EXPERIMENTNL

SCIENCE IN THE NETHERLANDS

Long live exotics? The benefit of alien species

The science of speed skating More gold with data analysis?

A wealth of finds Amateurs help archaeologists

Smart stuff Materials that do exactly what we want

NWO
Netherlands Organisation
for Scientific Research

FOREWORD

A new look

Wait, hold on! Don't put it down, read on!

This *ExperimentNL* looks different than the ones in the past. It's a little thinner. But the contents are just as interesting as in previous issues. Of course, we're devoting attention to the four winners of the Spinoza Prize – which you could call the Dutch Nobel Prize. Indeed, the winners have been in the news frequently these past months. That's why we asked them to highlight the talents that they think are going to be tomorrow's pioneering scientists.

This issue also contains all kinds of research that was made possible by NWO. Read about how Dutch speed skaters will hopefully take home even more medals thanks to research by Leiden University. Be amazed at how scientists at the University of Twente and the NWO institute AMOLF are developing 'smart material' that does what we ask of it. You will also encounter striking discoveries regarding water plants and archaeological finds.

But before you start leafing through the magazine, there's one other thing I have to mention. Not only has *ExperimentNL* been revamped, but NWO has been given a new look in the meantime too. We're working hard to improve the way we serve science in the Netherlands to ensure that it gets the attention it deserves. Science is fascinating. And our society needs science to be able to tackle problems such as the food supply, security and the climate. As chair of NWO's executive board, I'm proud to help guide scientific research in our country, and in doing so make a contribution to our society.

So, without further ado, enjoy the new *ExperimentNL*, produced by NWO in collaboration with *Quest*.

Stan Gielen
Chair NWO

CONTENTS

Will data analysis help Kjeld Nuis win gold at the Olympic Winter Games?

'Data answers questions that you haven't even asked yet'

Nimble with numbers

Skin suits, indoor speed skating tracks and clap skates: all inventions that helped skaters go faster in the past. In the run-up to the Olympic Winter Games in Pyeongchang (2018), the team of Jac Orie, coach of champions, is wielding a new weapon: comprehensive data analysis by scientist Arno Knobbe.

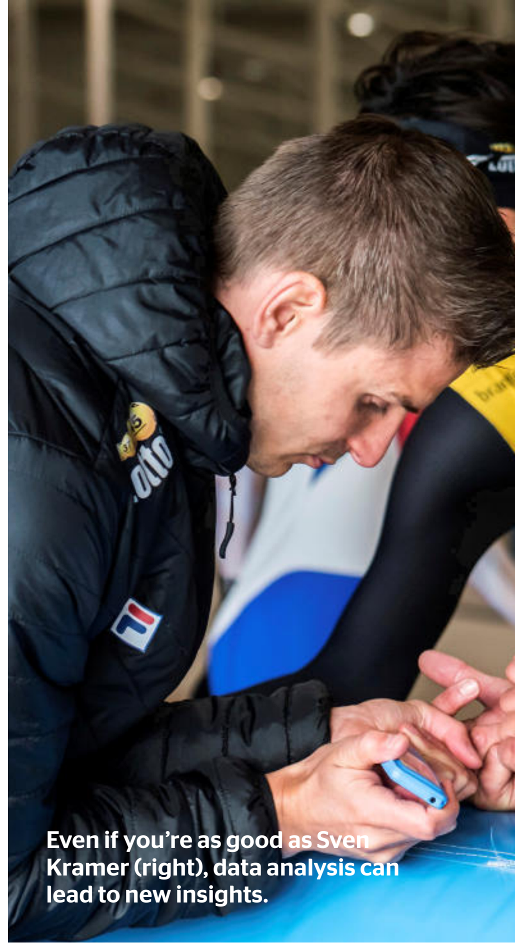
Text: Frank Beijen

Gerard van Velde in 2002, Marianne Timmer in 2006, Mark Tuitert in 2010 and in 2014 Stefan Groothuis. They all won gold at the Olympics under skating coach Jac Orie. In addition to a mountain of medals, the skaters left something else of value behind: a huge amount of data. For fifteen years now, Orie has been recording everything about the performances of 'his' skaters. With the help of Arno Knobbe, a data scientist who works at Leiden University and uses new methods for assessing the data, Orie can coach his team in an even smarter way in the run-up to the 2108 Olympic Games in Pyeongchang (South Korea). Jac Orie is not your average speed skating coach. It's not just his many victories that make him special but also his scientific background. Because he studied sports science, he was already familiar with the tests that measure sprint and endurance capacity (see box 'Killer tests'). 'A race can fail, but if you scored well in the test, then at least you will have had the capacity to perform on ice,' Orie says. 'If you're test values aren't high, then you can be sure you won't win.' The coach has been using test results to adapt his skaters' training programmes during the course of the season for years.

Computer generates insight

His wealth of sports data appears to conceal more insights than Orie can extract himself. Data scientist Arno Knobbe discovers them using different techniques than Orie. 'Jac's data are high quality. It's nice for a data scientist when the same tests are applied each time, producing stable data,' Knobbe says. 'Classic statistics enables you to draw interesting conclusions from that. But then you're only examining one question simultaneously.' Whereas Orie, trained in sports science, focuses mainly on the connection between test values and competition results, Knobbe has the computer automatically look for all potential correlations between the numbers in the database. 'Then you get answers to questions you haven't even asked yet,' says Knobbe. For example, about what the impact is of the time when a skater trains, the kind of training (such as cycling, rollerblading or skating) and its intensity.

That generates surprising insights. Kjeld Nuis, for example, a specialist at middle distances, got no benefit out of endurance training right before races in the morning. The numbers showed he did not improve from it. 'So we adapted his training programme based on that,' says Orie. And though Diane Valkenburg (now retired) got tired from training sessions



Even if you're as good as Sven Kramer (right), data analysis can lead to new insights.

that lasted less than two and a half hours, they didn't help her make any progress. 'I thought her training sessions were tough enough. But she only really made progress with sessions that lasted three to four hours. We have the numbers to thank for that insight.'

Knobs are well adjusted

The collected data has caused insights to emerge that are new to Orie. Still, they aren't generating an endless stream of eureka moments yet. 'There are a hundred knobs to turn,' says Knobbe, 'but we've noticed that most of them are already well adjusted. It's mostly about the details.' Not every correlation that the com-

Killer tests

One of the tests that coach Jac Orie has his skaters do is the Wingate test: cycle as fast as you can for thirty seconds on an exercise bicycle at high resistance. This test measures anaerobic capacity, the capacity to generate a lot of energy in a short time. The better you are at that, the better you can sprint. In another test, athletes pedal on an exercise bicycle with increasingly high resistance until they can't go on anymore. Athletes wear a mask during this test that measures their oxygen intake and CO2 output. That's how you measure the aerobic capacity: the capacity to absorb oxygen and transmit energy to the muscles. Sprinters aren't good at this, but all-rounders are. The downside is that these are killer tests. Even half a minute of the Wingate test will cause an athlete's performance to dip the following day. 'What you'd like best as a data scientist is to conduct tests that don't have an impact on the athlete,' says Arno Knobbe (Leiden University). 'But the advantage is that you can conduct these tests when training starts in April. Otherwise you only have the times from the skating races in the winter to go on. And the more data you have, the more you can discover.'

While coach Orie observes, Kjeld Nuis goes all out during a Wingate test. The test is such a killer that it causes your performance to dip the following day.

In 2017, Orie's team won every distance in the men's competition at the World Championships.

puter finds is useful or reliable. 'When two components seem to be linked, you start to think: how do they affect each other? You have to keep testing the statistical correlation. That can be done with a dataset that you haven't incorporated yet, but also by simply trying out a new finding.'

According to Orie, improving the training programme generates quick results. 'The athletes in my team have so much technique that their speed increases substantially as soon as you train them to boost their power a little,' says Orie. It helps if you already have a lot of data on these skaters. 'For example, I've been working with Kjeld Nuis for eight years now. I have so much data on him, that I can predict the effect of a given intervention pretty accurately.'

A complicated game

In order to get more insights out of the skating data, Orie wants to test his athletes even more frequently. Because the more data you have, the more reliable they are. And more data also generates better insights about individual skaters. 'We're planning to turn the training programme on its head more often,' Orie says. 'Do things that you normally don't do. You learn from that. Last year we trained really hard in August and September. But then our test results declined so rapidly that we slowed it down a notch. Then, smiling, Orie adds: 'And we still performed pretty well that winter.' At the World Single Distance Championships in 2017 Orie's team won every distance in the men's competition: Jan Smeekens on the 500 metres; Kjeld Nuis on the 1,000 and 1,500 metres; Sven Kramer on the 5,000 and 10,000 metres. Orie attributes last year's successes to the right timing of what's called 'supercompensation'. When you train hard, your performances dip temporarily. But as soon as you ease the training intensity, your body recovers and your capacities shoot up. 'Supercompensation is a complicated game,' the coach explains. 'Scientists of human movement have even discovered effects three months after a training exertion. Moreover, training for speed influences supercompensation during endurance performances and vice versa.' Coach Orie and scientist Knobbe hope that the skating data will enable them to understand even better how to best apply supercompensation.

A hundredth could be enough

All well and good, but some things that affect winning and losing cannot be captured in numbers. For example, skaters may not feel good about themselves at a given time or they may be having sleepless nights because of a baby. And we all remember the unbeatable champion in 2010 who was disqualified because he skated in the wrong lane. 'Of course, our method doesn't allow you to precisely predict the performances at the Olympic Games,' Knobbe says. 'But you can train more effectively using the patterns that we find, which does increase your chances of winning.' Which is why Orie adds that 'the difference between winning and losing is tiny. Every hundredth of a second may just be enough to give you the victory.' □

His scientific background helps Orie to meticulously collect and analyse data.

Smart glasses for a perfect stroke

You learn how to skate from your parents. You learn how to skate well from a coach. It may well be that you learn how to skate perfectly from smart glasses. Sports engineer Eline van der Kruk (TU Delft) and movement scientist Jeroen van der Eb (VU Amsterdam) are working on a way of teaching the perfect stroke. They had people skate with ice skates full of movement sensors. With the data from these 'measuring skates', they had a computer model calculate which stroke will enable you to reach the highest speed. The researchers are working on a way of adjusting the perfect stroke to individual skaters' body length, weight and muscle mass. In the future, skaters could wear a Google Glass-type pair of smart glasses that will give them instructions on how to adjust their stroke. The research on skating strokes is being done independently of the research with skating data being done by Arno Knobbe (Leiden University) and Jac Orie (LottoNL-Jumbo skating team).

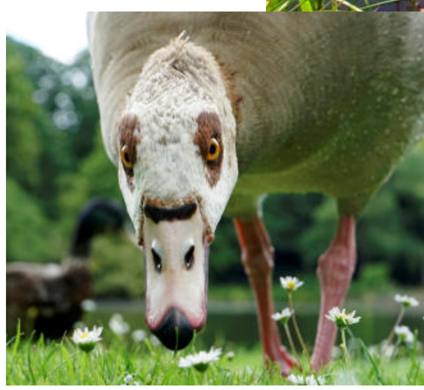
Not all alien plants are aggressive invaders ruining 'our' green habitat

Honouring exotics

Every summer, thick mats of water pennywort grow in many waterways. This alien plant species suffocates all other life. But it's an exception: most alien species do no harm. Is it time we changed how we view exotic species?

Text: Nienke Beintema

It seemed like such a good idea: bring over the water pennywort from the US to Europe. It's beautiful, it grows quickly and propagates easily through cuttings. But it's the last two properties that make it a major headache. Because plants obviously don't just stay in ponds. They've now infested entire waterways, from northern Scotland to southern Italy. Every piece of plant that breaks off can form its own mat. Indeed, there are other invasive exotic plants, introduced by humans or animals, that proliferate and become harmful. So, what to do? Exterminate them? No, according to aquatic ecologist Bart Grutters. Alien plants are not necessarily harmful. What's more, some are beneficial, as he discovered while conducting his PhD research at the Netherlands Institute of Ecology (NIOO-KNAW). He's in favour of taking a fresh look at exotic species and judging them based on their actual impact.



▲ **The Egyptian goose, originally from Africa, has been in the Netherlands since the 1960s.**

Water pennywort ended up in Dutch waters around 1994. Garden centres are no longer allowed to sell this exotic species as a water plant. ▶

Anecdotes or research?

The problem is that their impact is difficult to study. 'Most of what we know comes from anecdotes,' says Grutters. 'Tourists, for example, complain that their boats get stuck in the water pest. But are exotic species necessarily bad for nature? Opinions are divided on that.' Biologists like to study how the ecosystem changes under the influence of exotic species. Whether native species are vanishing as a result, for example. But freshwater systems are complex and influenced by a variety of factors. What are their cause and effect? The quality of freshwater in the Netherlands has improved considerably in recent decades as a result of stricter environmental regulation. 'Still, many native plants are slowly making a comeback.' And sometimes alien plants are the first to return. In such cases, water managers often blame exotic plants for the fact that you don't see native plants returning. 'Something like that is accepted as the truth, without good research having been done on the matter. As a scientist, I want to know: how does that work? What are the underlying mechanisms? And can't these alien plants be just as useful?' They can also convert nutrients in the water into food for animals, halt the growth of algae and provide oxygen. 'But hardly any experi-

Exotic rabbit

Rabbit, pheasant, the fallow deer: once upon a time they were exotic species, brought here by humans. Deliberately, because they had already been introduced as game a long time ago. 'Brought here by humans' can also be accidental. The Egyptian goose and grey squirrel escaped from captivity, the Chinese mitten crab hitchhiked in ballast water on ships and the tiger mosquito travelled with tropical plants. And the construction of a canal between the Rhine and the Danube has made it possible for fish species from the Black Sea region to reach 'our' waters. Another category of newcomers is not considered exotic, though humans have certainly played a part in their arrival: species such as the great egret, whose habitat is shifting as a result of climate change.

ments have been done yet on the ecology of exotic water plants.'

A single factor

It's hard to experiment in waterways. There are all kinds of influences that you have no control over, such as fertilization in adjoining plots of land, fluctuating water levels and waterway maintenance. 'You can't expect farmers and water managers to leave the entire landscape alone,' says Grutters. The composition of soil, the distribution of water and nutrients, and the species of fish, birds and water creatures differ in each waterway.

You can conduct experiments under controlled conditions in the lab. 'And at different scales, from petri-dishes to enormous tubs.' But are the dishes and tubs representative of the real, living waterway systems? 'That's hard to say, because it's so difficult to experiment in real waterways. But you can accurately manipulate and study a single factor in the lab. That would never be possible in the field.' This sheds light on the impact of individual factors. Such as how water pennywort affects the amount of nutrients and vice versa. Based on that you can design more targeted experiments in the field later.

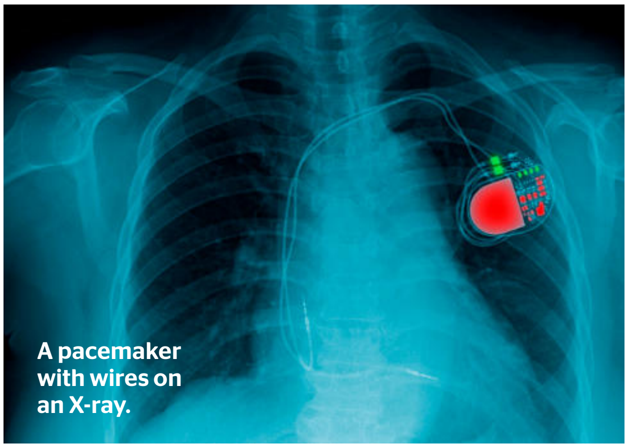
Use to your advantage

For one of his experiments, Grutters had as many as ninety tubs on the premises of NIOO-KNAW. Tubs full of native pondweed and green algae, some also with exotic species such as parrot's-feather and variable-leaf watermilfoil. Grutters put additional nutrients in some of the tubs, where small water creatures started to appear afterwards. In other tests, he used aquariums with water plants, predatory fish and prey.

Each time, the focus was on an ecological function of the plants. Such as their impact on the 'hunting success' of predatory fish, or their inhibitory effect on the growth of algae. 'We are getting the impression that both the native and the exotic plants only disturb these functions when there's high density. In lower densities, most exotic plants fit into the ecosystem just as well as native ones. In some cases, they function even better.' That's what evoked the image in Grutters of the 'infesting' exotics. 'Native plants proliferate too, depending on the circumstances.'

So should we let exotic species go about their business? 'It's more complicated than that,' says Grutters. 'Water managers have to understand that exotic species are sometimes the symptom of a disrupted system, not the cause. The cause is often a surplus of nutrients, together with other factors.' Look at the ecological properties of a species, he argues, and not only at its origin. Exterminate? That's usually not necessary. And that's only possible if they haven't spread yet. Grutters does think it's important to prevent new exotic species from being introduced into nature. There may always be a rotten apple among them, like the water pennywort. 'But once they've spread, it's best to just accept exotic species. Or even better, use them to your advantage.' □

IN BRIEF



A pacemaker with wires on an X-ray.

Left please

When your heart pumps too slowly you get a pacemaker. But this device, which usually stimulates the right ventricle, does have its disadvantages. For example, a pacemaker doesn't let the heart chambers contract simultaneously anymore, which can lead to heart failure. This problem doesn't exist when you stimulate the left ventricle instead of the right ventricle, according to research conducted by Maastricht UMC+. In that case, the heart pumps in a much more coordinated way. Until now, it was difficult for cardiologists to install it on the left, but the Maastricht researchers have successfully developed a new way of placing the device. It fastens a pacemaker wire to the left side of the septum between the heart chambers. So far, twelve patients have received a pacemaker using this method. 'And they're still walking around happily,' says cardiologist Kevin Vernooy.

Knot amused

The red knot is becoming smaller in size and its beak is becoming shorter. This discovery was made by a team of biologists, led by people from NIOZ Royal Netherlands Institute of Sea Research. Every year, this migratory bird flies from the North Pole region to the tropics and 'refuels' in places like the Wadden Sea. As a result of global warming, the Arctic spring now starts earlier and earlier, and so the emergence of insects on which red knot chicks feed. As these birds haven't adapted their migration schedule to these ongoing changes, their offspring find fewer insects and show retarded growth as a result. Because their beaks have shrunken too, it's becoming more difficult for them to find their favourite burrowed shellfish at their southern wintering grounds. Therefore, they're forced to eat less nutritious seagrass. Result: the survival chances of a young knot in its first winter are twice as small as that of a 'normal' knot.

The fungus turns bare wood black and makes it impenetrable.

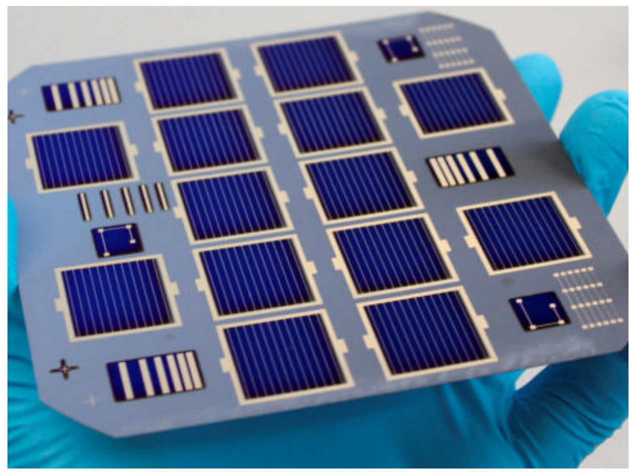
Super fungus

A wooden house should protect you against fungi and other unpleasantries. Yet a fungus was applied to the wood on the outside of the Da Costa care centre in Putten. Deliberately so: in fact, the fungus protects the wood. The building has been treated with a layer of finishing developed by TNO, the Eindhoven University of Technology and Xylotrade, among others. First the wood is impregnated with an oil. That's followed by a layer of the *Aureobasidium pullulans* fungus. You often find it on moist walls, in wood or in apple trees. The oil protects the wood and also feeds the fungus. It creates a black, living layer on top of the wood. The smooth fungus cells are water-repellent. Other harmful fungi and UV radiation are unable to penetrate the layer either. So there's no more need for environmentally unfriendly wood treatments, and the wood will last for years anyway.

Knots still become about 25 centimetres long, but that's likely to decrease.

More energy from light

It takes a year and a half before a solar panel generates the energy that was needed to produce it. That led researchers supervised by Ruud Schropp, former professor at Utrecht University and the Eindhoven University of Technology, to explore an energy-efficient method of making solar panels. The solar cells on most roofs are 'crystalline silicon cells'. They're produced at a high temperature that uses a great deal of energy. Manufacturing so-called 'heterojunction solar cells' uses less energy. These cells contain crystalline silicon, which creates a 'high-purity ordered atomic arrangement', says Schropp. But they also contain layers of disorderly amorphous silicon. This type of cell generates more energy from the same amount of sunlight than 'regular' solar cells. So a panel of heterojunction solar cells earns back the energy used to produce it in two ways.

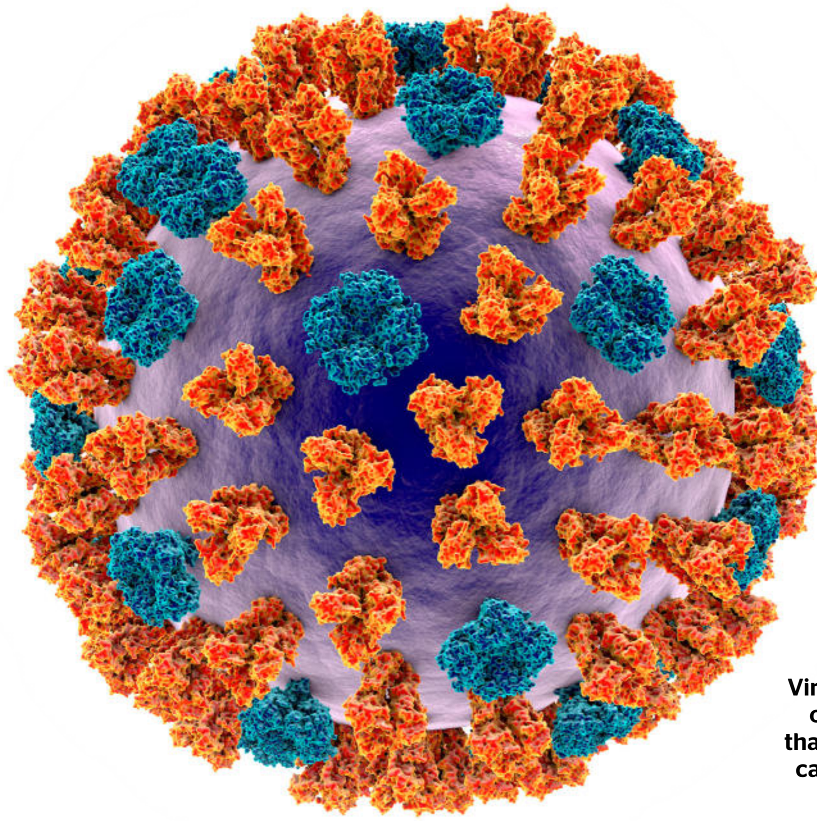


Which set of genes is behind that smile?

Well-being is in your genes

The feeling of well-being is partly hereditary, and genetic variants are involved. This was discovered by Meike Bartels, professor of genetics and well-being at VU Amsterdam, and her colleagues. The researchers gathered information from a large number of people about their feeling of well-being and compared their DNA. Different genetic variants emerged for well-being. 'There are probably a few thousand genes involved in well-being,' explains Bartels. 'Some of these genes are the same as the genes that determine your sensitivity to depression. But there are also genes that only play a role in well-being.' That your feeling of well-being is partly genetic makes it more difficult for some people to be happy than others. The thousands of well-being genes exist in countless combinations, but these combinations can be grouped. 'Knowing which genetic group someone belongs to, will make it easier to determine what will or will not work with that person to make them feel happier.'

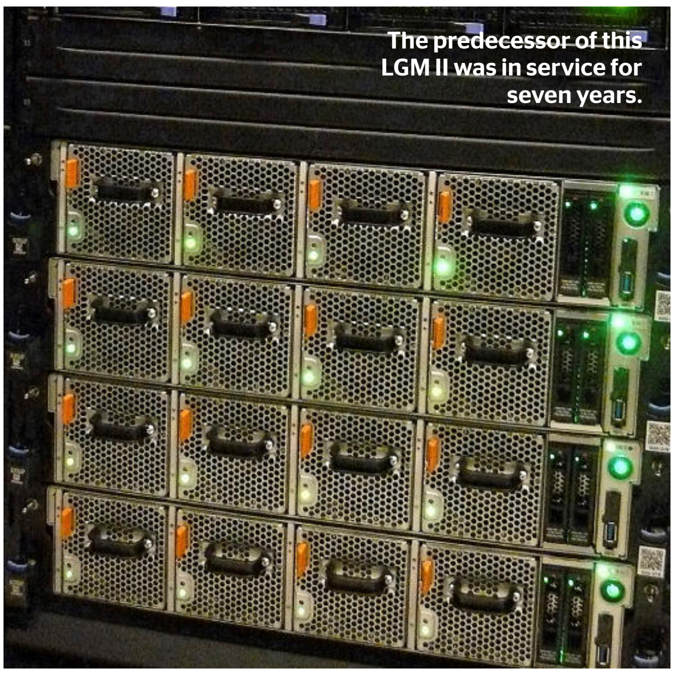
IN BRIEF



Viruses are full of molecules that antibodies can adhere to.

Predictable virus

There are years when the flu shot doesn't work. Vaccines stimulate our body to produce antibodies, but in bad years these antibodies fail to recognise the flu virus because it keeps mutating. The lab of virologist Ron Fouchier at Erasmus MC in Rotterdam has succeeded in predicting how the virus will develop. The virus was found to mutate in seven places in order to avoid being detected by our immune system. It has two to three mutation options at each of these places. The researchers can now create viruses with these adaptations. It appears that most of the mutations weaken the pathogen, so only a few 'realistic' options remain. The virologists are producing a vaccine against those virus variants ahead of time. In 2019, a select group of people should be the first to be vaccinated against a predicted virus.



The predecessor of this LGM II was in service for seven years.

Very small, very smart

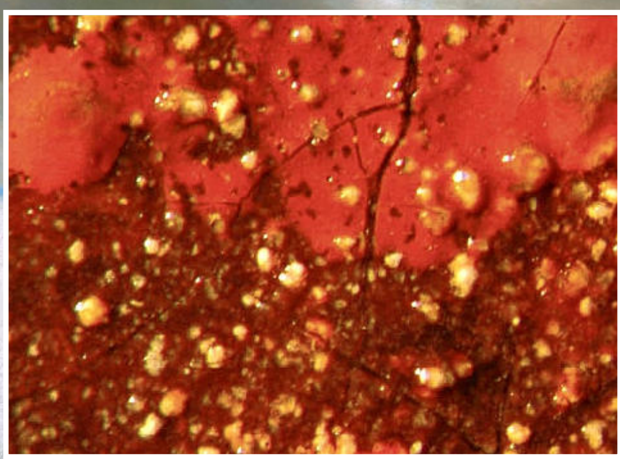
It's 10,000 times faster than a PC and isn't higher than four pizza boxes: supercomputer Little Green Machine II (LGM), built by a team of Dutch scientists. 'Its colour isn't green. We call it green because it's energy efficient,' says Simon Portegies Zwart from Leiden University. He's in charge of the project. Of course, large supercomputers for research already exist. But there's usually a waiting list if you want to use one of them, because obviously there are always other scientists who want to use a supercomputer too. 'With my own supercomputer I can start working without delay,' says Portegies Zwart. He uses the machine for complicated calculations, such as the chaotic orbits of planets around the sun. 'But we share the LGM with financial scientists from other universities, for example. They use it to study shares.'

Time = protrusions

The ravages of time can harm paintings, for one thing because the paint fades with time. Chemist Joen Hermans from the University of Amsterdam discovered how that happens in many oil paintings. The white paint used by painters in the past consisted of oil and a white pigment that contained either zinc or lead. White was also mixed with other colours, so most paintings contain those metals. White pigment reacts with fatty acid molecules that are released when oil is broken down by moisture in the paint. This reaction creates substances called 'metal soaps', which can grow to form large protrusions that penetrate the paint surface. At that point you can see many white spots on the painting. Hermans unravelled the precise steps in the chemical pathway of this type of paint deterioration. 'We can now determine what stage of deterioration a painting is in. Now, we're going to study what you can do in each stage to prevent things from becoming worse.'

Plausible thanks to lie

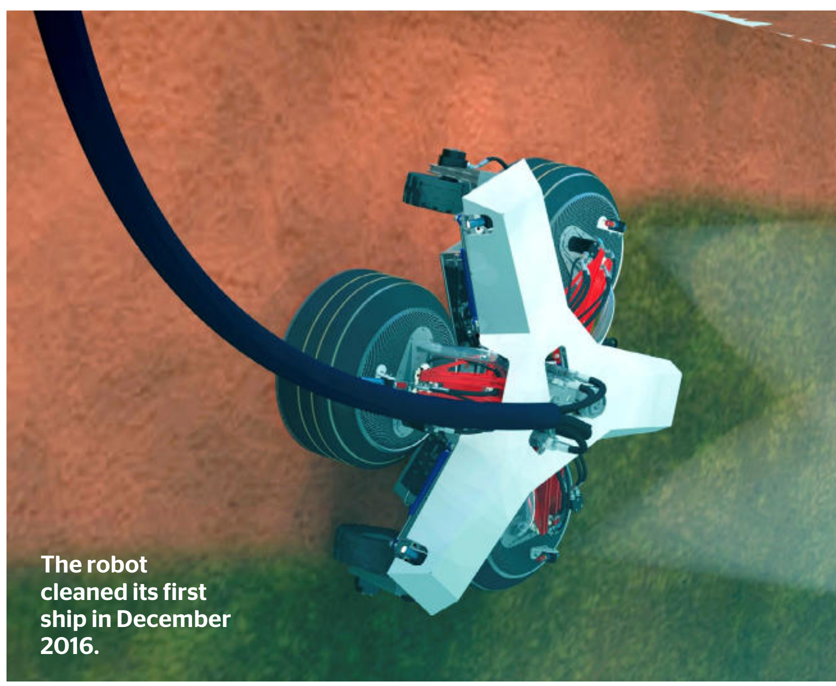
Are you a crime suspect, but your alibi is of a sexual nature (watching porn, for example)? Then it makes sense to initially lie about your alibi, and admit your lie afterwards. A salacious alibi that's tainted by sex is more plausible if you lie about it first, forensic legal psychologist Ricardo Nieuwkamp from Maastricht University discovered. 'Previous research revealed that people find changes to alibis unbelievable.' The opposite seems to occur with a salacious alibi. Why is that? 'The suspect confesses to something shameful, which makes it seem logical that he didn't talk about it at first.' It should be noted that Nieuwkamp tested participants from the community, who form judgements more easily than police officers. 'Detectives are usually more patient. They first examine whether a suspects' statement is true, before they believe an alibi.'



Some of the red in Johannes Vermeer's painting *View of Delft* (below) contains light clumps of metal soaps (above, magnified).

Robot makes a clean sweep

How do you clean a container ship's hull? Why not have a robot do the dirty work, thought researchers from TU Delft. They established a company called Fleet Cleaner and developed exactly this kind of robot. 'The robot attaches to the ship with magnets, but the magnets don't touch the surface of the ship. It moves around on wheels.' It uses water jets to spray away the filth. The waste water is sucked up and ends up going through a hose to the filtering system on the working vessel. The cleaning robot is more meticulous than divers, for example, who scrub a ship using brush karts. They can't always see whether they've missed a part underwater. 'The robot is always on top of that,' De Vet says. Which is important, because a container ship with a clean hull uses less energy when crossing the oceans. That saves money and protects the environment.



The robot cleaned its first ship in December 2016.

New materials doing strange things

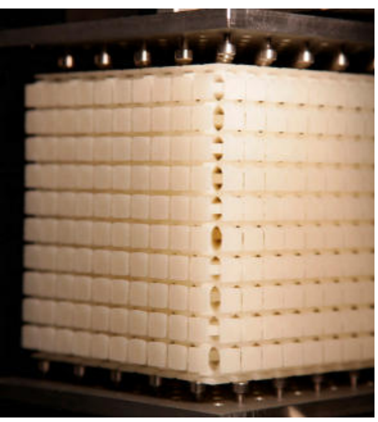
Smart stuff

A material that reacts to stimuli (such as light and touch) and which adapts to its environment is called a 'smart material'. How do you develop it, and what can you do with it? Two researchers, each with their own approach, explain.

Text: Pepijn van der Gulden

Fascinated, Martin van Hecke plays with the ridged foil that was peeled from the bottom of a pack of cookies. He is professor of organisation of disordered matter at Leiden University and affiliated with the AMOLF research institute. 'A friend of my daughter's gave me this. She thought that I'd like it.' It looks just like ridged foil, but as soon as Van Hecke stretches it a bit, something funny happens. Folds and ridged patterns emerge in places where you wouldn't expect them. Van Hecke realised that if you understand the physics behind this, you could adapt a material as you wish. That would create countless new opportunities and applications. That, Van Hecke, says, is the idea behind smart materials.

Van Hecke's smiley cube: pressure from above ensures that a smiley appears on the side.

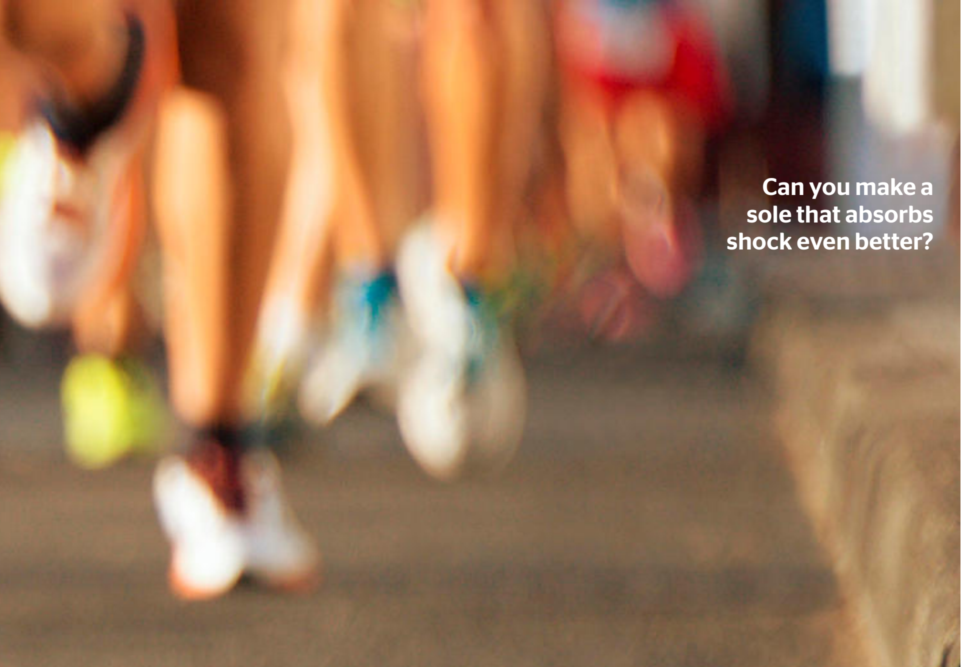


Push it in

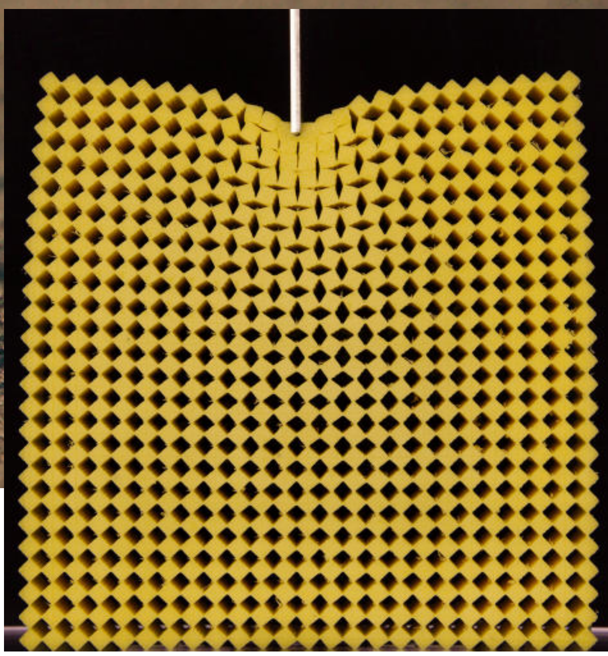
He shows an example. It started with a kind of soft rubber sponge, discovered by colleagues in the US. It has a pattern of small holes. As soon as you push the sponge, the small holes flatten. Only thing is, you'd expect these holes to be 'pushed closed' in the same way, for example from above to below if you push the sponge from above. But special patterns emerged during the pushing. 'Look carefully: the holes are pushing horizontally and vertically, one after the other.' One hole has been pushed flat from above to below, and the hole next to it from left to right. As a result, the flattened holes create striking shapes in the sponge. Many new sponge-like cubes followed, and increasingly Van Hecke understood why the holes didn't always close in the same way. The exact position of a hole in the sponge turned out to be crucial. 'And once you understand how the properties of such materials emerge, then you can start thinking about programming it.' How do you get a material to do exactly what you want? After carefully calculating this, Van Hecke managed to create a cube, the elements of which were positioned in such a way that it becomes a 'smart' cube. Push it, and a smiley appears on the side (see photos on left), which is exactly what it was designed for.

Control opens doors

Playing around with ridged foil and happy cubes, is that physics or tinkering about? 'I do have student who thinks: we can really muck about in Van Hecke's lab,' Van Hecke says, smiling. 'It looks simple, but it allows you to understand complicated matters.' Thanks to the understanding of the underlying complex physics it should be possible to get more out of materials. Van Hecke can already imagine shoe soles that provide more absorption on a hard surface than on a soft one. He's also working with scientists at Delft on a better lower leg prosthesis that will give you grip when you need it.



Can you make a sole that absorbs shock even better?



The holes close horizontally and vertically, one after the other.

Molecules first

At the University of Twente, professor of chemistry Nathalie Katsonis is working on smart materials, but in a very different way. The springs that she's developing are reminiscent of the brown sticky strips used to catch flies. But when light shines on them, they come to life. Then the springs begin to wind, like the tendrils of a plant twisting on a tether, reaching for the sun. This isn't a random comparison: Katsonis is inspired by living materials. 'We look for the physical origin of natural phenomena. We look at octopuses that change shape and colour, at carnivorous plants that shut when they catch a fly, and at seed pods that open up. That's what inspires us, but we're not just imitating. We're trying to reproduce the essential mechanism underlying these things.' In nature, movement is often generated by the work of biomolecular machines. 'For materials scientists,' says Katsonis, 'the challenge is to re-engineer these biological strategies, but with artificial molecules.'

Motors and switches

Katsonis uses a variety of dynamic molecules to preprogram movement: molecular switches, that switch from one shape to another, or molecular motors, that turn constantly and unidirectionally under illumination. The trick, she says, is to make all of these molecules work together. 'If each of these nano-objects works in a random direction, for example, then you'll notice that nothing happens at the level that can be seen by the eye.' But if you combine the molecules with the desired properties in the right proportions, then that may cause the spirals to start moving. 'We program them for that, so that they carry out the movement themselves when light shines on them.' The trick we use here: the molecules on top of the spring are oriented perpendicularly to the molecules at the bottom of the spring.' The molecules are thus well organised. Then there's no movement. 'But as soon as the light is turned on, the switches destroy that organisation. As a result, the spring starts to wind or unwind.' Just like in the cucumber plant, in which the fibres at the top are perpendicular to the fibres at the bottom.

A field in motion

Katsonis wants to understand the molecular origin of complex motion. The spreading of seeds, the beating of a heart, the contraction of a muscle – all these movements originate at the molecular level. 'That sets the stage for what we could do in the future,' Katsonis says. In contrast, there is still little we can do with man-made materials. For the time being, most man-made materials only have two settings: on and off. Back or forth. Enhancing the complexity of shape-shifting materials might pave the way towards soft robots, tissue-like materials, or other applications. At some point, maybe smart materials will reach the complexity of living materials, according to Katsonis, but scientists are still at the very beginning of this research field. 'Life also consists simply of molecules that move and carry out simple tasks. But there they're part of a larger entity consisting of many more processes.' Before smart materials are actually used, whether it concerns smart shoe soles or 'fake tissue', a lot of physical fiddling and chemical tinkering needs to be done. □

Why do the leaves close when the fly touches them? These are the kinds of things that inspire Katsonis' group.

Dutch material

Other Dutch research is also focusing on the development of new materials.

- Bas Overvelde from the AMOLF research institute is studying possibilities for spatial figures. He's examining in which direction structures can move, by creating clever, origami-like models.
- Wim Noorduin (also AMOLF) is gardening at the micro level. Structures look just like flowers under a microscope. He can give molecules a self-conceived structure. That could be useful when making solar cells, for example.
- Scott Waitukaitis (Leiden University) works with small hydrogen balls. They bounce easily. In fact, they never stop bouncing in a hot pan, where their surface creates a kind of engine which they could use to set other materials into motion.

The Roman gold treasure from Lienden.

Treasures on display

Researchers at VU Amsterdam set up a website where amateur archaeologists can display their finds. Not 'for fun', but for science. 'This is a huge opportunity.'

Text: Mark Traa

Roman wire fibula (brooch), about 100 AD.

Mercury, Roman god of commerce and financial gain, 40 AD to 350 AD.

Yes, even he had one. As a teenager in the town of Goirle in Brabant, Stijn Heeren walked around with a metal detector. It didn't yield much more than a few coins, but it wasn't just about the size of the find. 'It was also the kick of finding something. That's really exciting.' Heeren, who now works as an archaeologist at VU Amsterdam, can certainly empathise with these hobbyists with metal detectors. There are probably several thousand amateur archaeologists who have a collection of objects at home that they dug up themselves. Of course, professional archaeologists have been aware of these collections, but they never really did much with them. For a long time, detectorists had a bad reputation: they were perceived as doing it to make money. Conventional wisdom had it that real archaeologists were better off not engaging with them.

No longer forbidden

These days, the archaeological community is less suspicious of detectorists. And since last year, hunting for archaeological objects with a metal detector is no longer forbidden by law (it was already tolerated), as long as the findings are properly reported.

That paved the way for a project called Portable Antiquities of the Netherlands (PAN), which Heeren set up with professor of archaeology Nico Roymans. The result is a website making the findings of detectorists available to everyone. The VU archaeologists received almost 1.9 million euros from NWO last year for the

Late Romans

The PAN project at VU Amsterdam had barely been launched when a message came in: detectorists had made a special find in an orchard in the town of Lienden. Twenty-three gold Roman coins had been dug up. The youngest bore the image of Emperor Majorian, who ruled from 457 AD to 461 AD. The treasure of coins was most likely buried around 460 AD. That was just before the fall of the Western Roman Empire in 476 AD. Never before had a treasure of Roman coins from so shortly before the collapse of the empire been found in the Netherlands (or its surrounding areas). The find in Lienden shows that the Romans were active in our region until almost the very end. Research by archaeologists from the Amsterdam university, however, revealed that coins had been found in the same place before: in 2012, in 1905 and even in the mid-nineteenth century. The finds almost certainly come from the same treasure. Overall, 42 coins have been found thus far in Lienden. The gold treasure has been loaned to the Valkhof Museum in Nijmegen.

Iron socketed adze, between 800 and 250 BC.

project. That's a lot of money, but on the other hand there was plenty to do. Roymans and Heeren hired seven 'registrars', experts who visit people's homes to evaluate their findings. Sometimes they have to disappoint the finders. 'A finding may turn out to be much more recent than they thought. We're interested in seeing anything from before around 1500, but we're more selective about anything from after that time. Given our capacity, we have to draw the line somewhere.' Interesting finds are photographed on the spot. If it concerns a great deal of material, then it goes to Amsterdam and is photographed there. 'There's one private collection that has more than 4,000 finds. The owner was the only one allowed to search on the land of a certain farmer, year after year. Soon he'll have a tangible collection at home and an online version on the website.' The amateurs love having their finds online. 'It's a form of recognition. And a great opportunity for science.'

Priority for old detectorists

It should be noted that found objects are rarely unique. 'You have to assume that for every brooch found there are already at least three in a museum. Our main interest is the location of the find. The distribution of brooches in a larger area can reveal a great deal about the place in which people lived in a certain period.' Finds from dozens of years ago are especially interesting sometimes if the site is no longer accessible, because a residential neighbourhood has been built on it, for example. 'It's important to first record the findings of older detectorists,' says Heeren. 'They can still tell us the story of their findings.' Often he is pleasantly surprised by an amateur's knowledge. 'There are people completely specialised in knife handles or old keys. They also have books that we don't even have in our university libraries. That's how we're building a knowledge network of amateurs and professionals.'

Anonymous finders

About 2,000 amateur findings have been put online now. Many more findings are being processed. Indeed, the photos aren't uploaded immediately: first sample drawings have to be made of the many kinds of objects that are being found. These drawings make it easier for people to identify an object. If someone digs up an axe, for example, that strongly resembles a sample drawing, then you can read beneath the sample that it's a palstave, 'of the 'Vlagtwedde variety', made in the Bronze Age.

Not all examples are ready. 'Essentially we have to summarise many years of archaeological research. And we've only just gotten started,' says Heeren. 'When it's finished, we can instantly ascertain what exactly has been found.' There's no way of seeing who the lucky finder was on the web page with the photo of a finding and all of its details. Some of the detectorists may have wanted that, but most don't. 'There are amateur archaeologists out there with extremely valuable collections. If their name is linked to a certain search area, then they may get unwanted visitors at night. That's why we don't provide any exact finding sites on the public part of the website. Only registered researchers are privy to that information. Amateur archaeologists are very appreciative of that.'

Coin struck in Dorestad (now Wijk bij Duurstede).

Happy with knick-knacks

From 2020 onwards, the PAN project will be transferred to the Cultural Heritage Agency. The idea is for people to eventually upload their own photos of their finds, which will then be evaluated by volunteer experts. As far as Heeren is concerned, it makes sense that at a certain point the finds that emerge from 'real' archaeological digs end up in the system. At the moment, there's still a separate database for that.

Until that time, PAN will fill up with many thousands of objects tracked down with metal detectors. 'There are some real gems among them sometimes,' says Heeren. 'But then it's usually not the objects that the finders put in their showcase. People should definitely not think that we're only happy with silver and gold. A fragment of a clothing pin may have many stories to tell too. A crate full of copper knick-knacks is just as interesting to us.' ◻

MORE INFORMATION

portable-antiquities.nl: PAN's website, which not only contains an overview of the finds, but also a map that shows the distribution of finds.

Tomorrow's

Each of the recipients of the 2017 NWO Spinoza Prize, the highest scientific award in the Netherlands, introduce a major research talent. Who are tomorrow's pioneers, and what are their dreams?

Text: Elly Posthumus and Anne Vegterlo / photography: Adrie Mouthaan

The young brain

The talent: Lara Wierenga
'As a child, I already asked myself: what if my brain were to see things differently than other people's? What if I perceive red completely differently than my mother, for example? I was very interested in psychology and psychiatry, and that's why I decided to study psychobiology. Now I'm doing brain research in children and adolescents. We scan them with the aid of MRI from their fourth year to adulthood. How do their brains develop? And do certain areas of the brain develop more quickly than others? This kind of research has revealed that the adolescent brain, for example, is structured much differently than a child's or an adult's brain. Then you can try to find out whether that can explain typical adolescent behaviour, such as taking a lot of risks.'

Future dream
'For me, brains in which things work just a little bit differently are especially interesting. For example, what happens in a child with ADHD? Or a child that's extremely creative? The fun thing about this work is that in science there are always new questions to explore and it's exciting to work on the most novel topics. I've been fortunate to be able to work on major studies. This gave me access to a great deal of data and the opportunity to look at many aspects of brain development. Now I'm setting up my own experiment at Leiden University. In one of these projects I assess how hormones affect brain development. What I'd most like to do in future research is evaluate how much brains can differ in development. Ultimately I may discover how and when best to stimulate a brain that's "lagging behind", so that you help it to develop further.'

The pioneer: Eveline Crone
Lara Wierenga is a major science talent, according to Eveline Crone, professor of neurocognitive developmental psychology at Leiden University. In her lab, Crone studies the brains and behaviour of children and adolescents. She previously worked at universities in the United States. She has also written numerous books about the young brain. Her studies have been awarded several prizes, and this year she received the NWO Spinoza Prize.
Why is Wierenga such a major talent? 'Lara is one of the most promising young scientists in the field of neuroscience,' says Crone. 'She's independent, has a strong vision, and publishes with leading international researchers. She asks challenging scientific questions, which she can examine with innovative statistical techniques thanks to her technical knowledge. Her publications are having a major impact, and she also knows how to make her complex work accessible to the general public.'

pioneers

Monitoring particles

The talent: Sanli Faez
'I do research on nanophotonics at Utrecht University. We use light microscopy to see and monitor nanoparticles. These particles could be proteins, pieces of DNA, or viruses. By monitoring these extremely small particles, we can see how they undergo a chemical reaction. Many kinds of reactions take place in our bodies. Some of them have intermediate stages in which nanoparticles come and go, such as the enzymes that act as catalysts to accelerate a reaction. If you manage to monitor a particle, then you'll be able to see these intermediate stages. Generally, nanoparticles move so quickly that you can easily miss them if you use a regular microscope. Therefore, these measurements have to be done at high speed, for which you need to illuminate the sample with a lot of light. That's why we built a microscope capable of doing that.'

Future dream
'Nanoparticles can reveal a great deal about our health. I would like to develop a device which doctors can use to measure individual particles. Think of inexpensive microscopes that make it easy to see viruses. Perhaps we can help doctors in the coming few years to make quick diagnoses. You can also imagine applications for cancer. If you have cancer, there will be an excess of nanoparticles in your blood, which are called exosomes. Cancer cells use these nanoparticles to communicate with each other. If we were able to count these exosomes, then that would be a good indicator of whether someone has metastasis or not. Right now that's still difficult to measure because the particles are so small. In any case, I want the community to benefit from my work. I think that's more useful than writing a famous article that's only cited by other scientists.'

The pioneer: Michel Orrit
Michel Orrit views Sanli Faez as a major science talent. Orrit is a physicist and professor of spectroscopy at Leiden University. He has developed techniques to measure single molecules such as proteins. This enables you to see whether a cell is producing a certain protein or not. 'We're now trying to develop a technique that monitors the movement of a single protein molecule,' says Orrit. That could ultimately lead to a better understanding of the effects of medicines. He received the NWO Spinoza Prize in 2017. What makes Faez such a major talent? 'He's an extremely clever guy with good ideas. I have great confidence in his research. He has developed a technique that's sensitive enough to see the movement of nanoparticles, such as viruses. And I think there's a great future in that.'

Monitoring proteins

The talent: Fan Liu
'After conducting research for my doctorate in the United States and a postdoc period in Utrecht, I'm now doing research at the Max Delbrück Center for Molecular Medicine in Berlin. I'm focusing in particular on all of the interactions between proteins in the body's cells. Cells are the foundation of our bodies. Each cell consists of millions of proteins, and they all interact with each other. They determine a cell's properties. We're studying these proteins with mass spectrometry. This reveals how they normally behave and allows you to identify the changes taking place. Changes occur when someone has a disease, for example, such as cancer. We study how to prevent cells from dying off, or vice versa, encourage them to die off. This would enable you to let bad cells die off too.'

Future dream
'The most interesting work I've done thus far was at the lab in Utrecht. We developed a technique that makes it possible to monitor proteins interacting at a large scale. Previously we were only able to measure about ten interactions at a time. So to get a good dataset, you needed to carry out thousands of different tests. That took a huge amount of time. Thanks to our new technique, we can measure these interactions in a cell all at once. As a result, we don't need to do nearly as many experiments. Eventually I'd like to become a professor and run my own research group. That gives you a great deal of freedom to set up your own research. Ultimately, of course, you want to develop new therapies to treat diseases with. But I would already be happy with any contribution that I could make to science. There's still so much to learn and to discover about our bodies and those millions of cells and proteins.'

The pioneer: Albert Heck
Chemist Albert Heck believes Fan Liu is a major talent. Heck is professor of biomolecular mass spectrometry and proteomics at Utrecht University and specialises in the characterisation of proteins with the aid of mass spectrometry. His group is developing new ways of researching proteins and studying how they function. This year he received the NWO Spinoza Prize. 'Liu is an all-rounder with a tremendous scientific repertoire,' says Heck. 'She can programme, model and carry out experiments. She also understands the biology of what she's working on. She's ambitious, fearless and tackles her objectives head-on. As a Chinese women, she had the courage to start an academic career in Europe and is overcoming any resistance that this may provoke. And she has a strong drive and passion for her work, which I really appreciate.'

‘As a scientist, you should always doubt everything you see and measure things in different ways’

The pioneer: Alexander van Oudenaarden

Susanne van den Brink is a major science talent, according to Alexander van Oudenaarden. He is director and group leader at the Hubrecht Institute (KNAW), which works together with UMC Utrecht, and het is also professor of quantitative biology of gene regulation at Utrecht University. Van Oudenaarden has developed methods that make it possible to monitor activities in single cells. He was awarded the NWO Spinoza Prize this year.
Why does he think that Van den Brink is such a huge talent? ‘She’s a scientist in heart and soul. She focuses strongly on really understanding why certain things happen. That makes her enthusiastic, and I think that’s great to see. She’s also extremely thorough, and that’s very important. Basically you should always doubt everything you see and measure things in different ways. And then hope that your conclusions are still valid.’

Seeing cells

The talent: Susanne van den Brink

‘Every cell has the same genetic material or DNA. The difference between two cells is that different DNA is “active” in one cell compared to another. Which DNA is activated determines what the cell does. At the Hubrecht Institute I examine muscle stem cells, which are essential for repairing muscles after they’ve been damaged. Normally these cells aren’t active. But if you injure your arm or have a muscle ache, they wake up. They then divide and repair the damage. Usually during experiments you have to put thousands of cells together in one tube in order to have enough material to do measurements on them. But our new techniques enable us to measure which DNA is active or inactive in a single cell. As a result, we can study muscle stem cells in much more detail. In the future, our methods could help to develop cures for muscular disorders.’

Future dream

‘One day, I’d like to make living cells out of dead molecules. This will help us to understand the essence of life. If you can build life yourself, then this will teach you a great deal about how that life is built up. Compare it to a car that you assembled yourself from the very smallest part. At the end, you’ll have a much better understanding of how a car can drive. If you can build a cell from dead molecules, you will similarly learn a great deal about how a cell functions and how life works and came about. It wouldn’t surprise me if, in the long term, we will succeed in building synthetic cells. Initially, those will be very primitive versions of cells, but ultimately it might be possible to build a complete and healthy cell.’

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