Table 1. Free (unwelded) products from the 22.5-hour grinding of pulverized olivine in air and in partial vacuum. Each sample was initially of 10 g and between 147 and 177 μ in size.

Particles (μ)	Weight (g)	
	In air	In vacuum
> 177		0.18
177–147	0.45	.20
146–105	1.67	.67
104– 74	2.28	.47
73– 44	3.89	.25
< 44	1.31	.27

the system axis. This tilt was intentional to prevent powder from entering the pump in any quantity. When the tank was cut, about 0.35 g of olivine was dislodged from the surface near the cut.

The olivine attached to the balls and to the container walls was very firmly bonded and required hard scraping with a sharp instrument to dislodge it. Figure 2*a* shows the interior of the cut container; the pile of olivine is the 0.35 g dislodged from the surface during cutting; a reflection can be seen from the bare metal surface at the joint between wall and end cap of the right-hand section. Figure 2*b* shows the balls bearing a heavy coating of material; the three standing apart and lighter in color were not used.

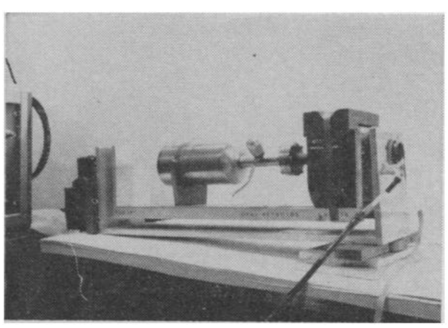

Fig. 1. Container ("ball mill") and vacuum pump.

A third sample was degassed in the manner described, but exposed to laboratory air before grinding began. The result of grinding was intermediate: adhesion was considerably greater than with the undried sample but less than with the sample ground in vacuum.

This experiment is quite qualitative, but it does demonstrate quite tenacious bonding of olivine to itself, to stainless steel, and to procelain. The vacuum conditions were good in that there were no oils, greases, or elastomers in the system, but the pressure was not very low even at the end of the grinding period. At the final pressure of 2×10^{-7} torr a gas monolayer would form on a clean surface in 10 to 100 seconds, depending on the sticking probability of the gas. Because the surfaces in question were freshly formed and the principal gas was most likely water vapor, the shorter time is the more probable. Despite this fact, enough clean or partly covered surfaces of olivine met to bond most of the material together.

A conclusion is that a solid particle returning to the lunar surface at moderate speed has a good chance to bond to the surface struck, since these surfaces should be relatively free of gas films because of the "ion cleaning" effect of the solar wind and the gas-desorption effect of the solar ultraviolet flux. The cleaning effect of ion and ultraviolet bombardment is well known (*4*).

Since the flux of returning particles would be nearly isotropic in the upward 2π solid angle, any projection of the surface would be more likely to be struck; thus, irregularity of the surface would increase. Such an irregular surface seems to resemble somewhat that required to satisfy the small-scale irregularity needed to provide the optical reflectivity observed on the lunar surface; it could also resemble the peaked surface seen in the Luna 9 photographs. Further more quantitative experiments with different materials are obviously required.

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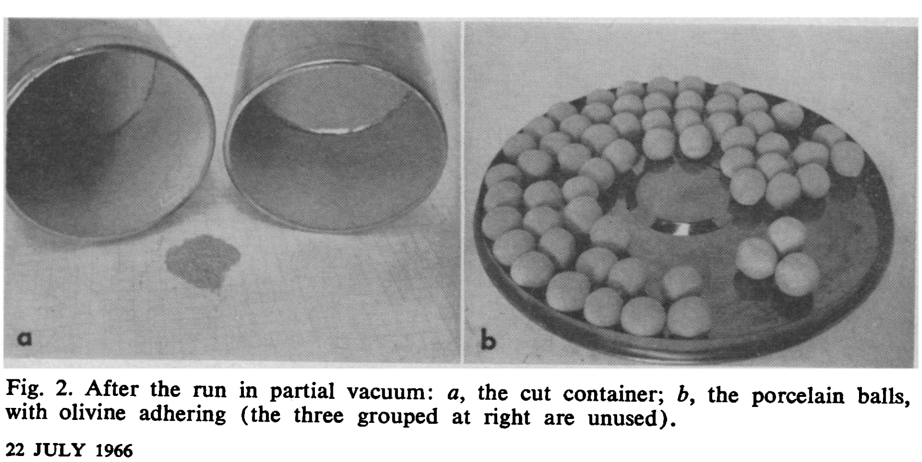

Fig. 2. After the run in partial vacuum: *a*, the cut container; *b*, the porcelain balls, with olivine adhering (the three grouped at right are unused).

References and Notes

1. Welding of metals under partial vacuum has been demonstrated, but most experimenters state or imply that oxidized surfaces prevent welding. See, for example: F. P. Bowden and D. Tabor, *Friction and Lubrication* (Wiley, New York, 1956); M. J. Hordon and L. R. Allen, "Adhesion and fatigue properties of materials in vacuum," Symp. Space Environmental Simulation 6th Annual, St. Louis, Mo., 17–18 May 1965. The adhesion of silicates in vacuum observed by Salisbury *et al.* [*J. Geophys. Res.* **69**, 235 (1964)] was weak, although greater adhesion was found by J. A. Ryan, "Ultrahigh vacuum silicate adhesion," Douglas Aircraft Corp. engineering paper 3736.
2. From Jackson County, N.C.
3. A similar experiment with rhyolite gave substantially identical results.
4. G. E. Fisher and R. A. Mack, "Vacuum design problems of high current electron storage rings," in Trans. Vacuum Symp. A.V.S. 12th 1964 (to be published); R. E. Clausing, "Exploratory experiments concerning the desorption of gases by bombardment with electronics," ORNL-TM-1166, 3 November 1965; W. J. Lange and H. Riemersma, in *Trans. Vacuum Symp. 8th Intern. Congr. 2nd A.V.S.* (Pergamon, London, 1962), vol. 1, p. 167.
5. Work sponsored by the AEC under contract with Union Carbide Corp. I thank S. M. Decamp, J. S. Culver, and S. W. Swicegood.

28 March 1966

Neutral Hydrogen Survey of Andromeda Galaxy

Abstract. *A neutral hydrogen survey of the Andromeda galaxy (M31) has been conducted with the 260-foot (80 m) Ohio State University radio telescope. The neutral hydrogen is concentrated in the spiral arm regions, with but relatively small amounts near the center of the galaxy. Similar deficiencies have been found near the center of M33 and our galaxy, suggesting similar evolutionary processes in the three galaxies.*

Studies of the neutral hydrogen distribution in the Andromeda galaxy were made by van de Hulst, Raimond, and van Woerden (*1*) in 1957, and by Burke, Turner, and Tuve (*2*). Both studies were based on observations along the major axis of the galaxy and selected axes at right angles. The first complete survey of the galaxy was made by Argyle (*3*) in 1963 with a

36-minute-of-arc beam width. Subsequently, higher resolution surveys have been made by Roberts (*4*) with a 10-minute-of-arc beamwidth, using the 3000-foot (91-m) telescope at Green Bank and by us (*5*) with the Ohio State University 260-foot (80-m) radio telescope which has a 10- by 38-minute-of-arc beam. Roberts' survey extends over a declination range of 60 minutes of arc north to 50 minutes of arc south of the optical center, but with complete hydrogen-line data only 30 minutes north and south. Our scans extend over a greater range, from 72 minutes north to 79 minutes south of the optical center, with complete hydrogen-line data except for the most northern declination. Both Roberts' and our surveys indicate that within the observed range of declinations the neutral hydrogen in M31 appears to be concentrated in a ring-like structure at a distance from the nucleus, a conclusion not drawn in the earlier surveys.

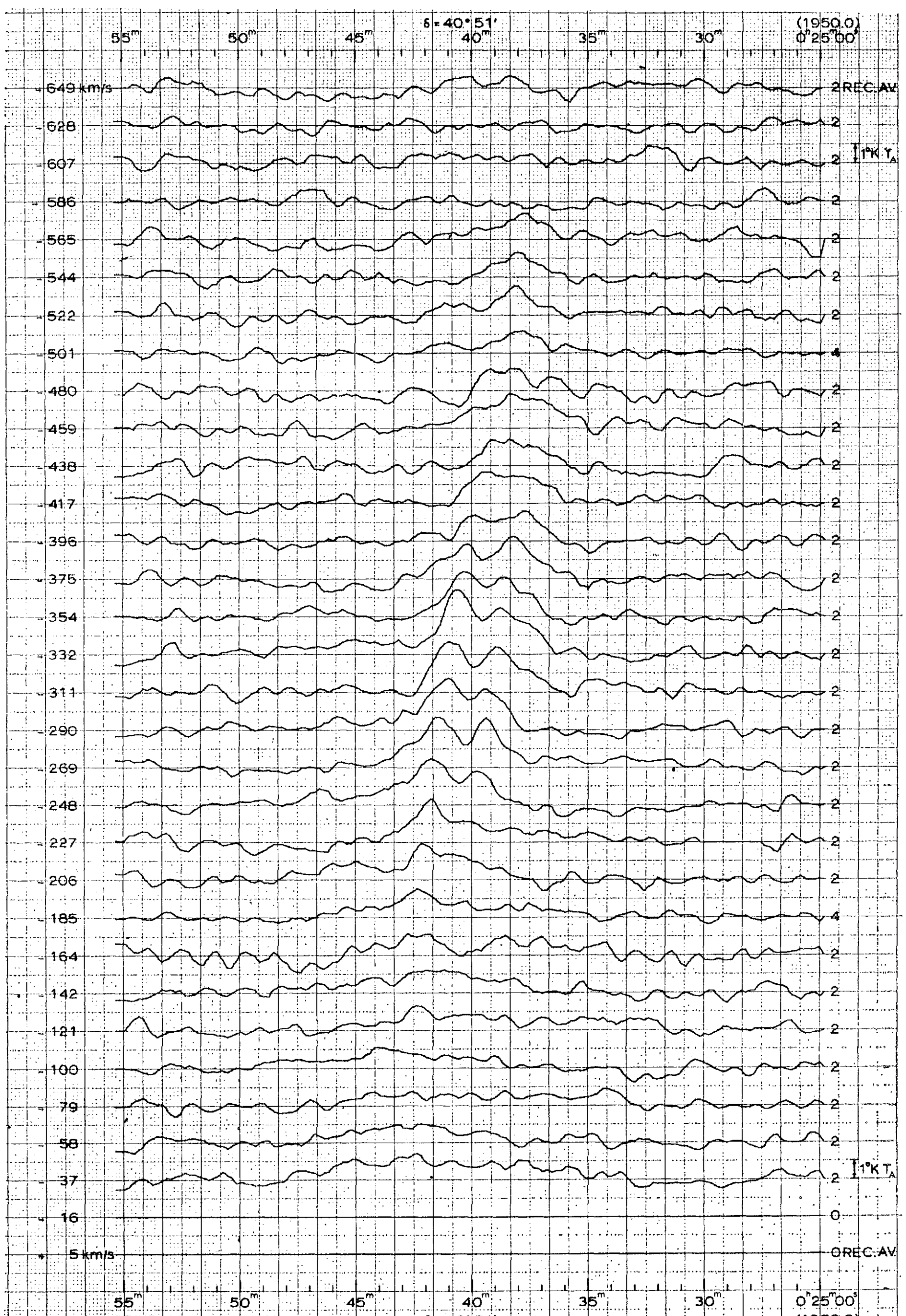

Fig. 1. Averaged drift profiles through the Andromeda nebula (M31) at a declination of 40°51′ made with the Ohio State University 260-foot (80-m) radio telescope. Thirty channels are shown, each having a width of 21 km/sec in radial velocity. The center velocity for each channel is given by the left-hand ordinate scale. The digit on the right indicates the number of profiles averaged.

Our observations were made between December 1964 and May 1965 and consisted of repeated scans at eight declinations between 39°41′ and 42° 12′N (1950.0) inclusive. A liquid-nitrogen refrigerated parametric preamplifier having a system temperature of 150°K was used with an eight-channel receiver of 100-kcy channel bandwidth, or a radial velocity width of 21.1 km/sec with recording on an eight-channel analog chart. By shifting the eight-channel receiver four times in frequency, a total of 30 adjacent channels was observed at all declinations. The observing program involved two drift scans under each condition so that a minimum of 8 days of observations was required for each declination. The analog data were converted to digital form. With a computer, two records for each condition were averaged with base-line drift removed. Next, right ascension profiles were machine-drawn for the 30 observed radial velocities at each declination (Fig. 1). By further computer programming, machine-drawn contour maps were made showing the neutral hydrogen distribution within each of the radial velocity ranges of 21 km/sec. Twenty-seven of the channels contained observable hydrogen. A display of these maps with smoothed contours is shown in Fig. 2 for nine selected channels covering a velocity range of 443 km/sec. The neutral hydrogen distribution shows a double-peaked distribution at the intermediate velocities with a systematic trend from one velocity range to the next. A map of the positions of these peaks for all velocity ranges with well-defined maxima is shown by the solid circles in Fig. 3. The positions were obtained from drift profiles (such as in Fig. 1) for better accuracy than possible from the contour maps, and have average estimated probable errors of 10 seconds of time in right ascension and 10 minutes of arc in declination. The ellipse in Fig. 3 is situated near most of the inner neutral hydrogen peaks and also lies close to the dashed lines which delineate the ridges of total neutral hydrogen found by Roberts. The plane of M31 is seen nearly edge-on (tilt angle about 14° with respect to our line of sight), and the ellipse corresponds to a circular ring about 9 kparsec in radius lying in the plane of the galaxy. A distance of 690 kparsec to M31 is assumed. Although the ellipse has its center displaced about 3 minutes northeastward with

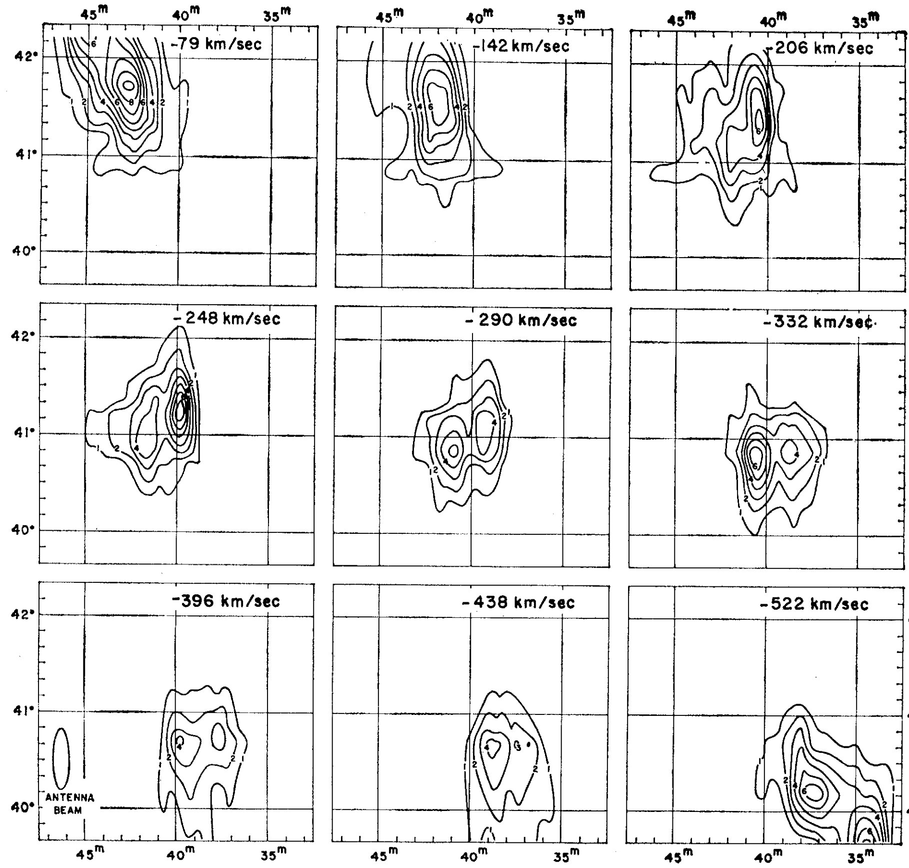

Fig. 2. Maps of neutral hydrogen distribution in the Andromeda galaxy (M31) as observed with the Ohio State University 260-foot (80-m) radio telescope. The maps are for nine selected channels each with a radial velocity width of 21.1 km/sec centered on the velocities indicated. The contour interval is 0.5°K of antenna temperature. The peaks of the hydrogen distribution move from upper left to lower right with increasing negative radial velocity, becoming double and moving along two ridges at intermediate velocities. The coordinates are north declination as ordinate and, as abscissa, the right ascension in 00 hours and minutes as indicated (epoch 1950.0).

respect to the optical nucleus or about ½ kparsec, this is not regarded as significant, owing to the scatter and uncertainty in the positions of the peaks.

The shaded areas indicate regions of concentrations of emission nebulae in M31 as given by Baade and Arp (*6*). The solid circles with arrows indicate neutral hydrogen concentrations that we observed whose peaks appear to lie outside the survey region. Those at the lower edge of the map probably correspond to the hydrogen companion observed by Burke, Turner, and Tuve (*2*), which is centered 115 minutes of arc southwest of the nucleus. The open circles (BTT) on the major and minor axes give the positions of hydrogen peaks observed by Burke, Turner, and Tuve.

The spread of the peaks of neutral hydrogen along the major axis (Fig. 3) suggests a considerable radial extent to the neutral hydrogen; that is, it would appear to be distributed in an annular disc with inner and outer edges bracketing the peak concentrations. Estimates of the radii to approximately half intensity are subject to considerable uncertainty but are probably about 5 kparsec to the inner edge and about 15 kparsec to the outer edge.

Meng and Kraus (*7*) have found a similar ring or annular distribution for the neutral hydrogen in M33. According to Westerhout (*8*) the neutral hydrogen distribution in our galaxy is also of this type. The estimated radii to the inner edge, peak, and outer edge

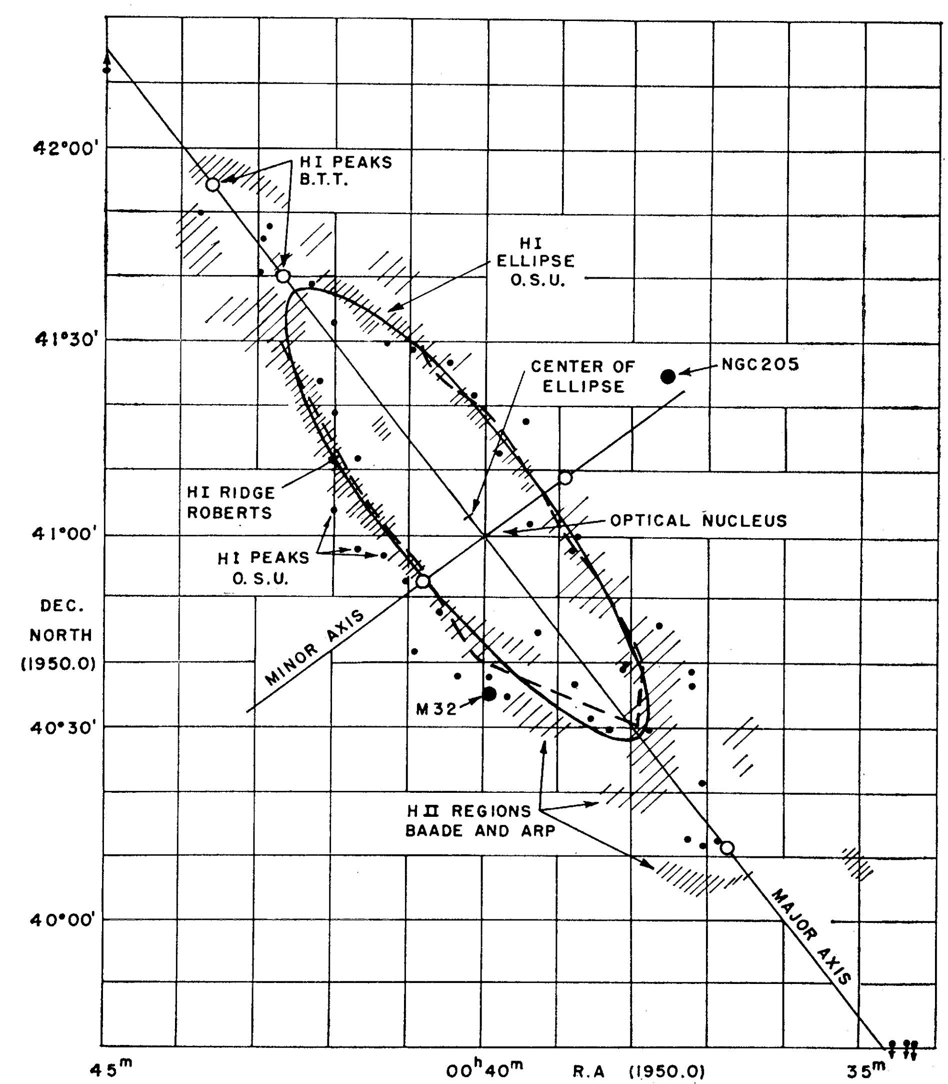

Fig. 3. Positions of neutral hydrogen peaks observed with the Ohio State University 260-foot (80-m) radio telescope (solid circles and solid ellipse), by Roberts (*4*) (dashed line), and by Burke, Turner, and Tuve (*2*) (open circles). The shaded areas are regions of concentrations of emission nebulae found by Baade and Arp (*6*).

Table 1. Neutral hydrogen distribution in three galaxies.

Galaxy	Neutral hydrogen annulus: Inside edge	Peak	Outside edge	Visible edge
	Observed radii (kparsec)			
M31	5	9	15	21
Our	4	6.5	12	
M33	2	3.5	5	6
	Normalized radii (kparsec)			
M31	5	9	15	21
Our	5.5	9	16.5	
M33	5	9	13	15.5

* Distance to M31 assumed to be 690 kparsec and to M33 630 kparsec.

of the annular distributions in M31, M33, and our galaxy are summarized in the upper part of Table 1. The visual radii for M31 and M33 to 25.8 magnitude per (sec of arc)^2 in blue light as determined by de Vaucouleurs (*9*) are also given. If all three galaxies had the same radius of the hydrogen peak as M31 the radii would be as listed by the normalized values in the lower part of the table. It is apparent from these radii that the neutral hydrogen has a similar relative distribution in the three galaxies. In particular there is a significant deficiency of neutral hydrogen in all three galaxies in the central region. This might indicate a similar evolutionary process in the three galaxies with perhaps an explosion in a prior epoch having swept out most of the neutral hydrogen from the inner regions.

M31, M33, and our galaxy are normal radio galaxies with relatively weak continuum radio emission from the nucleus. By contrast, Mathewson and Rome (*10*) have shown that the nearby galaxies NGC 253 and 4945 have strong continuum emission from the nucleus. It would be of interest to determine whether or not the neutral hydrogen distribution in these galaxies is also deficient in the central regions.

The velocities given in Fig. 2 are with respect to the local standard of rest. The systematic velocity of approach of M31 with respect to this standard is found to be -300 ± 10 km/sec. This is in agreement with Argyle's value of -296 and Roberts' of -310 km/sec.

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References

1. H. C. van de Hulst, E. Raimond, H. van Woerden, *Bull. Astron. Inst. Netherlands* **14**, No. 480, 1 (1957).
2. B. F. Burke, K. C. Turner, M. A. Tuve, in *Carnegie Institution, Washington Yearbook 1963*, p. 289; *ibid.*, p. 341.
3. E. Argyle, *Astrophys. J.* **141**, 750 (1965).
4. M. S. Roberts, *Astron. J.* **70**, 689 (1965); *Astrophys. J.* **144**, 639 (1966).
5. W. D. Brundage and J. D. Kraus, *Astron. J.* **70**, 669 (1965).
6. W. Baade and H. Arp, *Astrophys. J.* **139**, 1027 (1964).
7. S. Y. Meng and J. D. Kraus, *Astron. J.* **71**, 170 (1966).
8. G. Westerhout, *Bull. Astron. Inst. Netherlands* **14**, 215 (1958).
9. G. de Vaucouleurs, *Astrophys. J.* **128**, 465 (1958); **130**, 728 (1959).
10. D. S. Mathewson and J. M. Rome, *Observatory* **83**, 20 (1962).
11. We thank Dr. D. S. Mathewson for helpful suggestions. This work was supported in part by the NSF, the Air Force Cambridge Research Laboratories and by the Mershon and Development Funds of the Ohio State University.

7 March 1966

Enzyme-Coenzyme Complexes of Pyridine Nucleotide–Linked Dehydrogenases

Abstract. *Enzyme-reduced coenzyme binary complexes produce previously unreported shifts in the spectrum of the free coenzyme. These shifts give rise to difference spectra which resemble a general environmental change for reduced diphosphopyridine nucleotide (DPNH) in the glutamic dehydrogenase–DPNH complex, and indicate a more specific enzyme-coenzyme interaction for yeast alcohol dehydrogenase–DPNH, isocitrate dehydrogenase–TPNH, and lactic dehydrogenase–DPNH complexes.*

Addition of reduced diphosphopyridine nucleotide (DPNH) to a solution of liver–alcohol dehydrogenase (*1*) or of lactic deyhdrogenase (*2*) results in a shift of the reduced-coenzyme spectrum because of formation of binary enzyme-coenzyme complexes. Since the discovery of these complexes in 1951 and 1952, no such binary complexes have been demonstrated spectrophotometrically for other pyridine nucleotide–linked dehydrogenases, despite vigorous and continued search in many laboratories [although binary and ternary complexes have been shown by fluorometric measurements, and ternary complexes have been observed spectrophotometrically in the presence of substrates or products (*3*)]. Indeed several authors have categorically stated (*2, 4*) that addition of yeast–alcohol dehydrogenase or glutamic dehydrogenase (GDH) to DPNH does not change the DPNH spectrum.

We now show by means of tandem difference – spectrophotometric techniques that formation of spectrophotometrically observable binary complexes between dehydrogenases and DPNH is a more general phenomenon than has been thought; we present evidence of such complexes between reduced coenzyme and GDH, yeast–alcohol dehydrogenase, and isocitric dehydrogenase; and we describe some unusual features of these new signals that may give information on coenzyme-enzyme interactions.

Difference spectra were recorded on a Cary model-14 spectrophotometer using matched 1.000 cm quartz cuvettes arranged as follows: The sample compartment held two cuvettes: the first contained the enzyme; the second, the coenzyme (both in buffer). The reference compartment also held two cuvettes: the first with enzyme and coenzyme mixed, and the second with buffer alone. Artifacts arising from dilution errors, temperature differentials, and stray and scattered light were recognized and avoided by use of the criteria and precautions discussed in (*5*).

Figure 1*A* is the difference spectrum between the GDH-DPNH complex and its components; Fig. 1*B* is a solvent-perturbation difference spectrum of DPNH, presented for reference. This difference spectrum was recorded with the same cell arrangement as for the other difference spectra. In the sample compartment the first cuvette contained DPNH; the second, sucrose (250 mg/ml). In the reference compartment the first cuvette contained DPNH and sucrose; the second, buffer alone. All cuvettes contained 0.2*M* potassium phosphate buffer, *p*H 7.60. The refractive index difference for the sucrose perturbation of DPNH was 0.0344. The refractive index differences between the enzyme and enzyme-coenzyme solutions were negligible–on the order of 0.0002.

Such difference spectra have been shown to be caused by any change in the immediate environment of the