on the efficiency of surface decontamination using OPH foams.

Foam of dilute enzyme concentration produces greater than 99% detoxification of a mildly contaminated surface (0.27 μmol paraoxon $cm^{-2}$) in one hour (Fig. 1a). Such dilute enzyme concentrations are inadequate for increased levels of contamination when the foam is applied to a height of 1.2 cm. However, a higher degree of contamination was effectively treated with similar foams of increasing enzyme content. The attainable conversion in one hour under varying conditions is illustrated in Fig. 1b. Figure 1 shows that nerve-agent surface concentrations in the range expected from a nerve-agent attack (0.3 μmol $cm^{-2}$) would be satisfactorily decontaminated over a wide range of enzyme concentrations.

Does adding more enzyme foam to a fixed surface area accommodate a higher concentration of neurotoxins or increase the decontamination rate? If the reaction takes place only at the foam–surface interface, adding more foam would be of little use. However, if the foam and/or the aqueous fallen film extract paraoxon from the surface, and the reaction occurs throughout the foam, adding more foam should increase the decontamination rate. Increased application of foam not only provides greater release rates for enzyme and water from the foam, but also increases the rate of detoxification. A surface contaminated with 1.15 μmol paraoxon $cm^{-2}$ (nearly four times the typical level of contamination) was detoxified by an OPH foam (11.4 nM) to a moderate degree (43 ± 5% conversion) when a 1.2-cm foam height was used. Identical foam applied to a height of 3.0 cm achieved greater than 70% conversion in the same time. Because foam for fire-fighting applications and hazardous vapour containment are generally applied to heights exceeding 5 cm, our experiments are within typical operating parameters.

Our results show that OPH is catalytically active within fire-fighting foam. The primary limitation of the enzymatic bioremediation of chemical weapons lies in the strict specificity of a given enzyme for a particular substrate[2]. This issue is being addressed by the production of foams with several enzymes of varying specificity. Such multicomponent enzyme foams will provide a safe, environmentally acceptable means of performing wide-area decontamination of nerve agents.

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1. *Alternative Technologies for the Destruction of Chemical Agents and Munitions* (National Research Council Commission on Engineering and Technical Systems, Washington DC, 1993).
2. Orton, R. D. *Technology Report for Congress* (Department of the Army, Aberdeen Proving Ground, Maryland, 1994).
3. *Chemical Weapons Destruction, Advantages and Disadvantages of Alternatives to Incineration* (GAO/NSIAD-94-123, General Accounting Office, Washington DC, 1994).
4. *Convention on the Prohibition of the Development, Production, Stockpiling, and the Use of Chemical Weapons and on their Destruction* (United States Senate, Washington DC, 8th August 1994).
5. Grimsley, J. K., Rastogi, V. K. & Wild, J. R. *Bioremediation: Principles and Practice* pp. 577-614 (Technomic, Irvine, 1997).
6. Cheng, T. C. & Calomiris, J. J. *Enzyme Microb.Technol.* **18,** 597–601 (1996).
7. Hoskin, F. C. G., Waler, J. E., Dettbarn, W. D. & Wild, J. R. *Biochem. Pharmacol.* **49,** 711–715 (1995).
8. LeJeune, K. E. *et al. Biotechnol. Bioeng.* **54,** 105–114 (1997).
9. LeJeune, K. E. & Russell, A. J. *Biotechnol. Bioeng.* **51,** 450–457 (1996).
10. Xu, B., Wild, J. R. & Kenerley C. M. J. *J. Ferment. Bioeng.* **81,** 473–481 (1996).
11. Lai, K., Stolowich, N. J. & Wild, J. R. *Arch. Biochem. Biophys.* **318,** 59–64 (1995).
12. Grimsley, J. K., Scholtz, J. M, Pace, C. N. & Wild J. R. *Biochemistry* **36,** 14366–14374 (1997).

# Nematode phylogeny and embryology

Blaxter *et al.*[1] presented the phylogenetic tree of the phylum Nematoda based on the sequences of small subunit (SSU) ribosomal DNA (see also ref. 2). At the level of higher-order classification, this tree is substantially different to traditional taxonomic systems[3–5]. The first branching of the SSU-based phylogenetic tree divides the nematodes into three big groups. Here we point out that three distinct patterns of early embryonic development reported for nematodes are in good agreement with this new classification. Differences in development could be more consistent with the natural nematode system than with the usual morphological criteria.

The three nematode groups resulting from the first branching of the SSU-based phylogenetic tree are: clade I (orders Dorylaimida, Mononchida, Mermithida and Trichocephalida); clade II (orders Enoplida and Triplonchida); and a group subdivided into clades III–V that consists of Chromadoria and Secernentea.

Development of nematodes from clade II is different from development of nematodes of all other groups because the divisions in the early embryos (up to the eight-cell stage) are synchronous and produce blastomeres indistinguishable from each other by size, position and appearance[5,6]. Tracing cell fates with intracellular labels in group representatives *Enoplus brevis*[6,7] and *Pontonema vulgare* (our unpublished results) shows that the blastomeres at these stages have no regular cell-lineage pattern. One of the two first-formed blastomeres may contribute to anterior or posterior, left or right, or intermediate parts of the embryo, and the endoderm precursor segregated at the eight-cell stage may derive from either blastomere.

In contrast, nematode embryos from clades III–V and I generate blastomeres that are already clearly distinguishable from each other after the first division. Embryonic development of nematodes from clades III–V has been well studied, and, in *Caenorhabditis elegans*, the complete stereotyped cell lineage has been followed[8]. In nematode embryos from this group, the anterior blastomere is named AB; its progeny divides in a synchronized pattern and gives rise to the particular structures of the animal. Predominantly posterior and internal parts of the embryo, including endoderm, derive from another blastomere of the two-cell stage — $P_1$ (refs 5,8,9).

In nematodes from clade I, the first division also produces two blastomeres that are different to each other in size and fate, but are not homologous to AB and $P_1$ in nematodes of clades III–V. At the four-cell stage, two daughters of different blastomeres behave like AB progeny and another two resemble $P_1$ descendants. Endoderm in these species derives from the anterior blastomere of the first pair[5,10,11].

Thus, the cell-lineage patterns in the three large groups of nematodes seem to be very different. We realize that the above framework for different patterns of development in three taxonomic groups of nematodes is based on a few observations with varying degrees of reliability, but it gives straightforward, testable predictions.

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1. Blaxter, M. L. *et al. Nature* **392,** 71–75 (1998).
2. Aleshin, V. V. *et al. Russian J. Nematol.* **6,** 175–184 (in the press).
3. Chitwood, B. G. & Chitwood, M. B. *Introduction to Nematology* (Univ. Park, Baltimore, 1974).
4. Lorenzen, S. *The Phylogenetic Systematics of Freeliving Nematodes* (The Ray Society, London, 1994).
5. Malakhov, V. V. *Nematodes. Structure, Development, Classification, and Phylogeny* (Smithsonian Inst., Washington, 1994).
6. Voronov, D. A. & Panchin, Yu. V. *Development* **125,** 143–150 (1998).
7. Voronov, D. A. *et al. Proc. Acad. Sci. USSR* **286,** 201–204 (1986).
8. Sulston, J. E., Schierenberg, E., White, J. G. & Thomson, J. N. *Dev. Biol.* **100,** 64–119 (1983).
9. Skiba, F. & Schierenberg, E. *Dev. Biol.* **151,** 597–610 (1992).
10. Drozdovskii, E. M. *Proc. Acad. Sci. USSR* **222,** 1105–1108 (1975).
11. Malakhov, V. V. & Spiridonov, S. E. *Zool. Zhurnal* **60,** 1574–1577 (1981).