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INTERVIEW WITH PROFESSOR COLIN MURRELL

HAVE WE FINALLY BEGUN TO UNDERSTAND MICROORGANISMS AND THEIR ROLE IN THE ENVIRONMENT AND IN KARST PROCESSES?

cunducted by Janez MULEC

Prof. Colin Murrell, a distinguished microbiologist and Emeritus Professor at the University of East Anglia, UK, is well known for his contributions to various areas of environmental microbiology and microbial ecology. Prof. Murrell has received several awards, including election to membership of the European Molecular Biology Organisation, the European Academy of Microbiology, the Chinese Academy of Sciences Distinguished Professor (Einstein) Award. He was awarded a highly prestigious European Research Council Advanced Grant and has been member of many editorial boards of leading microbiological journals including Environmental Microbiology and the ISME Journal. He has graduated over 60 PhD students and supervised around 150 researchers throughout his career. His research interests are immense, extending from the development of analytical tools in molecular microbial ecology to their testing in the field, which is reflected in his extensive publication list of over 350 highly cited papers in prestigious journals. His pioneering research has significantly improved our understanding of microbial processes in diverse environments, from soil to aquatic and marine ecosystems. More recently, he has extended his scientific curiosity to karst and caves, in particular to the Movile Cave in Romania, which represents a cornerstone for understanding the role of chemolithoautotrophy in caves.

Prof. Murrell, your academic journey began with a BSc in Physiology and Biochemistry at the University of Southampton, followed by a PhD at the University of Warwick on nitrogen metabolism in methanotrophic microorganisms. Can you give us some insights into your early career and what initially sparked your interest in biochemistry and microbial ecology?

I started out studying chemistry but then switched to physiology and biochemistry at the University of Southampton but it wasn't until my final year research project which was on proton pumping in purple membranes in *Halobacterium halobium* that I really became interested in microbial biochemistry. This taster for independent research convinced me that I wanted to do a PhD in some form of microbiology, despite my personal tutor Chris Anthony, trying to persuade me for a few years before this that I should be doing microbiology! Fortunately, I ended up working for my PhD with Howard Dalton in the Department of Biological Sciences at the University of Warwick, on the most biochemical project he had at the time, studying nitrogen metabolism in methane oxidising bacteria (methanotrophs). This was the start of a very happy working relationship with these bacteria over the next 46 years. Howard was a fantastic scientist and a great mentor and I was lucky enough to get a very rigorous "upbringing" in research. I subsequently also had a great mentor and postdoctoral advisor when I went to work with Mary Lidstrom at the University of Washington in Seattle. I returned to the Department of Biological Sciences at the University of Warwick as a member of academic staff in 1983. Again, this was a fantastic collegiate environment created by the Head of Department, Roger Whittenbury, and a perfect place to conduct high quality research, sur-


Professor Colin Murrell

rounded by some outstanding colleagues. There I started my own research group on the microbiology of methanotrophs, studying initially their physiology and biochemistry, molecular biology and genetics and then using this biochemical information to study these bacteria in their natural habitats. This approach and associated philosophy (see below) has been passed on to many outstanding PhD students and postdocs which I have had the privilege to work with, many of whom have then gone on to establish their own research groups around the world.

We know that everything in nature is interconnected, thinking in particular about biogeochemical cycles. What have been the main challenges and breakthroughs in your research in this field?

Over the last 40 years or so, my research has focussed largely on the metabolism and ecology of bacteria that grow on climate-active gases and volatile organic carbon compounds and which drive many important biogeochemical cycles in our biosphere. The main challenges have been trying to understand their exact role in shaping the biosphere and how they also impact of climate. Advances in DNA sequencing have made it relatively easy to find out what microbes are present in the environment but a key goal for my research team has been to try to determine which of these microbes are active, what their metabolism is, and how their activity is regulated in the context of carbon, sulfur and nitrogen cycles, ie "who does what and where and how" in the environment? This has necessitated the development of techniques for molecular microbial ecologists such as functional gene probing (ie detecting and quantifying key genes in the environment, such as genes encoding methane monooxygenase, the essential enzyme for methane oxidation. To link phylogenetic structure and function, we also pioneered the technique of DNA stable isotope probing (DNA-SIP) which has now become a key method to link microbes with their specific function in the environment.

You and your research team are working intensively on the global carbon cycle, which is fundamental to regulating the Earth's climate and sustaining life. What new trends in microbial ecology do you consider particularly promising in this context?

One thing that actually concerns me is related to the ease with which it is possible to sequence the DNA from many environments. Metagenomics yields vast amounts of DNA sequence data but the key to interpreting these data is to have a good grasp of the metabolism that is occurring, or might be occurring, in the environment. The genomes of microbes retrieved through metagenomics only provide a metabolic blueprint of what the microbes might be capable of. It is then necessary for microbiologists to test out theories with experiments in the laboratory rather than rely on *in silico* guesswork about the metabolism that these microbes actually carry out in the environment. Combining metagenomics with for example DNA-SIP will at least target and identify the microbes that are active in metabolising key compounds, for example, as in methane cycling. It is also important to use the molecular information derived from DNA sequencing to formulate strategies for enrichment and isolation of key microbes because these isolates can then be used to test hypotheses on "who is doing what in that environment" and to gain a better understanding of how their metabolism is regulated by different environmental factors.

What role do you see microbial ecosystems playing in addressing global environmental challenges such as climate change and biodiversity loss? How do you see underground habitats in this context, how are they affected, could they perhaps serve as a "shelter" for surface organisms and later as a starting point for recolonisation?

Microbial ecosystems play a huge role in our quest to understand how climate change and biodiversity loss are impacted in our biosphere. By studying how the activity of key groups of microbes such as methanotrophs, ammonia oxidisers, sulfur oxidisers etc is regulated when physico-chemical parameters in the environment change, we can start to build up a robust understanding of what impacts their activity, how it does this and ultimately provide important information to model climate change. Underground habitats might indeed serve as a reservoir and shelter for key species of microbes, especially if they have not been impacted by above ground changes in the environment.

Over the last two decades there has been an increasing trend towards studies related to cave microbiology, which is a fascinating area of research due to the unique and extreme environments that caves offer. Recently, caves have even been considered as analogues for potential extraterrestrial habitats, such as subsurface environments on Mars or the moons of Jupiter and Saturn. Since caves on Earth have served as human dwellings, burial sites, places of inspiration, … and they do provide protection from some stressors such as UV radiation, in your opinion, prof. Murrell, do you believe that extraterrestrial caves could play a similar role in future exploration and colonisation missions?

Well, we worked for a number of years on a fascinating underground environment, Movile Cave in Romania, and showed that methane oxidation, and sulfur and ammonia oxidation helped to drive and sustain an ecosys-

Setting up DNA-Stable Isotope Probing experiments in Movile Cave, 2009

tem that has been essentially cut off from the external world for hundreds of thousands of years. A fascinating model system to study not only specialised types of metabolism such as methanotrophy and chemoautotrophy but also one which has great potential for the study of microbial food webs and microbial evolution. These sorts of cave environments, where specialised groups of microbes survive and indeed thrive, could potentially be good model systems to study in terms of analogs of extraterrestrial habitats but I won't be drawn into a philosophical debate as to the existence of life on other planets- however likely!

And to conclude our discussion, what advice do you have for students who want to get a degree in this field of research?

My advice for all PhD students who enjoy hard work and have a passion for research would be to make sure that your research is underpinned by interesting and relevant scientific questions, seek advice from your peers and senior researchers around you, constantly question and critically evaluate the results from your experiments and read the literature (including the older scientific literature – "no sense in reinventing the wheel") in order to place your research findings in context. Oh, and get yourself a really good mentor or two!