Chapter 3
Systems Biology and Integrative Omics Decoding Xenobiotic Metabolism in Environmental Carcinogenesis:
Xenobiotic Metabolism in Carcinogenesis

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ABSTRACT

This chapter explores how xenobiotics contribute to cancer development through interactions with DNA and disruption of metabolic processes. It highlights the role of drug-metabolizing enzymes in cancer risk. The chapter emphasizes the importance of an integrated approach, combining genetic, environmental, and metabolic factors for cancer prevention. The emerging field of cancer exposomics is discussed, with a focus on how environmental exposures, such as pollution and diet, alter molecular pathways involved in inflammation, oxidative stress, and cancer cell proliferation. The role of the gut microbiome in metabolizing xenobiotics is explored, as well as the potential for therapies like probiotics, prebiotics, and fecal microbiota transplantation to reduce cancer risk. Additionally, epigenetic changes are examined in the context of cancer susceptibility and detoxification. The chapter concludes with a discussion of how systems biology, omics technologies, and epigenetics offer new opportunities for personalized cancer prevention and treatment strategies.

INTRODUCTION

Cancer remains one of the most pressing public health challenges globally, and growing evidence implicates chronic environmental exposures in its development. While genetics plays a crucial role in cancer susceptibility, it is now clear that xenobiotics—foreign chemical substances originating from industrial pollutants, pesticides, pharmaceuticals, and dietary sources—significantly influence disease onset and progression. Despite this, the molecular mechanisms through which xenobiotics contribute to carcinogenesis are not fully understood, and their role is often underestimated in traditional cancer research.

Increasing environmental exposure to xenobiotics—such as heavy metals, pesticides, and endocrine-disrupting chemicals—has been implicated in the rising incidence of various cancers. These exposures disrupt normal metabolic processes and epigenetic regulation, leading to increased cancer susceptibility. Understanding the mechanisms by which xenobiotics contribute to cancer risk is crucial for developing targeted therapeutic strategies aimed at mitigating these effects. Particularly, xenobiotic-induced metabolic and epigenetic disruptions may play a critical role in cancer complications such as metastasis, underscoring the urgency of therapeutic interventions that address these underlying mechanisms.

This chapter addresses an urgent need to examine how xenobiotics interact with metabolic and genetic systems to disrupt cellular homeostasis, promote DNA damage, and drive epigenetic alterations that increase cancer risk. It comes at a critical time when the fields of systems biology, exposomics, and integrative omics are