Light-Triggered Vapor Nanobubbles and Nanomotors for Drug Delivery Applications

Juan Fraire[1,2], Maria Guix,[1] Ana C. Hortelao,[1] Noelia Ruiz Gonzalez,[1] Anna C. Bakenecker,[1] Pouria Ramezani,[2] Félix Sauvage,[2] Stefaan De Smedt,[2] Kevin Braeckmans,[2] Samuel Sánchez,[1,3]

[1]Institute for Bioengineering of Catalonia (IBEC), Barcelona, Spain.
[2]Laboratory for General Biochemistry and Physical Pharmacy, Ghent University, Ghent, Belgium.
[3]Catalan Institute for Research and Advanced Studies (ICREA), Barcelona, Sapin.

jfraire@ibecbarcelona.eu

Targeted drug delivery depends on the ability of nanocarriers to reach the target site, which requires the penetration of different biological barriers. Penetration is usually low and slow because of passive diffusion and steric hindrance [1]. Nanomotors (NMs) have been suggested as the new generation of nanocarriers in drug delivery due to their autonomous motion and associated mixing hydrodynamics [2], especially when acting as a swarm (emergent collective behavior) [3].

In this study, we present a unique nanotechnological approach based on the use of nanomotors with advanced photothermal effects for disruption of biological barriers (overcoming passive diffusion and steric hindrance limitations) [4]. For this, we explored the concept of urease-powered nanomotor swarms designed as such that they can exert disruptive mechanical forces upon laser irradiation. When exposed to pulsed laser light, a powerful vapor nanobubble (VNB) is formed from the nanomotors, which mechanical energy is used for the disruption of a biological barrier model based on Type I collagen fibers (model of the extracellular matrix).

In this talk I will describe the main results linked to the design of urease-powered nanomotors able to form VNBs upon irradiation with ns laser pulses and the subsequent mechanical disruption of a biological barrier model [5].
First, I will discuss the motion dynamics of individual nanomotors as well as the emergent collective behavior of swarms of these motors using optical microscopy, and the exploitation of this swarming effect for navigation on a lab-on-a-chip system.
Second, I will demonstrate the successful disruption of the collagen fibers with these nanomotors, both at the single fiber level and even with bulk measurement of the rheological properties.
Finally, I will show how the use of troops of swarms of nanomotors with different capabilities allows to overcome the limitations of passive particles for trespassing biological barriers in terms of passive diffusion and steric hindrance:

- Swarm 1: nanomotors that can induce micro-environment modifications upon irradiation.
- Swarm 2: fluorescent nanomotors acting as a reporter.

Our results show that the microenvironment modifications induced by Swarm 1 can enhance 10-fold the delivery of (Swarm 2) into a cell model.

References

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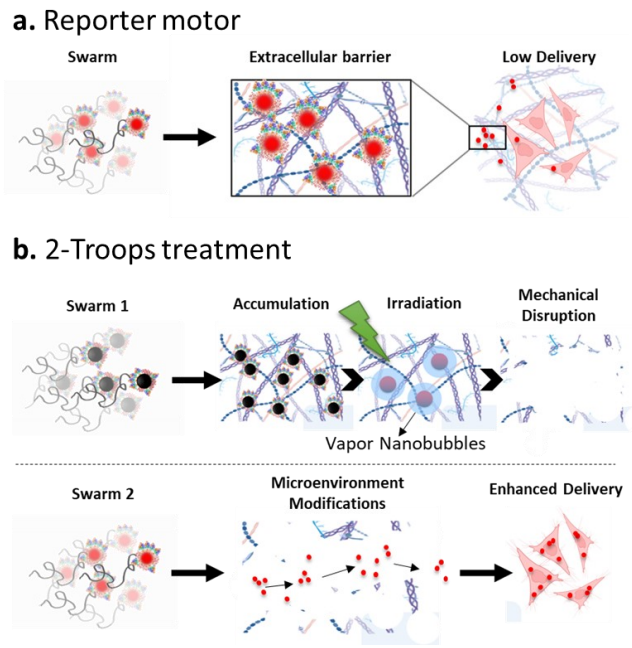

Figure 1. Troops of swarms of enzyme-powered NMs for enhanced delivery: a. Shielding effect of extracellular barrier model on the delivery of swarms of reporter motors. b. Swarm 1 (IONP NMs with photothermal properties) will penetrate the extracellular barriers encountered in the path to reach target cells; next, they will be irradiated, resulting in the barrier disruption due to the mechanical damage caused by the VNB formation/collapse from the IONP heated cores; microenvironment modifications generated by Swarm 1 will allow swarms of fluorescent polystyrene based motors (Swarm 2) to access the target cells (enhanced delivery).