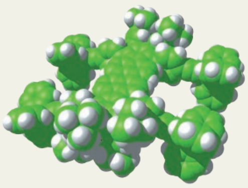
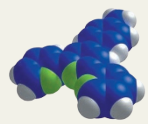
MOLECULAR RACE

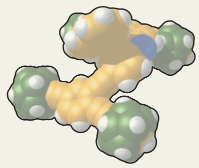
Six 'nanocars' will vie for supremacy in a race along a gold track.



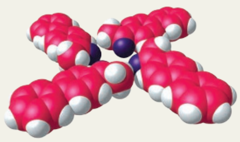
THE GREEN BUGGY
Chassis curved to minimize interaction with surface.



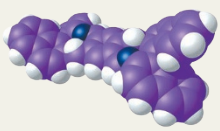
SWISS NANO DRAGSTER
Simple structure so that molecule won't fall apart during race.



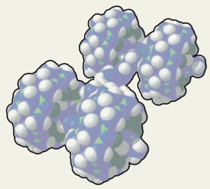
DIPOLAR RACER*
Has wheels, axles and a chassis.



WINDMILL
Four blades allow steering in four directions.



NIMS–MANA CAR
Flaps flutter like a butterfly's wings.



OHIO BOBCAT NANO-WAGON*
Pumpkin-shaped wheels may roll or slide on surface.

*Prototype model: final design not revealed

ADAPTED FROM WWW.NANOCAR-RACE.CNRS.FR

tunnelling microscope (STM) to help jolt their molecules along, typically by just 0.3 nanometres each time — making 100 nanometres "a pretty long distance", notes physicist Leonhard Grill of the University of Graz, Austria, who co-leads a US–Austrian team in the race.

Contestants are not allowed to directly push on their molecules with the STM tip. Some teams have designed their molecules so that the incoming electrons raise their energy states, causing vibrations or changes to molecular structures that jolt the racers along. Others expect electrostatic repulsion from the electrons to be the main driving force. Waka Nakanishi, an organic chemist at the National Institute for Materials Science in Tsukuba, Japan, has designed a nanocar with two sets of 'flaps' that are intended to flutter like butterfly wings when the molecule is energized by the STM tip (see 'Molecular race'). Part of the reason for entering the race, she says, was to gain access to the Toulouse lab's state-of-the-art STM to better understand the molecule's behaviour.

Eric Masson, a chemist at Ohio University in Athens, hopes to find out whether the 'wheels' (pumpkin-shaped groups of atoms) of his team's car will roll on the surface or simply slide. "We want to better understand the nature of the interaction between the molecule and the surface," says Masson.

Simply watching the race progress is half the battle. After each attempted jolt, teams will take three minutes to scan their race track with the STM, and after each hour they will produce a short animation that will immediately be posted online. That way, says Joachim, everyone will be able to see the race streamed almost live.

NANOSCALE RACES

Chemists have previously created tiny nanocars with wheels and axles — as well as molecular rotors and switches. The 2016 Nobel Prize in Chemistry, awarded to creators of nanomachines, has renewed interest in the field. However, the Nobel prizewinners worked mainly with large numbers of molecules in solution, Joachim says, whereas the researchers in this race are focusing on the interactions between single molecules and solid surfaces.

But cars on the nanoscale behave nothing like their real-life counterparts, making it hard to find uses for the machines. At these scales, electrostatic forces dominate and random thermal vibrations constantly shake molecules around. Consequently, nanomachines may end up behaving in unexpected or unpredictable ways, Grill says.

The Toulouse laboratory has an unusual STM with four scanning tips — most have only one — that will allow four teams to race at the same time, each on a different section of the gold surface. Six teams will compete this week to qualify for one of the four spots; the final race will begin on 28 April at 11 a.m. local time. The competitors will face many obstacles during the contest. Individual molecules in the race will often be lost or get stuck, and the trickiest part may be to negotiate the two turns in the track, Joachim says. He thinks the racers may require multiple restarts to cover the distance. ■

MECHANICAL ENGINEERING

Unravelling a knotty problem

Huge forces lead to runaway failure of shoelace knots.

BY ERIN ROSS

Oliver O'Reilly was teaching his daughter to tie her shoes when he realized something: he had no idea why shoelaces suddenly come undone. No one else seemed to know either.

So O'Reilly, a mechanical engineer at the University of California, Berkeley, roped in two of his colleagues to help work it out. In a paper published on 12 April, they show that a combination of forces act on shoelace knots to cause a sudden, runaway failure (C. A. Daily-Diamond *et al. Proc. R. Soc. A* http://doi.org/b5p5; 2017).

The scientists expected that the knots would come undone slowly. But slow-motion video footage — focused on the shoelaces of a runner on a treadmill — showed that the knots failed rapidly, within one or two strides. To find out why, O'Reilly and his colleagues measured the forces acting on a knot. They found that when walking, the combined impact and acceleration on a shoelace totals a whopping 7 *g* — about the same force that Apollo spacecraft experienced on re-entry to Earth's atmosphere.

Further experiments demonstrated that simply stomping up and down wasn't enough to cause a knot to fail; neither was swinging it back and forth. It took the interlaced effects of the two forces to undo the knot: the repeated impacts loosened it while the changes of direction pulled on the laces.

This interest in why knots come untied is more than purely academic, says Khalid Jawed, a mechanical engineer at Carnegie Mellon University in Pittsburgh, Pennsylvania.

Shoelace knots are the simplest type of knot, called the trefoil, he says. And most commonly used knots are just a combination of trefoils. "If we understand how simple knots work and fail, we can understand more complex knots," he says.

This could help to create better surgeon's knots and unravel why deep-sea optic cables become tangled and break. It could also improve how computer animators mimic the movement of hair, because it moves and twists in a similar way to strings and knots.

O'Reilly encourages people to experiment the next time they walk or run. They could tie their shoes with different knots and see how their laces fare. But tread carefully: you don't want to trip. ■