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Review

# Antibacterial Weapons: Targeted Destruction in the Microbiota

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**The intestinal microbiota plays an important role in health, particularly in promoting intestinal metabolic capacity and in maturing the immune system. The intestinal microbiota also mediates colonization resistance against pathogenic bacteria, hence protecting the host from infections. In addition, some bacterial pathogens deliver toxins that target phylogenetically related or distinct bacterial species in order to outcompete and establish within the microbiota. The most widely distributed weapons include bacteriocins, as well as contact-dependent growth inhibition and type VI secretion systems. In this review, we discuss important advances about the impact of such antibacterial systems on shaping the intestinal microbiota.**

## Highlights

The intestinal microbiota is a complex but stable ecosystem that plays a central role in human health, and disturbance of its composition and function is associated with many diseases.

Within the intestinal microbiota, bacteria exchange material and information.

The microbiota can be peaceful, but many bacteria fight with others to have a better access to their niche or nutrients.

Different antibacterial weapons have been identified and characterized, and many bacterial pathogens use these weapons to establish themselves in the intestinal environment, whereas some commensals use these weapons to specifically target pathogens, leading to protection of the host.

## The Intestinal Microbiota: Our Best Frenemy

The mammalian intestine is inhabited by a large and diverse community of microbes, referred to as the gut microbiota. The human gut microbiota, also referred to as a 'microbial organ', weights 1–2 kg, and consists of approximately 100 trillion ($10^{14}$) bacteria representing from six to ten phyla, including two predominant phyla – Bacteroidetes and Firmicutes – and about 500–1000 distinct species [1]. This highly complex **microbial community** (see Glossary) is controlled by various factors, such as host genetics and environmental factors. Moreover, microbiota diversity and composition is influenced by host diet as well as by positive and antagonistic interactions between bacteria within the microbiota.

The intestinal microbiota has an overall beneficial impact on its host by providing metabolic activities within the intestine and favoring the development of the **intestinal immune system** [2] (Figure 1). Exemplifying this notion is the observation that the immune responses in mice housed in germ-free conditions are abnormal compared to conventionally colonized mice [3,4]. Therefore, early exposure to microbes in the intestine is a critical factor to modulate intestinal immune responses [5]. A well-documented example of a single microbial member playing a central role in shaping the intestinal immune system is segmented filamentous bacteria (SFB), which can promote the robust differentiation of Th17 cells [6–8]. Moreover, if not well managed, the gut microbiota can become deleterious, for example, by inducing uncontrolled intestinal inflammation. In light of the benefits the microbiota confers, and on its potential to harm its host, the gut microbiota has previously been referred to as the host's best frenemy [9].

Collectively, the microbiota and its derived metabolites are critical components for the maturation of host intestinal immunity, and research has accumulated on the central role played by the intestinal microbiota in the protection of the host intestine against pathogens, a phenomenon called colonization resistance [10–12]. Bacterial competition occurs either by

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