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Perspective

Exploring the Potential of Marine Bacteria: Advanced Methods for Genetic Manipulation

Wu Yanqi*

Department of Resources and Environment, Huazhong Agricultural University, Wuhan, China

DESCRIPTION

Marine bacteria are a collection of unique metabolites and biotechnological potential, from natural antibiotics to enzymes capable of functioning in extreme environments. Genetic manipulation of these bacteria allows researchers optimize their capabilities for applications in medicine, environmental remediation and bioengineering. However, marine bacteria present unique challenges to genetic engineering due to their diverse physiology and adaptation to oceanic environments. The key methods for genetically manipulating marine bacteria and highlights the latest advancements that hold promise for marine biotechnology.

Marine bacteria often inhabit extreme environments, such as high-salinity ocean waters, deep-sea hydrothermal vents and polar regions. These unique adaptations, while beneficial for survival, complicate laboratory cultivation and genetic manipulation. Traditional transformation methods used for terrestrial bacteria do not always apply to marine bacteria, which are less well-studied and often have complex cell walls or restrictive gene expression pathways. Despite these challenges, recent advances in genetic engineering have opened new doors to manipulating marine bacterial genomes.

Transformation techniques

One of the primary methods for introducing foreign DNA into bacterial cells is transformation, which involves the uptake and integration of DNA from the surrounding environment. In marine bacteria, transformation can be challenging due to cell wall composition and resistance to traditional methods. However, some specialized approaches have been developed.

In electroporation, an electric field is applied to create temporary pores in the bacterial cell membrane, allowing DNA to enter. This method has been adapted for some marine bacteria by optimizing parameters such as voltage, pulse duration and osmotic conditions. While electroporation is effective for certain strains, it can be limited by the saltwater conditions required for marine bacteria.

Conjugation involves the transfer of genetic material between bacterial cells *via* direct contact, often mediated by plasmids. Marine bacteria are increasingly engineered with conjugative plasmids derived from terrestrial models, which can be modified for marine bacterial hosts. This approach is particularly useful for non-transformable marine strains.

Some marine bacteria, such as members of the *Vibrio* genus, naturally take up DNA from their environment, a process known as natural competence. The native ability of these bacteria to integrate foreign DNA, researchers can introduce new genetic material without the need for complex manipulation.

CRISPR-Cas systems for marine bacteria

CRISPR-Cas9 and its derivatives have revolutionized genetic engineering across a wide range of organisms. For marine bacteria, however, implementing CRISPR-Cas systems poses additional challenges due to their unique cellular environments and genetic diversity. Researchers have developed specific adaptations of CRISPR to suit marine bacteria. It is highly precise, allowing researchers to knock out genes in marine bacteria with greater accuracy than previous methods. By introducing CRISPR components optimized for marine conditions, scientists can efficiently silence genes associated with metabolic pathways or virulence, facilitating functional studies. CRISPR interference (CRISPRi) enables gene silencing without permanent gene alteration.

This approach is especially useful for essential genes that cannot be fully knocked out. Researchers use modified versions of Cas proteins that bind but do not cleave DNA, thereby inhibiting transcription. CRISPRi provides a versatile tool for understanding gene function and regulatory networks in marine bacteria. These CRISPR-based methods allow precise editing of single nucleotides without creating double-stranded breaks in

Correspondence to: Wu Yanqi, Department of Resources and Environment, Huazhong Agricultural University, Wuhan, China, E-mail: Wyanqui@mail.hzedu.cn

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DNA. They offer a solution for fine-tuning gene expression in marine bacteria, which may be sensitive to the DNA damage caused by traditional CRISPR-Cas9. Synthetic biology is expanding the scope of marine bacterial engineering by enabling the design of custom genetic constructs and regulatory circuits. Synthetic biology techniques allow researchers to program specific gene functions, turning marine bacteria into biofactories for valuable compounds.

CONCLUSION

Advancements in genetic manipulation techniques for marine bacteria are opening new avenues for biotechnological applications. From transformation and CRISPR-based editing to synthetic biology approaches, researchers now have powerful tools to study and the potential of these unique microorganisms. With continued development, the genetic control of marine bacteria promises to unlock new resources for medicine, environmental sustainability and industrial innovation.