

combine to produce antibodies of the same or higher affinity than the ones encoded by original V_H - V_L pairs. This is more likely to happen in experiments such as the one described in the table, dealing with early stages of hyperimmunization than when dealing with more elaborate hyperimmunization schedules designed to generate antibodies of the highest affinity. The second is the probability that a random combinatorial library may reconstruct the original V_H and V_L pair. Libraries containing 10^5 - 10^6 random pairs can clearly give rise to good antibodies but, at least in our case, (and as predicted in ref. 1) failed to reproduce known original pairs (table). This may not always be the case, especially as technology improves and the library size increases. However, as the complexity of the library increases, the problems associated with the recovery of individual pairs also increase. We consider that, short of more elaborate protocols, the recovery of such rare 'original' H and L chain pairs is critically dependent on very complex combinatorial libraries ($>10^8$) and well outside the capacity of plaque or colony-screening methods. It may be, however,

within reach of the phage technology^{2-4,11}, and this is highly relevant to human antibodies where hybridomas have not been easy to derive.

Ermanno Gherardi*
César Milstein
*MRC Laboratory of Molecular Biology,
 Hills Road,
 Cambridge CB2 2QJ, UK*

* Present address: ICRF Cell Interactions Laboratory, Department of Medicine, University of Cambridge, Cambridge, CB2 2QQ UK.

1. Winter, G. & Milstein, C. *Nature* **349**, 293-299 (1991).
2. McCafferty, J. A. *et al. Nature* **348**, 552-554 (1990).
3. Kang, A. S. *et al. Proc. natn. Acad. Sci. U.S.A.* **88**, 4363-4366 (1991).
4. Breitling, F. *et al. Gene* **104**, 147-153 (1991).
5. Clackson, T. *et al. Nature* **352**, 624-628 (1991).
6. Burton, D. R. *et al. Proc. natn. Acad. Sci. U.S.A.* **88**, 10134-10137 (1991).
7. Caton, A. J. & Kaprowski, H. *Proc. natn. Acad. Sci. U.S.A.* **87**, 6450-6454 (1990).
8. Lerner, R. A. *et al. Proc. natn. Acad. Sci. U.S.A.* **88**, 9705-9706 (1991).
9. Kang, A. S. *et al. Proc. natn. Acad. Sci. U.S.A.* **88**, 11120-11123 (1991).
10. Rada, C. *et al. Proc. natn. Acad. Sci. U.S.A.* **88**, 5508-5512 (1991).
11. Smith, G. P. *Science* **228**, 1315-1317 (1985).
12. Kaartinen, M. *et al. Nature* **304**, 320-324 (1982).
13. Berek, C. & Milstein, C. *Immun. Rev.* **96**, 23-41 (1985).

Amino acids from coal gasification?

SIR — Relatively large amounts of two nonprotein amino acids, α -aminoisobutyric acid (AIB) and racemic isovaline (ISOVAL), have been identified in sediments proximate to the Cretaceous/Tertiary (K/T) boundary at Stevns Klint, Denmark¹. An alternative explanation for the occurrence of these amino acids which does not require extraterrestrial impacts is that they were formed as a result of coal gasification. This hypothesis is based on the isolation and identification by gas chromatography/mass spectrometry of large quantities of amino acid precursors (hydantoin) in gasification condensate water². The major hydantoin was 5,5-dimethylhydantoin and 5-ethyl-5-methylhydantoin², which are indeed those that generate AIB and ISOVAL on hydrolysis by chemical³ or microbial⁴ agents. The ratio of the two hydantoin in gasifier water⁵ was in fact the same as that observed for the AIB and ISOVAL in K/T sediments¹. Because hydrolytic conditions were used to obtain the amino acids from the sediments, the actual species in the sediments is unknown.

Hydantoin was formed in the gasifier condensate water by the complex Bucherer-Bergs reaction of ammonia, carbonate, hydrogen cyanide and various ketones and aldehydes that collected in the gas cooling/condensing system of the gasifier and not from a high-temperature reaction in the gasifier itself^{6,7}. In the

upper pyrolysis region of the gasifier, hot gases produced in the high-temperature gasification zone heat the coal and release large amounts of organic components, including many ketones (mainly acetone and 2-butanone). The ketones react in the condensed state with the dissolved gases, giving yields as high as 4 g of the two hydantoin per kg of coal.

Intrusion of magma into a coal bed would produce the intense heat needed for natural coal gasification to produce the hydantoin precursors. Ground water may have helped to produce steam, which could have effectively driven the gasification, and ground or surface water may also have provided a coolant for the gases, so that they could react to form the hydantoin. From the yields given above, geothermal gasification of a small coal seam of 1 km² by 10 m thickness and subsequent hydrolysis could have generated 6×10^7 kg of amino acids, enough to explain the abundance in K/T sediments. Further evidence for this process is the sedimentary deposit of char and coal particles in the Lattengebirge, Bavaria, K/T section⁸.

Whereas the K/T iridium anomaly requires a mantle type of volcanic activity or bolide, any kind of volcanic or magmatic intrusion into a coal field could have been responsible for the formation of the hydantoin. This may have been an event at the periphery of

the European deposition area, as suggested by Graup *et al.*⁸, or perhaps associated with the North American Laramide magmatic trend⁹, such as the Raton area in Colorado, where large areas of charred coal have been observed¹⁰. Because coal deposits as well as geothermal activity were plentiful from New Mexico to Canada, coal gasification may have occurred in several localities.

Zhao and Bada¹ dismissed the possibility of a volcanic origin for the abiotic amino acids on the grounds that high temperatures associated with volcanism would destroy them, and concluded that they were delivered by a massive extraterrestrial object (bolide) colliding with the Earth. The improbability of survival of amino acids in a bolide collision of the magnitude postulated, and the unlikely amount of diffusion that would be needed to have distributed the two amino acids away from the iridium-enriched K/T layer into the sediments above and below has been addressed by others^{11,12}.

Edwin S. Olson
*Universal Fuel Development Associates, Inc,
 223 Circle Hills Drive,
 Grand Forks, North Dakota 58201, USA*

1. Zhao, M. & Bada, J. L. *Nature* **339**, 463-465 (1989).
2. Olson, E. S., Diehl, J. W. & Miller, D. J. *Analyt. Chem.* **55**, 1111-1115 (1983).
3. Ware, E. *Chem. Rev.* **46**, 403-470 (1950).
4. Yamada, H., Takahashi, S., Kii, Y. & Kumagai, H. *J. ferment. Tech.* **56**, 484-491 (1978).
5. Willson, W. G., Hendrikson, J. G., Mann, M. D., Mayer, G. G. & Olson, E. S. *Proc. Techn. Utilization Low-Rank Coals* **1**, 265-299 (1984).
6. Olson, E. S., Worman, J. J. & Diehl, J. W. *ACS Div. Fuel Chem. Preprints* **30**(2), 288-290 (1985).
7. Diehl, J. W., Olson, E. S. & Worman, J. J. *Fuel* **64**, 1019-1021 (1985).
8. Graup, G., Spettel, B., Herm, D. & Weidich, K. F. *Earth planet. Sci. Lett.* **95**, 271-290 (1989).
9. Officer, C. B. *J. geol. Educ.* **38**, 402-416 (1990).
10. Crelling, J. C. & Dutcher, R. R. *Geol. Soc. Bull. Am.* **79**, 1375-1386 (1968).
11. Cronin, J. R. *Nature* **339**, 423-424 (1989).
12. Zahnle, K. & Grinspoon, D. *Nature* **348**, 157-160 (1990).

Script handedness

SIR — Dale Sanders suggests (*Nature* **355**, 483; 1992) that the direction of writing of a script depended originally on the medium in which it was written; that a naturally right-handed stone-carver would tend to chisel from right to left while a right-handed scribe using liquid ink would tend to write from left to right to avoid smudging. Consequently, I wonder whether there is a greater incidence of left-handedness in countries that use Arabic script than in others that use Roman or Devanagari, for example?

Barry Knight
*Ancient Monuments Laboratory,
 English Heritage,
 23 Savile Row,
 London W1X 1AB, UK*