Meet the researcher

Erik Pillon

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If physics was a person, s/he would definitely be an influencer. When I started my PhD in theoretical physics at the University of Luxembourg two years ago, I would have never imagined how important the social aspect of research is. I work in close collaboration with mathematicians, chemists and biologists. All of them look at exactly the same problems as I do and all of them come up with different solutions.

Let's do a simple experiment: hold your arm out in front of you. Put out your thumb so that it points upwards. Raise your arm over your head. Next, bring your arm down to your side so that your thumb is now pointing backwards. Finally, bring your arm back in front of you. Your arm is pointing in the same direction it started in, but your thumb is now pointing 90 degrees from where it started. Great! We've just discovered what in physics is called holonomy; the failure of a physical system to return to its original state upon a cyclic evolution (in this case, the rotation of your arm).

Falling Cats, Parallel Parking and Quantum Chemistry

Believe it or not, the mathematical explanation behind this simple experiment also explains the Foucault pendulum's movement, why cats always land on their feet and even why parking a car in a narrow space is so difficult. Surprisingly, the same analogy works in the realm of quantum mechanics too, where holonomies play a fundamental role in superconducting materials and in our ability to see.

Even after two years of studies, I'm still surprised by the ubiquity of holonomies in science. The most interesting part, however, comes when we sit down and start to discuss what's actually going on! People with a mathematical background, like me, will try to explain everything with abstract structures and analogies, while physicists will try instead to grasp fundamental truths through mathematical descriptions of these problems. Chemists and biologist might – and often do – come up with a third, completely different explanation! Luckily for me, the Theoretical Chemical Physics group, which I'm a part of, is a melting pot of extremely smart people with completely different backgrounds, from computer scientists to mathematicians, from physicists to chemists, who collaborate with engineers and even economists!

The main problem that I'm investigating at the moment is how the presence of holonomies in the evolution of simple molecules governs their chemical stability and dynamics. Indeed, one of most interesting problems that we have in biochemistry is modelling the behaviour of a protein called rhodopsin. This pigment is found in our eyes and plays a key role in our ability to see; when a photon – a quantum of light – passes through our eye, it hits a molecule of rhodopsin, which triggers a chain of chemical reactions and ends up in the optic nerve and ultimately the brain. This process, which takes place countless times per second, is still a controversial issue in the scientific community. How can we accurately measure this process? And, more fundamentally, what role do holonomies play in this reaction? Which general principles can we infer from understanding this particular reaction?

Many people still think that theoretical physics is essentially about pen and paper calculations, like it was a century ago, but luckily things have changed a lot since then. Mathematical derivations remain an essential part of my work, but, as a scientific community, we can't ignore the potential of supercomputers. Today, numerical simulations are a valuable tool for understanding molecular systems. A large part of my work is developing algorithms and implementing state-of-art mathematical tools to improve existing methods. Paired with access to High Performance Computing (HPC) systems, these algorithms obtain results that would otherwise not be possible.

But even with these computing resources, the task is still challenging! Many applied and fundamental questions still remain unanswered and the scientific community is on the verge of one of the greatest scientific breakthroughs in history. This decade will probably be remembered as the twilight of quantum electronics; electronics based on quantum effects. The research I'm doing is, therefore, of fundamental importance for a number of cutting-edge fields, from gaining a better understanding of how chemical processes work (like rhodopsin) to developing new and more efficient drugs and, eventually, new and more reliable materials. ◆

Erik is a PhD Student in Computational and Theoretical Physics at the University of Luxembourg. He is also an amateur chess player and a stamp collector with the dream of making science communication a full-time job. Despite being 27 years old, he still looks at the world around him with the same curiosity as when he was ten.