

# Surface-Bound DNA Hybridization: Connecting Biology and Nanotechnology

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## DESCRIPTION

In the ever-evolving perspective of molecular biology and nanotechnology, the ability to manipulate and understand the behavior of DNA molecules has opened doors to revolutionary applications. Surface-bound DNA hybridization, a technique that involves the interaction of complementary DNA strands on solid surfaces, has emerged as a fundamental element in areas ranging from gene analysis to biosensing. This article delves into the principles, applications, and advancements of surface-bound DNA hybridization, showcasing its pivotal role in connecting the gap between biological information and nanoscale engineering.

## Principles of surface-bound DNA hybridization

At its core, DNA hybridization involves the pairing of complementary DNA sequences to form a stable double-stranded structure. This process relies on the specific base-pairing interactions between Adenine (A) and Thymine (T), as well as Cytosine (C) and Guanine (G). When it comes to surface-bound DNA hybridization, the technique capitalizes on these principles to immobilize DNA molecules on a solid substrate, often for analytical or functional purposes.

## Experimental workflow

**Surface preparation:** The first step involves preparing the solid surface, which can be a glass slide, silicon wafer, or functionalized nanoparticle. The surface is often coated with molecules that facilitate DNA attachment.

**DNA immobilization:** Single-stranded DNA molecules, referred to as probes, are attached to the surface through various chemical methods. The probes are designed to be complementary to the target DNA sequences of interest.

**Hybridization:** The prepared surface is exposed to a sample containing single-stranded DNA targets. Complementary DNA strands within the sample hybridize with the immobilized probes on the surface.

**Detection:** Depending on the application, the hybridization event can be detected using various techniques, including

fluorescence, electrochemical methods, or atomic force microscopy. The degree of hybridization indicates the presence or quantity of the target DNA.

## Applications

**Gene expression profiling:** Surface-bound DNA hybridization plays a crucial role in gene expression analysis. Microarrays, for example, consist of thousands of surface-bound DNA probes that allow researchers to simultaneously analyze the expression levels of multiple genes in a single experiment.

**DNA sequencing:** In next-generation sequencing techniques, surface-bound DNA hybridization is utilized to immobilize DNA fragments, enabling their identification and sequencing. This technology has revolutionized genomics and personalized medicine.

**Biosensing and diagnostics:** DNA-based biosensors capitalize on the specificity of DNA hybridization to detect the presence of target DNA sequences associated with diseases, pathogens, or genetic mutations. This approach has implications in early disease diagnosis and environmental monitoring.

**Drug delivery:** Surface-bound DNA hybridization has been explored for targeted drug delivery. By designing DNA carriers that release therapeutic molecules upon hybridization with complementary sequences, researchers can achieve site-specific drug release.

**Nanotechnology and self-assembly:** DNA hybridization has been applied in nanotechnology to create intricate structures through DNA self-assembly. This field, known as DNA nanotechnology, has led to the development of nanoscale devices, sensors, and even potential applications in quantum computing.

## Advancements and future prospects

The field of surface-bound DNA hybridization has witnessed exceptional advancements in recent years, driven by technological innovations and interdisciplinary collaborations. Some notable trends include:

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**High-throughput techniques:** Automation and miniaturization have enabled the analysis of thousands of DNA sequences simultaneously, revolutionizing fields like genomics and drug discovery.

**Single-molecule analysis:** Advances in microscopy and single-molecule techniques have allowed researchers to study individual DNA molecules during hybridization events, offering insights into kinetics and interactions at the nanoscale.

**Multiplexing:** Efforts to increase the information density of hybridization assays have led to the development of multiplexing approaches, enabling the analysis of multiple targets in a single reaction.

**Dynamic DNA nanotechnology:** The integration of dynamic DNA nanotechnology with surface-bound hybridization allows

for the creation of responsive and programmable nanoscale systems with potential applications in drug delivery and diagnostics.

Surface-bound DNA hybridization stands as a testament to the remarkable convergence of biology and nanotechnology. This technique's ability to precisely manipulate DNA interactions on solid surfaces has revolutionized fields such as genomics, diagnostics, and nanotechnology. As technological advancements continue to reshape the perspective, the intricate interplay of DNA on surfaces holds the potential to reveal new insights into biological processes, as well as fueling innovation across disciplines. The ongoing fusion of biology and nanotechnology through surface-bound DNA hybridization is a testament to human ingenuity and the power of interdisciplinary exploration.