Designing photo-actuating protocellular materials for new applications

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Background: Synthetic cells or "*protocells*" are a vital tool for chemical biology because they allow the study of complex biological phenomena (*e.g.*, transcription and translation, chemical signaling, adhesion, and enzyme-mediated metabolism) in a simple and controlled environment.[1,2] Within this new and interdisciplinary research field, we used an *interfacial strain-promoted alkyne azide cycloaddition reaction* to covalently join protocell units, producing novel materials that mimic living tissues which we call "*protocellular materials*" (PCMs).[3]

Project Goal: The project is co-funded by the ERC Starting Grant project PROTOMAT – 101039578. The aim of Work Package 2 is to synthesize novel biomimetic tissue-like materials capable of photo-actuation, that is, capable of converting light into a precise mechanical movement.

Preliminary results and next steps: Recently, we have succeeded in caging gold nanoparticles (AuNPs) and a thermoresponsive hydrogel within a protocell membrane and used this new protocell model to assemble PCMs (Figure 1). By irradiating these PCMs with 530 nm light, the AuNPs caused local heating and the contraction of the thermoresponsive hydrogel as a result of the photothermal effect. As a consequence, the entire PCM shrunk to 50% of its original size in less than 30 s. When the light was turned off, the PCM returned to its original size and shape in a similar amount of time (Figure 1). The PhD work will start from these exciting preliminary results. The student will subsequently develop this project according to their individual interests and attitudes. Some possible areas of development might include the production of individual protocells that could contract at different temperatures (*e.g.*, modifying the thermoresponsive hydrogel) or using different light irradiation wavelengths (*e.g.*, using gold nanorods or graphene oxide). They could then use these different protocell units to assemble structured PCMs capable of bending, twisting or closing like a flower, contributing groundbreaking advances in soft robotics. They could alternatively develop advanced substrates for tissue engineering capable of delivering specific mechanical cues to living cells for prompting their differentiation.

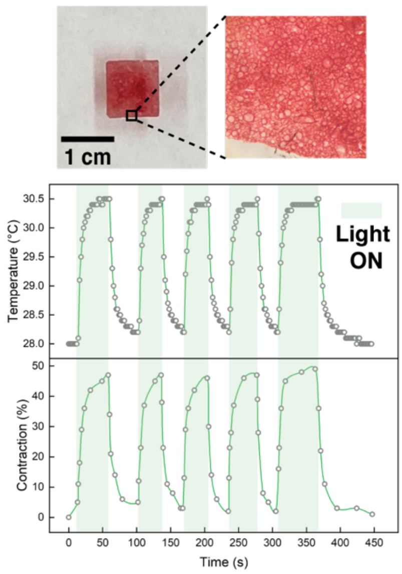

Figure 1: Top: microscopy image of a PCM composed of millions of protocells filled with a thermoresponsive hydrogel and AuNPs, which give the material a characteristic red colour. **Bottom:** graph showing dime-dependent changes in the PCM's temperature and contraction as a function of light irradiation cycles (green bands).

Student training: Through this project the student will develop skills in synthetic chemistry, soft materials chemistry, polymer and nanomaterials synthesis and characterization, and chemical biology. The designed materials will be characterized using state-of-the-art spectroscopy and microscopy techniques (brightfield, fluorescence, electron, and atomic force microscopies). The student will join a dynamic and highly interdisciplinary research group with important ties with the University of Bristol (UK) and the University of Western Ontario (Canada) where a period abroad could be organized.

References:

[1] Xu, C., Hu, S. & Chen, X. Y. *Materials Today* 2016, *19*, 516-532. **[2]** Liu, Z., Zhou, W., Qi, C. & Kong, T. T. *Advanced Materials* 2020, *32*. **[3]** A. Galanti, P. Gobbo *et al.*, *Adv. Mater.*, 2021, *33*, 2100340.