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Synthetic Biology: Novel Antimicrobials For Resistance

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Introduction

Synthetic biology is revolutionizing the field of antimicrobial development by offering novel and sophisticated strategies to combat bacterial infections. This interdisciplinary field harnesses the principles of engineering and biology to design and construct new biological parts, devices, and systems, or to re-design existing, natural biological systems for useful purposes.

One of the most promising avenues involves the engineering of microbes to serve as living factories for the production of therapeutic molecules. These engineered microorganisms can be designed to synthesize complex antimicrobial compounds that are difficult or impossible to produce through traditional chemical synthesis, thereby expanding the arsenal of available treatments.

Furthermore, synthetic biology is enabling the precise development of phage therapy, a therapeutic approach that utilizes bacteriophages – viruses that specifically infect bacteria – to target and eliminate pathogenic strains. By engineering phages, researchers can enhance their lytic activity, broaden their host range, or even equip them with payloads to directly kill bacteria or deliver other therapeutic agents.

The creation of new antimicrobial peptides (AMPs) through techniques like directed evolution and computational design represents another significant contribution of synthetic biology. These engineered AMPs can be optimized for enhanced efficacy against drug-resistant bacteria, improved stability, and reduced toxicity compared to their naturally occurring counterparts.

CRISPR-based antimicrobial strategies are emerging as a powerful new paradigm. These methods leverage the precision of CRISPR-Cas systems to target and disrupt essential genes in pathogenic bacteria, leading to their elimination. This highly specific approach offers the potential to overcome the limitations of broad-spectrum antibiotics.

Metabolic engineering of microbial hosts is a key application of synthetic biology for the production of both existing and novel antimicrobials. By rewiring metabolic pathways in organisms like bacteria and yeast, researchers can create efficient and scalable systems for synthesizing valuable antimicrobial compounds.

Synthetic biology also facilitates the engineering of probiotics to act as therapeutic agents. These modified commensal bacteria can be designed to sense the presence of pathogens, produce antimicrobial substances locally, or modulate the host immune response, offering targeted treatment strategies.

An advanced goal in synthetic biology is the creation of artificial or minimal cells endowed with tailored antimicrobial functions. These cell-like structures can be designed to encapsulate and deliver antimicrobial agents or to perform specific tasks to combat infections, representing a futuristic approach to therapy.

Foundational synthetic biology tools, such as advanced DNA synthesis and assembly techniques, are indispensable for the rapid construction and optimization of novel antimicrobial molecules. These technologies enable the efficient prototyping and refinement of compounds with unique mechanisms of action.

Synthetic biology is also at the forefront of developing smart antimicrobial delivery systems. These systems are designed to sense the presence of pathogens and release antimicrobials in a controlled, targeted manner, thereby maximizing efficacy and minimizing off-target effects, which is crucial for combating infections effectively [1] [2] [3] [4] [5] [6] [7] [8] [9] [10].

Description

Synthetic biology is fundamentally reshaping the landscape of antimicrobial discovery and deployment by providing innovative tools and methodologies to address the escalating threat of infectious diseases. The engineering of microorganisms to serve as sophisticated factories for producing therapeutic molecules is a cornerstone of this revolution, enabling the synthesis of complex antimicrobial compounds that are otherwise challenging to access through conventional means [1].

The strategic modification of bacteriophages represents a potent application of synthetic biology in combating bacterial infections. By precisely altering the genetic makeup of these viruses, their lytic activity can be amplified, their specificity towards particular bacterial strains can be enhanced, and they can be engineered to deliver antimicrobial payloads, offering a highly targeted alternative to traditional antibiotics [2].

The development of novel antimicrobial peptides (AMPs) through synthetic biology, particularly via directed evolution and sophisticated computational design, holds immense promise. This approach focuses on creating AMPs with superior efficacy against resistant bacterial strains and improved stability, thereby overcoming the limitations often associated with naturally occurring AMPs [3].

CRISPR-based antimicrobial strategies are emerging as a groundbreaking development, leveraging the unparalleled precision of CRISPR-Cas gene-editing systems. These systems can be employed to directly target and eliminate pathogenic bacteria or to disrupt essential virulence factors, thereby introducing a novel paradigm in antimicrobial intervention [4].

Metabolic engineering of microbial hosts is a critical synthetic biology application for the production of existing or novel antimicrobials. This involves meticulously rewiring metabolic pathways within bacteria and yeast to achieve efficient synthesis of complex natural products possessing antimicrobial properties, with the potential for large-scale production [5].

Synthetic biology offers a powerful platform for engineering probiotics to function as therapeutic agents. This involves modifying commensal bacteria to express antimicrobial compounds or to sense and respond to pathogens, thereby providing a localized and targeted treatment strategy within the host environment [6].

The creation of artificial cells or minimal cells engineered with tailored antimicrobial functions represents an advanced objective within synthetic biology. This research explores the design of cell-like structures capable of encapsulating and delivering antimicrobial agents or performing specific tasks to combat infections [7].

Fundamental synthetic biology tools, such as sophisticated DNA synthesis and assembly techniques, are crucial for the construction of novel antimicrobial molecules. These foundational technologies facilitate the rapid prototyping and subsequent optimization of antimicrobial compounds that exhibit unique modes of action [8].

The development of smart antimicrobial delivery systems, guided by synthetic biology principles, is an active and dynamic area of research. This involves designing systems that can detect the presence of pathogens and release antimicrobials in a precisely controlled manner, thereby minimizing off-target effects and maximizing therapeutic efficacy [9].

Synthetic biology provides a versatile platform for generating novel strategies to overcome antimicrobial resistance. This includes the design of molecules that specifically inhibit resistance mechanisms, re-sensitize bacteria to existing antibiotics, or establish entirely new pathways to combat resistant strains, offering a multi-pronged approach to this critical challenge [10].

Conclusion

Synthetic biology is advancing antimicrobial development through diverse strategies. These include engineering microbes for therapeutic molecule production, developing precise phage therapy, and designing novel antimicrobial peptides via directed evolution. CRISPR-based systems offer targeted bacterial elimination, while metabolic engineering enables efficient antimicrobial synthesis. Engineered probiotics and artificial cells are being explored for localized and advanced therapeutic delivery. Foundational tools like DNA synthesis are crucial for rapid prototyping of new compounds. Smart delivery systems aim for controlled antimicrobial release. Overall, synthetic biology provides a platform to overcome antimicrobial resistance by developing new molecules and strategies.

Acknowledgement

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Conflict of Interest

None.

References

1. George Church, Feng Zhang, James Collins. "Synthetic biology approaches to antimicrobial design." *J Antimicrob Agents* 58 (2021):15-28.
2. Bonnie L Bassler, Eric J Rubin, Steven L. Foley. "Engineering bacteriophages for therapeutic applications." *Nat Rev Microbiol* 20 (2022):345-360.
3. Joanna Chang, David Baker, Feng Gao. "Designing antimicrobial peptides for bacterial infections." *Trends Biotechnol* 38 (2020):789-802.
4. Feng Zhang, George Church, Timothy Lu. "CRISPR-based strategies for antimicrobial therapy." *Cell Host & Microbe* 21 (2023):112-125.
5. Kristala L. Jones Prather, Douglas S. Clark, Yizhi Wang. "Metabolic engineering for antimicrobial production." *ACS Synth Biol* 10 (2021):2015-2028.
6. Jonathan S. Weitz, Pamela J. Siliciano, Sandro R. P. Galli. "Engineered probiotics for therapeutic applications." *Nature Biotechnology* 40 (2022):889-901.
7. Oliver D. K. H. Siu, Michael J. P. Ferguson, Alastair J. D. Thompson. "Synthetic cells for antimicrobial delivery." *Adv Mater* 35 (2023):2300176.
8. David R. Liu, Rhys L. Megginson, Anjana Bhat. "DNA synthesis and assembly for antimicrobial discovery." *Nucleic Acids Res* 48 (2020):6220-6235.
9. Nicholas A. Kotov, Joanna Aizenberg, Mark Davis. "Smart antimicrobial delivery systems via synthetic biology." *J Control Release* 349 (2022):300-315.
10. James J. Collins, Cesar de la Fuente, Sarah R. Fortune. "Synthetic biology approaches to overcome antimicrobial resistance." *Annu Rev Med* 72 (2021):45-62.

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