FOLLOW THE NANOTUBE

Laurent Cognet – My aim is to understand how molecules move around between tissue cells, especially in the brain. It's an incredibly fascinating topic. You find all sorts of molecules in there, doing all kinds of jobs: some are food, others hormones, toxins, waste or even antibodies. I focus on finding out why and how our body orchestrates all these molecules and their different functions inside the same space. Now, suppose we wish to deliver specific medication in order to treat illnesses such as Alzheimer's or Parkinson's disease. How do the drugs manage to reach their target in such a mess; how does a molecule go from A to B? We just don't know how that works. A major hurdle is due to size: the dimensions involved are extremely small, often submicron, sometimes reaching nanometers. And we're not talking about an empty volume; there are all sorts of other molecules, particularly the extracellular matrix which certainly also plays a role in regulating the motion of our molecules, and we need to understand all that.

As a physicist, I develop optical methods to study that area, to first determine the characteristic sizes of our objects, and to probe the connections between them. Then, inside these spaces, I try to find the diffusion parameters - the average speed at which the molecules may travel. That's a very tall order, requiring that the tissues involved remain intact, alive and functional - we can't pin them down; nanoscale matter is essentially mobile, it swarms! Actually, living matter never stops moving around. Moreover, living tissues are not optically transparent, nor are our bodies, you can't see through a tissue using visible wavelengths. It so happens that my favourite objects are carbon nanotubes, because they are photoluminescent in the near infrared. And the super-resolution optical microscopy method we use in our lab is incredibly simple. If we can detect an isolated light emitter, we can determine its position very precisely, because it's right in the center of a characteristic image. We're then able to monitor these objects' motions and trajectories to within nanometer precision, inside a narrowly confined volume. As their name suggests, carbon nanotubes are extremely small tubes whose diameter is typically about a nanometer. They have very remarkable optical properties, emitting a huge photon density in the near infrared, the part of the optical spectrum to which tissues are most transparent. We've all played with a flashlight, putting it in our mouth to find that our cheeks get bright red. Well, I use that same effect with my carbon nanotubes emitting in the near infrared.

Of course, all sorts of problems arise when introducing these nano-objects inside neural tissues, developing their biocompatibility, being able to follow them and - especially - developing the optical microscopes that monitor nanotube motions not only in two, but also three dimensions when they move inside neural tissues.

It’s clearly a super-complex goal that with a group of neuroscientist friends, we set ourselves at least twenty-five years ago. Overall, we work at the interface between nanoscience, optics and neuroscience. The basic idea didn’t exist twenty-five years ago because we lacked the nano-objects providing means of detecting optical properties inside biological tissues. The idea of probing with carbon nanotubes was born from the latter’s very existence, i.e., from nanoscience; combined with optical spectroscopy, it suggested the possibility of opening that field of research.

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