Bioengineering enzyme-powered nanobots: towards programmable design and functionality

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In the last years, researchers have found inspiration in the rich multifunctionality of biological systems to engineer "intelligent" artificial active nanosystems able to move, interact, communicate and perform complex tasks at the nanoscale. While the self-propulsion of micro- and nanomachines may not be enough to ride above the blood flow, they may find promising applications in overcoming some of the biological barriers that limit the diffusion of traditional "passive" nanoparticles, which is a main challenge in nanomedicine.

Recently, artificial nanomachines that harness chemical energy from enzyme catalysis and convert it into active motion have been developed. These motor-fuel complexes hold a great potential towards nanomedicine thanks to their versatility, bioavailability and full biocompatibility. Although the field is still in its infancy, several milestones have been reached, such as enhanced anti-cancer drug delivery [1] specific targeting and penetration in 3D bladder cancer spheroids [2] and swarming behaviour within the bladder *in vivo* [3].
However, when biomedical applications are envisaged, several fundamental questions need to be resolved: what are the optimal design features of enzyme-powered nanomachines? How to integrate multiple and smart functionalities? How to achieve full biocompatibility?

In this talk, I will focus on the recent work carried out by our group on understanding the fundamental aspects behind the design of enzyme-propelled nanobots [4-7] and our last results towards the design of next generation nanobots, with safe and programmable design and actuation. We exploited the unique tunability and programmability of synthetic DNA to address these challenges. First, we designed hybrid DNA-enzyme micromotors with the capability to sense and monitor their own activity [8]. Moreover, we used synthetic DNA as building blocks to engineer nanobots with controlled enzyme binding, and studied the effect of enzyme density on the motion behavior. The unique programmability and biocompatibility of DNA could pave the way towards overcoming current challenges on the development of synthetic self-propelled nanomachines.

References

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