Protamine Promotes Direct Electron Transfer Between \emph{Shewanella Oneidensis} Cells and Carbon Nanomaterials in Bacterial Biocomposites

Invited for this month’s cover picture is the group of Dr. Mathieu Etienne from Centre National de la Recherche Scientifique (CNRS, France). The cover picture shows the building block of the bacterial biocomposite made of \emph{Shewanella oneidensis}, multi-walled carbon nanotubes, and protamine. The close look at the bacterial membrane shows how protamine, which is positively charged (in blue), promotes self-assembly between the negatively charged polymers on the bacterial membrane surface (in red) and the negative surface of multi-walled carbon nanotubes, allowing direct electron transfer reactions. The background of the image is a detail of a scanning electron microscopy image of the biocomposite deposited on a glassy carbon surface, forming the so-called electroactive artificial biofilm. Read the full text of the Article at 10.1002/celc.201801751.

What is the most significant result of this study?
We show that direct electron transfer reactions can be promoted in bacterial biocomposites when using protamine to assemble bacterial cells with carbon nanomaterials such as multi-walled carbon nanotubes or Ketjen black. Moreover, the protocol we describe is not favorable to mediated electron transfer, so in a sense we propose in this article a method to study specifically direct electron transfer reactions with bacteria. Some questions remain about the exact effect of protamine on the bacterial membrane, but this work opens possible developments for the optimization of the method, for a better description of the exact mechanism involved in these electron transfer reactions and for application to screening electroactive bacteria for electromicrobial technologies.

Did serendipity play a part in this work?
Yes, this study was initiated after a control experiment. Initially, we used cytochrome c to promote the self-assembly of bacteria and multi-walled carbon nanotube.[1] Cytochrome c is positively-charged at pH 7. This redox protein is also an electron mediator and we observed that it mediates electron transfer between bacteria and carbon nanotubes when formate is oxidized. To confirm our interpretation of these observations, we planned control experiments with two proteins that do not have redox properties, i.e. bovine serum albumin that is negatively charged and protamine that is positively-charged at pH 7. We observed that bovine serum albumin does not allow...
the self-assembly of bacterial cells with carbon nanotubes, supporting our interpretation of the self-assembly mechanism driven by electrostatic interactions. With protamine, we observed the self-assembly of cells with particles and discovered new redox signals when the biocomposite was deposited on electrodes, that can be only ascribed to direct electron transfer reactions with the bacterial redox systems.

Is your current research mainly curiosity driven (fundamental) or rather applied?
I have the feeling that funding agencies are more willing to support applied projects but our project was only driven by curiosity. A driving force is our wish to elaborate living composite materials that integrate living cells in an environment that is not occurring naturally. With *Shewanella oneidensis*, this can lead to an electroactive artificial biofilm. Finally, we see that this curiosity allows us to report an original protocols that permits to observe natural systems with a slightly different point of view. If robust enough, such approach can allow a more systematic analysis of direct electron transfer reactions with bacteria and we know that there is many applications in that field, CO$_2$ reduction, biohydrogen production, bioremediation, sensing, etc.

What aspects of this project do you find most exciting?
What is really exciting in that study is to be at the interface between two different research fields. On one side you have microbiology, and on the other side you have electroanalysis and modified electrodes. For microbiologist, I would say that we are using the microbe in an unusual way, I mean that we consider the cell as a brick of the biocomposite material, we re-seed the potential of microbes by embedding them in a well-controlled environment. On the other side, the object we study is not yet so usual in electroanalysis. There is many studies on biofilms, single strain biofilms, but the field of artificial biofilms is rather new and it allows some control of the metabolic state of the microbe we decide to study.