that lead to inhibition of ingestive behavior but are independent of the dissimilar affective states associated with nausea and satiety.

Although the effects of CCK on plasma OT resemble those of various chemical agents, it is provocative that CCK is an endogenous peptide found in gut and brain rather than an exogenous toxin. CCK immunoreactivity has been colocalized in many hypothalamic oxytocinergic neurons (*14*). Our results therefore also imply that multiple vagally mediated stimuli converge in the hypothalamus to cause secretion of CCK as well as OT. Together with the finding that ablation of the paraventricular nucleus can lead to hyperphagia and obesity in rats (*15*), these observations support suggestions that this hypothalamic nucleus plays an important role in the control of feeding behavior and related autonomic functions (*16*) and, further, that brain OT, CCK, or both are involved in this regulatory system.

REFERENCES AND NOTES

1. J. Gibbs, R. C. Young, G. P. Smith, *J. Comp. Physiol. Psychol.* **84**, 488 (1973); J. Antin, J. Gibbs, J. Holt, R. C. Young, G. P. Smith, *ibid.* **89**, 784 (1975); H. R. Kissileff, F. X. Pi-Sunyer, J. Thornton, G. P. Smith, *Am. J. Clin. Nutr.* **34**, 154 (1981).
2. G. P. Smith, C. Jerome, B. J. Cushin, R. Eterno, K. J. Simansky, *Science* **213**, 1036 (1981); D. N. Lorenz and S. A. Goldman, *Physiol. Behav.* **29**, 599 (1982); G. P. Smith, C. Jerome, R. Norgren, *Am. J. Physiol.* **249**, R638 (1985).
3. T. H. Moran and P. R. McHugh, *Am. J. Physiol.* **242**, R491 (1982); H. E. Raybould, R. J. Gayton, G. J. Dockray, *Brain Res.* **342**, 187 (1985).
4. J. Garcia, W. G. Hankins, K. W. Rusniak, *Science* **185**, 824 (1974); J. A. Deutsch and W. T. Hardy, *Nature (London)* **266**, 196 (1977).
5. J. E. Morley *et al.*, *Ann. N.Y. Acad. Sci.* **448**, 413 (1985).
6. B. O. Moore and J. A. Deutsch, *Nature (London)* **315**, 321 (1985).
7. J. A. Deutsch, in *Neural Basis of Feeding and Reward*, B. G. Hoebel and D. Novin, Eds. (Haer Institute, Brunswick, ME, 1982), pp. 137–148.
8. Lithium chloride, copper sulfate, apomorphine, and hypertonic saline were effective (J. G. Verbalis, C. M. McHale, T. W. Gardiner, E. M. Stricker, *Behav. Neurosci.*, in press).
9. J. Antin, J. Gibbs, G. P. Smith, *Physiol. Behav.* **20**, 67 (1978).
10. M. V. Sofroniew, in *The Neurohypophysis: Structure, Function and Control*, B. A. Cross and G. Leng, Eds. (Elsevier, Amsterdam, 1983), pp. 101–114.
11. Plasma OT elevations in response to feeding have also recently been reported in other species [K. Uvnas-Momberg *et al.*, *Acta Physiol. Scand.* **124**, 391 (1985)].
12. J. A. Deutsch and M. F. Gonzalez, *Behav. Biol.* **24**, 317 (1978).
13. P. J. Kulkowsky, *Ann. N.Y. Acad. Sci.* **443**, 330 (1985).
14. J. J. Vanderhaeghen, F. Lotstra, F. Vandesande, K. Dierickx, *Cell Tissue Res.* **211**, 227 (1981).
15. S. F. Leibowitz, N. J. Hammer, K. Chang, *Physiol. Behav.* **27**, 1031 (1981); P. F. Aravich and A. Sclafani, *Behav. Neurosci.* **97**, 970 (1983).
16. S. F. Leibowitz, *Pharmacol. Biochem. Behav.* **8**, 163 (1978); L. W. Swanson and P. E. Sawchenko, *Neuroendocrinology* **31**, 410 (1980).

17. Supported by research grants AM-16166 and MH-25140 from the National Institutes of Health and the Veterans Administration Career Development Program. We thank M. Drutarosky for technical assistance and Y. F. Jones for secretarial assistance. These data were presented at the annual meeting of the Society for Neuroscience in Dallas, TX, October 1985.

12 November 1985; accepted 24 February 1986

Synthetic Diamond as a Pressure Generator

AKIFUMI ONODERA, KATSUHISA FURUNO, SHUJI YAZU

Synthetic diamond crystals were used as opposed anvils whose small culet surfaces were driven into contact with each other to generate high static pressures. Pressures in excess of 68 gigapascals (680 kilobars) were achieved, as determined from the fluorescence line of a ruby fragment sandwiched between the diamonds.

During the last decade remarkable progress has been made in high-pressure science. Static pressures higher than 250 GPa (2.5 Mbar) have become attainable with single-crystal gem-quality diamonds used as opposed anvils (*1*). Measurements of the physical properties of condensed matter can now be made with diamond anvils (*2, 3*), sometimes with geophysical implications (*4, 5*).

The diamond-anvil technique was developed in the late 1950's (*6*), but its use did not become widespread until the feasibility of using the ruby fluorescence line for in situ pressure measurement was established (*7*). The ruby fluorescence scale was calibrated against the equation of state for NaCl to 19.5 GPa (*8*) and later to 29.1 GPa (*9*), and against the equation of state for heavy metals up to 100 GPa on the basis of shock compression data (*10*). The pressures reached with diamond anvils [to 100 GPa (*11*), 170 GPa (*12*), and 250 GPa (*1*)] were estimated from extrapolations of these calibrations, although the ruby scale becomes ambiguous above 185 GPa where the fluorescence line weakens and disappears (*1*).

A reproducible method for generating stable, very high static pressures is of great importance. The advantages of selecting diamonds as the anvil material have been discussed (*13–15*). Important factors are size, type, color, orientation, inclusions, and impurities. Beveling is also important, especially at extremely high pressures where plastic deformation is observable around the anvil surface (*12*). Some ideas for designing diamond anvils have been derived from stress analyses based on the use of the finite element method (*16, 17*).

All the aforementioned experiments have been carried out with natural gem-quality diamond used as the anvil material. Synthetic carat-sized diamond has recently become available (*18*); single crystals have been grown under prolonged high pressure and temperature inside a large-volume apparatus, and it now is possible to make anvils from synthetic diamond. Some advantages derived from the use of synthetic diamond instead of natural diamond as the anvil material are as follows: (i) imperfections are fewer and can be controlled, (ii) the concentration of nitrogen can be controlled so as to improve the strength (*19*), (iii) the pressure-temperature conditions for preparing diamond crystals can be determined, and (iv) suitable crystals can be obtained repeatedly.

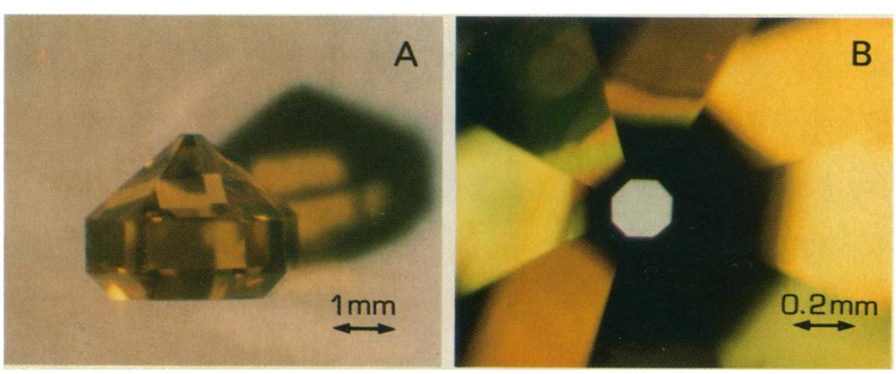

Fig. 1. Side view (A) and top view (B) of the synthetic diamond anvil.

A. Onodera and K. Furuno, Faculty of Engineering Science, Osaka University, Toyonaka, Osaka 560, Japan. S. Yazu, Itami R&D Division, Sumitomo Electric Industries, Ltd., Itami, Hyogo 664, Japan.

As far as we know, this is the first attempt to use synthetic diamond for pressure generation. Our diamonds, grown at Sumitomo Electric Industries, Ltd., were of type Ib, containing nitrogen, and hence were a deep yellow color. The nitrogen concentration, determined from the infrared absorption peak at 1130 cm^{-1}, ranged from 30 to 60 ppm (*20*). An x-ray topographic analysis suggested that the diamonds had very few imperfections (*21*). Two anvils of old single-cut style (*22*) were prepared from the diamonds. Each weighed approximately 1/10 carat, with the angles for the pavilion and crown about 45° and 50°, respectively. Figure 1A shows a side view of the anvil. The table surface (1.8 mm in diameter) was oriented parallel to the (100) crystallographic plane. The culet surface was octagonal and 0.2 mm in diameter (Fig. 1B).

The diamond crystals were driven by a diamond-anvil cell (*23*) while their culet surfaces were opposed. A stainless steel gasket was sandwiched between the culet surfaces, and a ruby fragment was placed on the culet surface of one of the diamonds so that pressure could be monitored. The ruby R line fluorescence was measured in terms of the reflection of monochromatic light at 442 nm from a helium-cadmium laser.

Figure 2 compares the ruby fluorescence lines (R_1 and R_2) (*7*) measured in the synthetic and natural diamond anvils. The reduced intensity of the fluorescence line inside the synthetic diamond anvil is ascribed to absorption in the visible region, yet the data are sufficient to permit pressure monitoring.

Figure 3 shows the shift of the ruby fluorescence lines with increasing pressure. The pressures were estimated from the amount of the shift (*12*). The shoulder peak at 699 nm is from diamond (*24*). Two peaks arising from the helium-cadmium laser did not interfere with the measurement when the pressure was increased slowly. The split R lines observed at ambient pressure (Fig. 2) merge into a single peak at high pressure. This result is attributed to the effect of a nonhydrostatic environment (*8*).

The highest pressure achieved in the present study was 68.3 GPa (Fig. 3). Increasing the pressure beyond this point caused one of the diamond anvils to fracture. The fracture was caused by cracks that developed in the center and at the periphery of the culet surface (Fig. 4). No plastic deformation was observed. The cracks remained very shallow near the surface and did not extend to the interior of the anvil. Small pieces of fractured diamond were also observed. This fracture mode is apparently different from the spalling or vertical fracture observed on the anvils of natural diamond (*12*). However, no explanation for the difference in fracture mode can be derived from this single experiment.

In natural type Ia diamond, nitrogen is localized in platelets (*22*). This localization of nitrogen can in some cases prevent the propagation of cracks, but in other cases the nitrogen sites can be the points where cracks are initiated. The nitrogen included in our diamond is dispersed and substitutional (*20*), as evidenced by the infrared absorption at 1130 cm^{-1} (*25*). Substitutional nitrogen improves the strength of diamond, depending on the concentration (*19*). Also, the Knoop hardness on the (100) and (110) planes of our synthetic diamond, ranging from 8,000 to 11,000 kg/mm^2, depends very little on either the plane or the direction, whereas in natural diamond the hardness is anisotropic (*20*). Thus we have confidence that the synthetic diamond has strength.

Our results suggest that the synthetic diamond can be used for pressure generation. Higher pressures could perhaps be attained if larger anvils were used and if the culet surfaces were beveled.

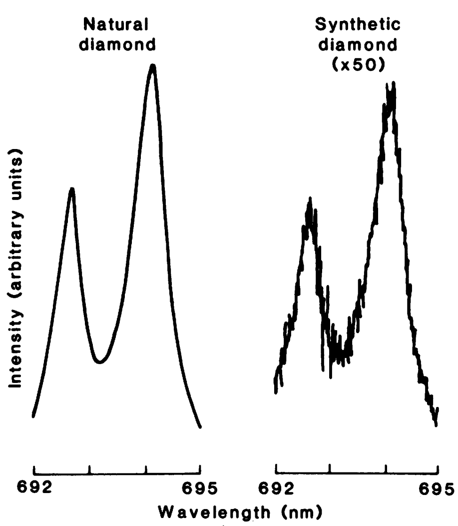

Fig. 2. Comparison of the R line fluorescence spectra of the ruby fragment in natural and synthetic diamond anvils at ambient pressure.

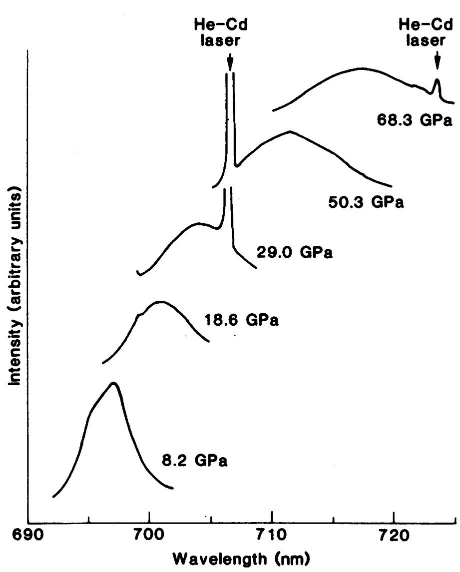

Fig. 3. Shift of the ruby fluorescence line with increasing pressure.

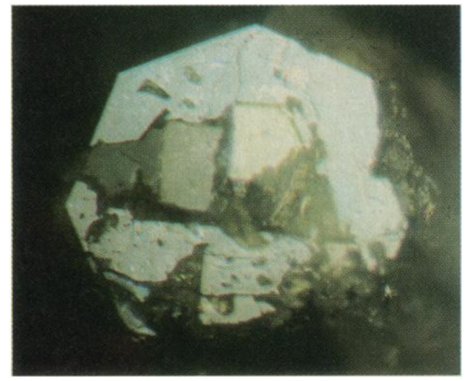

Fig. 4. Fractured culet surface of the synthetic diamond anvil.

REFERENCES AND NOTES

1. K. A. Goettel, H. K. Mao, P. M. Bell, *Rev. Sci. Instrum.* **56**, 1420 (1985).
2. S. Block and G. J. Piermarini, *Phys. Today* **29**, 44 (September 1976).
3. A. Jayaraman, *Rev. Mod. Phys.* **55**, 65 (1983).
4. A. L. Hammond, *Science* **190**, 967 (1975).
5. W. A. Bassett, *Annu. Rev. Earth Planet. Sci.* **7**, 357 (1979).
6. L. S. Whatley, E. R. Lippincott, A. Van Valkenburg, C. E. Weir, *Science* **144**, 968 (1964).
7. R. A. Forman, G. J. Piermarini, J. D. Barnett, S. Block, *ibid.* **176**, 284 (1972); J. D. Barnett, S. Block, G. J. Piermarini, *Rev. Sci. Instrum.* **44**, 1 (1973).
8. G. J. Piermarini, S. Block, J. D. Barnett, R. A. Forman, *J. Appl. Phys.* **46**, 2774 (1975).
9. G. J. Piermarini and S. Block, *Rev. Sci. Instrum.* **46**, 973 (1975).
10. H. K. Mao, P. M. Bell, J. W. Shaner, D. J. Steinberg, *J. Appl. Phys.* **49**, 3276 (1978).
11. H. K. Mao and P. M. Bell, *Science* **191**, 851 (1976).
12. ———, *ibid.* **200**, 1145 (1978); ———, K. J. Dunn, R. M. Chrenko, D. C. DeVries, *Rev. Sci. Instrum.* **50**, 1002 (1979).
13. N. B. Owen and J. E. Martin, *J. Sci. Instrum.* **43**, 197 (1966).
14. H. K. Mao and P. M. Bell, *Carnegie Inst. Washington Yearb.* **76**, 646 (1977).
15. M. Seal, *High Temp. High Pressures* **16**, 573 (1984).
16. D. M. Adams and A. C. Shaw, *J. Phys. D* **15**, 1609 (1982).
17. M. S. Bruno and K. J. Dunn, *Rev. Sci. Instrum.* **55**, 940 (1984).
18. H. M. Strong and R. H. Wentorf, Jr., *Naturwissenschaften* **59**, 1 (1972).
19. G. B. Bokii, N. F. Kirova, V. I. Nepsha, *Sov. Phys. Dokl.* **24**, 83 (1979).
20. Y. Doi, S. Sato, H. Sumiya, S. Yazu, in *Proceedings of the International Conference on the Sciences of Hard Materials*, E. Almond, Ed. (Adams Hilger, Bristol, in press).
21. T. Takano, K. Tsuchiya, K. Kobayashi, S. Sato, "Annual Report, High Brilliance X-ray Laboratory, Hokkaido University" (July 1985), p. 18.
22. E. Bruton, *Diamond* (N. A. G. Press, London, 1978).
23. W. A. Bassett, T. Takahashi, P. W. Stook, *Rev. Sci. Instrum.* **38**, 37 (1967).
24. The origin of this peak is unknown.
25. J. J. Charett, *J. Chem. Phys.* **35**, 1906 (1961); H. B. Dyer and L. du Preez, *ibid.* **42**, 1898 (1965).

16 December 1985; accepted 19 March 1986