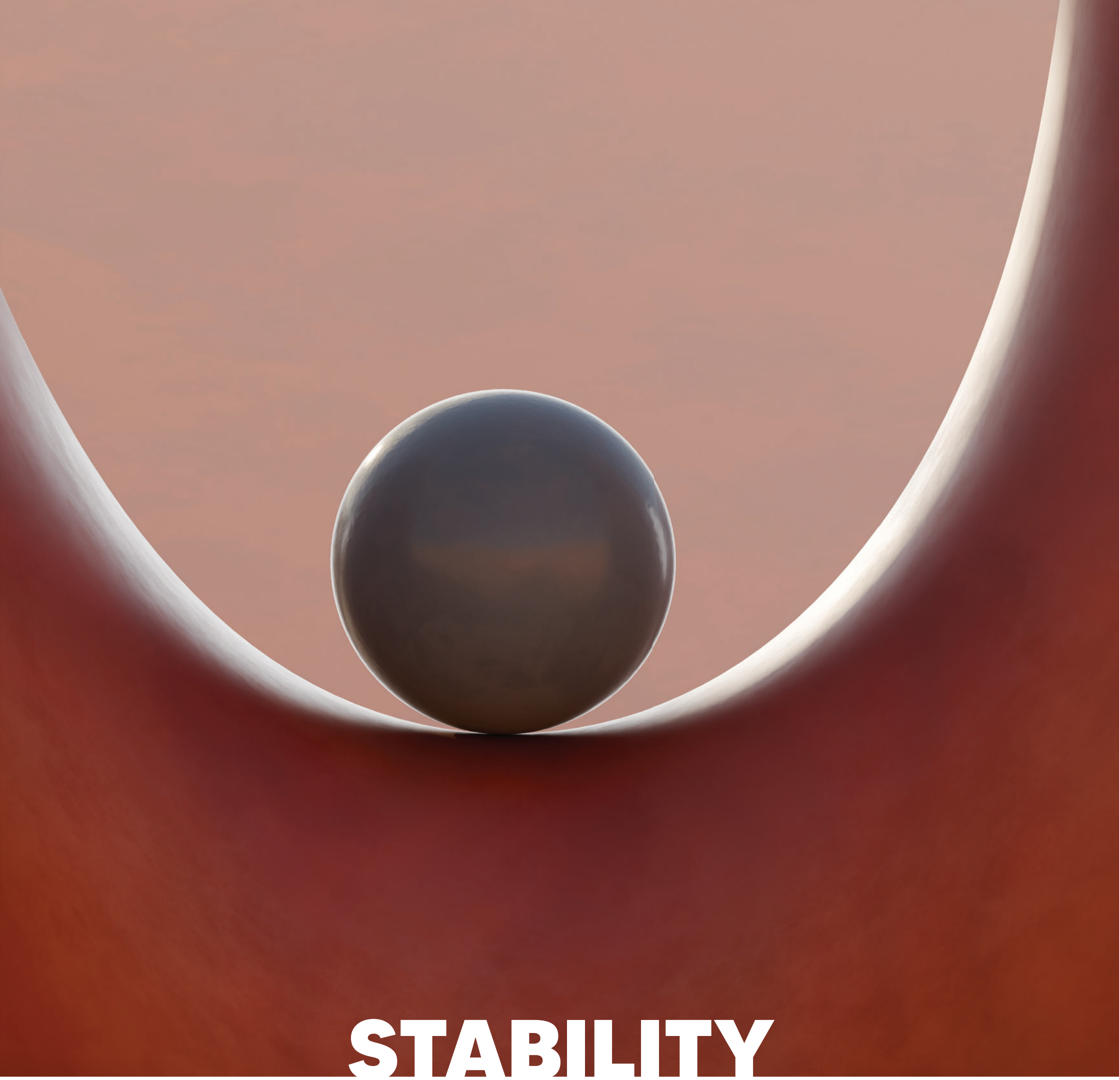
# FRANCKEN VRIJ

year 29 issue 3



# STABILITY

**Corky Lessons**

On the triple point of cork

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**Inside View**

Neuromorphic computing

For the bottom-up design of the future...


university of groningen / faculty of science and engineering

# Zernike Institute for Advanced Materials

## www.rug.nl/zernike

**You want to build the next generation of solar cells, starting from molecular building blocks? You want to change the world of computing by assembling revolutionary memory materials atom-by-atom? Or you want to develop materials preventing or curing disease? Then have a look at the Bachelor, Master and PhD programs related to and inspired by the Zernike Institute for Advanced Materials' research lines.**

We participate in programs of Bachelor and Master levels in the field of Physics and Chemistry. But, since it is our mission to train a new generation of researchers in cross-disciplinary approaches to research and equip them with the diverse skills required by modern science, we have initialized programs breaking the traditional boundaries between disciplines like e.g. the interdisciplinary Top Master program Nanoscience and the High Tech Systems and Materials Honours Master, which tackles real-life product development challenges in the same interdisciplinary fashion.

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**Not expecting to** outmatch last year's Francken Vrij committee, the edition that you now have in your hands (or in your e-mail) matches the amount of pages of the biggest Francken Vrij ever. Also fun fact: the total amount of pages produced for the Francken Vrij this year equals that of last year. The amount of pages seems to have reached stability, which also happens to be the theme of this edition!

I wish you a lot of fun reading the last Francken Vrij of this academic year with a lot of exceptional pieces!


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# Edition 29.3

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# Chair's preface

By Adriana van Harten

**Dear members,**

Our tumultuous love story finally concludes, the beautiful couple has found… **stability**!

Unfortunately, that means that my prediction of splitting was wrong but at least it's a happier ending. Just like the love story has come to an end, so has my board year. I cannot begin to express my gratitude and love for my fellow board members for making it an unforgettable year. And I think I speak for my entire board when I say that we love all of you members, and without you we wouldn't have had such a great experience.

I must say it's a bit funny, as the theme of the final Francken Vrij this academic year is stability, the association experiences another wave of instability: a new board, old members moving away, and finally a move to Feringa. You read that right, a move to Feringa! But, I will not say more in fear of jinxing it. On a more serious note, to the next board, good luck and I have no doubt

you will all do great, enjoy your time together and savour every moment.

So this is me, signing off my last chair's preface of my board year. Enjoy this edition of the Francken Vrij, and happy reading!

Sincerely,

The President of the 40th board of T.F.V. 'Professor Francken',

Adriana van Harten

# News of the Association

By Gerrit Boonstra

With this academic year almost reaching its end, there are once more a lot of fun activities to look back on! Most notably of course, we went on the foreign excursion, but so much could be said about this that we decided to make it its own column.

**Jam Session with Sirius A**

As in previous years, Fraccie once again partnered up with Sirius A to organize a jam session at Sociëteit de Walrus! I was quite surprised and impressed by the musical abilities of some of our members and, like everyone there, really enjoyed the event.

**Applied Physics dinner**

On the 4th of February we enjoyed a lovely dinner with some researchers of ZIAM. For the first time we organized this in the Feringa building canteen, which is quite a nice location. We enjoyed talking with the professors and of course the delicious food.

**Python workshop with Cover**

Did you know that in some applications, physics can be used to improve the results of AI? This is what we explored in our python workshop, which we organized together with Cover (the study association for

Computing Science and AI). Although the topic was quite interesting, some of the coding went over my head, but I think a lot of people still enjoyed the workshop.

**Tour de Francken**
Sometimes the most difficult part of organising an activity is picking a date, as was the case with this year's installment of the Tour de Francken. After changing the date several times, the Tour finally took place on the 10th of February. Not only were there some very competent teams from Francken participating, there were also several boards of other associations who did not want to miss this infamous event. Some of them performed very well, but in the end our Treasurer team emerged victorious.

**Demcon lunch lecture**
On the 12th of February we enjoyed a nice lecture given by a former secretary of Francken, Lars de Groot, who now works at Demcon. He explained how the company works and what projects they have worked on in the past years. The projects that he pointed out were quite interesting and the talk was well-received.

**Masters jeu de boules**
In February the MScie organized their first event. They went to Boel to play some games of Jeu de Boules with the Master students of Applied Physics and Nanoscience. I heard that they had a great evening and plenty of drinks.

**DNV excursion**
On the 21st of February we enjoyed a visit to DNV, which was not very far away since they are situated on the Zernike campus. We enjoyed talks by several of their employees, among which was former board member Pieter Wolff, who talked about all the projects that he has done at the company. We were quite impressed by the variety of their projects and facilities.

**SPIN Master's Day**
This year the annual SPIN Master's day was organized in Groningen. During this day several programmes related to the field of Physics set up their stalls in the Feringa Atrium to promote themselves to prospective Master students. I enjoyed a lot of interesting conversations with the people there, and I am glad that a lot of people were able to learn about the Master programmes that they might be interested in.

**Sjaars 'smurfs' party**
I must say that the sjaars this year have been rather amazing. After their wonderful Greek dinner, they did not step down their game and organized a great party at Café Tante Truus. There was an epic pubquiz, as well as a *grabbelton* with fun challenges. The event was very lively and the location very cozy. I also like that they stuck to the smurfs theme o their first event. Good job sjaars!

**Klaverjas tournament**
This year's installment of the klaverjas

tournament was casino themed, and participants were encouraged to dress up for it. I was quite surprised how many people actually showed up in suits. For me personally the tournament did not go so well, with my opponents making their pit bid 3 times in the first 4 hands, but it was still a nice evening.

*Rebecca locked in during the tournament*

### Francken Feud

Inspired by the popular TV game-show Family Feud, Borrelcie organized a borrel where attendees had to guess Francken members' most popular answer to a question. The game show aspect worked incredibly well, with Matko dressing up as our very own Steve Harvey, and all the attendees were very excited by the event.

### Francken auction

Continuing the tradition of the annual auction, the board raised 769.91 euros by selling anys, special services and relics from the Francken room! We also voted on what charity to donate this money to and thus we decided that the money will be donated to the Voedselbank in Groningen!

### SHINE borrel lecture

On the 6th of May we organized a borrel lecture together with SHINE, which is a company that intends to pave the way to commercializing fusion technologies. We enjoyed a brief introduction on what steps the company is taking to achieve this goal, after which we had a Q&A session with two employees from the R&D department in America.

### Thriathlon

On the 17th of May, Sportcie organized a triathlon! To make it a little bit easier for the more casual exercisers among us, they allowed the participants to choose one of 3 distances which they would travel by swimming, running and cycling. The weather was quite nice, (although a bit cold for swimming) and the participants had a lot of fun.

### Symposium: conquer the chaos!

On the 20th of May we enjoyed our annual symposium. This year the theme was aerodynamics and for the first time in two years it was held at a new location, namely de Loods. The location was nice and the talks even nicer. We learned about bird-inspired aviation, wind tunnels and the visualization of air flow among other things. It was really an inspiring symposium and I have heard a lot of enthusiasm from the attendees regarding the talks.

**SMART Photonics lunch lecture**

There are quite some companies in the Netherlands which work in the field of photonics. One of these companies, SMART photonics gave a lecture to us about what they do and what role they fulfill in the Dutch photonics industry. It was a nice talk and we also enjoyed a nice lunch.

**Blender workshop**

I bet all of you are wondering how our amazing covers are made. Well, we have a very talented committee member who has been working with Blender for a long time. It is a free, open-source 3d modelling and animation software, but it can be quite tricky to get started with. To help our members along, Bradley gave an introductory workshop where we learned to model and animate a gyroscope! The final result was cooler than I thought would be possible to make in the time we had, and the workshop was easy to follow along with too! Thank you Bradley for the amazing workshop.

*Atmospheric impression of the Symposium*

# Your new board 'Flux'

By Flux

**Chair & Commissionior of Educational Affairs**

**Howzit, fellow Francken** people! ("Howzit" is a South African way of saying hello.)

I'm Emily. If we haven't met yet, I'm probably the shortest person you'll find in the members' room on any given day. I'm currently nearing the end of my second year studying Applied Physics. During my first year, I was more of a non-active active member, but over the past year, I've become more and more involved in Francken life. Now, with the incredible opportunity to serve as a board member, I feel honoured, overjoyed—and just a little bit nervous!

I grew up in warm, sunny Johannesburg. After high school, I spent six months working in a tiny farming village in France before settling here in Groningen. I love watching rugby, though when it comes to playing sports, long-distance running is more my style. I'm also passionate about literature and music, and one of my goals is to learn a few guitar tunes in the members' room before the end of the year. More than anything, I want to give my all to Francken and its mooie (beautiful) members, helping to keep our association the special, welcoming place it is—and hopefully encouraging even more people to join. I'm super excited for what lies ahead and can't wait to see how we grow and evolve together this year.
See you around!

**Secretary & Commissioner of Internal Relations**

Dear reader, I'm Zoli a sjaars from Hungary. if it feels like déjà vu reading my name here; Just a few months ago I wrote my first piece for the Francken Vrij as a newly come first year. If you told me that I'd be introducing myself as the candidate for next year's board, I probably would've laughed.

Yet here I am, excited (and a bit surprised myself) to be running for Secretary and Commissioner of Internal Relations. It's been an unbelievable year, and Francken has played a big part in making Groningen and the university feel like home. That's why I'm so thrilled about being able to give something back and hopefully make the Francken community an even better place. In my role, I hope to bring not just neatly written newsletters and minutes, but also a lot of energy and genuine curiosity about the people around me, through conversations at the coffee machine, and at borrels. I really enjoy being involved in the little things that make this association feel alive.

Love,
Zoli


**Treasurer**
Hello! I'm Emma, at the moment of writing the kandi Treasurer of Francken. I fell for Francken in my first year. Since then you've maybe seen me filling the fridge, making posters, planning an absolutely awesome 3 week SLEF trip (totally unbiased opinion) and maybe occasionally studying.

But a small introduction on me, I'm half-Aussie, half-Dutch but I grew up between Australia and Germany. I started my studies with both Physics and Mathematics, but then decided to drop to only physics as I enjoy approximations too much. I play volleyball in a student team, sail or teach kids to sail when I get the chance as well as love to travel and explore.

I decided to apply for a board year as Francken has been the highlight of my student life. It's been a pleasure getting to know Groningen through the association. As for positions, I applied for the Treasurer role after my experience with SLEF as I really enjoyed being a treasurer. Surprisingly a year of working on a budget wasn't enough for me, so I'm in for another round. Plus I'm the first international kandi Treasurer :)

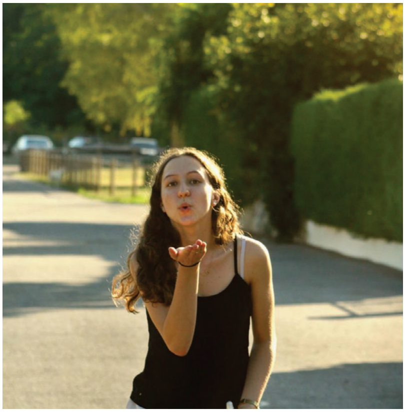
I look forward to next year and having all of you along for the ride

Xoxo Emma

**Commissioner of External Relations & Vice-Chair**

Bonjour! As some of you may know, I have joined Francken in my first year and have been active since. From rietadt to klaverjas, the association has shown me the way of life here. I have greatly enjoyed myself so far and have become kandi Extern this spring! I am very grateful for what Francken has given me, including a boyfriend. I hope to make many more core memories and have an amazing year to come with all of you guys. I am very excited and hope to see you very soon.

Oui oui baguette,
Solène




STABLE?
GEBOUW
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THAT'S
FOR
HORSES

# Corky Lessons on Triple Points

By Prof. Dr. Jeff Th. M. De Hosson

**Back to the seventies: elementary catastrophes**

**The year is** 1975: René Thom, a French mathematician and *Fields* medalist, published a groundbreaking book, titled 'Stabilité structurelle et morphogénèse' [1]. In this work, he introduced a new method for describing sudden changes of *'instability'* caused by gradually changing force fields, marking the birth of what we now call catastrophe theory.

Coincidentally, in the same year that catastrophe theory was gaining attention, I began my postdoctoral studies in the United States, first at Northwestern University in Chicago (*NU*) and then at UC Berkeley in California (*UCB*). In 1976, I had the opportunity to meet Sir Christopher Zeeman at *NU*, a prominent figure among the 'Catastrophe Godfathers' [2] during his lecture tour across the US. Naturally, I immediately purchased Thom's book (*Figure 1*). This significant publication accompanied me on my scientific Odyssey, a long *non-linear* journey I must admit when I returned later to the Universitas Groningana. The influence of this novel mathematics can still be observed in later developments such as bifurcation and chaos theory. During this era, the Math Department at Groningen emerged as an international leader in chaos & bifurcation theory, thanks to my fine colleagues Floris Takens and his successor, Henk Broer.

My fascination with this topic was and still is, that essentially the physical quantities I know of, from quantum to cosmology, are *non-continuous*. For example, 'time' is discrete (see Planck time lapse) rather than continuous and proceeds only because of 'dynamics' and 'changes' around us. It is hard to believe – as Isaac Newton did – that 'time' would be a relevant physical quantity in a completely stationary universe. Sorry to say this, a *nano*-blemish on the escutcheon of our colossal Newton: he was seriously wrong on this one. Nevertheless, in material sciences we often observe discontinuities in materials, e.g. phase transformations, mechanical and functional failures, as a function of time. The burning question is quite obvious: would it still be feasible to describe *instabilities and discontinuities* in physics with *continuous functions* of mathematics?

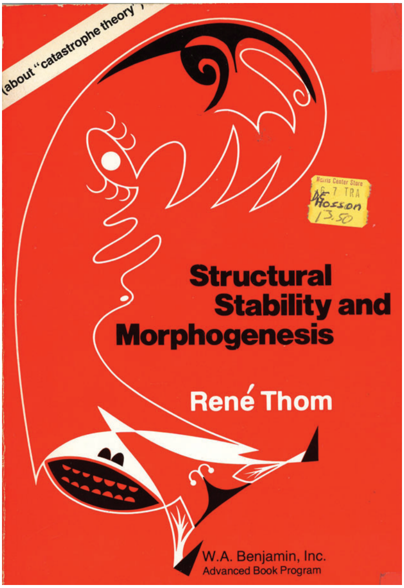


*Figure 1: René Thom, 'Stabilité structurelle et morphogénèse' (translation), 1975.*

René Thom's foundations are based on several theorems describing higher dimensions in geometry. This mathematical approach yields a classification of discontinuities, grouped according to a limited number of basic forms. René Thom calls these different classes 'elementary catastrophes'. One compelling aspect—though it may primarily thrill dedicated mathematicians like the brilliant Vladimir Arnol'd [3]—is that physicists can apply elementary catastrophe theory relatively easily. This is particularly significant since we tend to view ourselves as remarkably intelligent,......... especially in comparison to those immediately around us.

In physics, elementary catastrophe theory, with some thoughts and research, can describe phase transitions in solids, non-Newtonian behavior of polymeric fluids, optical bistability in laser physics, scattering on a crystal lattice, to predict the stability of a ship [1] and even the stability or rather instability of a *'Francken'* student on the Friday afternoon gathering. As regards applications of catastrophe theory, besides physics, there are quite a lot notable

> *"... and even the stability or rather instability of a 'Francken' student"*

examples in biology-medical sciences and social sciences, including management of conflicts, and stock exchange.

Notably, concerning the current geopolitics, and political conflicts politicians are excluded from this discourse in catastrophe literature, most likely due to the lack of proven truth in their field of expertise; it's worth mentioning here that in American-English the word 'truth' comes from 'trust', – not as one might suspect from the word 'thrust' in Wallstreet NY City (although you knew of course that Wallstreet was named for an earthen *wall* built by the Dutch pioneers in 1653).

In this light-hearted contribution, I will branch out from professional math-physics to explore a more relatable topic: the (in) stability of a cork in a wine bottle. Let's begin with a straightforward and perhaps the most appealing aspect of this concept, before delving into more complex ideas. By the end of my discussion, I will generalize Thom's concepts to phase transformations and leave the intrigued *'Francken'* die-hards with open questions as homework— both theoretical and experimental — for your summer break.

## Cork: the wonder material

Cork is an exceptional material with several remarkable qualities. It is lightweight, resilient, chemically stable, and non-flammable. Additionally, cork serves as an excellent thermal and acoustic insulator, effectively reducing heat and noise pollution. It has low diffusivity for gases and liquids—often outperforming even graphene, which is hailed as the wonder material of the century. Cork is also highly elastic, has a low density, and features high porosity when exposed to air. Amazingly, only a very tiny set of materials have remained unchanged for centuries, as cork has.

Plinius [4] – in the currently hyperactive USA #1 syndrome erroneously called Pliny though – writes in 77 AD that cork is used: 'to float fishing nets, to seal bottles and to provide *women's shoes with a sole in winter*'. Incidentally, no mention is made of *men*'s shoes! What's this? No one heard about 'equality equity' in the year of 77AD? More recent novel applications are also noticeable. In fact, the integration of cork in spacecraft and rockets was 'ignited' even so with the successful Apollo XI mission to the moon (and return!), in 1969 [5], see *Figure 2*. All these remarkable properties of cork can be traced back to its specific chemical

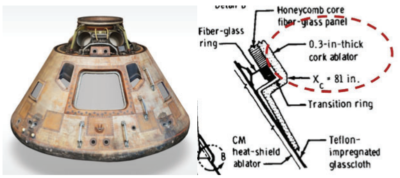


*Figure 2: Apollo XI; left: commander of the first crewed lunar landing & returning to Earth; right: Cork in USA aerospace commander, 1969 [5].*

composition, topology and cellular structure [6].

The Poisson's ratio of cork, which measures the negative ratio of transverse (lateral) strain to parallel strain in loading directions, is very low [6]. This unique property contributes to cork's numerous applications beyond its common use as a wine-stopper. As said cork is widely used in flooring and wall materials due to its excellent thermal and acoustic insulation but it is also found in various consumer goods such as decorations, footwear, furnishings, and bags, as well as in the automotive and the aforementioned aerospace industries, among others. Currently, global cork production exceeds 300,000 to 350,000 metric tons per year, which is roughly equivalent in volume to nearly 20 million metric tons of steel. Similar applications can be seen in composites made of elastomeric particles embedded in resin [7].

However, when these elastomeric materials like cork are exposed to sunlight, the surface reveals rapid aging due to the effect of UV radiation. Not that long ago, i.e. recently on the time scale of the Universe in 2022, I worked with Diego Martínez-Martínez, one of my top-of-the-top former PhD students and postdocs in Groningana, to protect cork, as an example of a cellular elastomeric material by the deposition of a UV-blocking protective film. It is with pleasure and pride to confirm that we wrote a very fine, first paper in the literature about depositing a protective thin film on a cellular elastomeric material, specifically cork, see [7], but I will avoid discussing that topic for now.

**The cork on the bottle: an engineering physics solution**

A property that will be most familiar to students in daily (?) life is the cork on top of a bottle of wine. The microstructure of cork can be regarded as a cellular structure with a specific density of 0.15 (average density 170 kg/m$^3$) and built up of hexagonal prismatic cells (see *Figure 3*).

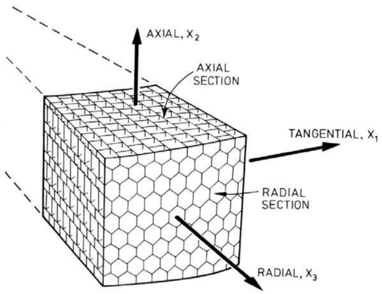


*Figure 3: Diagram of cork around the cork tree; radial direction $x_3$ is perpendicular to the axis of the tree (parallel to $x_2$), whereas $x_1$ is tangential along the circumference of the cork tree [6].*

If I am not mistaken, the term 'cell' was for the first time coined by Robert Hooke and Anthoni (van) Leeuwenhoek when investigating cork with their microscopes.

Due to the kind of 2D-honeycomb structure of the cells in cork, compression along the prismatic axis produces almost no lateral expansion, i.e. the Poisson's ratios are negligibly small ($\upsilon_{13}=\upsilon_{31}=\upsilon_{23}=\upsilon_{32}\approx 0$). Moreover, the modulus of elasticity is isotropic in the plane perpendicular to this radial axis, *Figure 3*. If you were asked to design a suitable cork for a bottle of wine, you would therefore choose the axis of the cork parallel to the symmetry axis of the hexagonal prismatic structure; the cork goes out with ease and goes back in, just as easily! Here, any multiaxial stress condition is tacitly and conveniently ignored.

But subsequently, a problem arises for the expert wine taster. After all, the channels along the axis of the cork offer a possibility of contact with the outside air via the elongated cells, which makes the wine susceptible to spoilage. A cheap solution is to take the axis of the cork wine-stopper perpendicular to the prismatic axis direction. However, then it becomes more difficult to get the cork out of the bottle and also very tedious to bring it back in again. The best 'engineering physics' solution, which is only applied to the more expensive wines, is to make use of the elastic anisotropy of cork by creating a composite: at the bottom of the cork a section in which the axis of the elongated cells lies parallel to the axis of the cork and on top of that a separate section in which the axes are mutually perpendicular to each other or disorderly (isotropic) arranged. You can get the cork out fairly easily and also you may seal the bottle rather well afterward, *Figure 4*.


*Figure 4: the engineer's solution of corks in practical service (left: wine stopper ; right: Champagne) .*

**Instability: Let's keep it simple**

In reality, cell walls (Figure 3) of cork are not perfectly straight as displayed but show corrugations. Under compression, these walls will warp and also buckle. *Figure 5* depicts SEM (scanning electron microscopy) images of cross-sections of cork taken in the past with MK, at stages of a compressive load, showing the phenomena of the corrugations and instabilities, like buckling, respectively.

Failure of these cellular structures under mechanical loading in compression occurs by bending, not by crack propagation through the cell walls; corrugations may play an important role in the local failure mechanism. Let's keep it relatively simple

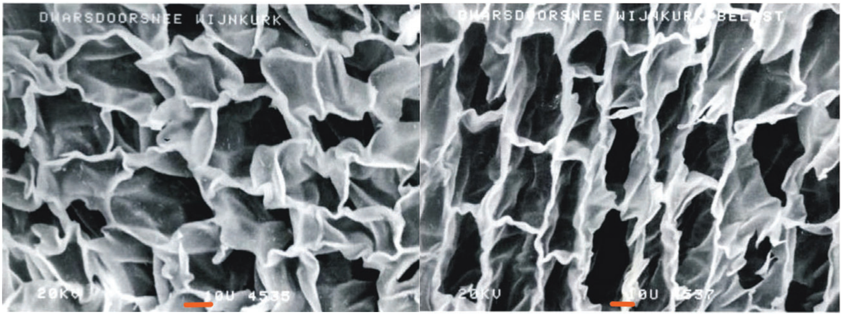


*Figure 5: MK scanning electron microscopy of cross-sections of wine-stopper cork showing cell wall corrugations and buckling; left: low compression; right: severe compression. Orange marker: 10 micrometers.*

and imagine a cell wall as a strut or a plate that is subjected to a load α in compression along, say a vertical plane and let's measure the displacements perpendicular to the plate (say in x) . After a certain critical load $\alpha_c$ the plane starts to buckle becoming like an arch. If $\alpha_c$ is now fixed and a gradually increasing load, β is exerted perpendicular to the arc, then the arc will support the load till a critical load $\beta_c$ is reached. At $\beta_c$ it suddenly snaps catastrophically into the horizontal direction, -x, perpendicular to the strut/plate (e.g. due to the bottleneck or other correlations in the microstructure, corrugations, etc). After $\alpha_c$ and subsequent $\beta_c$ the cell wall looks like a distorted sinusoidal.

The total mechanical energy as a function of the deflection x of the cell wall describing buckling and snapping obeys the mathematical form [1-3]:

$$V(x) \propto \frac{1}{4}x^4 - \frac{1}{2}\alpha x^2 + \beta x \qquad (1)$$

The 'equilibrium' (in)stability – i.e. force field $V' = \frac{\partial V}{\partial x} = 0$ – is a cubic equation in x. As we all know, the precise nature of the roots of this cubic equation depends on the discriminant D; for example, if D<0 we have three real roots but if D>0 only *one real* and *two complex* conjugates exist. Geometrically, this means that the nature of the roots, and therefore the stability in V(x), depends on the values of α and β in the discriminant, $D = 27\beta^2 - 4\alpha^2$.

This is illustrated in *Figure 6* for the (α,β) plane, the so-called catastrophe map C. In area I there are three real roots of V′=0 (D<0) but in E only one (D>0). In R all three roots coincide, while on the dividing bifurcation lines, of the three real roots, two are identical. The complicated behavior of the energy function $V(x)$ as a function of the deflection x in Eq.(1), is displayed through the surface of a smooth manifold M of V′=0, a cusp Manifold M, together

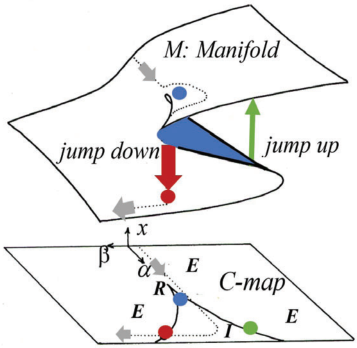


*Figure 6: The manifold* M *represents the* V'=0 *equilibrium surface of stability and instability situations of* $V_x$ *in* x,α,β *space. In the example of cork, the blue dot (top) around the cusp refers to the cellular wall when buckling first into an arc shape by loading , followed by snapping due to a transverse loading at the red dot on* M *and located on the bifurcation splitting line between* I *and* E *on the* C*-map. Please note the 'mirrored' bifurcation point at the green dot on the* C*-map represents a jump in the opposite direction on the manifold* M *compared to the red dot on the* C*-map!*

with its projection onto the α-β space (Figure 6) in the C-map. The blue-shaded area of the manifold M corresponds to a folded manifold. The unstable equilibria lie exclusively 'inside' this folded M, i.e. nowhere else outside the folded area!

When you ask yourself about 'stability', which is the topical theme of our present *Franck&Vrij* periodical, we may conclude: as regard dynamics, one stable equilibrium of V(x) appears in the parameter space E, whereas in the parameter space I, with three real roots in V', one unstable and two stable equilibria show up in $V(x)$, i.e. one maximum and two minima. The cusp point is mathematically more delicate since the first three derivatives of $V(x) = \frac{1}{4}x^4$ are all zero , i.e. not only the first derivative like in E and I. The point R of the cusp is given by V'''=0 and the winding line around by V''=0 as the manifold M is smooth everywhere! It follows that in the present case, the cell wall in the cellular cork buckles first at β=0 to an arc under a critical (parallel) loading as the splitting factor at the cusp point of $\alpha_c = \mu\left(\frac{\pi}{\lambda}\right)^2$, where λ is the length and μ represents the flexibility of the wall or strut. In fact the wall buckles first and the shape becomes a sine-curve, up to second order (i.e. first Fourier coefficient). Then the cell wall supports still an increasing (transverse) load of β followed by snapping at the red dot at $\beta_c$. An interesting outcome of this exercise is that the answer $\alpha_c$ is precisely Euler's expression in 1744 for the instability [8]!

This typical example is the so-called second catastrophe, out of seven and not more than seven elementary catastrophes, the so-called *'cusp'* catastrophe. Actually, it was called Riemann-Hugoniot by René Thom, i.e. not named *cusp*, which was introduced later by Sir Christopher Zeeman [2]. It is fair to say that the very first physicist – at least to my knowledge – to observe the *'cusp'* in the buckling problem of Leonhard Euler was Max Born [9] in 1906 , Nobel Prize Physics 1954, preceded one year earlier by the Nobel Prize to Frits Zernike.

Other catastrophes in Thom's classification listen to melodious names such as: *fold, swallowtail, butterfly* and *hyperbolic-, elliptic-,* and *parabolic umbilics*.

**Phase transitions: van der Waals and beyond**

Phase transformations play a central role in materials science & engineering, in which we reserve explicitly the term *'phase transition'* when a 1$^{st}$ order transformation is at stake; 1$^{st}$ order means, discontinuities in the first derivative of the thermodynamic potential with respect to a thermodynamic state variable, Paul Ehrenfest (Leiden, 1927). A classical example, everyone (in Holland) should be familiar with, is the famous van der Waals equation (1873), published for the first time in his PhD thesis, written in Dutch!:

$$\left(P + \frac{\alpha}{\nu^2}\right)(\nu - b) = RT \qquad (2)$$

with P and T the usual suspects and v = molar volume. I will skip the physical arguments put forward by van der Waals to this Eq.(2) – a revision of the ideal gas law of Boyle – since no one now believes they are correct. Nevertheless, an essential breakthrough in 1873 was the insight that gas particles / atoms should be considered being of a certain volume (not points) that are interacting with each other. These insights were formulated by van der Waals before Ludwig Boltzmann's contributions to statistical thermodynamics were made, and indeed the latter presented the correct physical picture. Fair to say that in van der Waals' PhD thesis, the word *spinode* was introduced in classical thermodynamics for the very first time, which made a big impact much later in material sciences through the use of *spinodal decompositions* in metallic systems.

It is not so difficult to see that van der Waals' Eq.(2) near the critical point (vapor-liquid, *Figure 7*) can be recast into:

$$x^3 + \left(\frac{1}{3}\right)(8t + p)x + \left(\frac{1}{3}\right)(8t - 2p) = 0 \quad (3)$$

replacing volume v with density $(x \propto \frac{1}{v})$ and p, t are taken normalized to the corresponding values at the critical point, i.e. $p = \frac{P}{P_c}$ and $t = \frac{T}{T_c}$. Eq.(3) is exactly the form of a catastrophe cusp surface $V' = \frac{\partial V}{\partial x} = 0$ of Eq.(1), with the critical point at R in *Figure 6*. Is this really shocking? No, not in particular, since the phenomenon near a critical point stands for the transition from one single phase to one other: i.e. vaporization of liquid vapor, or condensation of vapor liquid.

Besides the *critical point*, more intriguing to me is the *triple point* that appears in the phase diagram through the P-T cross-section at constant volume (*Figure 7*), where all three phases of solid-liquid-vapor seem to coincide in one singular point. Please note in P-T (at constant V) we distinguish a *triple point* as well as a *critical point*. The diagram suggests that starting from one particular single phase, with one

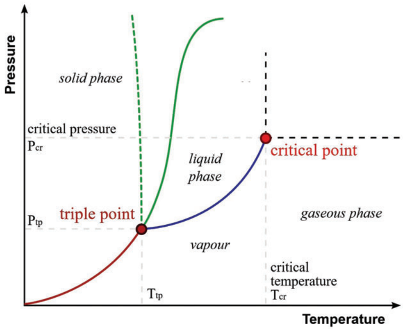


*Figure 7: P-T phase diagram (dashed green line refers to anomalous behavior of water) showing a* triple point *as well as a* critical point *(adapted from [10]).*

minimum, one could enter at constant volume directly into a phase point with three minima, i.e. defining a triple point.
For sure, it is not similar to a simple cusp catastrophe, where two stable minima and one unstable maximum converge into a single stable minimum point. Therefore, I have investigated (mathematically) the 'dynamics' around this triple point using all the catastrophes put forward by René Thom, i.e. employing the fairly complicated functions of *swallowtail, butterfly* and *hyperbolic / elliptic / parabolic umbilics*. To my enthusiasm, excitement & disappointment, sadness, dismay, whatever you like to name it, the answer is negative! Intrinsically that excursion turned out to be *impossible.*

A summary of what I discovered using the 'elementary catastrophes' is the following: as soon as you approach the *triple point* out of *a single phase somewhere in the* P-T at constant V , the parameter space in any of Thom's mathematical catastrophes around the triple point opens up smoothly, like unfolding a small envelope with a tiny dual phase area (which makes sense). Subsequently, you can proceed from a single to a dual and then from the dual-phase to the triple phase. But, never – mathematically within the set of the seven catastrophes – you can transit directly from a single phase into a triple point *with bypassing* a dual-phase area. It leads to my simple, delicate and provocative statement for today: *from a mathematical stability dynamics viewpoint singular triple points in a phase diagram do not exist!* An escape route is to broaden each of the two-phase border lines in *Figure 7* (red, green, blue) at constant V so as to illustrate the existence of a miscibility/spinodal gap of a dual phase area that terminates at a triple-phase area. However, that would imply in general that the transitions around the triple point for all generic cases become phase transformations of 2$^{nd}$ order, i.e. not all of them would execute phase transitions of 1$^{st}$ order in pure systems, which is hard to believe true.

It is noteworthy that in textbooks triple points in phase diagrams result only from *energy considerations*, i.e. based on the coexistence of phases in thermodynamic equilibrium. That is a '*static*' treatment of the problem. It does not say anything about the *dynamics* of how to reach from a nearby singular one-phase that particular

triple point at constant V. In other words, the thermodynamic equilibrium description does not give you the full physical picture as it does not involve the derivative of energy - i.e. dynamics based on force fields. In fact it should be considered rather as a neat, but at the same time an imaginary idealization.
Yes of course, my considerations are all based on a mathematical analysis but what about the physical reasoning for the dynamical behavior? If you think about it: triple points bear 'imaginary simplifications' of the physics behind them. Indeed, these exotic points appear in phase diagrams of pure systems but also in more complicated ones of phase transitions in multiple component systems, e.g. in ferroelectrics such as susceptibility vs. temperature. My intuition says that the stability *in reality* of so-called apparent triple points is likely affected at T>>0 by *statistical fluctuations* contributing to a local unfolding of the 'imaginary' triple point/line area, resembling a sort of set of spinodes (van der Waals!) in a dual-phase region. Herewith, I conclude that a well-determined *triple point* at constant V cannot be maintained in complex systems.

Homework:

- from a mathematical viewpoint: design a revised catastrophe theory of René Thom that describes correctly triple points in P-T physical phase diagrams;
- an even more challenging homework exercise from a physics viewpoint: show experimentally that the appearance of so-called apparent triple points depend critically on statistical fluctuations in P-V-T.

**Cork exists and triple points do not**

My conclusions read as follows:

- This contribution aims to show that *instabilities and discontinuities* in examples of mechanics ('buckling'), and physics (phase transitions etc.), can be described using *continuous mathematical functions*. René Thom's mathematical catastrophe theory offers an interesting starting point for this, as is shown by a practical example of uncorking the bottle of wine and $1^{st}$ order phase transitions in classical thermodynamics.
- In addition, some advanced *cork surgery* may offer insights into the quality of a wine bottle's contents. Notice the (an)isotropy of the pattern in cross-section (transverse & longitudinal). A cellular pattern that alternates between perpendicular and parallel cells points to a higher-quality wine.
- For the more cautious researchers among us, the advice is to consider the transverse contraction Poisson's ratio. If the cork returns smoothly into the bottle, the content is suspect. Then, switch to uncorking the (n+1)-bottle of wine, or if you consider catastrophe theory too crispy dry, order a super-duper cold beer!
- The overall conclusion is that during

the *'Francken'* drinks on Friday afternoon, it is no longer necessary to *pre-taste* the wine to assess its quality. Instead, a brief check of the cork will suffice. Please do not sniff the cork like some snooty waiters do; instead, take the time to explore the cross-section of the cork thoroughly.

- Finally, it is concluded that at the *'Francken' Meet & Greet* parties, even in the most dormant thermodynamic state of dreaming—where one stares and mulls over the scene while uncorking bottles of wine—it becomes clear that triple points do not exist in real space.

  All textbooks must be revised, with courtesy to *Franck&Vrij*, by replacing the term 'triple points' with 'finite triple areas'. This revision will emphasize the intriguing dynamics of apparent first-order phase transitions.

Enjoy your summer break and……
please keep stable!

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# To those who have FOMO from SLEF:

By Joel Alexander de Haan Sánchez

**Partaking in a** SLEF trip was a life experience for many. Organising one was a whole other thing. The trip began on April 12th, but this story should begin on the 18th of March 2024. This marks the first official meeting of SLEF with 3 sjaars and 3 old board members, deliberating about possible locations; indeed a group that would soon connect very well. 38 (Christian's board number ;) ) meetings flew by, and then, at our 39th (David and Liz's board number ;) ) meeting: 'SLEF HAS STARTED!!!'. Indeed, as we were all congregating in Schiphol, we realised that this trip that bore so many emotions for the board was not a figment of our imaginations, but now a tangible event.

As the plane landed in Ho Chi Minh, the excitement of all of us flooded the cabin to form an almost palpable atmosphere. Had it not been for our tiredness, most of us would have ran out of that airport faster than some of the planes taking off. Only one issue: the 1.5 hours long passport control… To mitigate possible jet lag it was decided that we would go to the famous war museum on the first day there. We were confronted with a lot of harsh images of the war and its aftermath which affects Vietnam to this day. The day after, we started with our visit to Intel. Most of us were strained due to the heat of wearing suits. This proved to be a challenge during the HUTECH visit later that day, as we had a 45-minute long campus tour in the heat. The day after we went to HCMUT, to hear about laser acupuncture. This was, to be brief, definitely one of the more interesting experiences of this trip… The last visit in Ho Chi Minh was HCMUS, which was a very positive surprise to all the participants, as the university and students presented themselves very enthusiastically and professionally. Unfortunately, we had to cut this visit short as we had to rush to the airport that day.

*Figure 1: Lovely dinner at a hot pot place in Vietnam*

Upon arrival in Bangkok, we were all relieved that the airport was far easier than in Vietnam as it was late in the evening. All participants slept soundly yet shortly as soon as we touched the hotel beds. The day after, we went to Chulalongkorn, a very pretty university with good academics. Had it not been for our flight delay and bad sleep, the struggle to keep our eyes open would have been less. The weekend came around while still in Bangkok, prompting us to explore the city's Palace and the Jim Thompson house. Then, after a long weekend of more 'tourist stuff', we visited SIIT, where we learnt a bit of the Thai language and about the analysis of materials.

Note that most Buixies are finished by the time we landed in Kuala Lumpur, but for us, there was still loads of fun to come. After barely any sleep, a mess up with breakfast times, and the first time using public transport; we arrived to Malaya University to meet Prof. Yap. We had to take a 1-hour bus ride with some of the Malaya students to visit the nuclear facility of the country, which had monkeys running around it. In this nuclear facility, we were surprised to see Cherenkov radiation and a fishing rod. Having not had enough group pictures, we met Prof. Yap the day after to visit her plasma research institute (PTRC). This visit ended with a panel discussion where Christian, David, and Dennis presented on our university. To close off the Kuala Lumpur adventure we visited the science museum in the iconic Twin Towers followed by the embassy's King's day reception, a big party where we got to speak with many Dutch people, including the IBR (Groningen) students and others from Maastricht.

Finally, we arrived in Singapore, where some smokers among us suffered losses at border control. Our visit to JCS took place the day after our arrival and we had a presentation on their projects in Singapore. The day after, we visited NUS, a top 20 university, and it did not take long to see


*Figure 2: SLEF '25 board at the National University of Singapore*

why. Thinking it would be hard to outmatch NUS, we visited NTU, which was as pretty as it was impressive. There they gave us plates with the RUG and the Francken logo which can already be found in the members room.

Now, I am back. I write this from my bed as I reminisce on the many stories and memories I have made. I have heard many 'Back in my day' stories in Francken; this will definitely be mine. I hope to stay friends with my board and all the people I connected with on this trip, and to let this memory never be forgotten.

# Metamaterials: How Breaking Material Stability Enables Unusual Mechanics

By Anastasiia Krushynska

**The term *stability*** has many definitions and is widely used as a property of machine learning algorithms, as a quality factor for the solutions of differential (systems of) equations, as the resistance of structures to buckling, as a measure of the turbulence in the ambient atmosphere, as a chemical compound or fluid dynamics condition, and so on. In this column, I want to draw your attention to a less obvious yet key role of stability in the fundamental mechanical properties of materials.

As you know, the mechanical behavior of most materials and objects around us can be considered elastic, provided small loadings or deformations are applied. It means that a piece of material or an object returns to its original form spontaneously after its shape or volume were changed. For instance, a metal spring elongates along the stretching direction, or a foam ball is compressed underwater. These behaviors are very familiar to us. In other words, we do not expect other behaviors in the described situations.

If we look deeper into the mechanics of materials, we can discover that the reasons behind such behaviors rely on the assumption of a material's *stability.*

Let us consider, for instance, the first mentioned example: the stretching of a metal spring. We assume that the length of the spring and spring constant is fixed at one end and pulled at the other end by a constant force $F_P$. If the force is applied slowly so that kinetic energy can be neglected and eventual energy losses in the material can be ignored, the work done by the force $F_P$ in extending the spring by displacement is fully spent to increase the internal energy of the spring. Then, assuming that this energy is positive definite, the stiffness must be positive.

One can ask why, actually, the internal energy should be positive definite? The answer brings us to the second law of thermodynamics that governs the principle of minimum energy [1] . This principle states that for a closed system, with constant external parameters and entropy, the internal energy will approach a minimum value at equilibrium. Reformulating it to our case, we can state that the undeformed spring, which is stable in an initial configuration, should have its minimum energy equal to 0 as there is no initial deformation. Upon loading, the internal energy of the spring can only increase restricting spring constant to positive values.

If the spring is replaced by a metal bar, similar arguments can be used to show that Young's modulus of the bar's constituent material can only be positive. Furthermore, due to the same reasons, the bulk modulus governing the behavior of the objects in the second example with the foam ball must also be positive. This explains our expectations, based on everyday experiences, about the behavior of different objects or materials under simple loadings.

Despite the fundamental nature of the derived limits on the elasticity moduli to be positive definite (who will argue with the laws of thermodynamics?!), it appears to be not impossible to go around these restrictions and develop materials with negative stiffness, negative bulk modulus, or even negative mass density. If so, such materials should contract along the stretching direction, expand under hydrostatic pressure, or move in the direction opposite to that of the applied force! This contradicts our experience and expectations about material's behavior.

Because of their counterintuitive properties, such materials belong to so-called mechanical metamaterials – materials with a precisely engineered microstructure that enables unusual properties or functionalities [2, 3, 4] . Apart from being mind-blowing examples of materials "breaking" conventional bounds on material behavior, mechanical metamaterials have promising and far-reaching prospects for multiple applications [5, 6] . Therefore, it is worth learning about the governing mechanisms behind achieving negative values of the elasticity moduli.

**Negative stiffness**

In our first example with the metal spring, a negative stiffness can be obtained by "redefining" the minimum energy state, i.e., preparing a spring with stored energy and considering this state as initial. The spring can, for instance, be pre-stressed. Prestress means the process of introducing initial stresses in a material or structure before subjecting it to loading or deformation, which enables achieving negative values for the spring constant. Note that the pre-stressed spring is unstable and, thus, one needs to find a way to stabilize it.

Taking this into account, we conclude that the mechanical behavior of the constrained pre-stressed spring does not violate the laws of thermodynamics and the principle of minimum energy but gives us a possibility

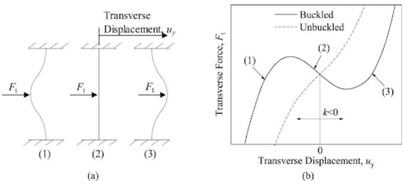


*Figure 1. The beam buckling process: (a) different transition states; (b) force-displacement relationship. Here states (1) and (3) represent the bistable states of the beam, while state (2) indicates an unstable equilibrium, where the beam can hold its configuration without external lateral force and any small disturbance can push it to one of the stable states, due to the release of restored energy (from [8]).*

to "relax" the definition of positive-definite strain energy and thus extend the bounds on the stiffness modulus.

If the idea of pre-stressed spring is transferred to the realm of materials, we have a way to develop materials with a negative elastic modulus in the form of composites with constrained inclusions, which have stored strain energy in their initial state [7] . It can be achieved through buckling or instabilities of slender flexible elements - flexible ribs, tubes, or membranes (Fig. 1a).

The buckling of prestressed elements results in the negative slope in the force-displacement curve, which describes snapping from one state to another under force control and, thus, the change between unstable and stable states. As can be seen in Fig. 1b, the structural stiffness in the vicinity of the unstable equilibrium (2) is negative. Imagine that a composite comprises multiple such slender elements that can buckle. If these elements undergo the unstable-stable change of states being physically constrained by a surrounding matrix, the negative-stiffness effect can be stabilized. One obtains a stable composite comprising a negative-stiffness inclusion phase in a positive-stiffness matrix. Examples of such materials are given in Fig. 2.

The amount of negative stiffness stabilized in this way is insufficient to result in extreme overall properties of the composite under static conditions. However, its effective dynamic properties can indeed reach extreme levels in the presence of stabilized negative-stiffness elements [9] .

If one interchanges the material parts with positive and negative stiffness parallel to the applied load, the overall material stiffness can be made small, which is very useful in vibration insulation systems, where compliant support is beneficial [10, 8] . Alternatively, if the same material is rotated by 90 degrees, i.e., oriented perpendicularly to the applied load, the overall material

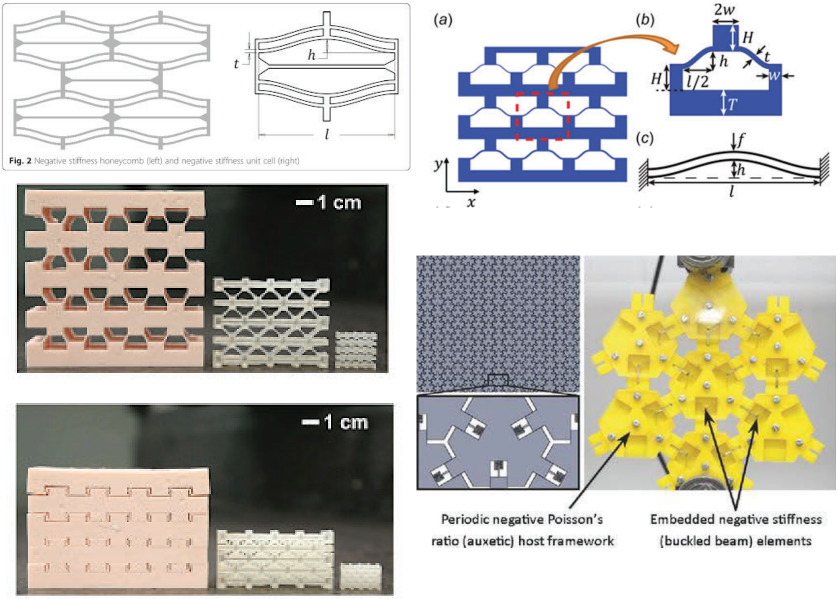


*Figure 2. Top-left: Negative stiffness honeycomb and its unit cell (from [12]); top-right: multistable mechanical metamaterials with negative stiffness and a deterministic deformation sequence (from [13]); bottom-left: negative stiffness metamaterial for trapping elastic energy (from [14]); bottom-right: double-negative mechanical metamaterials with simultaneous negative stiffness and negative Poisson's ratio (from [15]).*

stiffness can be made large, though at the stability limit. Such configurations near the stability limit can be used for attaining extremely high mechanical damping [11] .

Furthermore, an appropriately tuned negative-stiffness phase can produce advanced damping, thermal expansion, piezoelectricity[1], and pyroelectricity[2] far exceeding all standard bounds, opening fascinating possibilities for negative-stiffness materials in real-world scenarios [16] .

### Negative bulk modulus and mass density

After the discovery of the first negative-stiffness mechanical metamaterials, there emerged multiple examples of materials with other negative moduli. For instance, an epoxy matrix with arrays of bubble-contained water spheres and rubber-coated

[1] Piezoelectricity is the electric charge that accumulates in certain solid materials.

[2] Pyroelectricity is a property of certain crystals that allows them to generate a temporary voltage when heated or cooled.

gold spheres was shown to exhibit monopolar resonances of bubble-contained water spheres giving rise to a negative bulk modulus, while the dipolar resonances of rubber-coated gold spheres resulted in the negative mass density. This was the first solid-based material with simultaneous negative bulk modulus and mass density in the dynamic excitation regime [17] . Similar behavior with double negative properties can be achieved using a chiral microstructure shown in Fig. 3.

The most prominent phenomenon related to double-negative metamaterials is negative refraction. For dynamic excitation, negative refraction can be demonstrated through unusual refraction of sound waves. For this, the unit cells shown in Fig. 3b are tessellated to form a 30.0° wedged sample, which is placed, e.g., in water. Figure 4 illustrates that a Gaussian acoustic pressure beam of central frequency 14.53 kHz launched from the bottom, after going through the wedge, propagates as a refraction wave on the negative refraction side of the surface normal in the range of the double-negative pass band. Upon closer observation of the wave pattern of the hy-

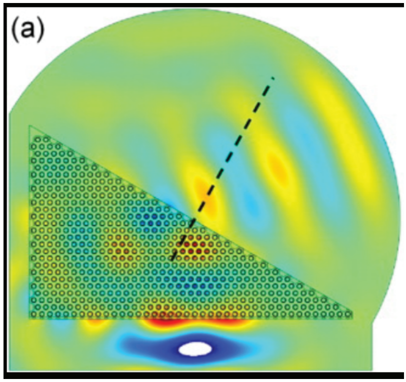


*Figure 4. Negative refraction: the intensity of pressure field in fluids and hydrostatic stress in solids for incidence and refraction are shown in different colors for Right-sloped wedge at 14.53 kHz (from [18]).*

drostatic stress field inside the solid wedge, the "back-wave" phenomenon inside the

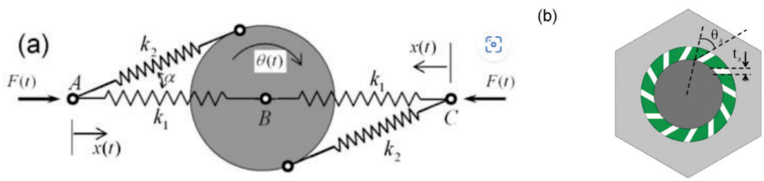


*Figure 3. Metamaterial with negative bulk modulus and mass density: (a) 1D representative mass-spring model; (b) the unit cell of the 2D metamaterial made from solid media. The unit cell is composed of three-component continuum media by a chirally soft-coated heavy cylinder core embedded in matrix (from [18]).*

metamaterial can be seen [18] .

To conclude, we have shown that negative elasticity moduli are forbidden based on energy arguments related to stability. It is, however, possible to expand these bounds by relaxing assumptions used to derive them. For example, one can change the initial state of a material, which should not necessarily be a minimum energy state. Stored energy corresponding to this new non-minimum energy state can be introduced by pre-stress, instabilities, or unstable state, in which material phases are constrained. Combining positive and negative definite material phases enables achieving negative effective values for the elasticity moduli of composite materials, which can be stable and even obtain extreme or unusual behavior (e.g., negative refraction) that allows metamaterial response.

This column provides a few examples of first metamaterials with negative stiffness and bulk modulus, which have inspired a vast bulk of research on metamaterials. If you want to know more about this exciting field, you can read multiple review papers, e.g. [2, 4, 5, 3] , to name a few, or join the Metamechanics group for your B.Sc. or M.Sc. research project.

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# Francken Abroad

By Lilly-Anne Kalderén

**Hej*! My name** is Lilly-Anne Kalderén, some of you might know me as Freefalls' extern! After spending 4.5 years in Groningen, I moved to Stockholm for the semester to do my thesis. Being half Swedish, I wanted to spend some time living here. Thanks to my board year, some extra courses and an injury, I had some extra flexibility and decided this was the perfect opportunity to explore my Swedish side and practice my Swedish. Spoiler alert: most of my friends aren't Swedish.

I joined the Quantum Nano Photonics group at KTH, but the project I'm working on is a bit different. As a part of a larger project, they want to use Near Infrared Spectroscopy (NIRS) to measure changes in blood oxygenation in the brain, which shows which parts of the brain are active, which is what I'm working on!

NIRS looks at the absorption spectra of oxygenated and deoxygenated hemoglobin in the 700-950nm range, because in this region, light is not heavily absorbed by the skin or water compared to hemoglobins. I am helping to assemble the setup and am testing the technology on the arm to see if it works and how to get results. The arm is simpler than the brain and measuring changes in muscle oxygenation is easier than measuring changes in blood oxygenation in the brain. We are applying a modified version of the Beer–Lambert Law using two wavelengths, which allows us to find the changes in the concentrations of oxygenated and deoxygenated hemoglobin, and thus calculate the overall change in blood oxygenation based on the known absorption spectra of hemoglobins. The setup works, however the data found contains a lot of noise. This noise includes changes in oxygenation occurring in blood flowing through the skin and other biological processes, so the next step is to try to filter that out!

Life here is great! I am 5-10 minutes away from the lab and 10-15 minutes away from the city center while still surrounded by nature, the best of both worlds! I've

*Hej means Hello in Swedish

started going on runs through the woods and along the water, and (like every twenty-something year old lately). I've convinced myself to train for a half marathon (TBD if I actually do it). I've made great friends, many of whom I met during a sauna night at KTH. Since sitting in a room with 15-20 people gets a bit smelly and is not super glamorous, we hang out in other places like the chapter pubs (same idea as a study association), student corridors, brunch, etc.

Student life here is the same but different than in NL, there are the strange traditions: every Tuesday at 10pm on the student campus people scream out their windows, it's terrifying the first time you experience it and don't expect it. They have chapters which are similar to study associations. Each chapter has their own color overalls covered in patches. You can earn patches by completing tasks or drinking certain drinks. Apparently the electrical engineering pub has a drink that will literally shock you, something which I haven't tried yet, but have to before I leave. They each have their own bar and like the Dutch study associations they all have their own vibe and plan random events. The chapter pubs are also, as far as I know, the only bars where you can get a drink for a 'normal' price. Alcohol is expensive and you can only get it at a bar or Systembolaget, which is run by the government and has very strict and limiting opening hours. However, the student pubs are usually open for everyone, so on Friday evenings we have a drink or two at a chapter pub.

I've integrated nicely in some ways! I take every opportunity to fika (a coffee break with a pastry) and have found the best kanelbulle (typical Swedish cinnamon roll) in the country. Laundry, however, is an event. You need to book a time slot for your laundry, these are hard to get and if you miss it you're waiting a few days until you can do laundry. These are precious and people will plan their lives around their laundry slot. I've definitely checked this box, just ask my parents about when they came to visit. However, in other ways I haven't integrated as well: The stereotypes that Swedish people are a bit more reserved and dress without much color are definitely true, but I have not adapted yet. Maybe if I stay for my masters, who knows!

People complain about the darkness and the cold, but since I arrived in February, I missed a lot of the darkness and the winter was unusually warm. Fortunately, I still got to experience real winter during a week in a place northwest of Stockholm, where I went cross-country skiing and saw the northern lights. Cross-country skiing was one of the coolest and most physically demanding things I've ever done. Luckily, we were rewarded with waffles in a very cozy hut that could only be reached by snowmobile or skis!

Aside from this trip and a weekend to Gothenburg, I spend most of my weekends enjoying Stockholm with friends and family. I can't wait for the weather to get nicer to enjoy the archipelago and the long days!

I'm incredibly grateful for the support I got from the KIVI Stichting Studie Reisfonds, which has allowed me to grow both academically and personally during my time in Stockholm. If you're ever looking to go abroad check out the KIVI Stichting Studie Reisfonds or send me a message for more information!

Hej då**!

**Hej då means Bye in Swedish (These were Ikea references iykyk)

BRADLEY'S WEEK

# LUST & RUM

AUGUST 4-8

## MONDAY

### CUPID'S ARROW

WILL YOUR ARROW SOAR BEYOND THE REST OR FALL SHORT WHEN IT MATTERS MOST?

## TUESDAY

### PLUNDER PURSUIT

YOU'LL NEED CUNNING, SPEED, AND A TOUCH OF MADNESS TO TAKE WHAT'S HIS.

## WEDNESDAY

### GLUTTON'S GAUNTLET

FLAVORS DECEIVE, TIME SLIPS. WILL YOU RISE TO THE FEAST OR CHOKE ON THE CHALLENGE?

## THURSDAY

### DRUNKEN ALCHEMY

FORGE THE ULTIMATE CONCOCTION. OUTLAST THE REST, BUT BEWARE THE PRICE OF POWER.

## FRIDAY

### 7 DEADLY SINS

DON YOUR GUISE,
EMBRACE THE NIGHT.
THIS ISN'T A PARTY
IT'S A MASQUERADE OF SIN.

# Brains, machines, and the symbols of thought

By Madison Coteret

**Modern artificial intelligence** is undeniably impressive. Large language models (LLMs) like GPT-4 can pass complex exams, write poetry, and even offer reasonable takes on personal dilemmas. Yet these computational marvels, consuming megawatts of power and fed the sum total of textual information known to man, fail miserably at tasks even small animals find trivial. A human child can effortlessly navigate a crowded room, climb stairs, or kick a ball, while robots — though meticulously designed by very clever people — still haven't got the hang of walking or opening a bag of crisps. The spotlight of inquisition thus turns to the squishy, million-year-old elephant in the room: how do biological brains handle such real-world complexity so efficiently, and can we engineer machines to match these capabilities?

## Be more brain

Biological brains perform astounding computations on a power budget of approximately 20 watts, less than a typical desk lamp. Neuromorphic computing aims to match the computational capabilities and efficiency of the brain by — wait for it — designing hardware and computational paradigms inspired by the principles and architecture of the brain itself. Unlike in conventional digital computers built from binary logic gates and the like, neuromorphic hardware uses networks of time-continuous neurons, mimicking the dynamics of their biological counterparts, that communicate with each-other through discrete unary pulses, called *spikes*.

The most common (and simple) model of biological spiking neuron dynamics is the leaky integrate-and-fire (LIF) neuron

$$\frac{\mathrm{d}u_i}{\mathrm{d}t} = -\frac{u_i}{\tau_m} + \sum_{j=1}^{N} w_{ij} \sum_{\text{spks } k} \delta(t - t_j^k) \quad \text{for} \quad u_i < u_\theta$$

where $\mathbf{u_i}$ is the neuron's membrane potential (broadly speaking, its state), $\boldsymbol{\tau}_\mathbf{m}$ its time constant, and the sums are performed over the spikes produced by all presynaptic neurons $\mathbf{j}$ at times $\mathbf{k}$, with synaptic weight $\mathbf{w}_{ij}$. When $\mathbf{u}_i$ exceeds the threshold $\mathbf{u}_\theta$, the neuron produces its own spike, which is communicated to all its downstream postsynaptic neurons, after which the membrane potential is reset to some subthreshold value.

These dynamics — though simplified compared to biology — contrast with the neurons used in traditional artificial neural networks (ANNs), which abstract the rich dynamics of biological neurons simply to a matrix multiplication and a nonlinearity. Spiking neurons are intrinsically temporal, and so well-suited for processing data in the real world. Crucially, they can also be compactly emulated by capacitive electronic circuits to physically realise these dynamics in silicon.

## But there is a catch

While digital computation is built on engineered layers of abstractions — transistors forming logic gates, gates forming memory and arithmetic, forming processors etc., neuromorphic systems currently lack such a set of clearly defined building blocks. Combined with the fact that neuromorphic hardware elements exhibit traditionally-undesired characteristics such as device-to-device variability and stochastic dynamics, it is a not-insignificant challenge to answer how a large number of these elements could cooperate to realise useful function. Said otherwise, how can we reliably "program" large-scale neuromorphic systems composed of inherently unreliable components?

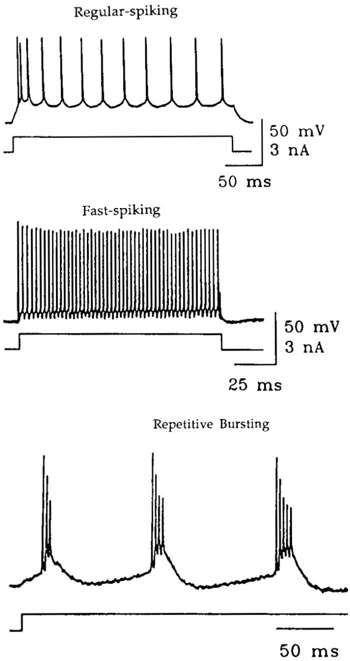


*Figure 1. The diverse dynamics of biological neurons in response to a step input. Point-like, unary signals are produced and sent to the neuron's friends whenever its membrane potential shoots upwards (the neuron spikes). How might this be used for computation? How do you get from here to monkey? What does a burst represent? We don't know, to be honest. Figure from Churchland & Sejnowski, The Computational Brain.*

**Symbols, not synapses**

A core tenet of my research is that approaches starting with low-level considerations like ``how should we wire neuron A to neuron B'' are not up to the task. The complexity quickly explodes, and the outcome will surely not be easily generalisable. Backpropagation-based training methods, for other reasons, are also not entirely satisfactory. An alternate approach is to consider possible theoretical abstractions of large neural systems, which are flexible enough to support diverse forms of computation, but which can easily be compiled into a neural representation. Vector-symbolic architectures (VSAs) offer precisely that.

VSAs represent symbols, concepts and relationships as random vectors in extremely high-dimensional spaces (and is thus somewhat grandiosely known to the yanks as *hyperdimensional computing*). Imagine a hypercube in 10,000 dimensional {-1,1} space, say. Each corner of the hypercube is a potential vector representing a distinct concept or idea. In such vast spaces, distances between vectors behave counterintuitively. Almost all of the space is approximately equidistant from a given vector, halfway across the space. Said otherwise, if a vector were represented by the north pole, and its inverse by the south pole, then practically every other vector would live very close to the equator. Any deviations from the equator can thus be used to convey meaning between two symbols, as it is astronomically unlikely to have occurred by chance, despite the vectors having been randomly generated.

One can then define a field-like algebra using these vectors, allowing arbitrarily-complex symbolic structures to be represented. For example, to construct a key-value data structure representing that ``Paris is the capital of France'', one could construct the vector:

$$\mathbf{data} = \mathbf{cap} \circ \mathbf{paris} + \mathbf{entry} \circ \mathbf{fra}$$

where the vectors on the right hand side are each randomly generated, representing their labelled concepts, and $\circ$ is a *binding* operation, which forms a vector representing the conjunction of the two symbols. For bipolar vectors, it is conveniently just an element-wise multiplication operation. While graciously skimming over very important details, if one wanted to retrieve information from our **data** vector, such as the capital city of France, one would *unbind* the **cap** vector from **data**, giving:

$$\mathbf{data} \circ^{-1} \mathbf{cap} = \mathbf{paris} + \\ + \mathbf{cap} \circ^{-1} \mathbf{entry} \circ \mathbf{fra}$$

which, due to the rightmost triple-product being mostly nonsense, will be very closely aligned to the **paris** vector, answering our query. Although this isn't a particularly compelling example, by combining random vectors in this way we can construct vectors to represent arbitrary symbolic data structures, such as graphs, images, or algorithms. Since the result of these operations is always another high-dimensional vector, then they can always be represented by a population of neurons of fixed dimension, where each index of the vector is represented by one neuron. By providing a link between high-level symbolic data structures, and low-level neural representation, they may just provide the elusive abstraction layer that neuromorphic systems so require.

### Neurons and magnets

What remains is to explain how these representations can be used to embed symbolic computational structures into spiking neuromorphic hardware. For this, we turn to attractor networks, one of the most famous being the Hopfield model, which controversially won the Nobel prize for Physics this year. Hopfield models generalise the Ising model of ferromagnetism, to allow all-to-all interactions between neurons, with arbitrary weights, rather than just nearest neighbour interactions. Then, instead of an energy landscape consisting only of two attractor states (all spins up, all spins down), we are free to place energy minima and thus stable attractor states at locations of our choosing.

We're now ready for our first party trick. Finite-state machines (FSMs) are a fundamental symbolic computational primitive underlying modern computing. An FSM consists of a set of states, inputs, and a rule book describing which transitions between states should occur for each input. To go from a high-level symbolic FSM to a robust neural implementation, we turn to our newfound vector-symbolic friends. Each state becomes a random vector, as does each input symbol. We can then construct an attractor network with minima at our chosen states and which has the correct transition dynamics, then transfer the network to neuromorphic hardware in a fairly headache-free manner. Moreover, we can implement the same FSM on different neuromorphic hardware platforms, whether they be spiking, analogue, or memristive,

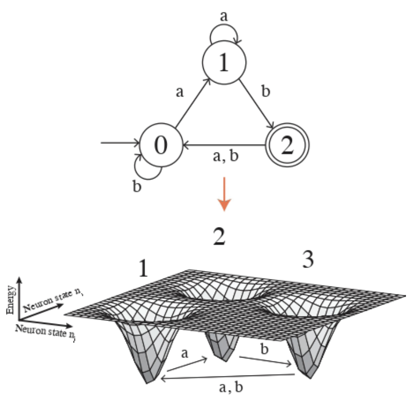


*Figure 2. Rather than training the weights of a spiking neural network, we can directly translate a symbolic structure (e.g. an FSM, above) into an attractor neural network (be-*

with little regard for what the underlying neural representations look like in each case. Much like how a block of iron will remain magnetised up to its Curie temperature, so too will these networks continue to properly function up to a certain level of stochasticity. In addition, because the symbolic information is distributed across all neurons and synapses equally, the system is not dependent upon the correct function of any individual component. If you just heard something, it was the collective breath of relief from neuromorphic hardware designers everywhere.

**Thinking on time and space**

Discrete computation is not everything. Many survival-critical tasks require computation with continuous variables, such as spatial navigation, evidence accumulation, or sensorimotor integration. In the hippocampal formation, for example, we've measured cells whose activity definitively represents one's position in space, forming a natural basis for spatial reasoning and cognition.

Extending our approach to continuous structures is as simple as replacing the independent random vectors with smoothly parametrised (but still-kinda-random) vectors, and storing those in an attractor network instead. Instead of embedding arbitrary FSMs, we can then embed arbitrary manifolds with whatever topology one so desires, such as spheres, tori, or Möbius strips if you're feeling spicy. Rather than jumping between discrete states, the system can then evolve smoothly across the manifold in response to input, enabling arbitrary vector fields to be *programmed* onto the manifold surface.

If a computational neuroscientist or neuromorphic engineer dreams up a new neural manifold to explain or perform some behaviour, then instead of going back to the drawing board to figure out which neurons should be wired together and how, they can directly translate their symbolic desires into a robust attractor-based neural implementation.

**The symbols of thought**

VSAs thus offer a powerful bridge between symbolic computational structures and their neural implementations, allowing us to program large spiking neural systems from a high level of abstraction. However, we have only begun to explore what is possible. The inability of conventional AI systems to represent compositional knowledge structures is thought to underlie their inability to generalise learned behaviours to new contexts. VSAs were conceived with this so-called *binding problem* in mind, and are thus positioned as a compelling solution to enabling AI systems with "true" general reasoning capabilities. Sitting at the intersection of computational neuroscience, dynamical systems, computer science and AI, the study of VSAs and neuromorphic computing may thus be key to enabling AI systems with the machinery and representational capacity necessary for the next great breakthrough in our understanding of intelligence, and the creation of artificial systems matching the capabilities, performance and efficiency of the human brain.

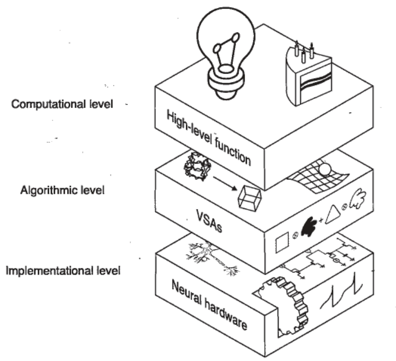


*Figure 3. VSAs as the glue between high-level function and low-level neural implementation.*

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*[4] Kleyko, D. et al. "Vector symbolic architectures as a computing framework for emerging hardware". Proceedings of the IEEE (2022).*

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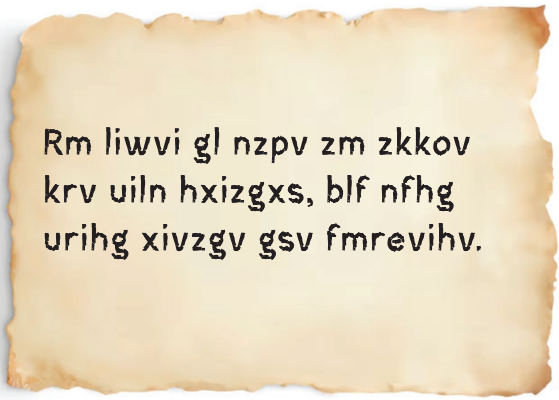
# Puzzle

By Omar Gutierrez Laafou & Hannelys Posthumus

Attention! Bob has disappeared and we don't know anything about his location. Please, help us decipher this note he left behind, it might lead us to Bob's location.

To solve the puzzle solve this cypher and return the sentence with a clue for us to find the location! Send your guess to franckenvrij@professorfrancken.nl.




*Solution to previous edition's puzzle:*
***The cat is dead***
***Long live the cat***

# In the shadows of chaos

By Tania Ovramenko

**We go about** our everyday life comforted by the idea of stability. It brings control, a feeling of safety and predictability. Bridges are built to be stable, planets are moving in stable orbits, stable algorithms are key in many fields, and, of course, we cannot exist without a stable power grid. What exactly does "stable system" mean?

Stability usually refers to how a system responds to small perturbations. When a system is stable it means that after a disturbance it will return to an equilibrium state. For example, a marble in a well, the system can be slightly perturbed but the marble will always return to the equilibrium state at the lowest point of the well – small perturbations do not spiral out of control. In contrast, the system is said to be unstable when these small deviations grow over time. That same marble, but on top of a hill, will roll down even with a slightest nudge. A small deviation, loss of structure, leads to instability, chaotic behavior in such systems. But what if order and chaos are not that different from each other? What if both of them are just two sides of one coin? Chaos theory can help us answer this question.

At a first glance you might think that chaos theory is about disorder, which is not wrong, but does not encapsulate the magic behind it. This theory is all about sensitivity, about how in the basis of some dynamic system there lies a set of deterministic rules which are so complex and tangled that the system appears random. That's where the concept of stability is really questioned: what does it actually mean for the system to be stable and can it ever be complete if chaos arises from order.

Everyone knows what a "butterfly effect" is, but not where it actually came from. Edward Lorenz was a meteorologist who was working on simulations to predict the weather up to a few minutes in advance (the computational power of the best computers in 1961 was only that good). He found that the tiniest differences in the initial conditions, such as 1/1000, led to drastically different forecast results. Lorenz made the famous analogy of a butterfly flapping its wings and causing a formation of a tornado in a different part of the world. It might seem like an exaggeration but really it is just the inevitable consequence of nonlinear dynamics.

Chaos, though it seems like it, is not random at all. Randomness lacks structure. Chaotic systems are unpredictable in the long run, but they do follow very intricate and strict patterns and remain deterministic. This is the main reason why they can be modeled and analyzed but never fully tamed.

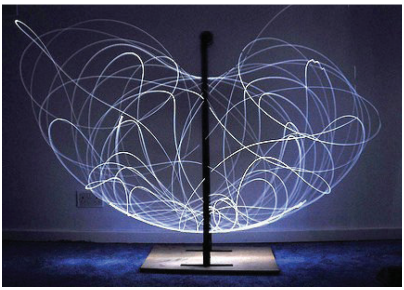


*Figure 1: a long-exposure trace of a real-world double-pendulum [1]*

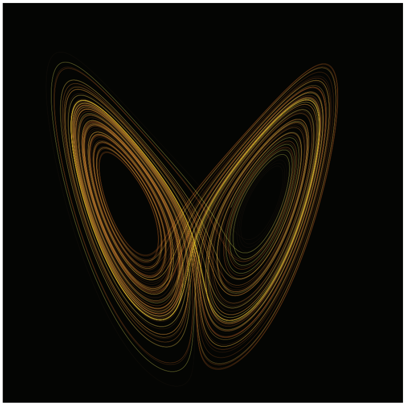


*Figure 2: the Lorenz Attractor [2]*

Some systems live on the edge between chaos and order. Although simple, the double pendulum system can transition from very smooth motions to wild swings by a slightest change in energy. Lorenz attractor clearly demonstrates this phenomena. It is a set of just 3 coupled nonlinear differential equations. The solutions to these do not spiral into one point like a stable system would or fly off to infinity as in unstable one. Instead they form an attractor, non-repeating structure with a clear boundary which slightly resembles a butterfly. Isn't it some sort of a beautiful portrait of chaotic stability?

We see chaos in physical systems all the time. Fluid dynamics is a great example, from the weather overhead to the fluids we study in the lab, chaotic behaviour is fundamental in our world. Turbulence is one of the most complex phenomena we are dealing with daily in various spheres of our lives. Despite that, there are ways to make it tangible for our understanding and further study.

To analyze such behaviours, Lyapunov exponents are often used. This characteristic measures how rapidly infinitesimally close trajectories in phase space of the system diverge. Each point in this space represents a possible state of the system (includes basic most important variables such as position and momentum, etc.). Then the system evolves over time and trajectories are traced in this space. Starting from two points that are very close to each other, each of them will trace their own path. If the system is chaotic, these paths diverge exponentially over time even though the system is deterministic. The Lyapunov exponent is basically the measure of this divergence rate.

We have long accepted that chaos is unavoidable, especially in real-world systems which are nonlinear. For decades, mathematicians and physicists, statisticians and engineers have learned how to control chaos. A method known as OGY (Ott–Grebogi–Yorke) control stabilizes chaotic systems by applying very small and precisely timed perturbations. It pushes the system to the desired stable trajectory. This was a major breakthrough at the time because it showed that chaos can be manipulated, it does not have to be suppressed to be able to work with it. Revolutionary!

From thinking that chaos means falling apart to finding a hidden order within, we started designing systems that can withstand disturbances and allow a degree of chaos to persist. It makes them flexible, responsive and resilient. We learned how to play with chaotic behaviour without losing the functionality, yet keeping it very adaptive. The perfect balance of something that seemed untameable not that long ago! True stability does not come from rigidity, but from a system's ability to embrace disturbance without losing its structure.

## References

*1. Wikipedia: https://en.wikipedia.org/wiki/File:DPLE.jpg*
*2. Wikipedia: https://en.wikipedia.org/wiki/File:Lorenz_attractor_yb.svg*

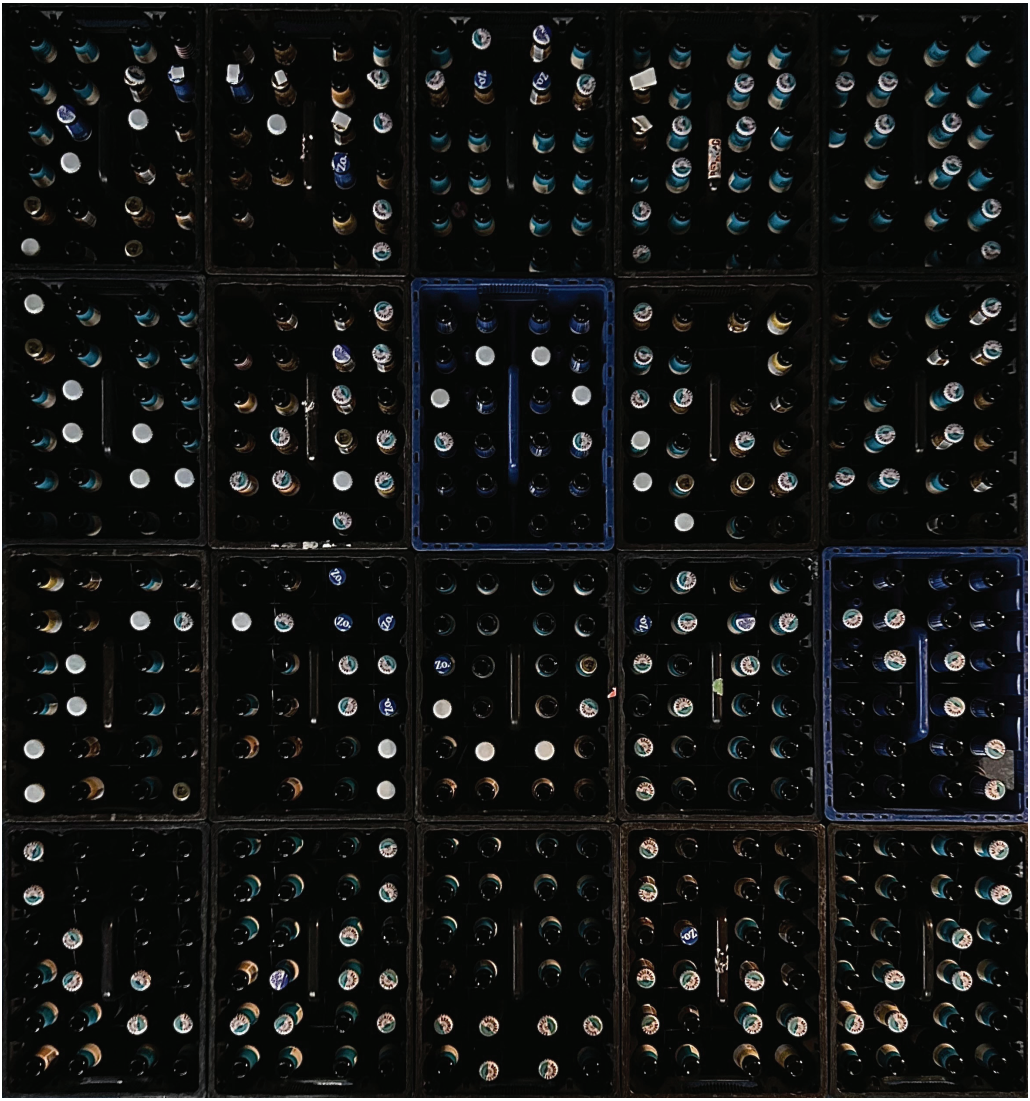
# Photo competition

By Matko Majstorović

As the winner of the Fotocie competition, I was asked to write a little something for the Francken Vrij. I think this photo really captures the spirit of Francken—because, in the end, we actually drank all those beers ourselves. It's a snapshot of the fun we had together: singing songs, playing Kalashnicup, and just enjoying the moment.

I want to give a special thanks to Filippo and Ian—they helped me come up with the idea and set everything up. In the end, it turned out even better than I imagined. Filippo was encouraging me to submit something on the very last day the submissions were open. After he said "Man, dots are all around us, these beers for example…" that really locked me in. It took me, and later Ian, about two and a half hours to get everything just right, and I finally got the perfect effect.

I'm really happy I won, and I want to give one last thank you to everyone at Francken. Because in one way or another, everyone played a part in the making of this picture.



# Physics of Ice Skating

By Hannelys Posthumus

**When I was** five years old, I stood on ice with easygliders for the first time[1], but to say I skated is a bit too bold to say. Since we lived only twenty meters away from the natural skating rink in my village, I could walk there over our ditch and skate everyday when the weather was cold enough, and so I did. I progressed, and two years later, when I was seven, I already did skating tours on the lakes and rivers of Friesland[2]. Skating was always enjoyable for me, and for an amateur, I was quite an okay skater. Hence, when I moved to Groningen, I decided to join Tjas so I could enjoy long track speed skating even more and get better at it.

To be able to be a good skater, you need a lot of stability. There is an optimal angle and timing to place your blades on the ice to get the maximum power out of your stroke. You have to stay low because of aerodynamics, place your hip outward, keep your hands behind your back, don't move your upper body too much, and so on… Next to your own technique, the quality of skates is also quite important to be a faster skater. To skate faster and smoother, your skates need to be sharpened, rounded and ideally you have clap skates, so the blades are in contact with the ice for a bit longer, meaning your take-off is a few hundreds of seconds longer. Also, to have better contact with the ice, you need skates with no damping. When you buy them, they ideally are formed to your feet after the leather shoe is put in the oven and you put your skate shoes on your bare feet, and they should be laced tightly (you have to get used to slightly hurting feet). In this article, I want to go into more detail in some of the physics (not all, then I could probably fill 39 pages of this Francken Vrij ;)), but let's first talk about some history of speed skating!

It was no less than 5000 years ago that Scandinavians tied unsharpened 'skates', made of bone, to their shoes. The early 'modern' skates started emerging around the twelfth century when, not surprisingly, the Dutch started to forge and sharpen iron, mount it onto wooden blades that were tieable to the shoe (so basically the predecessor of easygliders) [1]. Initially, skates were only used as a way of transporting oneself over frozen rivers and lakes, but they quickly

[1]https://www.youtube.com/watch?v=COGKUznKcoo

[2]https://www.youtube.com/watch?v=COvxxJ36RvA

became something people enjoyed doing during the winter. Before long, competitions were held to see who could skate the fastest. In fact, the first Elfstedentocht[3] was probably held in 1760. Three years later, the first known men's speed skating contest was held in England [2], and the first known women's competition was held only 42 years later, in 1805 in Friesland, with over 10.000 spectators [3]: quite remarkable given that first-wave feminism started only 65 years later!

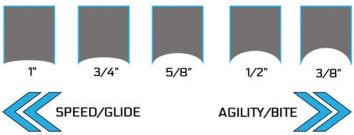



*Figure 1: From left to right: flat to hollow ground blades. Flat is used for speed skating, and hollow for ice hockey and figure skating [4].*

**Sharpening and rounding your skates**

There are two main types of sharpening your skate blades: hollow ground and flat ground (see figure 1). Whereas ice hockey skates and figure skates are sharpened hollow ground, speed skates are sharpened flat ground. The former is because this allows the skater to turn and stop more aggressively, but it also makes the skates more sensitive to turning and stopping. Hence, for speed skating this is less optimal, since speed skaters make long, smooth strikes and when they turn, the radius of the turn is usually way bigger. Compared to hollow ground skates, flat ground skates also have less resistance with the ice (they don't 'bite' into the ice), allowing the skater to be more speedy [5].

Skates are also rounded. This allows the skater to turn at all. As mentioned before, figure skaters and ice hockey skaters need to turn more aggressively. If you never took skating lessons, you might think that speed skaters don't turn at all during their strikes (of course they turn *themselves* when they go through the bend of the ice rink, but that doesn't necessarily mean the *skates* do). Actually, this is not the case. On the straight end of the ice rink, a skater should turn through the whole strike to get the most power out of it[4]. The rounding radius (figure 2) should be bigger for speed skates. This allows the skater to have more stability while being so speedy, and it also allows more contact with the ice to take-off power and force (see section below).

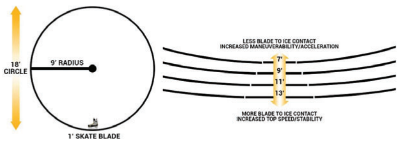



*Figure 2: The rounding radius of a skate, with the respective characteristics [6].*

[3]Famous 200 km skating tour that passes through all eleven cities of Friesland.

[4]Video demonstration of how a top skater subtly bends through a strike: https://www.youtube.com/watch?v=mi9bcc_w-Tw

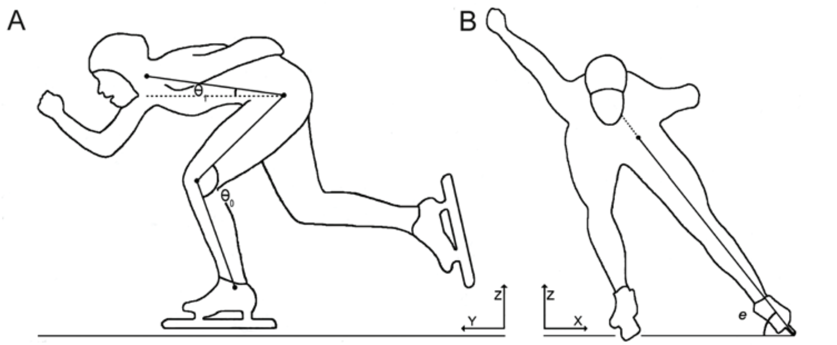



*Figure 3: Kinematic characteristics of the speed skating technique. (A) Preextension knee angle ($\theta_0$) and trunk angle ($\theta_l$) in the y–z plane. (B) Take-off angle (e) in the x–z plane [8].*

## Skating technique

So, you want to be a better skater? Then you need to improve your technique. Luckily you have a physics background, so you roughly know what to take into account.

### *Take-off*

Around 80% of the resistance in speed skating is due to the air, and 20% is due to the ice. We want to counteract this resistance, and possibly even reduce it. The first part is your take-off, so placing your blade on the ice and pushing on it sideways with your skates, causing you to go forward. It won't surprise you that you have to push perpendicularly to your skates to get the most force out of it (you can use some trigonometry if you aren't convinced), and thus go faster. Ideally, you have clap skates, so your take-off is effectively extended. But beware: If your skate is clapping too hard this is a bad sign. It means that you are not taking off perpendicularly to your blade, but with the front point. If this happens, this is probably the result of bad posture.

### *Posture is important!*

To reduce air resistance, the frontal area should be minimized. This means that your upper body should be horizontal, and on top of that you should sit low. Sitting lower also opens up another advantage: it allows your take-off angle (angle between the blade and the ice just before the end of the take-off, see figure 3) to become smaller, which means you get a longer take-off distance and thus a higher take-off force. Sitting lower also means that you will feel your glutes all the time. But when you train for long enough, you will actually have them.

To keep your stability, your shoulders should be relaxed and your upper body should not move too much: keep your abs tight! In the beginning it may feel a bit uncomfortable, but it also helps to keep your hands behind your back. And a very specific thing that really helped me for my stability: when you switch your take-off foot, don't lift the other foot too high, otherwise it's harder to balance [7].

There is probably a lot more to discuss, but I think these are the most fundamental parts. If you want to discuss more, you can always approach me in the Francken room!

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*Figure 4: Jutta Leerdam competing the 1000 m at the world championships in 2024. - Picture by Peter de Jong/AP*

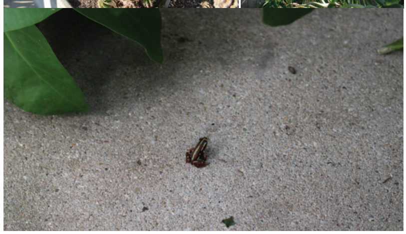
# Bob's Adventures

By Malo Blömker

A bustling train rattled through the frozen fields of Flevoland. Our story's protagonist, had departed from the frosty north of Groningen early that morning, embarking on a noble mission: to journey deep into the heart of the vastly inferior university town of Leiden. Luckily Bob wasn't alone, by his side was Francken's finest committee.

After a surprisingly swift and slightly sleepy journey, we arrived in the dense urban web of the Randstad. Our first task... cannons! Looking at them, sitting on them, I don't think an explanation as to why is required. They are scattered all throughout the city and are a symbol associated with the failed siege of Leiden.

With cannon curiosity satisfied, we proceeded to meander through the city, slowly approaching the hortus botanicus.
Yes, we went to look at plants. Yes, we went "wauuuw". You would have too, just look at these spiky cacti.
The spiky plants are cool, but it was in the tropical greenhouse where things took a surreal turn. There, Bob stumbled upon a mythical creature. A small, green, creature. One may refer to it as a frog. In a moment of pure cosmic connection, the two became friends. The frog's name is Bob, it's backwards for Bob.



That was an intense amount of flora for one afternoon, especially for Tania, who gracefully collapsed onto a bench for a moment of existential reflection. What she pondered about, no one knows. Perhaps the ethics of baby-eating?
But don't be fooled. This wasn't just a trip of frogs, foliage and baby consumption. There were many further educational benefits too. At the Rijksmuseum Boerhaave, Bob admired Einstein's iconic general relativity equation and encountered the cutest Tuberculosis known to man, it was far too adorable to be an evil bacteria.


Now that was a packed day. As the sky put on a display of colours and Leiden's ancient buildings cast longshadows, the committee wandered through the twinkling streets. Tired, curious, and a little wiser, we admired the architecture at night fall and made our way back to the station.

# Addicted to stability

By Sep Epema

**Stability is necessary** in every part of life. Without it, you'd fall while walking. Without financial stability, your freedom is limited. And without emotional stability, happiness can collapse with a single push. But this column isn't about the importance of stability, we all know it matters. Instead, it's about something more uncomfortable: the quiet danger of too much stability.

Because as strange as it sounds, I believe that the constant (and often unconscious) pursuit of stability, especially social and mental stability, can make us fragile. It can trap us in a carefully constructed bubble, where change feels threatening and difference feels wrong.

You're walking across campus, heading to the same lecture as yesterday. Your study mate cracks a few jokes about the lecturer, you laugh. During the break, you get coffee from the same machine as always and chat about politics, music, your courses, or last Friday night. After the lecture, you stop by the study association room to play a game of klaverjas or chess with a friend. On the way, you pass two students; perfect center partings, one in a Ralph Lauren shirt, the other in a New Amsterdam tee, walking toward the economics building. Typical economics students, you think. You can't imagine how anyone would prefer economics over physics. Later, in the Francken room, you joke about how physics is way harder than economics. Your friends laugh and agree. After some self-study, you bike home. A group on fat bikes in training gear passes by. Silently, almost instinctively, you start listing reasons why they're losers.

You don't feel the need to talk to people who look or think differently than you and you embrace those who share your interests, your habits, your worldview. You draw in what aligns with you and push away what doesn't. And in doing so, you keep yourself stable.

When you're constantly surrounded by people who think and act like you, you'll get constant confirmation that most of your own thoughts and actions are the right ones. That feels safe. But over time, your perspective starts to harden. You stop challenging your views, not out of stubbornness, but because nothing around you really demands it. Your world becomes smaller, more fixed and in that way more stable. And eventually, you don't just seek stability. You depend on it. You become addicted to it.

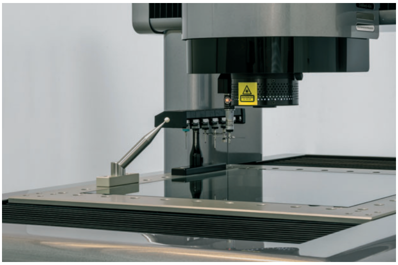
And in a way, this is a good thing. You enjoy being around people who are on the same page, who you can talk to easily, laugh with, and understand without much effort. Surrounding yourself with like-minded people brings comfort, ease, and often real joy. These can be some of the best years of your life, precisely because you're not constantly navigating big differences in how you think or act.

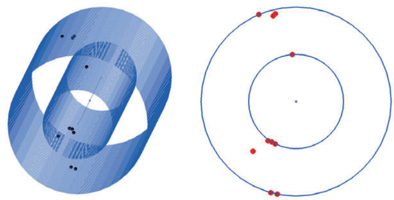
But while this kind of stability offers short-term happiness, it comes with serious long-term risks. The more you isolate yourself within this safe, familiar circle, the more you begin to depend on it. You get addicted to the stability it brings and when that stability suddenly disappears, whether because you move to a new city, start a new job, or lose a key relationship, your balance can collapse. Not because you didn't have support, but because the tightrope you were walking on was narrow to begin with.

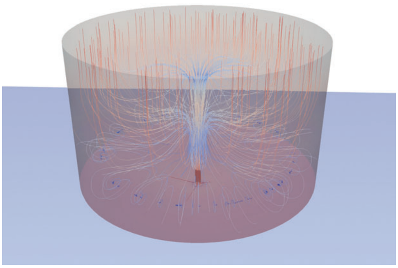
You may have had people holding you steady on that narrow line, but the line itself was never broad or resilient. And if you suddenly find yourself surrounded by people with different views, it can feel like an attack. Because if their perspective makes sense, even just a little, it forces you to question the beliefs you were once so sure of. It challenges the thoughts that shaped your actions, your identity, maybe even your sense of morality. That's a deeply uncomfortable place to be.

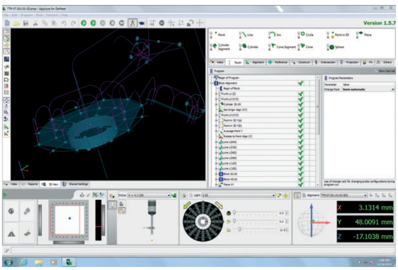
So, to avoid that discomfort, we often default to assuming those who disagree with us must be wrong. It's a defense mechanism. But once you reach the point where you're no longer able to learn from people outside your bubble, your so-called stability becomes rigid. You're not standing strong, you're just stuck, glued to your narrow little platform, afraid to look down or step off.

So the next time you're on campus, talk to the people you normally wouldn't if you get the chance. Go look at the study association of economics. Maybe join a football club, start working somewhere where different kinds of people work or join Vindicat. So you'll end up having conversations with people outside your usual circle. And maybe most importantly: stop going to the Francken room too often ;). That way, instead of gluing yourself to a small platform, you'll start expanding it. Because real stability, I think, only exists when you can move without falling down.









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