

a car, playing cricket and making tea. Although seemingly coming from left field, much of his previous research had in fact focused on where other animals look, how they sample what they see, and how they then act, based on what they see. In typical style and with much butchery of bike helmets and concave mirrors, Mike invented the instrument to do this work, based in part on his knowledge of deep-sea invertebrate eyes. Early forays into this area were, in his own words, “greatly helped by a collaboration with Jenny Rusted, a proper psychologist with the background I lacked” (also at Sussex at the time). It is interesting that many young vision scientists are surprised to find that Mike Land did research besides just that on human eye movements; such was his impact on the field. Ben Tatler describes the typically delightful experience of working with Mike here:

“Mike had a huge impact on my life from the day that I met him. I travelled to Sussex to talk to him about insect eyes — my planned PhD topic after spending time in Simon Laughlin’s lab as an undergraduate. But the day turned out very differently than planned — Mike introduced me to his home-made mobile eye tracker and work on everyday tasks and, despite my complete ignorance of human eye movements, I was hooked by his enthusiasm and excitement for this research. Reading the papers he had given me on my way home, I was struck by the clarity and engagement of his writing and knew then that I wanted to work with him — and to work on humans rather than flies. Research was always fun with Mike — I remember, in particular, how much we both enjoyed spending several days hanging around in the pits with the Formula 3 Stewart Racing team, albeit preceded by one awkward day spent with an angry driver, frustrated racing team and the Formula 3 health and safety officials, after we ruined a very expensive helmet by screwing an eye tracker on to it (version 2 used Velcro)! Mike was a great mentor and friend and we continued to collaborate after the six years I spent in his lab. Mike’s work on human eye movements was pioneering (a word that is often — and rightly — used to describe many aspects of Mike’s work) and has

truly shaped the current state of this research field.”

As we have sketched out here, Mike did many things superbly. It’s no surprise that he was awarded his Fellow(ship) of the Royal Society of London (FRS) in 1982, before his 40<sup>th</sup> birthday, a feat few biologists have ever achieved. He also won other prizes, including becoming a member of the Academia Europaea in 1998 and garnering the Rank Prize for Optoelectronics in the same year.

Along with the great family of science colleagues and friends, Mike leaves behind a wonderful and loving family. His first marriage to Judith (née Drinkwater) produced their son Adam and later two grandchildren. Rosemary (née Clarke), whom he married in 1980, lived with Mike in a splendid Arts and Crafts house overlooking Lewes, a place where many of those mentioned here have spent happy hours with this warm and welcoming couple. That union produced two daughters, Penny and Kate, and ultimately two more grandchildren.

We have reserved the last word here for Jochen Zeil, another fortunate PhD student and academic child whose career Mike helped launch:

“Mike had a wonderfully inspiring way of looking at the natural world as an intellectual challenge, as a source of awe and of entertainment. As a deep admirer of Darwin, he had a sense of the beauty and elegance of natural design and he cherished the challenge of describing and understanding it. But what I loved most about him — and am most grateful for having learnt from him — is his way of seeing the funny, the hugely entertaining side of animals. He saw that science, especially that of invertebrates, is as an intellectual and aesthetic enrichment of life and — well how to best capture it (?) — a source of happiness.”

Mike was a great explorer who understood more about science than most but was himself in multiple ways a source of happiness, and someone whom we all miss greatly.

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## Q & A

### Audrey Dussutour

*Audrey Dussutour, a French-born ethologist, is a CNRS Senior Researcher in the Animal Cognition Department of the Center for Integrative Biology in Toulouse (Paul Sabatier University). She studies collective behavior and cognition, working with ant colonies and slime molds. Her topics of interest include decision-making, foraging behavior, and integrative nutrition. Her work has been published in technical articles as well as a popular book (Le Blob, 2017; winner of the ‘science for all’ book award in 2018) and has also been featured in the documentary The Blob: A Genius without a Brain (winner of the silver award at the AAAS Kavli Science Journalism Awards 2020).*

#### **What are you working on right now?**

I’m studying learning in slime molds: giant single-cell organisms that look like piles of scrambled eggs. Slime molds are unicellular organisms and thus by definition do not have a nervous system. Yet, we recently demonstrated that they can learn to ignore a repetitive stimulus, a process called habituation (Proc. R. Soc. B (2016) 283, 20160446). Now we are trying to identify the mechanisms that support learning in such organisms. We also want to decipher the extent of learning abilities in slime molds.

#### **What do you think is the next big question to be answered in your field?**

Are cognitive abilities such as learning pervasive and can they be found in all living organisms? This idea, when it was first brought up, generated an outcry. Yet, some researchers kept asking this same question again and again in spite of strong criticism. Among them were my dear colleagues Pamela Lyon and Michael Levin. I met both of them three years ago in what turned out to be one of the most interesting workshops that I have ever attended: ‘Basal cognition: conceptual tools and the view from the single cell’. Around the table were philosophers, molecular biologists, neurophysiologists, embryologists,

computer scientists, and so on, all focused on this single question. That day, I felt that our research was helping to lay the foundations for finding an answer. Since then, a special issue has been published in *Philosophical Transactions of the Royal Society B* on basal cognition (Philos. Trans. R. Soc. B (2021) 376, 20190750), as well as two papers on ciliate behavioral plasticity (Curr. Biol. (2019) 29, 4323–4329 and eLife (2021) 10, e61907). This idea does not seem so provocative anymore!

To go further in exploring the mechanisms that could enable learning in single-cell organisms, we now need more indisputable evidence that learning occurs in such organisms. Methodological advances offer a wealth of new tools for the study of learning in single-cell organisms. For instance, novel imaging techniques and recent advances in genomics are now allowing us to monitor single-cell transcriptional activity in real time, and this will enable us to observe the transcriptional activity in single-cell organisms while they are learning. This approach, combined with computational simulation and computer-based artificial intelligence, might enable us to crack the molecular basis of learning in single-cell organisms. Yet, new technologies do not replace the need for an extensive understanding of the ecology of single-cell organisms. We need to acquire knowledge of what might constitute an appropriate stimulus repertoire for these organisms. Indeed, due to differences in scale, niche, and sensory apparatus, single-cell organisms experience a totally different environment than most animals. Hence, we must invent creative and inspired protocols that might have some relevance for such systems and conduct thorough investigations.

**Who made you the researcher that you are today?** I have four scientific mentors without whom I would not be a researcher today. I met the first person, Raymond Campan, when I was doing my bachelor's, and he introduced me to the field of ethology. He was one of the most amazing and inspiring professors I ever had

the pleasure to cross paths with. At the time, he was about to retire and I begged him to take me on as his last intern. I will always remember our long talks about autopoiesis. The second person was my master's and PhD supervisor Jean-Louis Deneubourg (Brussels University, Belgium). He's one of the smartest people I have worked with and at the same time the humblest. Jean-Louis is one of the pioneers of the field of collective behavior and he introduced me to social insect behavior. The third person is Vincent Fourcassié, my PhD co-supervisor (University of Toulouse, France), who taught me everything from running statistical analyses to writing a proper paper. Vincent gave me the autonomy I needed while always being at my side. Jean-Louis, Vincent, and I worked for more than four years on the fundamental question of why ants never get stuck in a traffic jam (Nature (2004) 428, 70–73). My last mentor is Steve Simpson (University of Sydney, Australia). I worked with Steve as a postdoc and it was the best time of my entire career as a researcher to date. Steve started his career by tickling the legs of locusts and he became one of the greatest nutritional specialists in the world. He's now the head of the Charles Perkins Centre, a multidisciplinary research center committed to improving global health. Together with his colleague David Raubenheimer, Steve developed an integrative modeling framework for nutrition (the Geometric Framework), and while it was originally tested using insects it has since been successfully applied to improving our understanding of human obesity. It was while working with Steve that I started to study slime molds. The original idea was to test Steve's framework on a single-cell organism, which quickly appeared to be a nutritional genius!

**Is it difficult for women to be successful in science?** As you may have noticed from my previous answer, I was mostly trained by men and never felt that I was treated differently because I was a woman. However, after being recruited by the CNRS in 2008, I quickly realized that I had been lucky earlier in my career because



my mentors were some of the 'good guys'! Right now, the thing that I hate the most, apart from the sexist jokes, is that, each time you accomplish something in your career (a promotion, a grant, an award, and so on), there is always a man to tell you that the only cause of your success is because you are a woman! No matter how hard you work, there will always be a man that makes you feel like an impostor... a 'quota woman'. Fortunately, I feel that things are changing now!

**Why do you invest so much time in science communication?** I think that the earlier you get into science, the earlier you become aware of the world around you. If kids understand the basics of science, it will be easier for them to grasp the challenges that they will later have to face (climate change, biodiversity decline, pandemics, and so on). They will be able to better judge political decisions and fight for the environment. I believe that education and knowledge are the most fundamental pillars on which a society needs to be built to thrive; unfortunately, as they offer no direct profits, they are often the first victims when governments need to make budget cuts... Hence, I like to visit classes and encourage kids to learn about the world in which they live. I especially enjoy showing them all the unknown creatures that live around them without them noticing. Kids are 'knowledge vacuum cleaners' — they can't get enough of science! And I

have to be honest, seeing their eyes opening wide when I show them the slime molds crawling around makes my day!

**What are the main difficulties in your line of work?** There are two major issues. The first one is that it is getting more and more difficult to get funds for basic research... I don't blame people for thinking that cancer research is more important than knowing how a slime mold finds its way through a maze or how ants feed their young... But again, it's a question of appreciating how essential it is to understand the world around us. Right now, our governments prefer to prioritize applied research and encourage us to develop interactions with industries. I fear that numerous lines of research will be abandoned in the near future, and this would be a terrible loss. Research that seems pointless today might well become invaluable in the future...

The second issue, which is a direct consequence of the first, is that, due to budget cuts in France, we have almost no support in labs. For instance, we only have one animal/lab technician for a dozen PIs studying animal behavior, from slime molds to ants to fish. We have one administrative assistant and one accountant for the whole department (>30 PIs). The time I spend doing research disappears like smoke in the wind... but on the bright side I'm now getting really good at accounting!

**If you could invent a machine to make your work easier, what would it be?** A machine that translates my papers automatically into English! Joking aside, I find it very difficult to write and express ideas in a language that is not my mother tongue. I get quickly frustrated, and it takes me ages to write a single paragraph... I have heard that DeepL is doing a good job now, so my dream might come true one day!

**What is the best thing about your job?** Despite the problems encountered, I would not trade my work for anything in the world. Being a researcher means learning new things on a daily basis, traveling to meet people that share the same passions,

and inventing ways of solving new problems. Being paid to think, debate, and investigate is a luxury that few can enjoy. Every day, I go to the lab to check my slime molds and admire how they solved the problems with which they were faced. What's not to like?

**If you had not made it as a scientist, what would you have become?** A writer! I have written two books for a general audience, one about slime molds that was published in 2017 (*Everything You Always Wanted to Know about Slime Molds but Were Afraid to Ask*) and one about ants that will be published this year. I love writing: being cosy in my office with a tea, reading about science, and trying to put into words the things that I just learned and attempting to add a funny side to it.

**What is the craziest thing that you have been doing lately?** Preparing a slime mold for space travel! My slime molds will be leaving this summer with Thomas Pesquet (French astronaut) for the International Space Station (ISS). Once onboard, Thomas Pesquet will launch an experiment that we designed and made fully automated with the CNES/CNRS. At the same time, 2,000 schools in France will receive a slime mold from my lab and will run the same exact experiment on Earth.

A main objective of this project is to engage kids in interesting scientific experiments. By comparing their results with the ones obtained by Thomas Pesquet, they will be able to observe if slime molds behave differently in microgravity. Will they float in their containers like the astronauts in their spacecraft? Will they adopt different shapes? We do not know yet! The opportunity to send a scientific experiment into orbit is both huge and scary. My slime molds are leaving Earth in a dormant state, as the shaking during the first few minutes of launch could actually kill them, so I really hope that the slime molds will wake up once in the ISS!

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## Quick guide

# Pygmy hogs

Manon de Visser<sup>1,2,3,\*</sup>, Langqing Liu<sup>3</sup>, and Mirte Bosse<sup>3</sup>

**What are pygmy hogs?** The pygmy hog (*Porcula salvania*) is the world's smallest and rarest pig species. Compared to an adult wild boar (*Sus scrofa*), which weighs around 80 kilograms, an adult pygmy hog is relatively small and weighs only eight kilograms (Figure 1). Pygmy hogs can breed from around the age of two and live for approximately eight years in total. They have relatively long, slender snouts, sharp teeth and a small tail. Adults have thick, brown hairs, which are visibly darker along the back. Their natural range is limited to a small and isolated area within Manas National Park in Assam, India. It is estimated that around 250 mature individuals live in the wild, which means this species is threatened and is currently living on the brink of extinction.

**How are pygmy hogs related to other pig species?** Nineteenth century taxonomists considered the pygmy hog as the only member of the genus *Porcula*, before it was wrongfully classified as being one of the *Sus* species. The genus *Sus* is well known to humans worldwide because of the domesticated pig (*Sus scrofa domestica*) that originated from the wild boar. However, genomic techniques provided enough evidence to conclude that the former classification of the pygmy hog was actually correct. Thus, the pygmy hog was re-classified to its own, unique genus *Porcula*, as a sister lineage to *Sus*. Both lineages share a common ancestor that lived during the early Pliocene, around six million years ago. In the past, there may have been more such suids, but those were likely wiped out by *Sus scrofa* due to the 'wild boar expansion'. The pygmy hog is the only extant species of *Porcula* that outlived this colonization. Other genera within the phylogenetic tree of Suidae are *Hylochoerus*, *Potamochoerus*, *Phacochoerus* and *Babyrousa*.

**How do pygmy hogs live?** Pygmy hogs are true ecological specialists. They occupy a highly restricted range of

