Periodiek

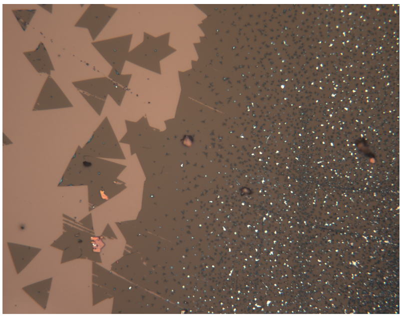
Recurring at regular intervals Issue 2025-1

Perio Interview: Catherine Rigollet - 8

Long time readers of the Periodiek will remember Cathetine's "Ramblings and Tribulations" from issue 2021-2. In this issue, we interviewed Cathetine and got answers to important questions about teaching, France, and aliens.

16 - Flatlands Unfolded

Living in the Netherlands, we might think we are very familiar with the "flatlands" but when the ZIAM zooms in to the atomic level, they can study truly flat materials. Doing this opens the door to fascinating and unexpected physics.



Shape Composition - 28

Learn a bit more about drawing with Rick's explanation of Shape Composition, an integral part of making (character) illustration. If you want to see more of what he makes, you can see it here.

Want to have your own art/hobby/contribution in the next periodiek? Send us a mail!

In this Periodiek

From the Editor in Chief

This issue, we're happy to have curated a healthy balance of Physics and Mathematical articles as well as an interesting history piece as an exchange with GHD Ubbo Emmius' Ubdate. We also share our favourite (and second favourite) submissions for the writing competition. Thank you to everyone for you submissions, we enjoyed reading all of them.

We also welcome two new faces to the Periodiek, Qianyi and Luci are our two new enthusiastic editors.

For the more artistically inclined among us, there is plenty to read about shape composition and the art of illustrating Mathematics, which you might recognise from the previous FMF Symposium.

Robert Mol

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From the Board
Commissioner of Internal Affairs

AUTHOR: **Y. SAVOVA**

Hi, guys, I am Yoana, and I commission some internal affairs as part of the 66th board of the FMF. If you have not had the pleasure of meeting me yet, maybe you should consider joining a committee or several committees to increase your chances exponentially. It is this magical opportunity to pursue your interests, make friends for life, follow your dreams, or something like that. If any of that sounds appealing to you, hit me up.

But that is beside the point. So what do I do, you might ask if you have not yet become acquainted with all the FMF lore. In that case, you can probably find me staring at our internal events calendar for an excessive amount of time, bothering the university reception desks on the daily, randomly appearing in committee group chats, and running around with a bunch of posters under my arm - living my best life, to summarise. Luckily, I get to do it with pretty cool people around me, and the end result tends to be successful if I dare say so myself. But to put it short and clear, my job as a commissioner of internal affairs is committees and events.

When I am not doing the abovementioned activities, you can probably find me somewhere at uni pretending to study. I am currently in my third year of BSc Physics, somewhere between the Particle and Nano tracks, with some CS courses sprinkled for funsies (my minor). I am originally from Bulgaria, made the slightly spontaneous decision to study physics here, and I have not regretted it so far, so we roll. My plans for the future tend to be pretty vague, mostly because I am very indecisive and interested in quite a few areas of physics.

"Despite my utter lack of coordination, I am a pretty sporty person."

When I'm not crying over my code, I'm pretty good at just wasting time, but I'm doing my best to stop that and actually do things I enjoy. I love reading and wish I had been more consistent with it since coming to university, so please talk to me about books as motivation. I like a variety of genres, but fantasy will always have a special place in my heart. Despite my utter lack of coordination, I am a pretty sporty person. I usually resort to the basics - running and gym, although I love trying different sports. I can admit that I have definitely given in to the bouldering hype in this country. I also really enjoy cooking, but what I love even more is baking.

Figure 1: Yoana, sunburned

To be honest, I kind of dreaded writing this piece for quite a while before actually starting, but now, after I am done, I am pretty happy that I had the opportunity to. If you have stuck to the end, thank you for reading! Make sure to say hi if you swing by the room and catch me there. Sometimes I even like to socialize with people.

Greek Fire: Gift from Heaven, Fire from Hell

Exchange article

AUTHOR: **T. NIJBOER**

It is the year of Our Lord, 673, though it seems The Lord has abandoned us Romans. The Arabs have overrun the Empire, ousting Roman authority from Syria, Egypt and Africa. As the Arab fleets sail the Sea of Marmara, even Constantinople, the Queen of all Cities, the New Rome, the shield of Christianity, is under threat. Surely the coming siege marks the heralding of the Apocalypse, for the fall of Rome means the fall of the world.

Divine punishment, that's how the Romans (anachronistically called Byzantines), felt about the sudden Rise of Islam in the seventh century. Five decades after the Persians were driven back from Constantinople (626), the Arabs were surrounding the Theodosian Walls. Though its formidable fortifications had saved the city before, the odds looked grim against the *Umayyad* forces. Against all odds, the Romans persevered. In 678, the Roman fleet destroyed its opponents in a heads on engagement. Key in this daring tactic was their secret weapon: Greek fire. What was Greek Fire? How was it used? And was it really that useful?

Figure 2: The Theodosian Walls of Constantinople

Greek Fire, also called *Wildfire* by the Crusaders, is a Roman invention still capturing contemporary fascination. Like is the case with Roman concrete, we still have not found the original recipe, making it impossible to know what Greek Fire really was. Nonetheless, historians and scientists alike have tried reconstructing what Greek Fire would likely have been. The main ingredient of Greek Fire was (most likely) petroleum. Other possible ingredients were quicklime, sulphur, resin/pitch and potassium nitrate. Some nineteenth- and twentieth century historians suggested gunpowder as a possible ingredient, but this was likely implausible. The invention of the flammable mixture is credited to Kallinikos of Heliopolis (Romanized: Callinicus), a Greek-speaking refugee from Syria. Little is known about this saviour of the Romans, no date of birth or death. Theophanes the Confessor (760-818), an important source on Byzantine History, only mentions him briefly. Encyclopedia Britannica mentions that Kalinikkos might have been Jewish. If proven true, it carries a dark irony; the Eastern Roman Empire, which Kallinikos saved with his invention, was highly anti-Semetic.

Though we may never know the secret recipe of Greek Fire, we know how it was used. Historians place the first use of Greek Fire either in 671 or 673, but the 'perfected formula' was first put to its destructive purpose during the First Arab siege of Constantinople. Greek Fire was sprayed with high pressure from firing devices, made from bronze tubes, syphon pumps, and swivelling nozzles, mounted on their Dromonds (fast warships). When the petroleum mixture came into contact with an enemy ship, or their own, it would immediately set the ship (and its terrified crew) ablaze. Terrified sailors would try to extinguish the flames, or escape by jumping into the sea, only to discover a terrifying fact about Greek Fire: it burns on water. Greek fire soaked in bales of cloth or in clay pots was also catapulted onto enemy formations. There is even textual evidence of handheld firing devices (read: flamethrowers) dating to the tenth century. Greek Fire was used both on land and sea until the 1204 siege, and fall, of Constantinople, during which the Romans sent unmanned flaming ships to the Crusader's fleets. Though the Romans eventually regained the city (holding it until 1453), Greek Fire disappears from the historical records. Did the Romans lose the knowledge or resources to use Greek Fire, or was it never as useful as commonly believed?

Was Greek Fire even that effective? It for sure did not stop the Crusaders from taking Constantinople. Greek Fire was used effectively in multiple confrontations between the Romans and their many enemies. The Romans burnt down the Umayyad fleets a second time when the Arabs besieged Constantine's city again (717-718). Greek Fire beat back the Rus' in 941 and 1043. Basil II (r. 976-1025) put down a rebellion in 988/989. These successes can also be attributed to other factors: the Arabs were hindered by an extremely harsh winter and the Theodosian Walls, the Rus' were beaten by the Romans numerical and technological advantage' and Basil II's victory can be attributed to his Varangian Guard and his military genius. Naval Historian John Pryor describes Greek Fire as a potent weapon, but not the 'shipkiller' that the battle ram was in Antiquity.

Greek Fire's highly flammable nature made it difficult to control, endangering the Romans themselves. The enemies of Rome also did not sit idly by as their ships burned; they adapted by using sand and vinegar against the fire, or by staying out of the firing devices' range. Nonetheless, it is important to stress the importance of Greek Fire for the survival of the Eastern Roman Empire. According to J.J. Norwich, 'It is impossible to exaggerate the importance of Greek fire in Byzantine history.' It can also be argued that it was the idea of Greek Fire that made it such a powerful weapon for the Romans. It is hard to think of a more effective way to demoralise your foes than promising them a horrifying death, burning to a crisp.

Greek Fire was a terror to behold, like the fires of Hell itself. For the Romans, it was a gift from the heavens, saving their Capital and holiest city in its hour of need. For centuries, the Romans used this gift to protect their Empire and to wreak havoc on their foes. Greek Fire was not the ultimate weapon, nor did it prevent the Eastern Roman Empire from ceasing to exist.

Figure 3: Depiction of the use of Greek Fire, from the The Madrid Skylitzes a twelfth century illuminated manuscript.

Image shows a ship belonging to Emperor Michael II (r.820–829) burning an enemy ship belonging to Thomas the Slav.

Yet it is difficult to imagine how history would have changed if Kallinikos did not present the idea of Greek Fire to Emperor Constantine IV (r. 668-685) during a time when the Arabs trampled the Empire and many thought the world was coming to an end.

Figure 4: Clay grenades that would have been filled with Greek Fire (National Historical Museum, Athens Greece).

Select Bibliography/Further Readings

- Britannica."Greek fire." Encyclopedia Britannica. May 22, 2024. https://www.britannica.com/technology/Greek-fire

- Cartwright, Mark. 2017. "Greek Fire." World History Encyclopedia. November 14, 2017. https://www.worldhistory.org/Greek_Fire/

- Shepard, Jonathan, ed. The Cambridge History of the Byzantine Empire, c.500-1492. Revised edition. Cambridge: Cambridge University Press, 2019.

- Hansley, C. Keith. "Mysterious Kallinikos of Heliopolis, the Creator of Greek Fire" The Historian's Hut. July 10, 2024. https://thehistorianshut.com/2024/07/10/mysterious-kallinikos-of-heliopolis-the-creator-of-greek-fire/

- Figure 2: "Theodosian Walls." n.d. World History Encyclopedia. https://www.worldhistory.org/image/7742/theodosian-walls/.

- Figure 3: Image found on Encyclopedia Britannica: "Greek Fire | Byzantine, Naval Warfare, Incendiary | Britannica." 2024. In Encyclopædia Britannica. https://www.britannica.com/technology/Greek-fire#/media/1/244571/201691. Copyright: © Fine Art Images—Heritage Images/Getty Images

- Figure 4: Badseed. 2007. "Grenades That Were Filled with Liquid Fire (Υγρό Πυρ) and Caltrops from the Fortress of Chania (Χανιά) 10th and 12th Century." National Historical Museum, Athens, Greece. Wikimedia Commons. July 7, 2007. https://commons.wikimedia.org/wiki/File:Liquid_fire_granades_Chania.jpg.

Perio Interview: Catherine Rigollet

Literature and Animal Lover

AUTHORS: **I. BALINT, L. ADDAMS**

Catherine Rigollet is a French lecturer who cares dearly about her students, has a passion for Greek and Latin history and mythology, and loves spending time at home with her animals. In this issue of the Periodiek, we get to know her a little better.

What motivated you to become a lecturer?

I used to do research, and then there was a restructuration and my group disappeared, or the group that I was part of disappeared. At the same time, I started to lecture and I really enjoyed it, so then I had to make a choice, and that's what I wanted to do. I just want to teach and that makes me happy. I like it, I like my students. I enjoy teaching and the contact with the students, whether it's a small class or a large class.

Figure 5: Catherine Rigollet

Can you tell us more about your interest in Nuclear Physics and Astrophysics?

I participated in a few experiments labelled Nuclear Astrophysics and they sparked my interest, and then I developed my first course, the Nuclear Astrophysics course. I read a lot and I follow what's happening, so then I can bring that into the lectures as well. So it's fun. I did my PhD and the rest of my research in nuclear physics, what we call fundamental physics. I did that in France and then the postdoc in South Africa. And then I came here and I was in a group where we used nuclear physics, but on a more practical level, it was called the nuclear geophysics division; long gone. We used radioisotopes (or long leaves of uranium, thorium, and potassium) as fingerprints of different types of sediments. I would measure the gamma rays from the uranium, thorium, potassium; also cesium-137, which comes from Chernobyl, and then you can find the rate of sedimentation to see if the sediments need to be removed in an area. That was quite fun, very interesting.

How was your experience in South Africa?

Oh, well, I met my husband there. We got married and I brought him back to the Netherlands. The first thing everyone told me was that when you get into your car, you lock your doors. I was like, come on guys. I mean, when I went there I didn't know much about South Africa at all, but yeah, I found out that you get into your car and you lock your doors. The crime rate is atrocious, but for my husband it was normal, for me after three years it was a little bit oppressive. And then we came to Europe so we could actually walk on the street instead of driving. But I mean, the people were so great, the weather, the food, you know, then you come here and the weather, the food, the sights are flat. South Africa was nice, it showed me something other than Europe.

Do you enjoy being a lecturer more than a researcher?

Yes, I'm really happy. I think I was made for that. When I started teaching I was not sure because I started being a TA and I really hated it because I was not actually sure what I was doing. But then when it's your own course, it takes some time, but now I'm in my element.

What brought you to Groningen specifically?
I met this professor in South Africa from the nuclear geophysics division, who offered me a postdoc here. So I said yes. Sometimes you meet people and they say come work for me, and you say yes.

What languages do you speak?
French, English. My Dutch is really bad for the amount of years I've lived here, which is 24. Let's put it that way: I'm too lazy.

If you hadn't studied physics, what would you have chosen instead?
Well, I asked myself the same question, because my father was an engineer and he said: "You will study physics." So I said "Okay". I mean, I was not half bad at Physics. I think I would have liked to study Latin and Greek, so I could read old books, not translated and not embellished. But, you know, when you're 18 you don't know what you want to do. So, I'm happy with my career, but yes, I would've liked to do that.

> ***"I think I was made for lecturing."***

Are you passionate about mythology and history?
Yeah, I took Latin and I had this amazing teacher and she would tell you stories like she had been there. And I was blown away, you know? I think that stayed with me. I like books, I have lots of books about lots of things, I collect them. I don't always have the time to read them. I read half of it and then I say, okay, I'll read the rest of it later. I never do. Maybe I romanticized the idea of going into secret libraries and taking books and having access to all this knowledge.

Do you have a favourite experiment?
No, but what I'm going to do this block is build a can crusher. It's a very simple circuit: you have a capacitor, a switch, a copper coil. You charge your capacitor and put the can in the coil, flip the switch and the capacitor discharges, and the current creates a magnetic field, so the Lorentz force goes perpendicular to the field and crushes the can.

What is your favourite course that you taught?
I think at this moment it's Nuclear Energy. But I like my course on Plasma Physics and Nuclear Astrophysics. I like Nuclear Energy very much, I have a lot of students and they're actually interested, and I had lots of questions, and sometimes I cannot answer the questions, so I come back the next time with the answer. I took it over from people who retired but I really made it my own, and every year I add more stuff because I read a lot, and from questions that students ask me, it's ever-evolving.

> ***"Maybe I romanticized the idea of going into secret libraries and taking books and having access to all this knowledge."***

My goal is to show the students that you should not be afraid of nuclear energy, to show them that it's safe and why it is safe. Nuclear energy is clean, the waste problem can be sorted. If you compare the nuclear industry with the coal industry, the nuclear industry takes care of everything, from the mining of the uranium to the disposal of the waste. And, if you reprocess the fuel in the reactors, you can reprocess 96% of it, and then with that you make more fuel, new fuel, so the amount that needs to be buried is minimum. It's a lot less than people think. So I suppose the end goal of the course is to show them that even though stuff like what happened in Fukushima happens, you can always prepare to prevent it in the future. Plus, it's not that you can build your own reactor in your backyard. I mean, this is highly, highly regulated. There's a lot of things to do before you can even think of building a power station. Then there's the efficiency: there's a loss of steam in the plants, but you can recuperate that steam, heat it up again, and then use that for other applications. Like desalination of water, and district heating.

What's the most memorable or inspiring experience you've had during your education?
Oh, so, apart from the Latin teacher, in France I had a kind of affinity with nuclear because I thought it was secret and magical. I had this teacher who was so passionate, so he would lecture, and then he had to go because he was traveling to the UK for an experiment. This guy actually later became my PhD supervisor. So, yeah, I thought, this is what I want: to be happy like that.

What is it like to be a female lecturer in a male-dominated field?
I don't care. I really don't care; I really couldn't care less what they think of me. Of course, that doesn't advance my career, but I do my stuff.

"So, you're clearly a wannabe drug dealer, buy a train ticket!"

Can you tell us more about where you're from originally?
I was born in France, close to Paris, Genevilliers. Then when I was 7 my father got promoted to go to Annecy, in the Alps, close to Geneva. So on the weekends we would go skiing, and in the summer we'd go to the lake. I mean, it was nice, I'm not complaining. My parents would drag me walking up and down the mountains. I hated that. When I was 15 we moved to Alsace, or Mulhouse, which is close to the German border. Then I moved to Strasbourg, living on my own. I did my master's, and then I did my PhD there as well. Then I had a Postdoc lined up in Italy, but I had another offer from an English professor (who has such a strong accent, so funny, I couldn't understand a thing) to go to South Africa. I was like, well, Italy, I can go anytime, let's go to Africa. It was funny, because then research did not come first, they had a hospital where they did proton therapy, and at night they would produce radioisotopes for medicine. And then on weekends we had the beam, so we could then do experiments during the weekend. I came here on the 2nd of January, 2000. And I thought, okay, it's just another postdoc, and then we'll settle down somewhere. And then look at me, 24 years later, I'm still here. I'm not going to die here. I will retire somewhere else.

Do you miss France?
Well, as I get older, yes. Before, no. But I will buy some dilapidated farm somewhere in the middle of nowhere, and then live there. With my books and my chickens and my cats and my goldfish. My husband, he's a builder. Well, he can do anything. But originally, he was a woodworker. So he makes furniture, and he builds all sorts of stuff. He started to garden so now I have all these little tiny pots on the window. We have amazing vegetables, I must say. I don't like peas, you know, but he grew peas, and there is no comparison. I love peas from my garden, not from the shop. Home-grown peas, corn, tomatoes, potatoes, and carrots.

What is your favourite cuisine?
Oh, no, don't ask me that. I don't know. Of course, I like French, but I like Indian, and I like Asian. And we try a little bit of everything. But my favourite food is cheese. Not the Dutch cheese. Cheese from proper countries, like Italy, France, of course, Spain. The good stuff. Here, it's all the same, except it's young, less young, and very old, just yellow cheese. I had a student, Italian, he was going home for the holidays and I said bring me back cheese when you come back to Groningen, and he did. He brought me pecorino, I never tasted that before, oh–it was so wonderful. I think my students think I have a very short attention span, because I would be talking about something, and suddenly something pops in my head. So I just say it, and usually, it's weird or funny, you know. And then I carry on.

"I'm not going to die here."

Do you talk about cheese in the lectures?
Yeah, yeah, definitely. Like, anything that happened, there was a story on the Dutch news: there was a guy on the train, he didn't have a ticket, they took him out of the train, he didn't have papers... but he had a lot of cocaine in his bag. So I told them this because we were talking about how drugs and explosives have the same compound: it's hydrogen, carbon, nitrogen, and oxygen, but in different quantities. It just popped into my head because I heard it in the morning. So, you're clearly a wannabe drug dealer, buy a train ticket! I just say it, it's nice, you don't want to sit there for two hours with a little break in between and me going blah, blah, blah. That would also bore me as a lecturer. So, what was your question? [It was your favourite cuisine.] Definitely not Dutch. My husband makes amazing curries. I think cheese is a good answer. Cheese is my favourite cuisine. I will eat it like that, straight out of the fridge. I'll put it in anything and everything. [Do you like brie?] Yes, but the one you know here is not really brie. The brie you want is the one with the unpasteurized milk. So brie de Meaux. But this one will stink up your fridge, right? And you want to scrape off the rind because that's too strong.

"Cheese is my favourite cuisine."

What are your hobbies?
Actually, I took up knitting, right? I'm not very good, but, you know, it occupies my hands while, and this is my hobby, I watch TV. I watch series. Yeah, not movies, too long but we binge series, me and my husband. So what did we watch? We watched White Collar. Oh, that was really good. That was excellent. Then we watched Suits. Oh, The Blacklist, that was great.

What about reading, do you consider it a hobby?
Well, yes, but the last fiction book I read was two years ago. And I read it just like that during the summer holidays. Otherwise, I read textbooks, which is also nice. When I was younger, like, 12 or so, I read all the Agatha Christie books, you know, Miss Marple, all the Sherlock Holmes books. I was a big fan. And then I went to Stephen King. And this one book, It, you know, with the clown. I could only read it during the day because I was too scared. Otherwise, I was so young and impressionable. I like crime stuff, crime detective books. I actually started reading Harry Potter when I was pregnant with my oldest, so 22 years ago. And I read them all. I have them all. I mean, I don't know exactly where, but I have them in the house. And I watched the movies as well with the children. Of course, for me, but they also liked it. Usually, I cry very easily when I watch a series or a movie. And my husband's like, are you crying? I'm like, yes, it's so sad. Anyway, um, there's only ever one book that made me cry, and that's Gone With The Wind. And I never cried reading a book before. It was very well written, I guess.

What are your favourite places in the city, things to do in your free time in the city?
I stay in my house. I mean, I live like just outside Groningen and I have a big garden and I like my house and my garden, so I stay at home. I don't like to go to town.

> ***"And my husband's like, 'are you crying?'."***

During an alien invasion, which professor would you like to have on your side?
None of them. What I would do is take my boys. So my husband, build anything. The youngest, I don't want to say computer genius, but he can do anything. [Computer genius sounds cool, we'll put that in.] And my oldest son who's now in the army. So sniper, telecommunication, everything. And he can fight and he's very strong. So that's what I would take. I actually learned to shoot guns when I was younger, I really liked it, but I haven't shot since.

What excites you?
You know what? Sitting in my nice comfortable chair and watching TV. I'm quite chill. Let's say I like to chill. Away from people.

What did you have for breakfast?
Coffee, I drink instant coffee. It's quick and easy and I just need something hot. That's it.

Do you have pets?
I have several. I have four cats. I used to have nine at some point. Also, I've got two goldfish. One is old, the other one is younger, but they were always two. And two summers ago, one of them died. The one that was left, he was searching for that other fish, so I bought him a new one, because otherwise it's boring. Now they chase each other around. I have four chickens, which lay an egg once in a while.

Do you have anything to add?
If you were my students you will always be my students, that means you can always come to me.

Illustrating Mathematics

Why and how to get involved

AUTHORS: **M. DHUME** (M.DHUME@TUDELFT.NL) **AND M. SKRODZKI** (MAIL@MS-MATH-COMPUTER.SCIENCE)

Imagine transforming abstract mathematical concepts into captivating visual forms: fractals that spiral infinitely, geometric shapes that reveal hidden symmetries, or visual proofs that make complex ideas instantly intuitive. This is the world of mathematical illustration, where equations and theorems meet art and design, making the invisible visible. In this article, we'll explore how researchers and enthu- siasts use creative visuals to communicate math's beauty and how mathematical illustrations are currently growing to become a field in its own right. Finally, we will share how you can make the first steps to begin illustrating mathematics yourself.

We will start with an example. A fundamental concept in calculus or analysis is series. Here, the object of consideration is an infinite sum of values, for instance:

$$\frac{1}{4} + \frac{1}{16} + \frac{1}{64} + \ldots = \sum_{n=1}^{\infty} \left(\frac{1}{4}\right)^n$$

Two typical questions are: Does this infinite sum have a finite value, i.e., does it converge? And if so, what is that value? A typical mathematics course will then go into sets of technical tools that allow one to prove the convergence of a series (and hopefully also reveal the value it converges to). This frequently boils down to abstract manipulation of formulae. At this point, the concept of visual proof can help. Look at the two visual proofs for convergence of the above mentioned series. From the visuals, what do you think the series converges to?

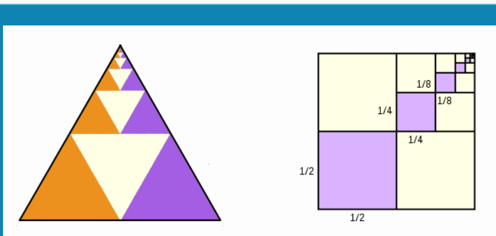


Figure 6: Two visual proofs that the sum of powers of ¼ converges. [1]

The visualizations (Figure 6) correctly reveal that the series converges to ⅓. You can verify this, for instance, in the left visualization:

The triangle is split into four triangles of equal area—one is orange, one is beige, and one is purple. The last triangle is split again into one orange triangle, one beige triangle, one purple triangle, each triangle with an area of one sixteenth of the total area. The fourth triangle is split again in the same way. This continues ad infinitum. The triangles of one color represent the elements of the series. Since they divide the total area of the triangle into three equal parts, the visualization shows that this series converges to ⅓. A similar argument can be made for the other visualization on the right of Figure 6. These visual proofs provide some intuition about the convergence of the series and help us arrive at the convergence value without algebraic manipulations.

Let us turn to a second example. Figure 7 shows us how to cut a bar of chocolate, re-arrange some pieces, and finally have the entire bar of chocolate re-assembled, with one additional piece. We could repeat this process and create an infinite amount of chocolate. What else could we wish for? Well, not so fast. While creating chocolate out of thin air seems nice, it sadly violates some principles of thermodynamics. So, what is going on here, where did the visual proof of infinite chocolate go wrong?

Physically performing the trick (or some rigorous calculations) will reveal that the final re-assembled bar in the last step is slightly shorter than the bar that we started with. This shrinking provides an additional piece of chocolate. The shrinkage is minimal enough to fool us visually as the final bar seems to be of equal size. Take this example as a warning that illustrations, while helpful, can also be misleading [1].

[1] For another example of a misleading visual proof, see Joel Hamkins' essay at https://jdh.hamkins.org/all-triangles-are-isosceles/.

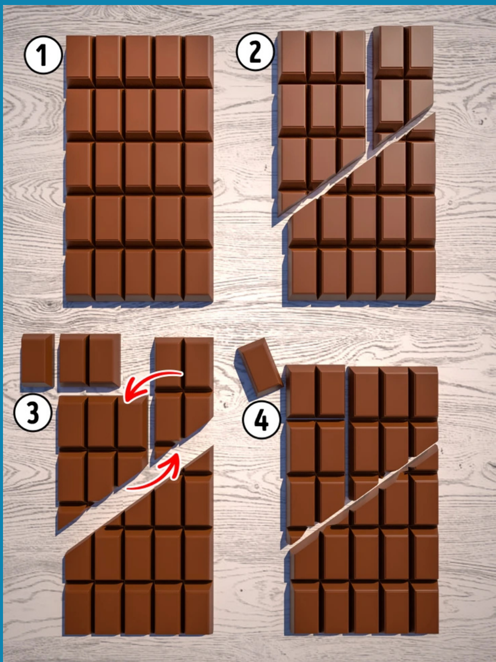


Figure 7: The "infinite chocolate" trick [2].

These examples are glimpses into the power of illustration in mathematics: they highlight how visual representations are more than just aids—they are essential tools that reshape our understanding of complex concepts. The art of math illustration transforms abstract ideas into accessible forms, fostering new insights that can even inspire breakthroughs in research[2]. Yet illustrations can mislead and have therefore to be treated as objects of research to understand both their powers and their limitations.

When we say "illustration", we use the term to encompass any of the many ways one might bring a mathematical idea into physical form or experience, including computer visualization, 3D printing, and virtual reality, among others. Today, modern technology for the first time places the production of far more complicated illustrations within the reach of many individual mathematicians. And indeed, there are a lot of illustrations to be found and explored. A prominent outlet is the "Bridges" conference for mathematics and the arts[3] or the "Journal of Mathematics and the Arts"[4]. Their respective archives are treasure troves of mathematical illustrations, see Figure 8. Aside from these, several collections of illustration projects exist, also in printed form[5].

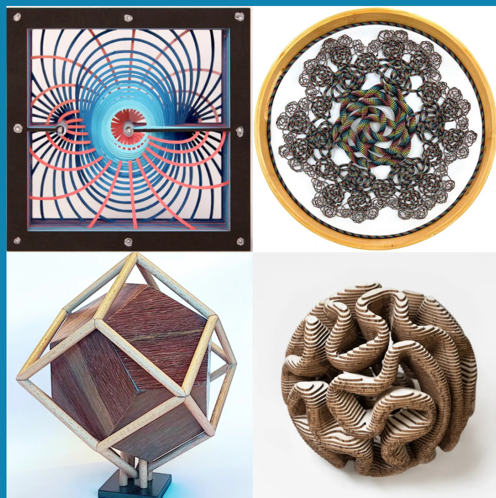


Figure 8: All taken from the "Bridges 2024 Exhibition of Mathematical Art, Craft, and Design".

Top left: **Caroline Bowen: "The Real and Imaginary Parts of ArcSech(z)"**,
Top right: **Carol Wang - "Warlow's Fractal Mat"**,
Bottom left: **Josep Rey Nadal - "Dos dotzes (Two twelve)"**,
Bottom right: **Söhnke Vetter - "Stratify"**

All these examples stand as monoliths, created from personal experiences and individual insights. They showcase the skill and creativity of their authors but are often developed in isolation, without a shared foundation for what constitutes a 'good' mathematical illustration. Despite the importance of visual representation in mathematics, there is surprisingly little overarching literature that systematically explores how to design effective mathematical illustrations. This absence of best practices leaves illustrators to rely on personal trial and error, making it challenging to learn from each other and avoid common mistakes.

[2]For more information, please read *On the importance of illustration for mathematical research* (2023) [3] and *The art of illustrating mathematics* (2022) [4].

[3]See https://www.bridgesmathart.org/ for the organization. All articles in the archive, http://archive.bridgesmathart.org/, are open access and the art galleries are also freely accessible online: http://gallery.bridgesmathart.org/.

[4]https://www.tandfonline.com/journals/tmaa20.

[5]Consider, for instance, *Mathematics and art: Mathematical visualization in art and education* (2002) [5], *Math Art: Truth, Beauty, and Equations* (2019) [6] and *Illustrating mathematics* (Vol. 135) (2020) [7].

While illustrations in mathematics may currently stand as isolated creations, we can look to the evolution of other fields to see what's possible. Diagrams, graphs, and charts began as specific tools within disciplines like physics, biology, and data science. Over time, however, they developed into comprehensive fields of study with established structures, theories, and even dedicated conferences[6]. Today, the fields of data visualization and scientific illustration have unified principles, shared methodologies, and communities of practitioners who push these disciplines forward[7]. The same trajectory is possible for mathematical illustration: with enough collective effort and shared knowledge, it, too, could evolve into a fully recognized field, complete with its own standards and a robust body of research.

Regarding research mathematics or mathematical education, illustrations quickly become scarce. Illustrations are considered as 'dangerous' as they might create false intuitions. To that, e.g., Bill Casselman writes: "Even small errors in a drawing can be confusing, frustrating, annoying, and distracting—and an accumulation of them can be deadly" [9]. This stance goes back to the Bourbaki movement in mathematics: A group that "carefully avoided using illustrations, favoring a formal presentation based only in text and formulas" [10]. Even now, these reservations towards illustrations are still present in formal mathematics.

Opposed to this, data visualization and scientific illustration provide clear examples of how a field can develop beyond initial concerns about misrepresentation or oversimplification. With a growing number of projects, these fields have gained the volume of work needed to study how users interpret visuals, assess what succeeds or fails, and refine their methods. These fields have established a nuanced understanding of how visuals impact comprehension and intuition through targeted user studies and iterative design.

Applying these principles to mathematical illustration would allow for a similar approach: by examining many projects, we could build a systematic understanding of how illustrations support or potentially mislead mathematical intuition. This knowledge would empower us to harness the strengths of illustration effectively while remaining alert to its limitations, using visuals as a powerful, intentional complement to traditional mathematical discourse.

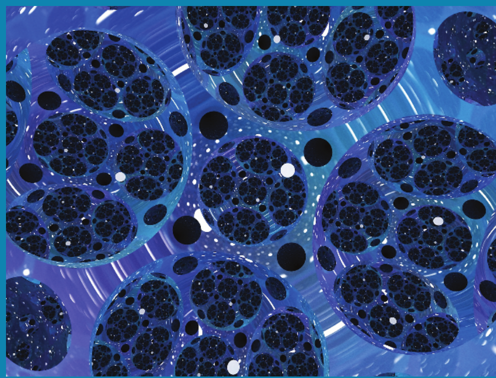


Figure 9: In-space view of a finite-volume hyperbolic 3-manifold lit by a single white light, Rémi Coulon, Sabetta Matsumoto, Henry Segerman, and Steve Trettel.

Pursuing such development is the goal of the "Illustrating Mathematics" group. Their mission statement reads: "Illustration reveals the hidden structures of mathematics, broadening access to its inherent beauty and pushing the boundaries of research. We seek to enhance professional support and recognition for illustration, pursuing mathematical depth and high-quality communication"[8].So far, there have been two community events at the Institute for Computational and Experimental Research in Mathematics (ICERM) in 2016 and 2019.

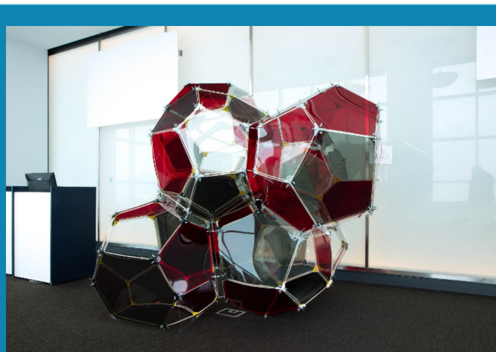


Figure 10: A fully constructed W-P foam model, Edmund Harris.

[6]https://diagrams-conference.org/

[7]Consider the IEEE Vis conference or guidelines like *Building science graphics: an illustrated guide to communicating science through diagrams and visualizations* (2022) [8].

[8]https://illustratingmath.org/

See the website of the 2016 event here and the 2019 event here. Refer to a description of the 2019 outreach activities here: Skrodzki, M. (2023). Science communication and outreach events during the illustrating mathematics semester program at the institute for computational and experimental research in mathematics (ICERM). In *Handbook of Mathematical Science Communication* (pp. 165-181). Figures 9 and 10 shows a virtual reality experience and a larger model of a space-filling foam, both created during the 2019 event.

If you want to get involved with the activities of the Illustrating Mathematics group, here are some options for you:

1. Join the "Illustrating Mathematics" Discord Server: Whether you're just starting out or are already well-versed in illustration, the "Illustrating Mathematics" Discord server is the place to connect. Here, you can ask questions, brainstorm ideas, get feedback, and share your work with a supportive community of like-minded creators and enthusiasts. This space offers an open, collaborative environment where illustrators of all levels can learn and grow together. An invite link can be found on the homepage: https://illustratingmath.org/.

2. Attend the Monthly Online Seminar: For those eager to dive deeper into the techniques and theory behind mathematical illustration, the monthly online seminar is a perfect opportunity. Each session explores various illustrating methods, showcases projects, and offers practical insights from experienced illustrators and mathematicians. Additionally, in a "Show-and-tell" segment, it offers the opportunity to ask questions to the community and get advice for your own illustration projects. This regular seminar is an ideal way to stay up to date on new developments, learn in-depth techniques, and engage in inspiring work in the field. Find the next seminar talks announced here: https://illustratingmath.org/node/42.

3. Look Out for Community Events in 2025 and 2026: The excitement continues with community events on the horizon! We're planning gatherings in summer 2025 at ICERM (Institute for Computational and Experimental Research in Mathematics) and in 2026 at the IHP (Institut Henri Poincaré). These events will offer hands-on workshops, discussions, and networking opportunities, bringing together a vibrant community dedicated to the art and science of illustrating mathematics. Mark your calendar for the 2025 event: https://icerm.brown.edu/program/topical_workshop/tw-25-imre and keep an eye out for a longer trimester at IHP in 2026.

References

[1] Byrd, D. (2013, August 16). *Baby's First Infinite Series*. Whymystudentsdidnt. https://whymystudentsdidnt.wordpress.com/tag/visual-proof/

[2] How the Infinite Chocolate Trick Works. (2021, December 16). *5-Minute Crafts*. https://5minutecrafts.site/learn-world/how-the-infinite-chocolate-trick-works-1860/

[3] Coulon, R., Dorfsman-Hopkins, G., Harriss, E., Skrodzki, M., Stange, K. E., & Whitney, G. (2023). On the importance of illustration for mathematical research. *Notices of the American Mathematical Society*, 71(1)

[4] Harriss, E., & Segerman, H. (2022). The art of illustrating mathematics. *Journal of Mathematics and the Arts*, 16(1-2), 1-10

[5] Bruter, C. (Ed.). (2002). Mathematicsandart: Mathematicalvisualizationinartandeducation. Springer Science & Business Media

[6] Ornes, S. (2019). MathArt:Truth,Beauty,andEquations. Sterling

[7] Davis, D. (2020). Illustratingmathematics (Vol. 135). American Mathematical Soc.

[8] Christiansen, J. (2022). *Building science graphics: an illustrated guide to communicating science through diagrams and visualizations*. AK Peters/CRC Press

[9] Casselman, B. (2000). Pictures and proofs. *Notices of the AMS*, 47(10), 1257-1266.

[10] Wikipedia contributors. (2024, August 21). *Nicolas Bourbaki*. Wikipedia. https://en.wikipedia.org/wiki/Nicolas_Bourbaki

Flatlands Unfolded

Exploring the physics of two-dimensional materials

AUTHORS: **A. GRUBISIC-CABO, G. FERACO**

We all understand that the dimensions of an object matter—after all, a large bar of chocolate is always preferable to a small one. In physics, however, dimensionality plays an even more critical role. When a system becomes sufficiently small, the familiar rules of classical mechanics break down, giving way to the intriguing realm of quantum mechanics. But what happens when we reduce the dimensions of a material in just one direction, creating a two-dimensional structure within our three-dimensional world? Surprisingly, this opens the door to fascinating and unexpected physics!

In physics, the dimensionality of a system is crucial for a variety of reasons. It determines the statistical frameworks you can apply, the approximations that remain valid, and the point at which classical mechanics—used to describe most everyday objects and interactions—must give way to quantum mechanics.

At the Zernike Institute for Advanced Materials, we focus on studying materials, their properties, and their behavior. Many of the materials we investigate fall under the category of quantum materials. But what does that mean? Simply put, quantum materials exhibit properties that cannot be explained using classical physics alone; they require the framework of quantum mechanics—or even quantum chemistry—for a proper description [1]. While this might sound unusual, quantum materials are more common than you might think. Superconductors, topological insulators, quantum dots, and two-dimensional (2D) materials all belong to this category.

Among these, we'd like to share some insights about 2D materials, which are a particular focus of our work. These materials derive their remarkable and unique properties directly from their reduced dimensionality—being two-dimensional structures in our three-dimensional world.

Being 2D in a 3D world

The simplest way to imagine 2D materials is to think of them as sheets of paper that are atomically thin. Because of this extreme thinness, 2D materials consist entirely of surface; they completely lack a bulk interior or the "inside" typical of everyday materials. This distinction makes them fundamentally different—not only in their structure but also in the unique physics they exhibit. Actually, these materials are so unusual that for a long time it was believed that they simply cannot exist. It was assumed that such materials would inevitably curl, roll up, or crumple into 3D structures.

This paradigm shifted in 2004 when A. Geim and K. Novoselov successfully isolated a single layer of graphite, which they named graphene [2]. Remarkably, they discovered that charge carriers—electrons and holes—in graphene behaved as if they were massless, a property typically associated with photons. The significance of this breakthrough was so profound that Geim and Novoselov were awarded the Nobel Prize in Physics in 2010, laying the foundation for the rapidly growing field of 2D materials.

Historically, graphene's unique properties were hinted at long before its isolation. In 1947, P. R. Wallace theoretically predicted graphene's electronic structure while modeling graphite [3], as calculations for a single layer were far simpler than for an infinite stack. Furthermore, throughout the 20th century, surface scientists frequently encountered graphene in experiments. However, it was dismissed as contamination on metallic surfaces, with its extraordinary nature remaining unrecognized until 2004 [4].

Graphene's properties are nothing short of extraordinary. In addition to its massless charge carriers, it boasts exceptional thermal and electrical conductivity and is one of the strongest materials ever discovered: if you could produce a perfect, large sheet of graphene, it could theoretically support the weight of an elephant—an astonishing feat for a material composed of a single layer of carbon atoms!

Flatlands

Today, graphene is just one among many 2D materials that we study and use, each with vastly different and exciting properties. As the first discovered 2D material, graphene remains the most extensively researched and is already being used in applications such as batteries and sensors. Following graphene is hexagonal boron nitride (hBN), a material with a structure similar to graphene's hexagonal lattice. However, unlike graphene, which is a semimetal, hBN is an insulator.

Another prominent group of 2D materials are the transition metal dichalcogenides (TMDCs), a diverse family whose properties range from metallic to insulating. Among them, semiconductors like MoS_2, WS_2, $MoSe_2$, and WSe_2 are particularly interesting due to their air stability and potential applications in next-generation 2D electronics. Beyond these, the realm of 2D materials includes even more exotic systems, such as 2D topological insulators and 2D superconductors.

So, how are 2D materials made? These remarkable materials can be fabricated using various methods. One common approach is the top-down method, such as the famous "sticky tape" technique used in the Nobel Prize-winning discovery of graphene. This method involves peeling layers from bulk crystals; by repeating the process enough times, you can isolate a single atomic layer, which can then be transferred onto a substrate of interest.

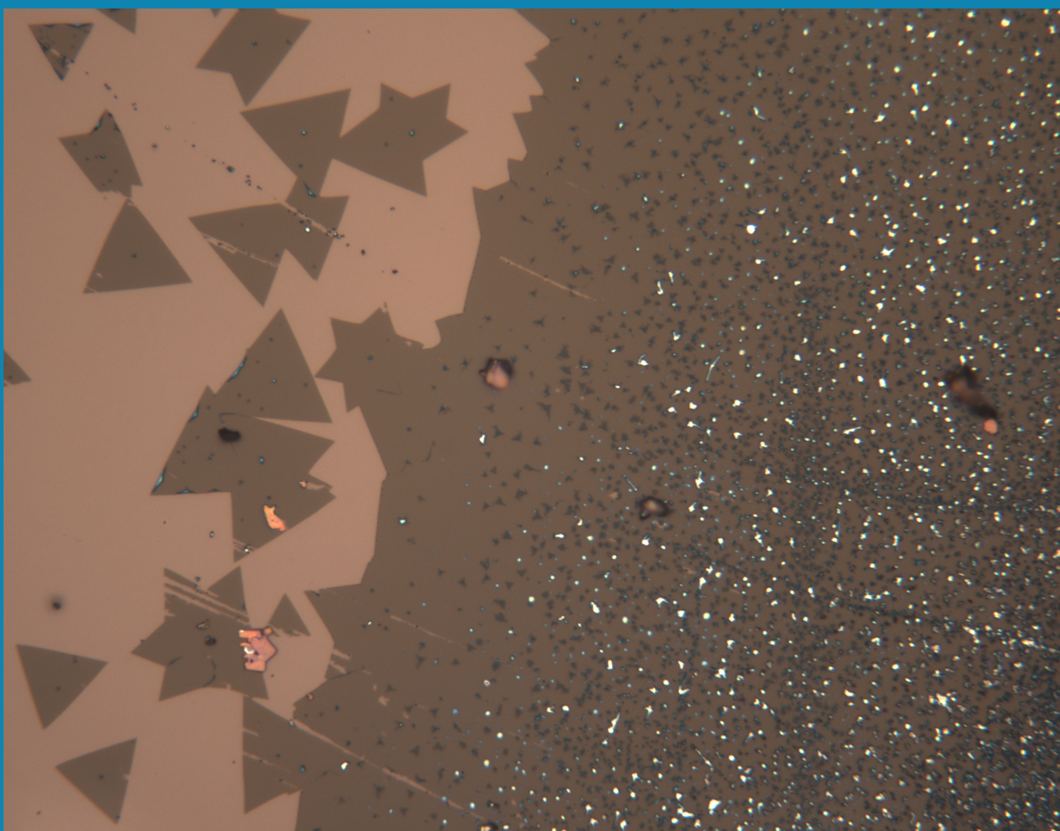


Figure 11: Optical Microscopy image of MoS_2 film (dark brown) grown using chemical vapour deposition (CVD) on SiO_2/Si wafer (light brown). MoS_2 starts growing in triangular islands (left) that merge into a continuous film (middle and right).

In our group, we also employ the kinetic *in situ* single-layer synthesis (KISS) method. This technique allows us to directly prepare 2D materials in an ultra-high vacuum environment, eliminating the need for sticky tape and ensuring the material remains extremely clean [5].

Bottom-up methods, like chemical vapour deposition (CVD, see Figure 11), grow continuous 2D films directly on a substrate. Finally, 2D materials can be transferred onto or grown on different substrates, and intriguingly, their properties can change dramatically depending on the substrate. This phenomenon arises from the reduced screening effects due to confinement in two dimensions, making it possible to probe a wide range of physical effects using just one material. What is even more impressive it the fact that you can create completely new properties by combining various 2D materials, or by stacking them under an unusual angle that does not appear in nature.

Hello twistronics!

Twisted bilayer graphene (TBG) consists of two graphene layers stacked with a relative rotational angle. While regular bilayer graphene in its common AB stacking is a gapless semiconductor, Figure 12, limiting its potential for switching applications, introducing a twist between the layers opens a band gap and unlocks exciting new possibilities for electronic applications [6].

In TBG and other van der Waals systems that are commonly used to create 2D materials, the layers are held together by weak van der Waals forces, which allow for relative rotation—something impossible in most other materials. Twisting the layers creates an interference pattern known as a moiré pattern, Figure 13, determined by the twist angle. This pattern profoundly influences the material's electronic properties, enabling their modulation by simply changing the twist angle. At certain angles, known as magic angles, the electronic bands flatten, resulting in completely flat bands in momentum space. These flat bands correspond to strong electron localization in real space, drastically altering the system's behaviour, and at magic angles, the strong electron-electron interactions in flat bands give rise to exotic phenomena, including superconductivity, state where material is able to conduct electricity without resistance.

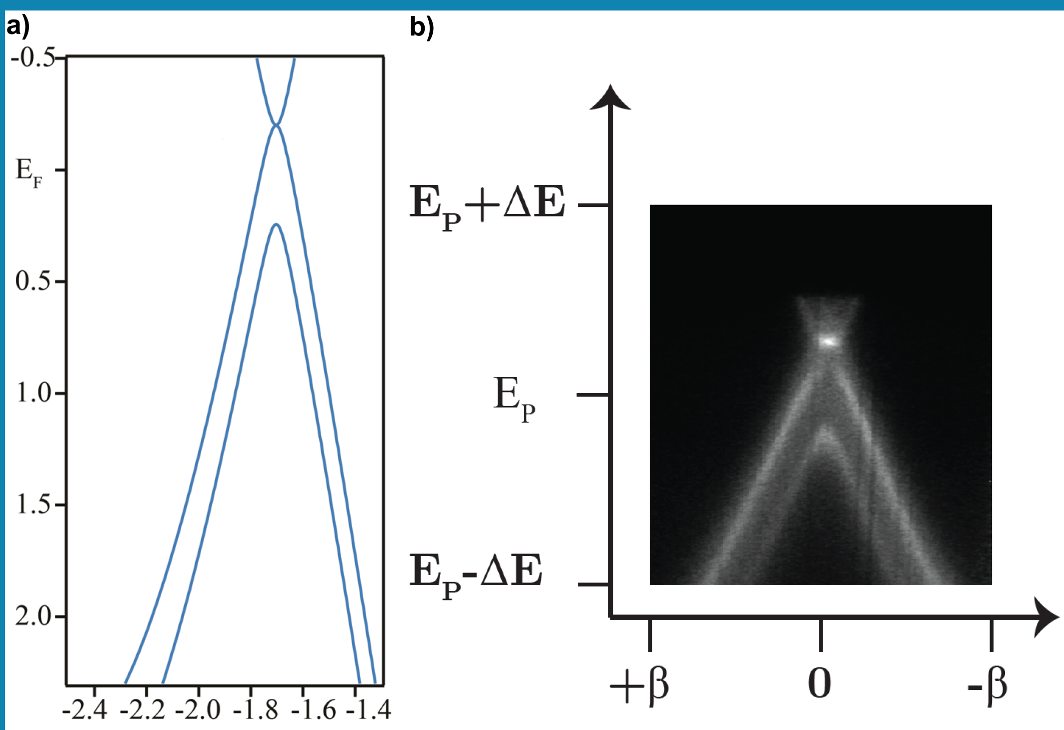


Figure 12: Electronic structure of AB stacked bilayer as predicted by tight binding calculations (a) and as imaged by angle-resolved photoemission spectroscopy (b).

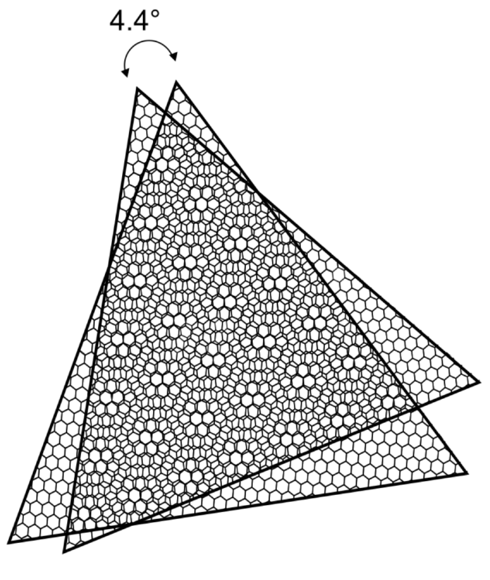


Figure 13: Example of a moiré pattern that appears when two 2D materials are twisted under an angle of 4.4 degrees.

Generally, the parameter that plays a crucial role in the electronic properties of the material is the band filling, which is given by the number of charges occupying available states near the Fermi energy. In classical model where electron-electron interactions are negligible, a half-filled valence band would result in electrical conductivity and material would be a metal. However, in TBG at magic angles, the interactions are so significant that correlated insulating states emerge, akin to those seen in Mott insulators—materials where electron localization prevents conductivity even when bands are half-filled. These interactions not only lead to insulating behaviour but also enable superconductivity. where the material conducts electricity without resistance.

Correlated states and moiré flat bands are not limited to magic angle TBG. Similar phenomena are observed in more complex systems such as twisted bilayer-bilayer graphene and twisted double-trilayer graphene. Beyond graphene, twisted bilayer transition metal dichalcogenides (TMDs) and their heterostructures, like WSe_2/WS_2, $MoSe_2/MoS_2$, and MoS_2/WS_2, also exhibit correlated states across a broader range of twist angles. TMDs provide a versatile platform for studying correlation effects, with systems like WSe_2 demonstrating these properties at varying angles.

One major advantage of van der Waals materials is their tunability. Charge density in these systems can be precisely controlled via electrostatic gating, allowing researchers to map the entire phase diagram of a material using a single device. This eliminates the need to fabricate new samples for each experimental condition, as is often required in other systems such as cuprates, a class of high-temperature superconductors.

Not all is easy, many questions still remain...

Despite their promise, studying twisted 2D materials presents challenges. Flat bands exist only within a narrow range of twist angles, carrier densities, and temperatures. Superconducting states, in particular, are highly fragile. Furthermore, at small twist angles, the layers can form relaxed domains to minimize the additional energy caused by misalignment, as observed in twisted bilayer WS_2 at 4.4° [7]. These structural relaxations further complicate the understanding of correlated states.

While many questions remain, the advent of twisted 2D materials marks a revolutionary chapter in condensed matter physics. These systems, and the emerging field of twistronics, provide an unparalleled platform for exploring the mysteries of correlated systems, offering a playground to uncover novel quantum phenomena and advance the understanding of condensed matter.

Future is flat

From graphene to twisted 2D structures, the field of 2D materials—often called ”flatlands”—is remarkably vast, uncovering new frontiers in physics and materials science. As research continues to push the boundaries of what these materials can achieve, it is clear that the innovations they bring will shape the future for years to come. Indeed, one might say that the future is flat!

References:

[1] R. Cava, N. de Leon & W. Xie, Rev., 121, 5, 2777–2779 (2021)

[2] K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S. V. Dubonos, I. V. Grigorieva, & A. A. Firsov, Science 306, 666 (2004)

[3] P. R. Wallace, Phys. Rev. 71, 476 (1947)

[4] S. Hagstrom, H. B. Lyon, and G. A., Phys. Rev. Lett., 15:491–493 (1965)

[5] A. Grubišić-Čabo, M. Michiardi, C.E. Sanders, M. Bianchi, D. Curcio, D. Phuyal, Q. Guo & M. Dendzik, Adv. Sci. 2301243 (2023)

[6] G. Feraco, W. Boubaker, P. Rudolf & A. Grubišić-Čabo, arXiv:2411.00854 (2024)

[7] G. Feraco et al., arXiv:2312.04205 (2023)

Fibonacci in the bathroom
A different type of Golden Ratio

AUTHOR: **R. MOL**

Where there is smoke, there is fire. And where there is the Fibonacci sequence, there is the Golden Ratio. You might have heard claims of this sequence *"existing everywhere in nature"* accompanied by a photograph with the golden spiral pasted onto it. In this article we will step away from such a proof by picture and provide a simple argument to prove that the Golden Ratio shows up organically a place that you might have heard of or even visited yourself, the men's bathroom.

What is the Golden Ratio?

We'll construct a sequence called f_n, with $f_1 = 0$ and $f_2 = 1$ and subsequent terms are determined by $f_{n+2} = f_n + f_{n+1}$. That means that the first few terms are 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144 [9]. When you look at the ratio between subsequent terms, f_{n+1}/f_n, the limit of this fraction, as n tends to infinity, is equal to the Golden Ratio, φ, which satisfies the identity

$$\varphi = \frac{1+\sqrt{5}}{2} = \frac{1+\sqrt{5}+2}{1+\sqrt{5}} \approx 1.618....$$

The Golden Ratio also satisfies the quadratic equation

$$\varphi^2 = \varphi + 1.$$

For our case, it enough to remember that the (one of) the ways the Golden Ratio emerges, is by taking the limit of the ratio of subsequent Fibonacci sequence terms.

Social etiquette

When using a urinal in the men's bathroom, one must be aware of the accompanying social etiquette. Specifically that of personal space. If possible, it is desirable to maintain a comfortable distance of at least one empty urinal between yourself an a peer. In essence, you would avoid occupying a urinal directly neighbouring a urinal that is currently in use. For example, if five urinals are available, at most 3 could be used simultaneously while maintaining social etiquette.

Finding the maximum amount of simultaneously available urinals is rather straightforward. Simply half the total amount, rounded up in case of an odd total. Instead of looking at that, we will look at the total number of socially acceptable possible distributions over n urinals and show that is this equal to f_{n+3} for $n \geq 1$. We will make a proof by induction.

The proof (base case)

Let the amount of total urinals be n and the amount of socially acceptable urinals be $p(n)$. We will denote each individual urinal from left to right by u_i with $1 \leq i \leq n$, and denote occupied urinals as $u_i = \bullet$ and unoccupied ones by $u_i = \circ$.

In our base case, $n = 1$, we find that we have 2 options. Either $u_1 = \bullet$ or $u_1 = \circ$. This is indeed equal to f_4.

When n is equal to 2, we have 3 possible distributions, $u_1 = \circ, u_2 = \circ$, or $u_1 = \bullet, u_2 = \circ$ or $u_1 = \circ, u_2 = \bullet$. For readability, we will leave out the "$u_i =$" part of the notation. Instead, we'll denote the set of u_i as $U := u_1u_2u_3...u_n$. In our case of $n = 2$ have found the following possibilities for U: ($\circ\circ$), ($\bullet\circ$), ($\circ\bullet$).

The combination ($\bullet\bullet$) is not socially acceptable so we have 3 total, which in indeed f_5.

Lastly, for $n = 3$, we find the possible distribution for all empty ($\circ \circ \circ$), one occupant ($\bullet \circ \circ$), ($\circ \bullet \circ$), ($\circ \circ \bullet$), and two occupants ($\bullet \circ \bullet$). So 5 in total, showing that $p(3) = 5 = f_6$.

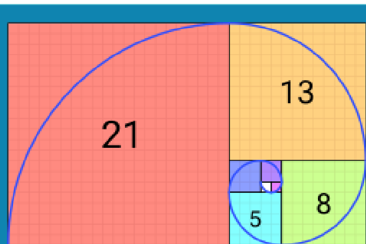


Figure 14: The 'Fibonacci Spiral' often associated with the Golden Ratio

[9] In some texts, the sequence may start with two 1's or a 1 and a 2. Here, we chose the first entries to be 0 and 1.

A quick lemma

The amount of socially acceptable positions on n urinals is the same as the number of acceptable positions on $n+1$ urinals if the rightmost urinal is unoccupied.

$$p(n+1|u_{n+1} = \circ) = p(n).$$

Proof *(lemma):* Adding an *unoccupied* urinal, does not increase the number of possible distributions. Since it has to be empty, we have the same amount available. At the same time, this does not decrease the amount of possible distributions. This is because empty urinals don't place any restrictions the way occupied ones do. Every existing distribution in p_n is still valid and no new distributions are created. See also figure 15.

Proof (induction)

Using the lemma above, we can quickly finish our proof. The possible distributions on $n+2$ urinals fall in two categories, the last urinal u_{n+2} is either occupied or unoccupied. So we have

$$p(n+2) = p(n+2|u_{n+2} = \circ) + p(n+2|u_{n+2} = \bullet).$$

The first term of the right hand side of this expression is equal to $p(n+1)$ by the earlier lemma.

The second term of the right hand side expresses the amount of possible distributions on $n+2$ urinals, with the last one being occupied. This can only be the case when u_{n+1} is unoccupied (because we are still only interested in socially acceptable distributions).

So we now know that

$$p(n+2|u_{n+2} = \bullet) = p(n+1|u_{n+1} = \circ).$$

And this we can simplify further by applying the lemma again, which gives us.

$$p(n+2|u_{n+2} = \bullet) = p(n+1|u_{n+1} = \circ) = p(n).$$

Combining these two gives us the final identity.

$$\begin{aligned} p(n+2) &= p(n+2|u_{n+2} = \circ) + p(n+2|u_{n+2} = \bullet), \\ p(n+2) &= p(n+1) \qquad + p(n+1|u_{n+1} = \circ), \\ p(n+2) &= p(n+1) \qquad + p(n) \end{aligned}$$

This shows that the sequence $p(n)$ is distributed the same way that the Fibonacci sequence is. Paired with the base case that showed $p(1) = f_4, p(2) = f_5$, and $p(3) = f_6$, conclude that $p(n) = f_{n+3}, \forall n \in \mathbb{N}$.

Conclusion

Whether or not you believe the Golden Ratio shows up in nature, hopefully you remember its existence the next time you visit a public bathroom. And if you are ever in charge of designing one and decide to place an arbitrarily large number of urinals, you can remember that each additional urinal adds around 62% more possible distributions.

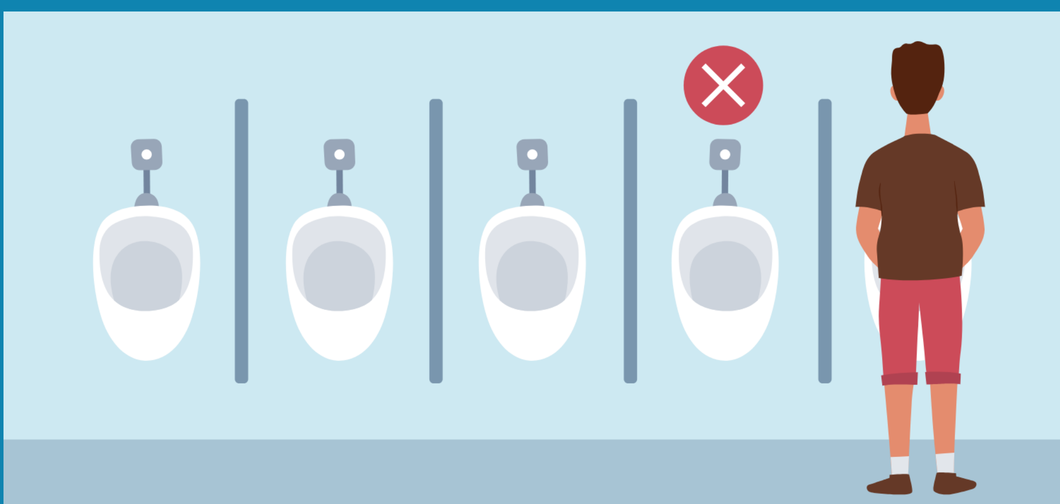


Figure 15: The occupation of the rightmost urial reduces the amount of avaiable distribution to be the same amount aswe would have for urinals

Mechanics of Ice Skating

AUTHOR: **M. WESTERHOF**

The life of a physicist is sometimes difficult. While you are cycling, you suddenly start calculating all kinds of things (on the racing bike I burn about two raisin buns per hour). Sometimes that is useful, such as when skating. Many skating phenomena can be easily explained with physics: hip in the turn, sitting deep, making long strokes, there is an explanation for everything.

One of my favourite topics within physics is mechanics. Wikipedia describes mechanics as "Mechanics is the area of physics concerned with the relationships between force, matter, and motion among physical objects." and on the Dutch version, it also mentions balance in its definition of mechanics. This certainly affects skating.

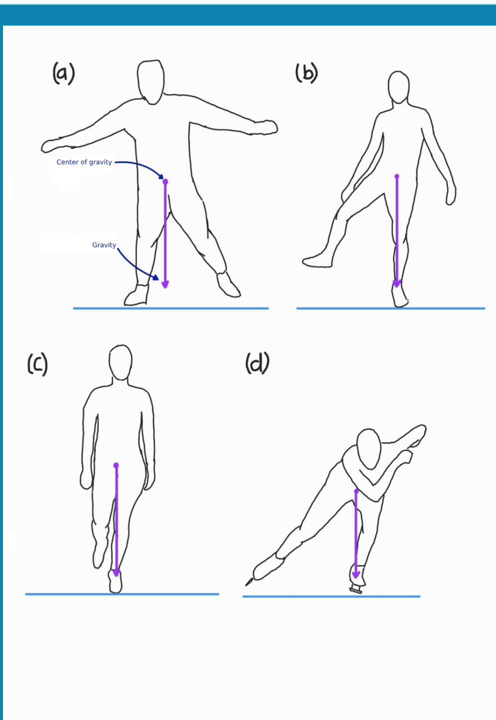


Figure 16

In this issue, I want to write something about balance, which is very important while skating. Being balanced has everything to do wit hthe centre of gravity. The center of gravity is the place where the weight of an object comes together, a kind of average place. For a half-empty bottle this is more at the bottom than for a full one; on a plate this is in the middle.You can also think of the center of gravity as the place where gravity acts on something. You can also try this out yourself. If you have an empty breakfast plate, you can balance it on a finger by placing it under your center of gravity.

But what does this have to do with skating? If you stand on one leg while skating, you can do this in different ways. In picture (a) the person lifts his foot but does nothing else. He falls back on his foot because his center of gravity is not above the leg he wants to stand on. Now gravity works next to his foot and pulls him back down. In picture (b) this is already going better. This person is standing stable; gravity acts above the supporting leg and therefore does not pull to the side. However, in this position it is impossible to skate quickly. That's why we go to picture (c). This person is also balanced because he puts his hip to the side. The center of gravity is still above the supporting leg, but some skating can be done from this position. This is perfected in figure (d). By sitting deeply, the center of gravity is lower, which provides more stability. You can also use a lot more energy in your push by sitting deep, but that's another story.

The Forgotten Truth of NB Building

Writing competition winner

AUTHOR: **L. JASLOVSKA**

Our university is not what it seems. Beneath its grand image, and long history lies a very dark truth. Have you ever wondered why the NB Building is being demolished, and why its employees were hastily relocated to the Feringa Building? The official explanation points to asbestos and age of the building, but that is not the real reason. We have stumbled upon the university's darkest secret by accident. An asbestos leak had been reported in the NB basement, and as student campus safety committee, we were tasked with locating it.

While inspecting the lower storage rooms, we noticed something strange. The reported leak was from a hole in a wall that was supposed to be a solid part of the building but wasn't. With a few tools and a lot of effort, we broke through the drywall. Behind it were old metallic stairs leading deeper into the ground. Our curiosity got the better of us and we have decided to explore this newly found entrance to the underworld. The stairs led us to a large room far below the university grounds.

The room was clinical, its dirty white tiles cracked and stained. Rusted tables with restraining straps lined the walls. Instruments lay scattered—scalpels, syringes, and strange devices whose purposes we could only guess. Large, cylindrical glass containers filled with murky, yellowish liquids. Something floated within each one—twisted, malformed shapes that vaguely resembled human forms. Coolers with containers marked with words such as: Brain, Intestine, Eyes... A nearby desk was littered with notebooks, their pages covered in faded handwriting. The experiments detailed within were containing the psychological behaviors, chemical testing, and more grotesque endeavors involving genetic manipulations. Each entry was marked with a date and a name with a picture of a person. At the left end of the room was a metallic door that led us to another section. The smell hit us first, a sickly blend of rot and chemicals. Rows of steel tables stood in the center, each one fitted with drains leading to a central pit. Human remains littered the area. Some were skeletal, others mummified, their faces twisted in eternal agony.

We pieced together the story as best as we could. The NB Building had been the center of secret experimentation for decades, disguised as a simple science facility. The university had used its prestigious reputation to attract the brightest minds, only to subject some of them to unspeakable horrors in the name of progress. One entry in the notebooks caught our attention more than the others. It read: *"Darwin Trials: Breaking the Human Limit. Subjects must endure for the sake of knowledge. Science cannot advance without sacrifice."* But something must have gone terribly wrong. Maybe the experiments yielded results too monstrous to control, or maybe someone had finally grown a conscience. Either way, the NB Building testing was abandoned, its secrets buried until now. We knew the horrible truth: the demolition wasn't about safety. It was about erasing the past. The Feringa Building now houses those who once worked in NB, their relocation a calculated move to distance them from the horror.

When we tried to bring our findings to light, we considered our positions as students who want to just finish their studies and move on with their life. But what we saw that day will haunt us forever. We are left with our memories, our fear, and a single question: How far would the university go to protect its legacy? At night, when the campus is quiet, I sometimes hear faint whispers where the NB Building once stood. Whispers of pain. Whispers of those sacrificed for the pursuit of knowledge. And we wonder, what else lies hidden beneath this place? But another question is... who will be next?

Secrets like these don't just vanish with the rubble of a demolished building. They linger, waiting for new participants, fresh minds,... and bodies to continue the work. You've read this far, and that means you're curious. Curiosity is dangerous here. It's the same curiosity that led us to the hidden door, to the stairs, to the horrors below. The same curiosity that made those who came before us easy targets. So, this is a warning: stop asking questions. Stop looking for answers. Because if you keep digging, the student council won't need to find a new test subject. You'll be their next fresh flesh supply.

Scam
Writing competition runner-up

AUTHOR: **K. KARBOWSKI**

"The University is hiding a Machine under Nijenborgh."

The email's first line glowed on Lucas Smit's screen, cutting through the rainy Tuesday gloom. Lucas reread the sender's address—it belonged to someone from the faculty. He frowned, scrolling down.

"The Machine tells only the truth. So far, no one outside the closest circle has accessed it, but that changes now."

The email continued:

"If you're reading this, you are one of a group of students chosen by the Machine. Submit a question. The one it finds most worthy will be asked in person. You have 24 hours to respond."

Chosen. The word unsettled him. It reminded him of his morning—of the exam results he still couldn't wrap his head around.

For two months, he had done almost nothing. He hadn't studied. He hadn't prepared. This time, he was sure the illusion would dissipate, that his professors would finally see through him. But the results were undeniable: he had passed. Not just passed—excelled.

"And so my scam continues," he thought. Lucas stared at the email again, its language digging under his skin. The mail had to be a scam—but what if it wasn't?

What if I were to respond?

Another strange stroke of luck. Another chance he hadn't earned.

"I would be laughed at," he thought swiftly. "They would finally recognise that I don't belong here."

But the possibility of embarrassment didn't stop him from clicking the reply button. "And so what if they do?"

The sun had sunk behind the city, plunging his room into shadow. His reflection in the window stared back—a tired, hollow face. "All it ever takes is my single mistake for them to realise that there are hundreds of other people more worthy of my place."

"This way, at least I'll get to make the mistake intentionally," he muttered to his reflection.

It stared back at him as he typed the question that had haunted him for years. Before the ever-present doubt could creep in, he pressed 'Send' and stepped away.

It was over, and somehow it felt... good.

Not for a single moment did he think that this ridiculous affair would result in anything. He did not expect some researcher to contact him, saying that his silly question was chosen.

When he searched his heart, he had no hope like that. And despite all of it, he fell asleep quickly that evening and slept well the entire night, unbothered by any worries. Thinking about it, it might have been the best sleep he had in years—the sleep of an honest man.

The next day went about as if nothing had happened. By the end, he almost forgot anything out of the ordinary happened. Then came Thursday, and it, too, passed without any excesses. And so his scam continued.

On Friday afternoon, when wiping his bike seat, he felt someone approach him from the back. Two steps from him, the person stopped, as if waiting for him.

"I'll let you through in a second," he said, still not looking back. He felt the person shift uneasily behind him.

"Lucas Smit?"

The voice was older and high-pitched. As Lucas turned he saw in front of him a skinny, tall man with long, unkempt hair and patchy beard.

"Yes, how can I help you?" He was sure that he had never seen that man before. The man's gaze seemed frantic, drilling into his face.

"You have a question to ask."

Lucas froze, memories of the email flooding back as the cloth slipped from his fingers. He picked it up, meeting the stranger's frantic gaze—and saw madness.

"Walk with me," the man said, already heading towards the Nijenborgh. Lucas hesitated, then followed. "I won't confirm or deny anything in the message," the man began, his voice steady but sharp.

"You get one shot to ask your question. After that, this will never be spoken of again. Tell anyone, and you'll find no proof the Machine exists. Do you understand?"

Lucas stopped.

"No."

The man turned, his gaze boring into him. "What part don't you understand?" "Why me?" he blurted.

The man's stare softened, almost imperceptibly.

"It liked your question," and without any further elaboration, he continued walking.

"But if what you're saying is true, this Machine's a powerful source of knowledge. It could be used for great things. Why my question? Why not choose someone more worthy of spending all this power on?"

The campus was nearly empty now, the last stragglers rushing home for the weekend. The man didn't answer for a while.

Then, without looking back, he asked, "Why did you ask that question, the one you sent?" asked the man, not turning to face Lucas.

Lucas faltered. "I don't know. I think... I was tired."

The man stopped in his tracks, waiting. Lucas' legs shook beneath him, and his words spilled out like a confession.

"I think I still am tired of this constant tension." Lucas sank to the pavement.

"I'm tired of being unable to relax, of having no sense of reserve or resilience. I'm tired of pretending everything's fine while everyone tells me how smart I am."

He felt his tears welling up, but he could not care less.

“Tired of being glad things are over instead of proud they’re done. Tired of this façade I’ve built, knowing one day it will all come crashing down. And that day is coming—the day I am found out for who I am.”

“And who are you, then?” the man asked, his tone calm. Lucas hesitated, staring through his tears into the blur of lights around him.

“A fraud. I tricked the world into thinking I belong. That I deserve to be here—to be praised.”

“And you’ve never accepted the praise?” The man crouched beside him, his voice low. “Never thought they might see something in you that you don’t?”

Lucas wiped his face, laughing bitterly. “They don’t know me like I do.”

The man studied him for a moment, then asked, “How proud must you be to think you alone can judge your worth?”

“Maybe the problem isn’t how the world sees you—it’s how you see it.”

The man turned away, but in his harsh tone, Lucas thought he heard something that could only be a pain. Pain of a man, who knows of a subject matter more than he would have ever wished to know.

Lucas froze. He felt shaken, but he forced a calm reply. “Well, if you believe me, you’ve fallen for my scam too.”

“Stand up. You have a question to ask, that is if you still wish to.” Without waiting for any sign that his words were received, he started walking towards Nijenborgh. Lucas followed without a word.

When they reached Nijenborgh, the man opened a series of doors, each with a different key. With each corridor they passed, descending down, underground, Lucas felt more swallowed by the building, he thought he knew so well.

Finally, they entered a room where the man stopped. The lights were off, and it was pitch black, but Lucas could feel something great looming over them, stemming from the very centre of the room. They stood motionless.

At first, he thought it was a machine—just a cluster of mechanical parts, like a relic from another age. But the longer he stared, the more alive it seemed.

Cables pulsed like arteries. Wires stretched like veins, forming a giant silhouette that seemed to breathe. The connections twisted upward, a tangled mass of tendons coiling into deformed heads of spinning fans that scraped the ceiling. The room hummed with life.

Lucas’ legs buckled, and he sank to the floor under its weight.

And then the lights turned on.

In the middle of the room, on a table sat a laptop with a terminal displaying: “Please, enter your question.”

Lucas stood up, on shaking legs, as if not fully in control of his actions, he approached the small device and typed his question. Before the ever-present doubt could creep in, he pressed ‘Send’ and stepped away.

It was over, and somehow it felt... good.

The Machine processed his question. The loading circle spun endlessly, each rotation in perfect sync with Lucas’ pounding heart. He stared into the circle, daring it to respond—and dreading the answer. With each passing second, a new thought crept in: What if it never comes?

And then it did. The text read:

"YOU DID A GOOD JOB."

Lucas left. On his way out, he didn't see the man.

Later, walking through the city, he thought of the Machine and felt a smile creep onto his face.

"And so my scam continues."

Art section

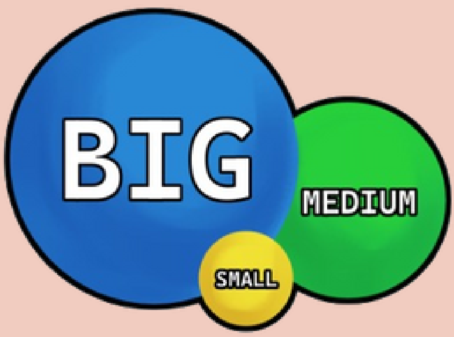
Big, medium, small: Shape Composition

Author: R. Bonhof

Hi there,

From the years I have spent on making character illustrations and concept art designs, one of the major principles I always come back to is shape composition.

Now this might sound daunting, but I will do my best to explain it in a way that should help clear up what I mean and for you to hopefully be able to work on designs in a more comfortable way. Of course this is not the only way to make art, nor is it something you absolutely need to do in order to make good looking art. But what actually is this shape composition I'm talking about? Well, shape composition is in reference to the size of elements in an art piece and how they relate to each other. As an example I have put a little scheme that I'll use later to explain how I work on making my art look more appealing. Just like the three spheres below, a piece is generally composed out of a large element, some medium elements and a few small elements (which often are the small details that are spread across the design).



The trick here is to not fill up every part of the piece with the same level of detail and instead let each element stand on its own. By doing this, you allow the eye of the viewer (fancy way to say the people you show your art to) to travel across the piece. Even more so, by having the small elements only in certain parts, you allow the eye to rest on the less detailed parts.

Think for example of the doodles you might have scribbled in the margins of your notebook. If you have these doodles everywhere along with your notes on the page, the page will look busy due to a lack of empty space. By having larger elements that are not as riddled with additional details, the composition as a whole is allowed to have room to breathe. However, I do need to emphasise that this does not include texturing, as consistent textures with small details are not necessarily busy. For example a lot of fantasy armour designs (think anything from Beserk to Final Fantasy) have a ton of detail on the armour, but they do not look cluttered. A major reason to that is that while there is a lot of detail, they are consistent elements that work moreso as textures than additional small titbits.

But enough rambling withoutany examples, let me show you how I apply this to one of my works, specifically a banner Ihave made. This piece I made with the focus on shapes in mind, but there is no need to only use monochrome colours for this.

I have highlighted in blue the large elements, in green the medium elements, and in yellow the small elements. My goal for this piece specifically was to have one spire with skulls really pop out towards the viewer, with the main character being the next focus. Lastly, the additional spires that are in the background should allow the piece to have a few more pieces to look at and pick apart. With this I got my order in which I want the viewer to see the piece, so I match this to the order of the element size with the major focus being the largest element.

While I am matching the size of the elements with how much focus I want on them, I don't order them from left to right exactly from large to small. This is where a lot of freedom and fun can be had with how you spread the different elements across the piece, and I highly recommend that if you want to try some shape composition yourself that you make a couple of small sketches with each a different placement of the shapes. That way you get to see what clicks best (and often your initial sketch does not turn out to be what you use in the end, which is okay!). But that is not all! Even the elements on their own have their own distribution of shapes within themselves, just like a fractal. You can go pretty ham with this and get some pretty sweet results with it.

But to send you off with a bit of an exercise, try and determine the shapes of Marcel (the tentacle lad on the previous page), and if you are still hungry for more, try and determine the shapes and their hierarchy on art you really like and think on why the elements are placed in the way they are.

Best of luck (and may you make many horrors yourself)!

Rick Bonhof

(And if you want to see more of what I make, be sure to check out GBroatic on artstation for my art portfolios)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Recipe

Oyakodon: Japanese Donburi (Rice Bowl)

AUTHOR: **L. ADDAMS**

I fell in love with cooking through exposure to culinary science, and making Japanese food allows me to connect to my favourite part of my heritage. Being a student in Groningen also makes this dish extremely appealing, for reasons coming up below. Whether you are Japanese or not, you can take sheer delight in the interesting process of making this 150+ year old dish. How so? Because the extraction of multi-layered, satisfying flavours, in a rather simple dish, allows the ingredients to shine and give you their all. This is an integral part of Japanese cooking!

Figure 17: Oyakodon topped with furikake.

Origins

Oyakodon has a fascinating name. Oya means parent, while ko means child. This comes from the chicken and the egg. It might be strange to imagine eating a bowl of a parent and their child, but it is hilariously accurate regardless. In fact, other, similar rice bowls utilise this meaning to name their dishes, such as salmon with salmon roe. Don simply comes from donburi, meaning rice bowl. The traditional method of making this dish is by simmering the ingredients in a signature sauce. It is commonly used in Japanese cuisine, and they use it in other dishes too (such as gyu—don, a beef bowl you can make when you get tired of chicken). For the sauce, I will be giving you the measurements needed for the amount of ingredients you will use in the recipe. If you need more sauce, like if you make two chicken thighs instead of one, you need to double the measurements. Do not forget to double the water, too, or you will end up with a very salty sauce! Lastly, although we will no longer remain true to the name, I will also provide vegetarian alternatives.

Summary

Oyakodon is a popular, comforting donburi (rice bowl) commonly eaten by Japanese people. Whether they make it at home as a family, as students, or at speciality restaurants, this staple is never far. It makes sense, as it is quick and easy to make, flavourful, relatively healthy (can be made healthier with additions and/or substitutions), and really cheap.

Recipe

Preparation time: ∼ 40 minutes (incl. rice).
Cooking time: ∼ 8-15 minutes (or less, see below).
Portions: 1-2 servings.
Yield: 1 bowl per serving.
Allergen information: soy, sesame (optional), eggs, chicken (can be replaced).

Main Ingredients

- 1 cup of rice per serving (or per person).
- 1/2 of a white (or yellow but not recommended) onion. You can use a whole onion if it is small.
- 1 boneless skinless chicken thigh (per serving). You can use chicken breast, but it won't be as juicy.
- For a vegetarian alternative, portobello mushrooms or tofu are a great substitute.
- 1-2 (eggs based on preference).
- 1 tsp minced ginger (optional).
- 5x3 cm piece of *konbu*.
- *furikake,* green onions, *shichimi togarashi*, or *kewpie* mayo for garnish.

Sauce Ingredients

- 50 ml water.
- 4 tsp soy sauce.
- 1 tsp sugar.
- 1 tsp mirin.
- 2 tsp sake.
- 1 tsp dashi liquid concentrate (or powder). This is to taste, you can add 1 or 0.5 tsp extra to make it a bit richer in flavour.

Tips and Product Information

If you are new to Asian or Japanese cooking in particular, I will make life as easy as possible by providing as many tips and sources for ingredients as needed. First of all, I highly recommend owning a rice cooker. Although I can teach you how to cook rice in a pot, you can make your life a lot easier by investing in a decent rice cooker. Not only does it make rice, you can make a whole meal in there! For example, you could actually make this entire dish in the rice cooker if you had one, and all you would have to do is dump all your ingredients in there.

Rice For your rice, I *highly* recommend getting *koshihikari* rice. This might sound intimidating, but it is basically what is typically marketed as sushi rice. This is the rice Japanese people eat daily, and you would be missing out on a lot of flavour and texture if you opt for worse rice. You can find many different brands of this type of rice at the Amazing Oriental (AO). Some of them can be quite expensive, but for a student, you can never go wrong with the *Rakki Koshihikari* rice. It is a red bag with a white *maneki-neko (beckoning cat)* on it.

Figure 18: Rakki Koshihikari rice, found at AO.

It is the cheapest option I have found here, and it is perfectly delicious. For those who are more health-conscious or simply dislike white rice, a brown *koshihikari* rice variety can also be found at the AO. It is about €3 more expensive than the white rice I suggested, but that is the tax you pay for health! It is called *Yume Nishiki* brown rice. It is also the only one they have as far as I can see, so you should be able to find it easily.

When you use this rice, you absolutely *must* wash it thoroughly and soak it beforehand, at least for 30 minutes. The beauty of a rice cooker is that if you have one, you can set a timer for the rice to be cooked by the time you return from university, when you wake up in the morning, or whenever else. And it keeps your rice warm for you! And no, sadly, we are not sponsored by a rice cooker brand, it just truly is that excellent.

Sauce Next, we will discuss the sauce. I will give instructions for making it with pre-made dashi products, but if you want to make dashi broth yourself (which you can store in the fridge for up to a week and 3 months in the freezer, in an airtight container), feel free to look up a recipe. It is easy to make and only needs 2 ingredients.

Cooking Instructions

1. Begin by making your rice. Do not forget the 30 min pre-soak. If using a rice cooker, you can simply measure out your rice with the measuring cup, rinse it 3 times, then pour it into your rice cooker with a (cold) water ratio of 1.1 to 1. Place your piece of *konbu* over the rice. Remove it only after cooking (this infuses your rice with umami. Do it in a pot, too). If using a pot, follow the same instructions as above (measure your water in your rice cup), but into a stovetop pot. Put the lid on. Turn the heat on high and wait for the water to boil. If you are unsure if it has begun to boil, listen for the bubbling sound from the pot, or watch for a bouncy lid. Once it boils, turn the heat down to low and let it simmer for 12-13 minutes. Do *not* open it during this time, it can ruin your rice. Think of it like this: you are creating a steaming environment for the rice, and if you disturb the closed system, you disrupt the process. Trust that it will come out delicious. Turn off the heat and do not open the lid for another 10 mins.

2. Slice your 1/2 onion. Next, thinly dice your chicken thigh/breast. Cut the onion first, since you would need to disinfect your cutting board after cutting the chicken. If using portobello mushrooms, cut it any way you like, bite-sized. Same goes for the tofu. Set aside.

3. Prepare the sauce. In a bowl, combine *50 ml* of water, *4 tsp* of soy sauce, *1 tsp* of sugar, *1 tsp* of mirin, *2 tsp* of sake, and *1-2 tsp* of dashi stock concentrate or dashi powder. Mix the sauce together, since it will help the sugar dissolve better. Place the cubed chicken/mushrooms/tofu in the bowl and leave it to marinate (max 15 mins) while you follow the next steps.

4. Place your pan over medium heat. Pour 1/2 tbsp of neutral oil into your pan. Use any oil you like except olive oil, as it has a unique flavour that would ruin the dish. Seriously, do not do it. Add in a teaspoon of ginger (if using) and stir the onions around in the ginger. The point here is just to get the onions slightly soft and translucent, and to get the ginger flavour to permeate the base of your dish.

5. Pour the chicken/mushrooms/tofu with its marinade into the pan. Keep the heat on medium so the chicken (or its alternative) is simmering. Make sure to mix it around from time to time so the chicken/mushrooms/tofu does not stick to itself or the pan, and so the sauce coats everything.

6. While the chicken/mushrooms/tofu is cooking, crack 1-2 eggs in a small bowl and lightly mix them. You want clear whites and clear yellows, so resist the temptation to over-mix. I know it is very tempting, but the result is far better this way.

7. Once your chicken/mushrooms/tofu is fully cooked (7-8 minutes for thighs, 5-7 for breasts, 5-6 min for firm tofu, and 2-3 mins for silken tofu [not recommended]), turn the heat up to high and pour your egg(s) over the mixture in the pan. Do it as evenly as possible. Place your chopsticks into one end of the pan and quickly rotate it in a half-circle anticlockwise, moving your chopsticks in the opposite direction. Do it once along the x-axis, y-axis, then diagonally. Let the eggs cook briefly, so they are still slightly runny. Turn off the heat.

8. Fluff your rice before serving it in a bowl, as much of it as you'd like. Pour your oyakodon mixture carefully over the rice,

9. You can now garnish with green onions, furikake, shichimi togarashi, sesame seeds or kewpie mayo, or a combination of a few of those that you like. Do not overdo it. Enjoy!

Brainwork

Crossnumber

AUTHOR: **R. MOL**

Across (A)

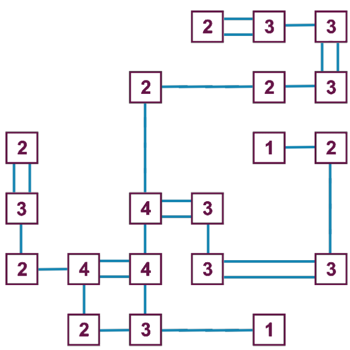
1. The first digit of this number tells you how many 0's this number has. The second digit tells you how many 1's it has. The third digit tells you the amount of 2's, etc.
5. A number that satisfies $AB = A^B + BA$ where AB is $10 \cdot A + B$, and **not** $A \cdot B$. Vice versa for BA
7. A multiple of 10001
9. A divisor of 2025
10. A multiple of **28A**
11. A multiple of 11
13. A perfect number
17. A sexy prime with 37
18. A multiple of 5
19. A number where each of its digits appears as often as its value (i.e. *if* there is a 3, *then* there are three 3's)
23. A Composite number with exactly 5 prime divisors
24. The numerical part of the postal code of the FMF
25. The smallest composite number, squared
28. A prime which is the sum of consecutive primes
30. The digits of **10A**, multiplied by 5, reshuffled
32. The biggest number whose factorial is less than a googol
33. The founding year of the FMF
36. Add 64 to this number to get a number whose digits are in strictly increasing order
37. A square number squared
38. A lucky number
39. The second prime higher than **43A**
41. A multiple of **5A**
43. The sum of two factorials
44. A palindromic number that contains a 9
46. The same as **48A**
47. A multiple of 3
48. The same as **46A**
49. A square, smaller than **49D**
51. All but one of the digits of this number are the same
52. A prime number with strictly increasing digits

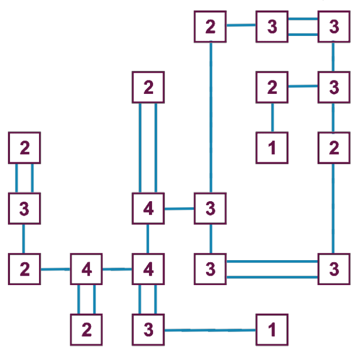
Down (D)

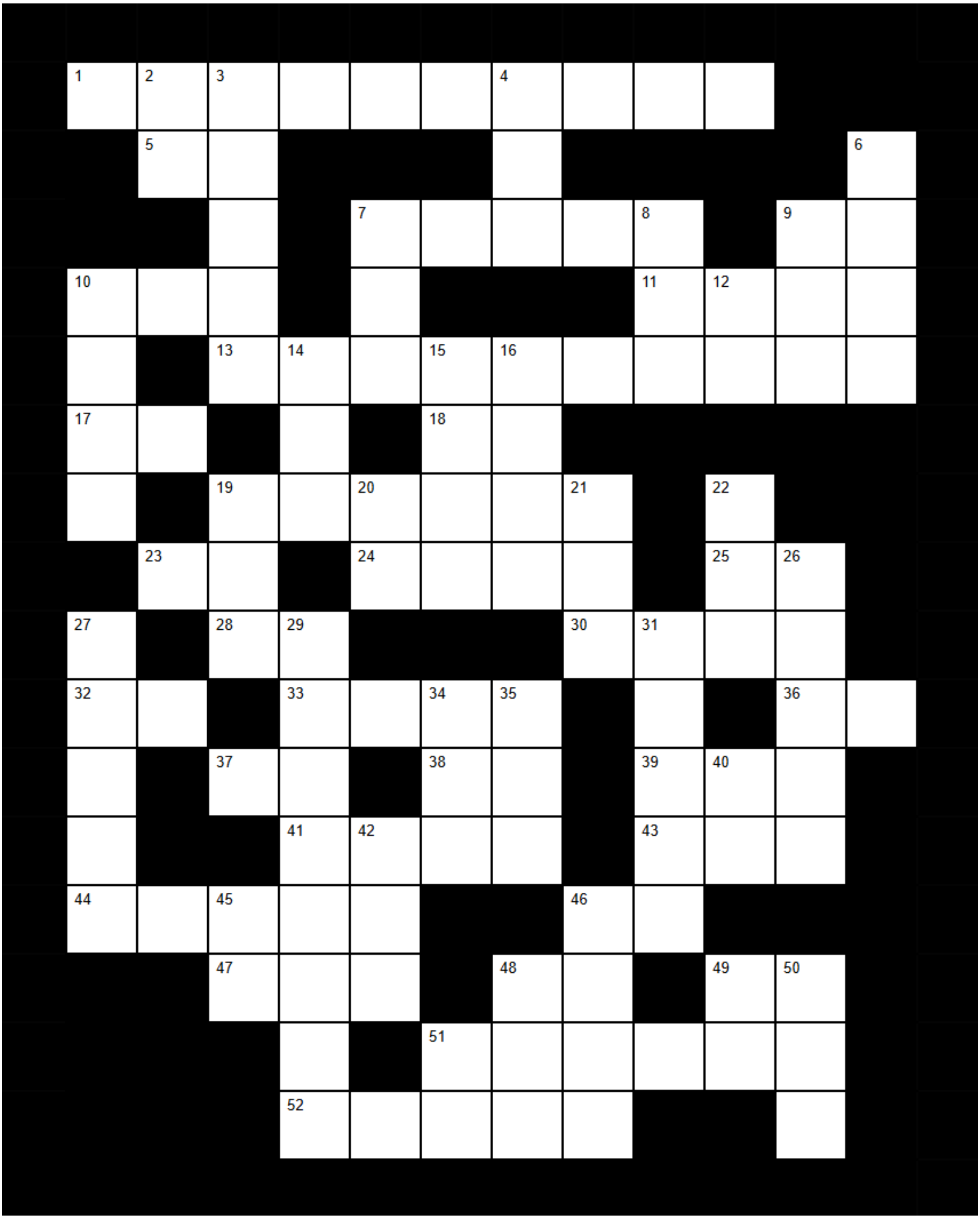
2. An even number
3. The largest number that cannot be represented as the sum of distinct cubes
4. A number that is a square regardless of which base you read it in
6. The second smallest number that is the product of ten primes
7. A Happy number
8. The answer to **29D** in base 10
9. A number whose digits are in strictly decreasing order
10. **5A** times **38A**
12. $2^n + n$ for some $n \in \mathbb{N}$
14. An Impolite number
15. **10D** + **33A** + **41A**
16. A multiple of 3
19. Webpage not found
20. A number which is not a square
21. **19D** + **32A**
22. A triangle number whose digits add up to 3
26. The zenzizenzizenzic of 4
27. A Fibonacci number
29. A binary number
31. A multiple of 7
34. A triangular number
35. Another triangular number
40. The product of a square and a cube
42. A multiple of 97
45. A multiple of 7
46. A Taxicab number
48. A number which, when expressed as a binary number, only has a single 1
49. An Emirp that does not appear anywhere else in this puzzle (neither up nor down)
50. The maximum rectangular area that can be enclosed by 100 meters of fence, in square meters
51. A divisor of **24A**

Solution to the previous Brainwork

The previous puzzle was successfully solved by Hannah Jager and Diana Ionescu. Two solutions are given below.







Fill in numbers that fit the associated hint on the previous page, just like a crossword puzzle. Each square contains exactly one digit (0, 1, 2, 3, 4, 5, 6, 7, 8, or 9). If you are reading the Periodiek online, you can copy the empty puzzle here to fill it in online.

Note that the notation **10A** refers to hint **10** in **Across (A)** and **10D** refers to hint **10** in **Down (D).**