Review Article: Clinical Oncology Case Reports

Innovative impact of the bacteria – fungus symbiosis: clinical applications in modern synthetic biology

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Abstract

Synthetic biology has revolutionized modern science by allowing the reprogramming of microorganisms to perform specific and useful functions. In this context, the symbiosis between bacteria and fungi emerges as a promising strategy for the development of innovative and efficient applications. This article explores how the symbiotic interaction between these microorganisms can enhance advances in synthetic biology, with special emphasis on the production of broad-spectrum antimicrobial compounds and the mitigation of antimicrobial resistance.

Keywords: synthetic biology; bacteria-fungus symbiosis; antimicrobial resistance

Introduction

The increase in antimicrobial resistance currently constitutes a serious threat to health. Globally, 700,000 people are estimated to die each year from antibiotic-resistant infections. If nothing is done, they are expected to cause millions of deaths annually; by 2050, antimicrobial resistance and linked infections could become a more common cause of death than cancer. The growth in the number of infections caused by drug-resistant bacteria exceeds the appearance of new antibiotics, which points to a shocking future. Rodríguez & Rodríguez, (2022)

Synthetic Biology can be defined as a discipline useful for designing and building new biological parts, mechanisms and systems, or re-designing existing biological systems and giving them new and better qualities with a defined purpose. From it, it is possible to develop new methodologies to study the functionality of biological systems themselves. Muñoz et al., (2019)

Synthetic Biology is an interdisciplinary field that combines principles of biology, engineering and computer science to design and build new biological functions in living organisms. Bacteria and fungi, due to their diversity and ability to adapt to different environments, are key players in this field. The symbiosis between bacteria and fungi, a mutually beneficial relationship, offers new opportunities for innovation in synthetic biology. This article focuses on the impact of these symbiotic interactions and their potential to address contemporary challenges in health and sustainability.

Mechanisms of Bacteria-Fungus Symbiosis

Metabolic Interactions:

Production of Secondary Metabolites: Symbiotic bacteria and fungi often exchange metabolites that promote the growth and survival of both organisms. These metabolites can include antibiotics, enzymes and other bioactive compounds.

Nutrient Cycling: Symbiosis facilitates the recycling of essential nutrients, improving metabolic efficiency and sustainability of the microbial consortium. Rodríguez, (2021)

Chemical Communication:

Chemical Signaling: Symbiotic microorganisms communicate using chemical signals, such as quorum sensing molecules in bacteria, which coordinate gene expression and community activities.

Gene Regulation: The chemical interaction between bacteria and fungi can induce the expression of genes that are beneficial for both organisms, enhancing their metabolic and defense capabilities.

Applications in Synthetic Biology

Production of Broad-Spectrum Antimicrobials:

Synthetic Microbe Design: Use synthetic biology to engineer bacteria and fungi to produce antimicrobial compounds effective against a wide range of pathogens. These modifications may include the insertion of genes that code for the synthesis of peptidoglycan in bacteria and chitin in fungi.

Production Optimization: By designing genetic circuits that optimize the production of antimicrobials in the presence of specific signals from the environment, production efficiency can be increased and cost reduced.

Mitigation of Antimicrobial Resistance:

Development of New Antibiotics: Explore the ability of symbiotic consortia to produce new antibiotics that avoid resistance. These new compounds may be derived from secondary metabolites produced in the symbiotic interaction. Carrillo et al., (2023)

Use of Bacteriophages: Integrate the use of bacteriophages in synthetic biology to attack resistant bacteria. Fungi can be modified to produce bacteriophages that specifically target resistant pathogenic bacteria.

Challenges and Future Perspectives

Understanding Symbiotic Interaction:

Any microorganism that is capable of causing disease in an organism host is called a pathogen. When a pathogenic microorganism (bacteria, virus or protozoan parasite) infects the human body, a battle occurs between the systems innate and adaptive immune systems of the host and the various mechanisms and pathogen virulence factors. The outcome of this battle determines whether the host survives and recovers, and how. Complete recovery involves the achievement of physiological (and immunological) homeostasis in the host, and the time this takes will depend on the nature and severity of the infection and whether there has been any prophylactic or therapeutic intervention. Many Pathogens are equipped with immune evasion mechanisms to achieve invasion of the host cell and its colonization, although they can also use with success to its cells to access the target tissues. Among the immune evasion strategies, we find: (1) hiding from the immune system (for example, inside cells); (2) interfere with its function (e.g., blocking signals) or (3) destroy some of its elements (for example, the structures that present microbial antigens to immune effectors to initiate an answer). Virulence generally involves the use of various mechanisms to destroy or cause malfunction of the host's cells, even if the host latter may also employ defense strategies in response. Williamson, (2022)

Bacterial-fungal symbiosis represents an emerging area in synthetic biology, with promising clinical applications that could revolutionize disease treatment and biological systems engineering.

In the clinical field, the study of the epigenetic mechanisms involved in the bacteria-fungus symbiosis has shown potential, discovering new antimicrobial treatment alternatives. For example, membrane vesicles (MVs) derived from gut microbiota and probiotics have emerged as a promising therapeutic strategy to combat infections caused by multidrug-resistant (MDR) super bacteria. These MVs, which are natural nanoparticles released by bacteria, contain various molecular components, such as proteins, lipids, and nucleic acids, which can modulate the host response and exert antimicrobial effects.

Probiotic-derived MVs, such as *Lactobacillus* and *Bifidobacterium*, have demonstrated the ability to inhibit the growth of MDR pathogens, such as multidrug-resistant *Escherichia coli* and methicillin-resistant *Staphylococcus aureus* (MRSA), through mechanisms such as competition for nutrients and stimulation of the immune system. This approach represents an innovative alternative to traditional antibiotics, which are becoming less effective due to bacterial resistance. Srivastava, (2022), Céspedes, (2024)

Another innovative application is the use of symbiotic systems in the detection and degradation of pathogens. Recent engineering has made it possible to design bacterial-fungal biofilms capable of identifying and eliminating antibiotic-resistant infections, such as those caused by *Candida albicans* and *Pseudomonas aeruginosa.* These advances highlight the potential of bacteria-fungus symbiosis in the development of personalized therapies and in the fight against antimicrobial resistance. Mohamad et al., (2023); Wu et al., (2025); Seneviratne al. ,(2008)

Conclusions

The symbiosis between bacteria and fungi offers fertile ground for innovation in synthetic biology and opens new frontiers in clinical medicine, offering innovative tools for the design of more effective and sustainable treatments. Potential applications in antimicrobial production and mitigation of antimicrobial resistance underline the importance of this area of research. With a deeper understanding of symbiotic mechanisms and the development of appropriate technologies, these microbial interactions are likely to transform modern synthetic biology, contributing to solving some of the most pressing challenges of the contemporary world.

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