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FIRST PERSON

First person – Norman R. Groves

First Person is a series of interviews with the first authors of a selection of papers published in Journal of Cell Science, helping early-career researchers promote themselves alongside their papers. Norman R. Groves is first author on 'A nuclear localization signal targets tail-anchored membrane proteins to the inner nuclear envelope in plants', published in JCS. Norman is a PhD student in the lab of Iris Meier at the Ohio State University, Columbus, OH, where he investigates trafficking, identification and function of inner nuclear membrane proteins.

Norman R. Groves

How would you explain the main findings of your paper in lay terms?

Our study has focused on determining what signals allow proteins to travel to one particular compartment in plant cells – the inner nuclear membrane. The trafficking of proteins in the cell is akin to driving your car on highways. Some roads you can freely travel, while some roads and bridges require a toll for passage. In our case, the endoplasmic reticulum (ER) membrane, outer nuclear membrane (ONM) and inner nuclear membrane (INM) are interconnected roads, and the nuclear pore complex is the toll booth, preventing passage to the inner nuclear membrane. Our research has shown that, in plants, a short protein signal – a nuclear localization signal – allows for proteins to travel to the INM. Addition of this protein signal to membrane proteins at the ER or ONM is sufficient to re-direct these proteins to the inner nuclear membrane.

Were there any specific challenges associated with this project? If so, how did you overcome them?

The most challenging aspect of this research was adapting Airyscan high-resolution confocal microscopy for use in differentiating the INM from the ONM. Traditionally, INM localization has been shown through the combination of immunogold labeling and electron microscopy. However, we wanted to differentiate the INM from ONM localization for a variety of proteins, necessitating a higher throughput approach. In addition to optimizing imaging and experimental conditions for our proteins in the Airyscan system, we had to devise an analysis scheme that would allow for quantification of the INM localization. I spent weeks trying out different ways of quantifying and analyzing the localization data before we settled on an analysis workflow, in coordination with our wonderful collaborators at Oxford Brookes University.

When doing the research, did you have a particular result or 'eureka' moment that has stuck with you?

Two moments in particular stand out to me. For the first, I had just begun to test different nuclear localization signals for their ability to target a chimeric tail-anchored membrane protein to the nuclear envelope. Spending many hours at the confocal laser scanning microscope, I had become accustomed to seeing the green fluorescent signal that showed that proteins localized to the nuclear envelope, but also to the endoplasmic reticulum. As I began my day's experiment, I started with the chimeric membrane protein lacking an NLS and saw that familiar broad, nonspecific signal. However, when I looked at NLS-fused varieties, I began to see nothing but perfect rings of green fluorescence, the sign of specifically labeled nuclear envelopes. It was then I knew we were heading in the right direction in our research.

The second 'eureka' moment was when I was visiting our collaborators at Oxford Brookes University to use Airyscan high-resolution confocal microscopy. I was trying to distinguish the ONM from the INM. I had only a limited amount of time to collect a lot of images and I will never forget the first time I saw a clear separation between the fluorescent signals coming from two proteins associated with the two membranes. This separation confirmed what we had long suspected: that our NLS-fused proteins were trafficking to the INM.

> "…I began to see nothing but perfect rings of green fluorescence, the sign of specifically labeled nuclear envelopes"

Why did you choose Journal of Cell Science for your paper?

As plant cell biologists, we are eager to share our work beyond the plant community and to the larger cell biology community. We

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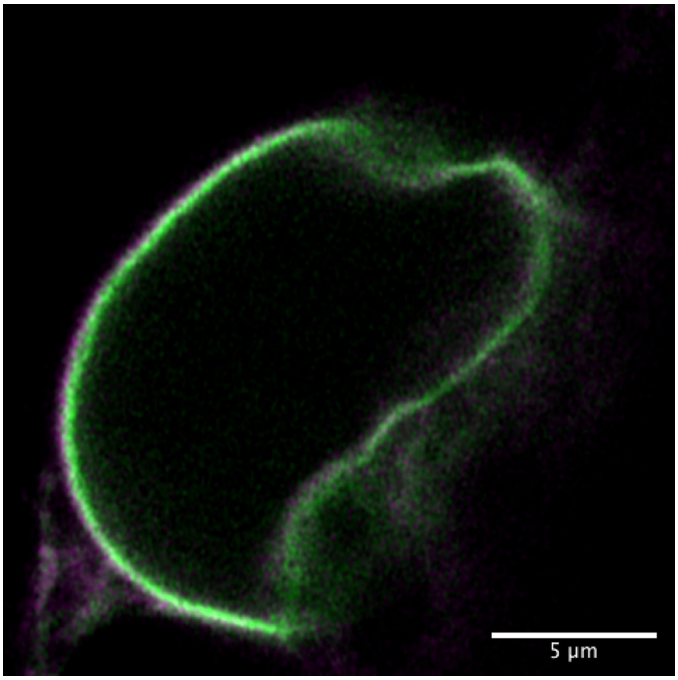

NLS-PICL, an NLS-fused tail-anchored ER membrane protein, is localized to the INM in *N. benthamiana* leaf epidermal cells. NLS-PICL is in green; calnexin–RFP (an ER marker) is in magenta.

believe that our findings – that nuclear localization signals can serve as INM targeting signals in plants – is of broad interest to the Journal of Cell Science readership.

Have you had any significant mentors who have helped you beyond supervision in the lab? How was their guidance special?

When I started my doctoral research in the Meier lab, I was mentored by a senior graduate student, and later the postdoc Xiao Zhou. In addition to being an excellent mentor at the bench, Xiao would often champion curiosity, both at the bench and in our conversations on life outside the bench.

What motivated you to pursue a career in science, and what have been the most interesting moments on the path that led you to where you are now?

From a young age, I have always been interested in problem solving. As a student, I excelled at logic puzzles where you use clues to deduce relationships between people. That same instinct led me to become interested in genetics in high school, where pedigrees and Punnett squares piqued my interest. I love doing work that is intellectually challenging and still view myself as that same problem solver I was as a child. Now, the problems I solve are how to design an experiment to answer a biological question, or fixing a technical challenge at the lab bench.

Who are your role models in science? Why?

My primary role model in science is my advisor, Dr Iris Meier. Iris has said that she views herself as a 'crime scene investigator', and that our jobs as scientists are to view a biological phenomenon and sort out why and how it occurs. Under her mentorship, I have been able to direct my own 'investigation' in the form of the research published here. Taking this research from inception to publication is not something I could have done without her guidance and patience, and I am a better scientist for it. Iris has also taken a leading role in exposing scientific concepts to a non-scientific audience by founding a class that exposes art students to different biological topics. Iris's dedication to fostering a love of science in the broader community around us is something I aspire to.

What's next for you?

In the short term, I am staying in the Meier lab as a postdoc. I am looking forward to applying my doctoral research to more applied research topics. Namely, developing tools to study genome organization at the plant nuclear periphery in order to change plant traits.

Tell us something interesting about yourself that wouldn't be on your CV

I am an active member of the powerlifting community and have recently been certified as a USA Powerlifting National Referee.

Reference

Groves, N. R., McKenna, J. F., Evans, D. E., Graumann, K. and Meier, I. (2019). A nuclear localization signal targets tail-anchored membrane proteins to the inner nuclear envelope in plants. *J. Cell Sci.* **132**, jcs226134.