Minuscule forces measured for the first time

No financier saw any future in their research proposal. Nevertheless, Wageningen researchers succeeded in cobbling together the apparatus to measure the smallest forces ever registered. 'The forces between molecules are very important for how the plant embryo develops, but you couldn't measure them until now.'

TEXT TESSA LOUWERENS **PHOTOGRAPHY** SAM RENTMEESTER

Molecules exert forces on each other, pushing against each other very subtly. As minuscule as those forces may be, they are important in life processes such as the growth of a plant or the development of a foetus, as well as in the recovery of self-repairing materials.

Those forces between molecules are so tiny, however, that scientists cannot get a grip on them. Not even the most precise of instruments could identify the mutual influence accurately. Wageningen researchers have changed that.

'Highly sensitive measurements on such a small scale, of a few molecules deep inside a material or a cell, are not possible with large measuring equipment,' explains Joris Sprakel. He is a researcher at the Wageningen Physical Chemistry and Soft Materials chair group.

In order to sidestep this problem, his team developed molecules which function as measuring equipment themselves. In order to read this measuring instrument, which consists of a single molecule, and to identify the force it records, the researchers shine a laser light on it. The molecule then sends light of another colour back. Using that colour, the research team then figures out how much force is being exercised on the molecule.

'It was very difficult to build the apparatus for measuring that properly. Very little light is reflected back from just one molecule,' explains Sprakel. He was also working on a small budget; no financier saw any future in his research proposal at the time. The researchers therefore had to use all their creativity to cobble together their experimental apparatus. 'We've got a team of young, enthusiastic colleagues, all with different areas of expertise. Without their cooperation I don't think we would ever have succeeded.' The research led to a publication in the scientific journal *Chem* in January.

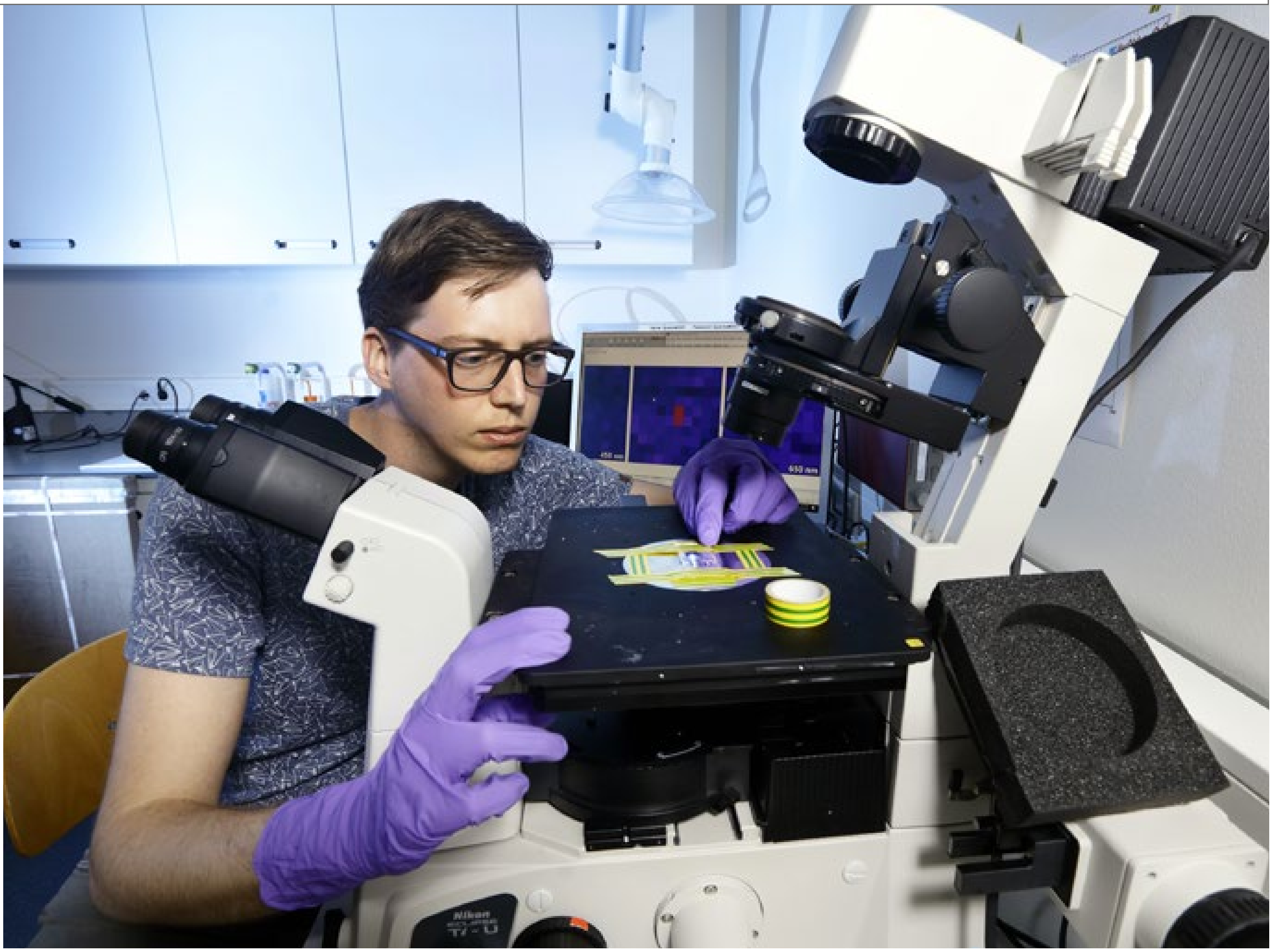
FIFTY SHADES OF GREY

The sensor molecules that were developed measure forces hundreds of times more precisely than the existing instruments for measuring minuscule forces. Previously, it was only possible to ascertain whether or not force was being exerted between molecules. 'With this new method, mechanical force can be measured not just in black and white, but in 50 shades of grey,' says the research leader.

Expressed in scientific terms, the force sensor reaches a resolution of 100 femtonewtons (0.0000000000001 newtons). One newton is more or less how 100 grams feels. 'A molecule is itself unbelievably small, roughly a nanometre, one millionth of a millimetre,' says Sprakel. 'The force of 100 femtonewtons pressing on a molecule of one nanometre is comparable to the force a grain of sand exerts on a human shoulder. So we can now measure such small forces in proportions that are one trillion times smaller.'

EMBRYONIC DEVELOPMENT

The new method of measuring makes it possible to get a better grasp of the forces that are significant in the living cells of plants, animals and humans at the molecular level. Scientists know that these physical forces play a role in many processes, but because the



Researcher Ties van de Laar with the experimental setup for measuring minuscule forces.

forces could not be measured precisely, or at all, they couldn't really make use of them. 'With this technique we can literally shed light on these processes. Take the embryonic development of plant cells, for instance. We know that minuscule forces determine when a cell is going to divide and in which direction. So ultimately, those mechanical stimuli are very important to how the plant embryo develops; but up to now that couldn't be measured,' explains Sprakel. 'Then it is also practically impossible to understand how those forces play out. If you know the role of the minuscule forces in biological processes, you might eventually be able to understand how you can combat certain diseases caused by little faults in those forces. But that is all still in the future; for now we have demonstrated how we can measure these kinds of "unmeasurable" forces. Together with Dolf Weijers from the Biochemistry chair group, we are now working on applying this approach to cellular processes.'

Sprakel is also thinking about applications beyond the traditional Wageningen domain. He is working with the Technical University of Delft, for example, on further developing material for spaceships that repairs itself after being damaged, just like the human skin. Although such materials are already being made in Delft, no one understands quite how they function. 'Research is often largely a matter of trial and error. If we can see precisely how it works, then we can also develop and improve that kind of material with more precision.' ■

0.0000000000001 newtons: you couldn't measure that until now

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