

# Foreword

Insects and other invertebrates ranging from nematodes to earthworms, isopods and millipeds usually host many microorganisms in both their intestinal tracts and tissues. Outside of the gut these organisms are usually found in the hemolymph or are restricted to specialized bacteriocytes (mycetocytes) and mycetoms. Many microorganisms have been characterized morphologically (for example, compilation by Edward A. Steinhaus 1967) and their transfer to other developmental stages has been studied thoroughly (Paul Buchner 1953). In the gut this intra- and extracellular microbial diversity is often reflected by culturable forms but due to molecular techniques more and more species can be identified taxonomically. It also became evident that arthropod digestive tracts – with their outpocketings such as foregut caeca, or malpighian tubules and their unidirectional bulk flow of ingested food – represent primary habitats for microorganisms including bacteria, fungi, yeasts and protozoa. These organisms may occur intraepithelially, adhere to the gut wall or are free floating in the lumen of the digestive tract. Number and composition of microorganisms can vary considerably, depending on longitudinal gut position, temperature, pH, anaerobic or aerobic conditions and various natural or laboratory diets.

These digestive tracts are characterized by an excess supply of more or less degradable food, controlled water activities and often rather stable pH and temperature conditions. On the other hand guts may represent unstable environments because food composition may change in time and cuticle linings of fore- and hindguts are lost with each molt. This reestablishing of microbiota is especially interesting in holometabolous insects where larvae and adults are found in different habitats.

The interaction between microorganisms and their host and the host guts respectively is so far unknown. They may pass through the gut with food, stay there for a longer period of time (as compared with the transportation of food) or represent true symbionts. In addition intracellular symbionts from outside the gut must be transferred through the digestive tract at some point in order to settle within the body cavity. The “symbiosis”-concept can be seen from a broad or narrow angle. Today symbiosis has strong connotations of strict mutualism and completely excludes parasitism (as symbiosis was defined in 1891 by Antom de Bary (1831–1888)). Paul Buchner (1886–

1978), who dedicated most of his life to the study of endosymbiosis, defined it as cohabitation between two partners of different species, where one is taken up in the body of the other, usually more highly organised, partner.

The biological role of these microorganisms may vary considerably: gut microorganisms of exotic hosts such as larvae of the oil fly *Helaeomyia petrolei* might be interesting due to their pronounced solvent tolerance or may be a future source of industrially useful solvent-tolerant enzymes. In addition these microbiota may detoxify allelochemicals or may be responsible for the biosynthesis of essential compounds such as vitamins, sterols, or nitrogen-containing constituents. Generally these microorganisms may be the source of novel metabolic capabilities such as defense substances and antibiotics or may fixate atmospheric nitrogen. It has been known for many years that enzymes in the gut which originate from ingested fungal tissue or gut microbes may mediate cellulolysis. A large number of insects and invertebrates which usually utilize internal or external microbes have evolved beneficial associations with these microorganisms.

The editors Helmut König and Ajit Varma deserve credit for compiling articles on these interesting phenomena. With *Intestinal Microorganisms of Termites and Other Invertebrates* they – together with the authors – present a fascinating and stimulating collection of articles focusing on intestinal microorganisms of soil invertebrates and especially of termites, which have been studied extensively. Finally, this book in the series *Soil Biology* is highly innovative in covering both molecular and micromethods.

I am sure that the recently founded working group of the German Society for General and Applied Entomology (DGaaE) entitled “Microbiology and Arthropods” together with this promising and comprehensive book will truly inspire this fascinating area of interdisciplinary research and I thank both editors and Springer for realizing this project.

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# Preface

The soil is an important natural habitat for a large number of taxonomic groups such as bacteria, archaea, protists, fungi, algae as well as plants and animals, which have adapted to the environmental conditions in soil. It represents not only a steady state, but rather a constantly changing environment, which is influenced by natural environmental factors and human activities.

Soil biology describes the systematics, complex activities and interactions of the soil inhabitants. A special discipline, the soil microbiology, characterizes the microbial community in the substratum. It plays a major role in the degradation and recycling of organic material. Microbes are involved in the first step of the soil food web, soil fertility, degradation of xenobiotics as well as in plant pathology. In particular, the degradation of lignocellulose, the most important renewable natural material, is mainly a domain of microorganisms. It is therefore imperative to study ecological and agricultural aspects of soil microbes. In the past, attention was mainly directed towards the free-living or particle-bound microorganisms, and the role of intestinal microbes occurring in gut systems of soil animals has been neglected.

The primary decomposers of organic soil litter are the lumbricids, the diplopods, the isopods, and dipteran larvae as well as termites in subtropical and tropical regions. Only a small percent of the soil microbes have been screened axenically. The same is true for the intestinal microbes of soil invertebrates. However, with the aid of molecular methods (e.g. total 16S rDNA sequence analysis), it was possible to get a rough estimate of the total population in a given environment. In the last few years, the intestinal microbial communities (microbiota) of some soil invertebrates such as collembola, earthworms, nematodes, isopods, millipedes and termites have been studied in more detail. The most intensively studied group is that of the termites because of their interesting microflora and global role in the decomposition of organic material.

The intestinal microbiota has only been investigated from a few soil invertebrates. For the first time, the authors highlight this aspect and give an overview on the intestinal soil community in order to underline their role in the soil food web. The goal of this book is to bridge a gap and to add a new

mosaic stone to our knowledge of soil biology. The book is divided into three sections. The first describes the intestinal microbiota of the investigated soil invertebrates, while the second deals with termites, the best investigated soil invertebrates with respect to their gut microbiota. The third part presents novel techniques introduced in ecological microbiology, which have been successfully applied to studies of the intestinal microbiota. The book covers several novel facets and presents insights into the intestinal microbiota of soil invertebrates. The text is mainly directed towards graduate students and professional scientists with a general interest in the soil or intestinal microbiota or in ecological microbiology in general.

We are grateful to all authors for providing their expertises and contributions, making this special edition possible. We also express our thanks to Springer-Verlag for accepting this unconventional and less investigated, but ecologically important, subject for publication in this prestigious book. We appreciate the efforts of Dr. Dieter Czeschlik and Dr. Jutta Lindenborn from Springer Life Sciences Editorial, who managed this special book.

Mainz and Noida, April 2005

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