Symbiosis, 22 (1997) 5–8
Balaban, Philadelphia/Rehovot

Anatomical Localization and Ultrastructural Traits of the Bacterial Symbionts of Entomopathogenic Nematodes

NOEL BOEMARE
Laboratoire de Pathologie comparée, INRA-CNRS URA 2209, CP 101, Université Montpellier II, 34095 Montpellier Cedex 05, Tel. +33-467143740, Fax. +33-467144679, E-mail. boemare@ensam.inra.fr

Figure 1: *Photorhabdus luminescens* cells (arrow) from the strain HP88 in the anterior part of *Heterorhabditis bacteriophora* intestine after escaping from an insect cadaver. Differential interference contrast micrograph; scale bar: 5 μm. Reprinted from Boemare et al. (1996) and courtesy of C. Laumond (INRA Antibes, France).

The bacterial symbionts of both nematode genera are located in the intestine of L3 juvenile larvae. *Xenorhabdus* spp., symbionts of *Steinernema* spp. are isolated in a special intestinal vesicle, and *Photorhabdus* spp., symbionts of *Heterorhabditis* spp., are aggregated in the lumen of the gut anterior part in early nematode infective stages.

Figure 2: Cells of *Xenorhabdus nematophilus* strain F1 in culture stationary phase, showing protein crystals (arrow) in the protoplasm. Transmission electron micrograph; scale bar: 0.25 μm. Reprinted from Boemare et al. (1983).

All *Xenorhabdus* and *Photorhabdus* produce protein inclusions in their protoplasm from which pathological and/or physiological properties have not been yet identified.

0334-5114/97/$05.50

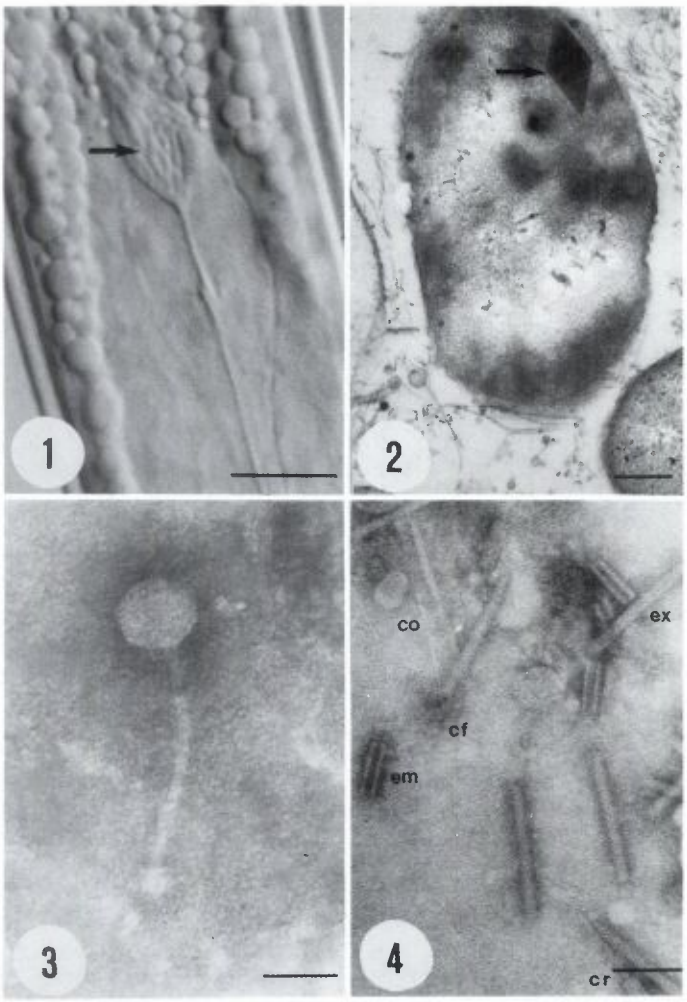
1
2
3
4
co
ex
cf
em
cr

Figure 3: Transmission electron microscopy of a complete bacteriophage particle with flexible tail obtained from mitomycin C-induced culture of *X. nematophilus* strain A24. Scale bar: 50 nm. Reprinted from Boemare et al. (1992).

Most of the *Xenorhabdus* strains are lysogenic. The purified DNA contained in the phage heads used as a probe, hybridizes on gel with several bands on a restricted genomic DNA of the producer strain, assessing that several copies of prophage occur in the genome of the given strain. This fact demonstrates that the producer strain is lysogenic. For more details see Boemare et al. and Thaler et al. (pp. 167–176 and pp. 205–216 in this issue).

Figure 4: Purified suspension of xenorhabdicin, bacteriocin of *X. nematophilus* (Thaler et al., 1995), showing particles with extended sheath (ex), contracted sheath (cr), loose core (co), complete bacteriocin with caudal fibers possessing adhesive extremities (cf) on baseplate, empty sheath (em). Transmission electron microscopy from mitomycin C-induced culture of strain F1; scale bar: 100 nm. Reprinted from Baghdiguian et al. (1993).

Many *Xenorhabdus* and *Photorhabdus* spontaneously produce bacteriocins which are bacteriolytic against closely related bacteria, including other species of *Xenorhabdus* and *Photorhabdus*. It was hypothesized that these elements with the other produced antibiotic molecules possessing a larger antimicrobial spectrum, prevent any contamination from foreign bacteria during the nematode development in the insect cadaver. In *Xenorhabdus* spp. bacteriocins are 1,000–10,000 fold more produced than the spontaneous production after the action of a mutagenic agent as mitomycin C, inducing the complete lysis of the culture with concomitant production of bacteriophages. However, the tails of *Xenorhabdus* phages are flexible (Fig. 3), while bacteriocins produced by the same strain are rigid and contractile phage tail like particles (Fig. 4). Bacteriocins do not possess a genetic material encapsided in a head as phages do. They have been sometimes called "defective bacteriophages". In *Photorhabdus* phages have not been yet identified, but *Photorhabdus* produce bacteriocins different from those of Xenorhabdus. For more details see Boemare et al. and Thaler et al. (pp. 167–176 and pp. 205–216 in this issue).

REFERENCES

Baghdiguian, S., Boyer-Giglio, M.-H., Thaler, J.-O., Bonnot, G., and Boemare, N. 1993. Bacteriocinogenesis in cells of *Xenorhabdus nematophilus* and *Photorhabdus*

luminescens: Enterobacteriaceae associated with entomophathogenic nematodes. *Biology of the Cell* **79**: 177–185.

Boemare, N., Boyer-Giglio, M.-H., Thaler, J.-O., Akhurst, R.J., Brehélin, and M. 1992. Lysogeny and bacteriocinogeny in *Xenorhabdus nematophilus* and other *Xenorhabdus* spp. *Applied and Environmental Microbiology* **58**: 3032–3037.

Boemare, N., Laumond, C., and Mauleon, H. 1996. The nematode-bacterium complexes: Biology, life cycle, and vertebrate safety. *Biocontrol Science & Technology* **6**: 333–345.

Boemare, N., Louis, C., and Kuhl, G. 1983. Etude ultrastructurale des cristaux chez *Xenorhabdus* spp., bactéries inféodées aux Nématodes entomophages Steinernematidae et Heterorhabditidae. *Comptes Rendus de la Société de Biologie* **177**: 107–115.

Thaler, J.-O., Baghdiguian, S., and Boemare, N. 1995. Purification and characterization of xenorhabdicin, phage tail like bacteriocin, from the lysogenic strain F1 of *Xenorhabdus nematophilus*. *Applied and Environmental Microbiology* **61**: 2049–2052.