlin (*10*). This sample was superconducting at 2.1 ± 0.2°K. Measurements of critical fields were made down to 0.3°K with the plane of the disk-shaped sample parallel to the magnetic field. The results can be extrapolated to a critical magnetic field at $T = 0$°K of 1.1 kgauss. This high value is undoubtedly due to strains (*11*).

S. GELLER
D. B. MCWHAN
G. W. HULL, JR.

Bell Telephone Laboratories, Murray Hill, New Jersey

References and Notes

1. H. A. Gebbie, P. L. Smith, I. G. Austin, J. H. King, *Nature* **188**, 1095 (1960); A. Jayaraman, R. C. Newton, G. C. Kennedy, *ibid.* **191**, 1288 (1961).
2. J. C. Jamieson, private communication; P. L. Smith and J. E. Martin, *Nature* **196**, 762 (1962); M. D. Banus, R. E. Hanneman, A. N. Mariano, E. P. Warekois, H. C. Gatos, J. A. Kafalas, *Appl. Phys. Letters* **2**, 35 (1963).

3. B. T. Matthias, *Phys. Rev.* **92**, 874 (1953).
4. M. D. Banus, J. A. Kafalas, S. D. Nye, H. C. Gatos, *Solid State Res. Rept. Lincoln Lab. No.* 3 (1962), p. 18.
5. F. R. Boyd and J. L. England, *J. Geophys. Res.* **65**, 741 (1960).
6. G. C. Kennedy and P. N. Lamori, *Progress in Very High Pressure Research* (Wiley, New York, 1961), p. 304.
7. G. C. Kennedy, Institute of Geophysics and Planetary Physics, U.C.L.A., private communication.
8. P. W. Bridgman, *Proc. Am. Acad. Arts Sci.* **81**, 165 (1952).
9. P. W. Montgomery, in preparation.
10. A. L. Schawlow and G. E. Devlin, *Phys. Rev.* **113**, 120 (1959).
11. In the course of the running of our final experiment we were informed that H. E. Bömmel and W. F. Libby and their coworkers A. J. Darnell and B. R. Tittman of U.C.L.A. had found that InSb was superconducting. Bömmel informed us that the transition temperature that they found was 2.1°K, and therefore, our result corroborates theirs. We thank Dr. T. H. Geballe for his interest and part in the superconductivity measurements, Dr. R. L. Batdorf for the high-purity InSb crystals, and Mr. A. L. Stevens for technical assistance.

4 March 1963

Root Hairs, Cuticle, and Pits

Abstract. *The filamentous roots of mustard* (Raphanus sativus), *radish* (Brassica nigra), *squash* (Cucurbita pepo), *and wheat* (Triticum aestivum) *are covered throughout their length with living nucleated root hairs which may measure 1600 μ or more. The outer walls of piliferous and nonpiliferous cells consist of successive layers of mucilage, cutin, and the cellulose-pectic framework of the cell. Plasmodesmata and pits occur on all cell walls. Under the electron microscope individual pores and pits in the microfibrillar wall are evident throughout the length of the root hair. The "semipermeable membrane" of the root hair zone is thus structurally complex.*

The term "semipermeable membrane" appears to dominate current discussion of the entrance of solutes into the root-hair zone of the higher plant, while the structure of the outer epidermal wall of the root is ignored. Cutinization of root hairs is evident in the Windsor bean (*Vicia faba*) and the castor bean (*Ricinus communis*) (*1*). The outer epidermal wall of the root of the onion (*Allium cepa*) is also cutinized (*2*). Root hairs are consistently rare or lacking in onion bulbs grown in water in the laboratory. As seen under the light microscope, with the use of appropriate microchemical tests, the onion root wall consists of a pellicle of mucilage and a cuticle, beneath which lies the cellulose-pectic framework of the cell (*3*). All cell walls are pitted so that epidermal and cortical protoplasts are interconnected. Plasmodesmata are anchored in the pits in the outer tangential wall and presumably function in the transport of the precursors of mucilage and cutin.

The roots of seedlings and of mature plants of the common species, mustard (*Brassica nigra*), radish (*Raphanus sativus*), squash (*Cucurbita pepo*), and wheat (*Triticum aestivum*) provide excellent material for the study of root hairs. These species and others were grown in ordinary garden soil during the summer, fall, and winter of 1962–63.

The root system of all species consists of a primary or tap root with numerous laterals of the first, second, and higher order. In addition, however, all seedling roots and the feeder roots of the older plants possess a wealth of filamentous or transitory roots which may equal in length the tap roots and the longest laterals. In seedlings, all filamentous roots, frequently 15 cm or more long, are entirely covered with living nucleated root hairs. In contrast, as is well known, the root-hair zones of the main roots generally measure not much more than 1 cm. The root hairs of the main roots and of the filamentous roots range in length from 2 or 3 μ in the initial papillae to 1600 μ or more.

For examination under the electron microscope, the filamentous roots of mustard, radish, squash, and wheat, after brief clearing, were ultrasonically fragmented, mounted on Formvar-coated grids, and shadowed with palladium. Ultrasonic fragmentation has proved to be a useful technique in the study of the cell wall, since cell orientation and structure are demonstrated by isolated cells, three-dimensional segments, and fragments of the various layers of the cell wall. The contraction of the microfibrillar wall, inevitable in fixation, is avoided.

The root hairs of all four species are similar in submicroscopic structure. The primary wall of the youngest cells examined, piliferous and nonpiliferous, consists of a network of cellulose microfibrils. The wall of the piliferous cell, cell body and root hair, is thickened by the deposition of additional reticular microfibrils that are later generally parallel in orientation (*4*). Amorphous substances, pectins or noncellulose polysaccharides, fill the minute interfibrillar spaces except in the pit areas. Plasmodesmata occur in the outer epidermal wall and also throughout the entire length of the root hair, from tip to base (Fig. 1, *A* and *B*). They appear as the ends of minute protoplasmic strands. When plasmodesmata are removed during the preparation of material, solitary pores and pits, defined here and in previous papers as groups of pores, remain as visible perforations (Fig. 1, *A* and *B*). The cuticle of the epidermis, including the root hairs, when isolated, resembles in its ultraporous texture the cuticle of the onion leaf (*2*). In the leaf of the higher plant the plasmodesmata function in the transport of the precursors of cutin and wax, if present.

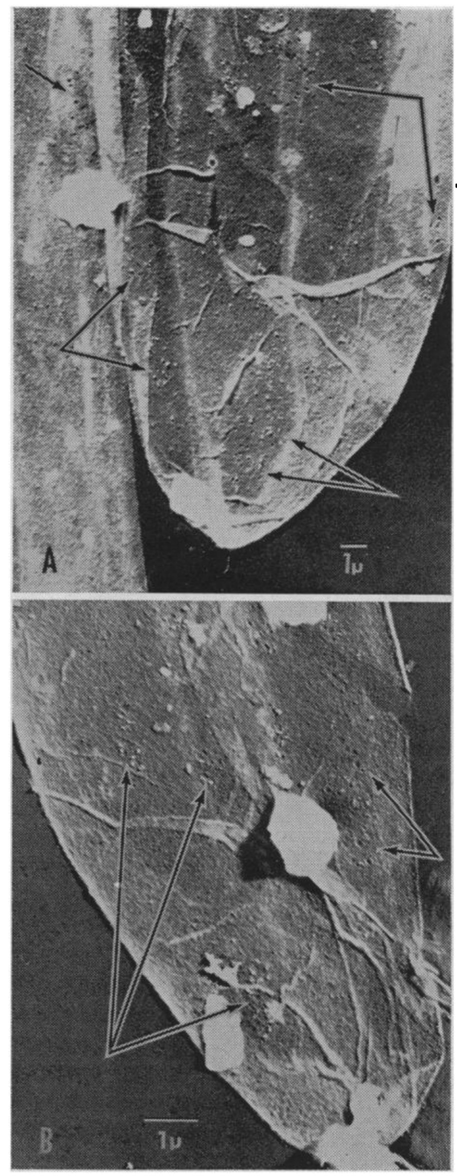

Fig. 1. *A*, Electron micrograph of squash root-hair tip and part of another root hair. *B*, Electron micrograph of wheat root-hair tip. Arrows indicate examples of pits and pores, with and without plasmodesmata.