

How to make a poster

...also how you shouldn't, why you should care, and how they matter

SUMR Meeting 7: Making a maths poster

Wednesday 28th August, 3pm



Joseph Webber
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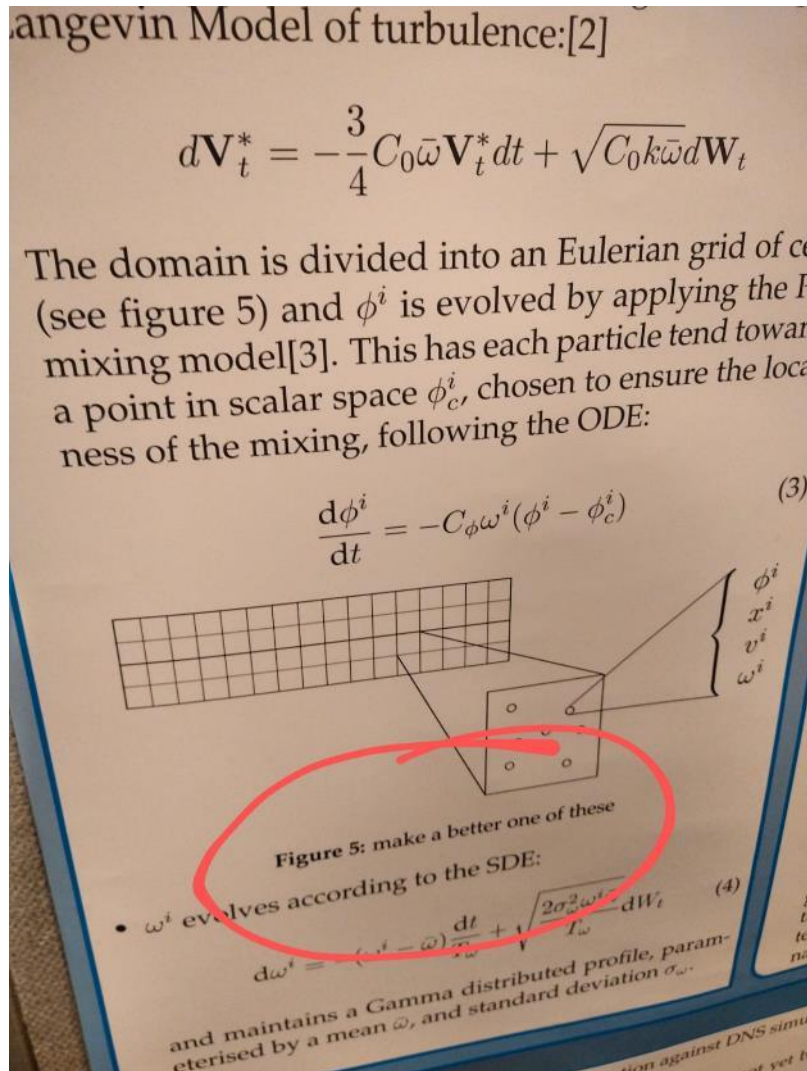
What are posters?

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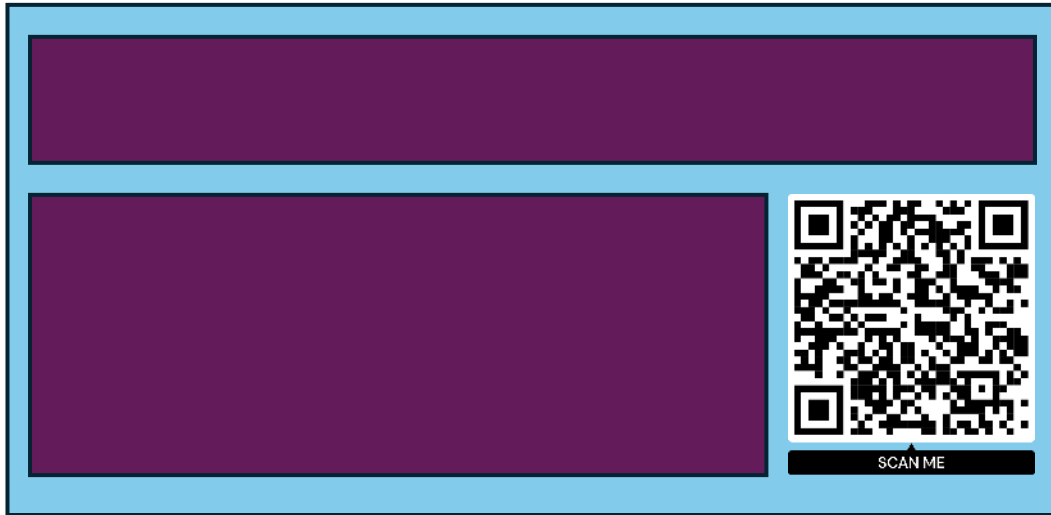
- Posters are usually presented in one of two ways:
 - In a huge poster session (pictured)
 - As part of a ‘flashtalks’ event (rarer, but common for early-career stuff in some fields)
- Physically, usually A0/A1 (big!)

Take-home messages



- **Posters are important** – they’re not just a “I didn’t get a talk, so I’ll just make a poster” cop-out
- **Posters need to be good** – unlike in a talk, people have no politeness incentive to stick around
- **Posters need to stand out** – there’s usually lots of them, all next to each other
- **Posters need to serve a dual purpose** – they’re a presentation aid, like slides, for when you’re there, but they need to make sense on their own

Purposes of a poster



The “paper advert”

- Catchy – should stand out
- Centred around the key finding
- Light on detail
- Make it easy to get to the paper – a reference won’t be enough

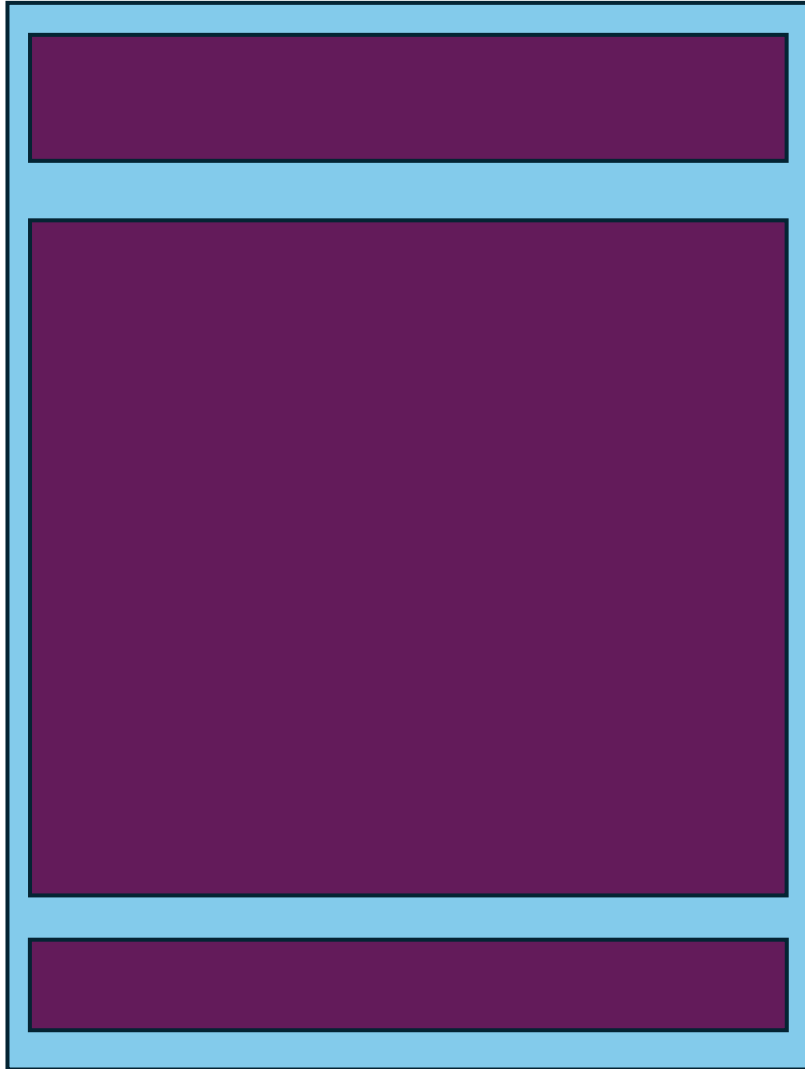
The “project summary”

- Gives detail to a level short of a paper, but more in-depth than a talk
- Walks through the key points so somebody can understand what you’ve done
- Can be dense – often best avoided

The “talk guide”

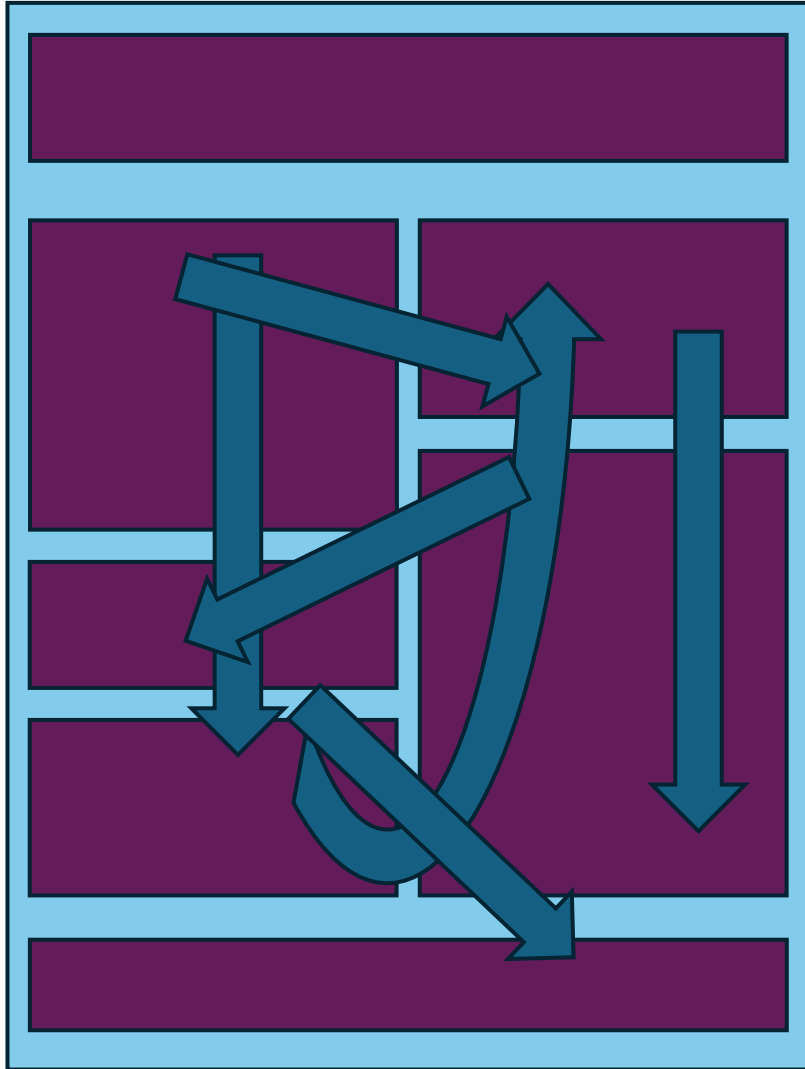
- Gives graphical pointers and equations that let you explain your work
- You *need* to be present the whole time or it’ll make no sense

Structuring a poster



- Hard to read
- Remember that this is *not* a paper and needs to be spotted from across a room
- Pictures are important! Include graphs, but remember that axis labels and numbers need to be bigger

Structuring a poster



- If someone *is* interested, it needs to be easy to follow
- Can't tell a story if there's no clear order to it

- Text is too small
- No clear story
- Contrast is low between elements
- Too much content
- Generic, vague, title
- Text style is too much like prose from a paper

Dynamics of super-absorbent hydrogels

JOSEPH WEBBER *Institute of Theoretical Geophysics, Department of Applied Mathematics and Theoretical Physics, University of Cambridge*
Supervised by Prof Grae Worster, DAMTP

The current understanding of transport of water in plants relies on significant negative pressures¹ in the xylem to draw water up against gravity.

We expect such pressures to lead to cavitation, spontaneous boiling, and xylem collapse², especially in plants subjected to water stress.

The pit membranes separating one xylem vessel from another both constrict flow but also contain hydrogels formed from organic polymers and water³. These can be modelled using our new approach.

We propose a contribution from discontinuities in the liquid pressure arising at the interface between hydrogel and water in pits between xylem cells.

The negative pressure problem

Assuming a steady evaporation flow rate, there must be a pressure difference in the water of the xylem in a tree which balances the hydrostatic pressure, in order to drive flow against gravity. Order-of-magnitude scalings can be used to deduce a representative pressure drop required in a tree to produce such a flow.

This rises to around 2 MPa if the effects of friction in the xylem are factored in⁴, suggesting water at the top of a tree will be at pressures of -1 to -4 MPa relative to the atmosphere.

At pressures of around -0.1 MPa, water spontaneously boils and we expect cavitation, collapse of xylem vessels and damage to the tree. Though some authors claim to have measured such pressures^{5,6}, they are difficult to reproduce even in laboratory environments without cavitation. This motivates seeking an additional driving mechanism in the transport of fluid, in addition to classical cohesion-tension theory.

Linear-elastic-nonlinear-swelling gels

Hydrogels comprise hydrophilic polymer chains (of volume fraction ϕ) surrounded by adsorbed water. In many cases, the polymer volume percentage may be as small as 1%. Modelling of hydrogels needs to couple an understanding of the gel as an elastic material with its porous nature, and therefore is a key problem in poroelasticity. Existing models can be grouped into two main approaches:

- **Fully-nonlinear models**^{7,8} use a microscopic understanding^{9,10} of polymer and water molecule interactions to describe the macroscopic behaviour of the gel.
 - + Accurately models gels under large strains due to swelling and drying
 - Relies on a complicated chemical understanding of water-polymer interactions with parameters that are hard to measure macroscopically.
- **Fully-linear models**¹¹ use linear poroelasticity to relate the stresses and strains on a gel, with Darcy's law used to describe the flow of water.
 - + Describes only gels using only macroscopic parameters which are easy to measure, and separates out fluid flow from elasticity.
 - Linear elasticity is invalid for large strains¹² - hydrogels may swell with isotropic swelling strains of much greater than 100%.

In our linear-elastic-nonlinear-swelling model, we allow for nonlinearities in the (potentially large) isotropic strains corresponding to the swelling and drying of gels, whilst linearising around deviatoric strains corresponding to shearing deformation. In effect, a hydrogel swollen to any given degree is treated as an instantaneously incompressible linear-elastic material.

STRESS TENSOR

$$\underline{\sigma} = -[p + \Pi(\phi)]\mathbf{I} + 2\mu_s(\phi)\underline{\epsilon}$$

PRESSURE

In a two-component system we separate the bulk pressure P into two parts:

- A pervadec pressure p which is the pressure of the liquid phase as measured by a transducer, separated from the gel by a partially permeable membrane.
- An osmotic pressure Π dependent only on polymer fraction. This can be viewed as the pressure which must be applied to prevent the uptake of water by a gel, where hydrophilic polymer chains attract water molecules.

SHEAR MODULUS

Measures resistance to shear deformation, and depends on degree of swelling.

DEVIATORIC STRAIN

Strain can be separated into an isotropic part due to swelling and drying (changes in polymer fraction) and a part due to deviatoric deformation, $\underline{\epsilon}$. The key assumption of our model is that ϵ is small.

Pits and bordered pits

In between adjacent cells comprising the xylem of vascular plants lie pits, which permit the transport of sap laterally in addition to the vertical transport which occurs through the hollow lumen. These pits comprise a permeable membrane spanning a small gap of around 1-10 μm in diameter, with examples shown in cross-section in the first two images¹³ on the right. In some conifer species the pit structure is more complicated, forming a so-called bordered pit. Here, as shown in the final four images of the figure, a solid torus structure (labelled T) is held in place by a flexible and permeable elastic margo (M) which surrounds it and deforms in response to pressure and flow.

These elastic pit structures comprise organic polymers surrounded by water, and some authors have suggested that the resulting hydrogel could play an important role in the transport of fluid in plants¹⁴. They are able to bend as a circular membrane, swell and dry¹⁵.

reproduced from 6

Swelling and drying of hydrogels

The dynamics of gels can be understood as being driven by the flow of water throughout. The interstitial velocity of water is given by Darcy's law:

$$\mathbf{u} = -\frac{k(\phi)}{\eta(\phi)} \nabla p$$

When coupled with Cauchy's momentum equation, it becomes possible to derive a nonlinear diffusion equation governing the polymer fraction ϕ as a gel swells or dries.

$$\frac{\partial \phi}{\partial t} = \nabla \cdot \left(\frac{\partial k(\phi)}{\partial \phi} \left[\frac{\partial \phi}{\partial t} \nabla \phi + k(\phi) \nabla \left(\frac{\partial \phi}{\partial t} \right) \right] \right)$$

Involving only a handful of material parameters of a gel:

- The osmotic pressure and how it relates to polymer fraction.
- The permeability
- The shear modulus
- The equilibrium polymer fraction ϕ_{eq} , which is the polymer fraction reached by a given hydrogel if placed in water and allowed to swell with no constraints¹⁶. This depends on temperature and can be as low as 10% for some gels.

In addition, the shape of the hydrogel can be deduced from the forced biharmonic equation describing the displacement ζ of any given point from its position at equilibrium:

$$\nabla^4 \zeta = -3\nabla^2 \nabla^2 \left(\frac{\partial \phi}{\partial t} \right)^{1/3}$$

Gel membranes & surface tension

To apply our model to understand the flow of water through pit membranes in a plant cell, we start by considering a single thin circular membrane. Under a load Q per unit area, the vertical deflection ζ of a circular linear-elastic membrane satisfies

$$\nabla^4 \zeta = -Q/D$$

for D the bending moment¹⁷. Thus, if we assume that the membrane has a constant curvature K , the curvature under a given load is set by

$$Ek^2 = Q$$

At curved interfaces between gel and water, there is a discontinuity in the pervadec pressure arising from an effect akin to surface tension¹⁸. This can be quantified by the relation

$$\Delta p = \gamma \kappa$$

Therefore, under a load which arises purely from hydrostatic pressures, there exists equilibrium solutions where

$$2\gamma \kappa = Ek^2 \Rightarrow \kappa = 0, \pm \sqrt{\frac{2\gamma}{E}}$$

A simple experiment

Consider a U-shaped tube with a circular gel membrane placed in the left-hand arm, with equilibrium water heights h_1 and h_2 on the left and right sides, respectively. Then, the pressure difference across the membrane is given by

$$\Delta p = \rho g(h_1 - h_2)$$

Which, for nonzero γ , admits an equilibrium solution where $h_1 > h_2$ and thus a column of water is supported against gravity by the surface tension effect of the membrane.

Membranes in trees

As we have seen, a single hydrogel membrane can support a certain height of fluid against gravity due to discontinuities in the pervadec pressure across curved water-gel interfaces. If each bordered pit contains such a curved membrane, it is possible that water can be transported to great heights against gravity without the need for significant negative pressures (relative to atmospheric pressure) at the base. Each membrane need only contribute a small amount to the overall effect, $\partial \gamma \Sigma \gamma$.

- Webber et al. (2017) *J. Integr. Plant Biol.* 59:384-389
- Zimmermann et al. (2006) *New Phytologist* 162:729-743
- Webber et al. (2015) *Science* 351:1009-1012
- Stilla, L. (2015) *J. Appl. Phys.* 118:1033-1040
- Webber et al. (2015) *Science* 348:1230-1244
- Zimmermann et al. (2010) *Plant Physiol.* 153:1819-1831
- Reinhardt et al. (2010) *Phys. Rev. Applied* 6:044011
- Flory, P. J. and Rehner, J. (1943) *J. Chem. Phys.* 11:512-519
- Flory, P. J. and Rehner, J. (1943) *J. Chem. Phys.* 11:501-510
- Stilla, L. (2015) *J. Appl. Phys.* 118:1033-1040
- Stilla, L. and Gnanou, Y. (2015) *Hydrogels of Elasticity*
- Reinhardt et al. (2010) *Phys. Fluids* 17:081001
- Stilla et al. (2017) *Ann. Rev. Cond. Matter. Phys.* 8:99-118

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- Clear colour, eye-catching image background
- Pictures used to illustrate points
- Judicious use of equations
- Summary points on top left-hand corner
- List of further information references

Practicalities

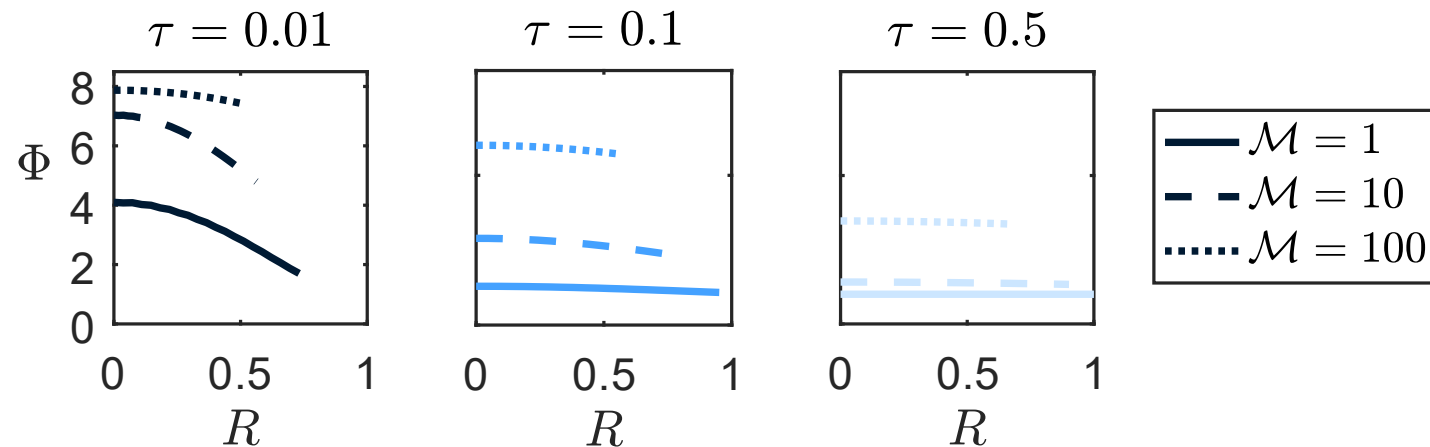
- **Format:** paper size (and orientation) usually specified by organisers. If not, think about whether landscape or portrait suits your subject better.
- **Visibility:** as a rule of thumb, the title and key subject matter should be readable from 3m away. Everything should be visible from 1.5m away.
 - Remember that, statistically speaking, you'll have better eyesight than the average attendee. If in doubt, make things bigger.
 - Sources of unnecessary clutter include gridlines/too many axis ticks on figures, complicated shadings, irrelevant labels, etc. Be ruthless.

Formatting tips

- **Font sizes:** always bigger than you think it should be (24pt is often too small for body text)
- **Font families:** unless you have a really good reason otherwise, body text should be sans serif (though just because a font is sans serif doesn't mean it's a good choice)
- Titles need to be huge – 120-150pt. Make sure they're a dark(ish) colour.
- A note – this will all look silly on screen, and as it begins to come out of the printer. You'll panic and think you've overdone it.

Formatting tips

- **Figures:** make sure labels are “too big” – you need to exaggerate...



- Don't just lift figures you've made for papers – they need to be designed **for** the poster:
 - No extraneous labels
 - No patterns/grids
 - Minimal axis ticks, thick lines and clear legend

Formatting tips

- **Equations** – people have some *strong* opinions on this:

...In general, reducing M and increasing P leads to a faster deswelling as the shear resistance is decreased and the pressure driving flows is increased. Thus, as $t \sim P/M$, we can see in figure X that...

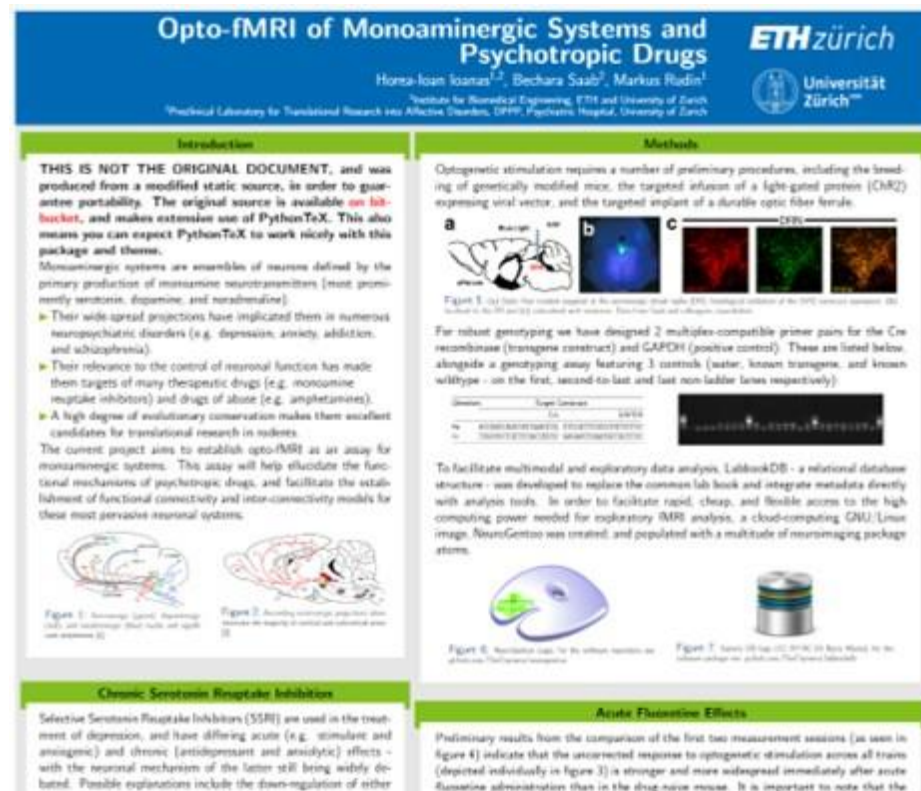
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Formatting tips

- **Thoughts on LaTeX** There are lots of beamer-based approaches to making posters, which *can* produce some good-looking results



Short summary: don't bother

Formatting tips

My go-to tools for putting together a poster



- You know how to use it already
- Fine degree of control over formatting/layout
- Native vector support
- Shape Format > Size > expand arrow and use the Size+Position pane
- Easy export to PDF at high resolution
- Design > Slide Size > Custom Slide Size... to set A0/A1 etc.

colorcet.com

Gives colour maps and palettes that are “perceptually uniform” and also has options that suit various types of colour blindness. Easy to include in basically any software tool you’re using.

viereck.ch/latex-to-svg

The best free online one of these (I usually use my own version on Windows).

warwick.ac.uk/about/brand

Get hold of university logos and read the guidelines for their use. Gives specific colours and resources in a number of formats.

Stokes drift through corals

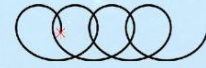
JOSEPH WEBBER Trinity College, University of Cambridge

Project supervised by Prof Herbert Huppert FRS at the Institute of Theoretical Geophysics, Department of Applied Mathematics and Theoretical Physics. Funding from the Heilbronn Fund at Trinity College.

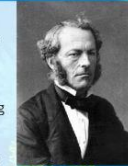
Stokes drift

Waves in the ocean result in a drift effect of water under the surface, in a phenomenon known as *Stokes drift*, named after Sir George Gabriel Stokes FRS (1819-1903, pictured).

If we follow the path of an individual 'parcel' of water below the surface undergoing wave motion, we find that it spirals along, drifting with the direction of the wave propagation. In the adjacent diagram, a fluid parcel starts at the position of the red asterisk, and travels with the wave to the right.



The drift is an entirely horizontal effect, and is well-documented, in, for example, Stokes' (1848) and Phillips' (1977). In a shallow sea, of depth 1m, and with waves travelling at -1.5ms^{-1} , with $\omega=2\text{s}^{-1}$, a typical velocity is -0.05ms^{-1} .



Applications

Koehl *et al.*³ and other papers emphasise the importance of flow of water through coral reefs to bring nutrients and oxygen to inhabitants – understanding the flow profile is vital for understanding these ecosystems. We plan to compare these results with those of fieldwork.

Explanation

We describe the fluid flow in two distinct regimes – the porous layer, dominated by viscous effects and described by Darcy's Law, and the upper layer, which is essentially inviscid.

Matching the layers at their interface, we derive the wavenumber k as a function of frequency ω , which is a complex number – the waves have both an oscillatory part and a decaying effect due to damping.

$$i\omega \tanh k(D-d) - i\nu \tanh \left[\arctan \left(\frac{\omega^2}{gk} \right) - kd \right] = 0$$

Parameters: Frequency of waves, Viscosity of water, Depth of upper layer, Permeability of porous layer, Depth of porous layer, Gravity, Wavenumber.

The vertical drift can be understood by considering a small particle undergoing wave motion. The particle moves **forwards and down**, followed by **backwards**, and then **back up again**. But as the magnitude of vertical velocity reduces with distance due to damping, there is net motion perpendicular to the wave propagation.

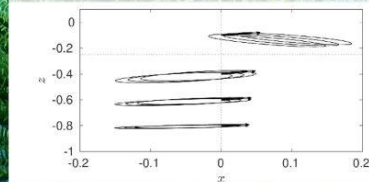
Effect of a porous layer

Placing a porous layer, like a coral reef, below the wave surface, as shown in the diagram below, damps the waves and means that the amplitude decreases as horizontal distance increases in the direction of wave propagation, denoted x .

As the horizontal drift speed is dependent on the amplitude of the waves, the horizontal drift speed reduces with distance in the direction of wave propagation.

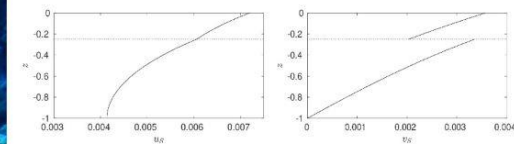
Most notably, a vertical drift effect is introduced as a result of the damping.

This small drift effect can be seen by tracing out particle paths – in the below case, $D=1$, $d=0.25$.

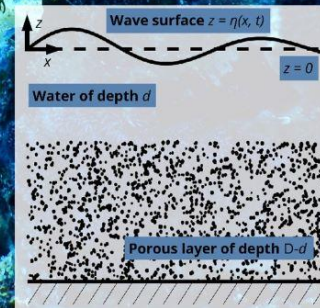


Velocity profiles

Fluid is naturally seen to drift faster in the upper layer, where there is no viscous resistance to its motion. The velocity profiles reduce to those for no reef in the limits as the reef becomes more porous, or thinner.



Stokes drift velocities in the horizontal (left) and vertical (right) directions at $x = 0.00$ when $D = 1.00$, $d = 0.25$ and waves have a frequency $\omega = 2$



Putting this into practice

Things to consider

- Order of content – how do you make this clear?
 - Placement and number of figures
 - How to catch peoples' eyes
 - What are the 3-5 key points you want people to take away?
 - How can you tell a story both with and without involved mathematics?
- **Sketch out a plan of what a poster summarising your summer research might look like**
 - Don't need the actual content, but layout/figures/take-home messages/title should all be there
 - What poster pitfalls do you think your project might be especially prone to?