

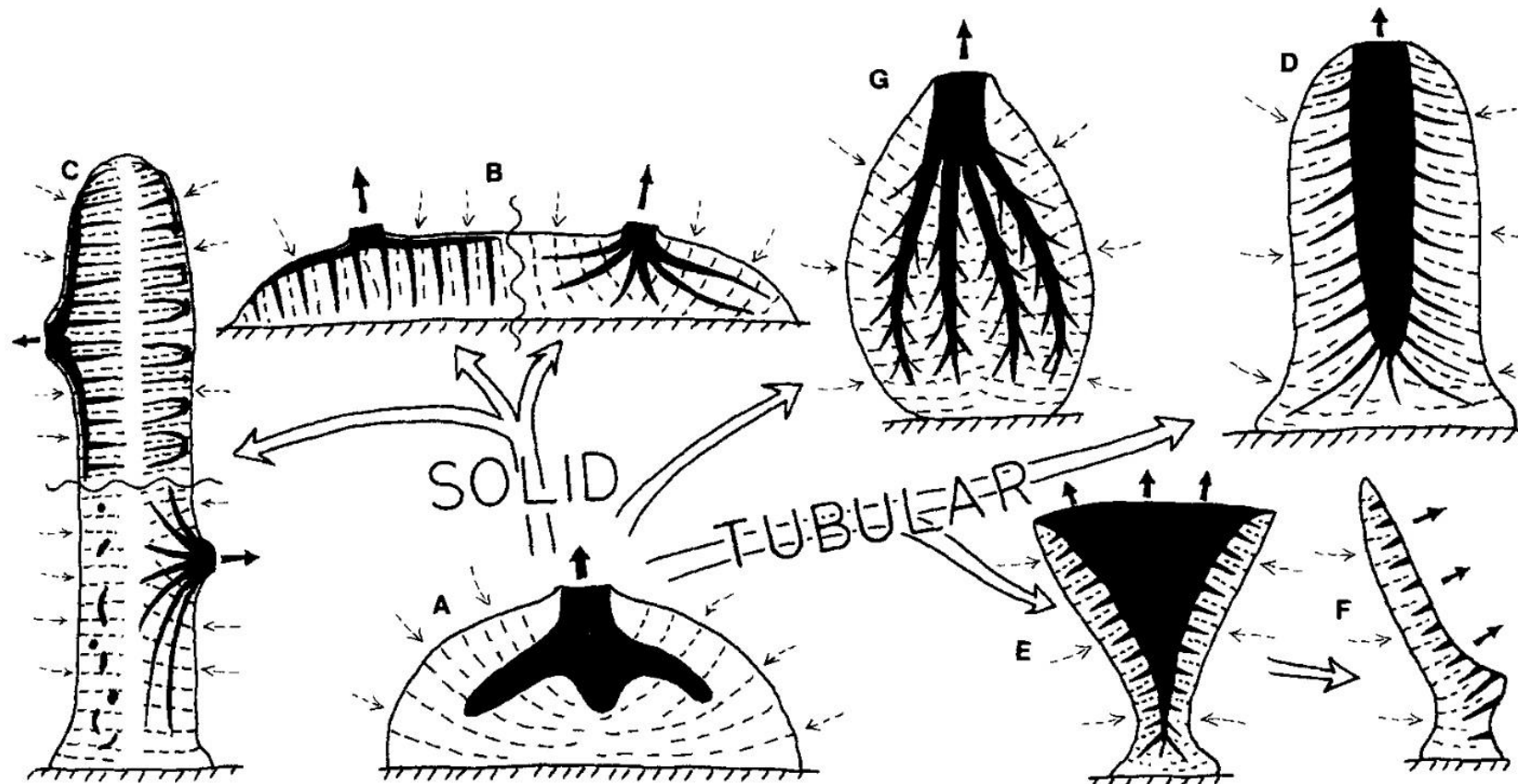


Rheology of Marine Sponge Tissue Reveals Anisotropic Mechanics & Tuned Dynamics

Emile Kraus, Lauren Mellenthin, Sara Siwiecki, Dawei Song, Jing Yan, Paul Janmey, Alison Sweeney

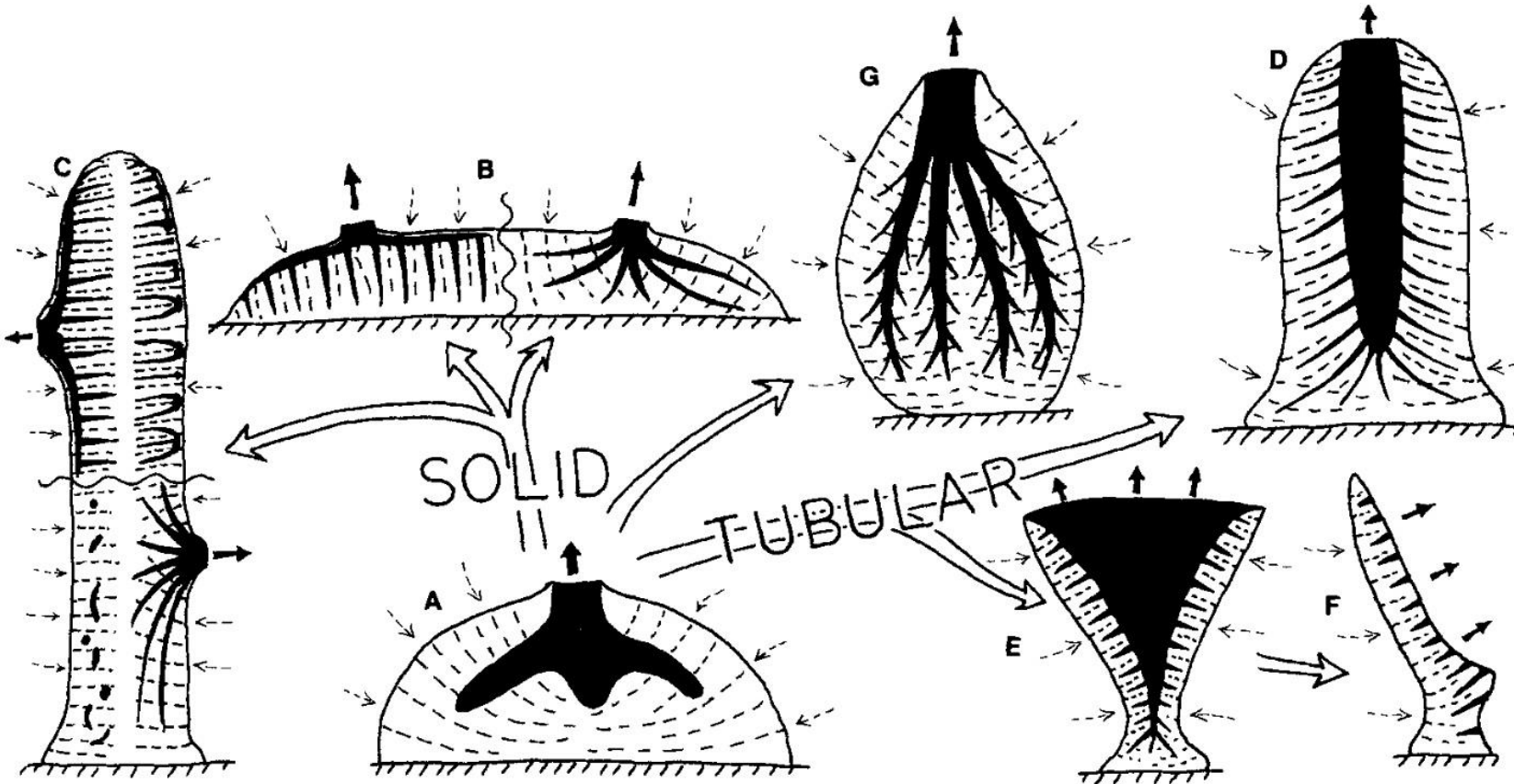
**6th Edwards Symposium – Soft Matter for the 21st Century
7 September 2022**

Sponges as Soft Matter



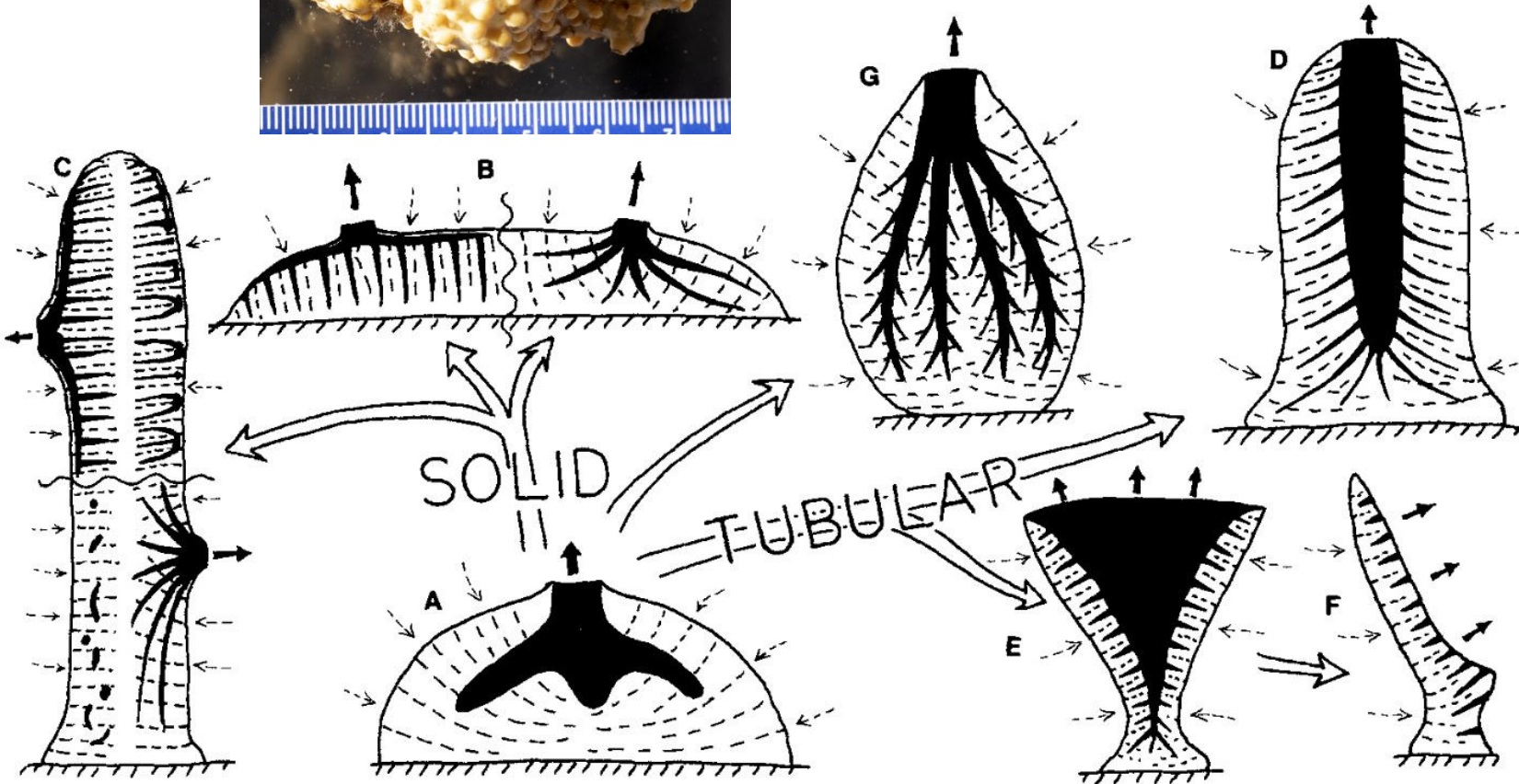
REISWIG, 1975

Sponges as Soft Matter



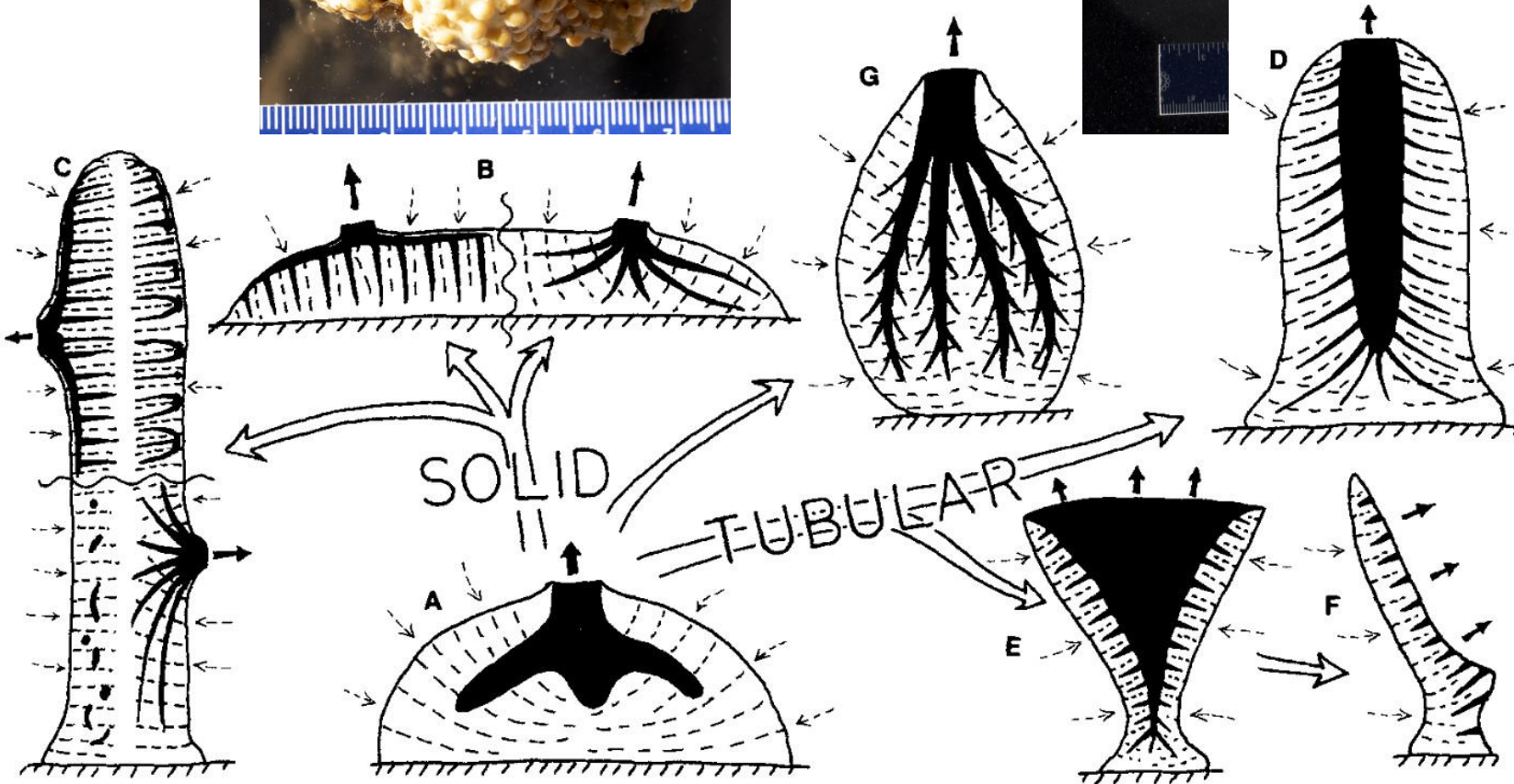
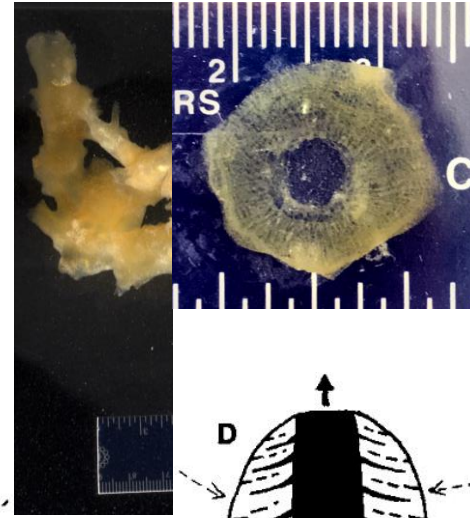
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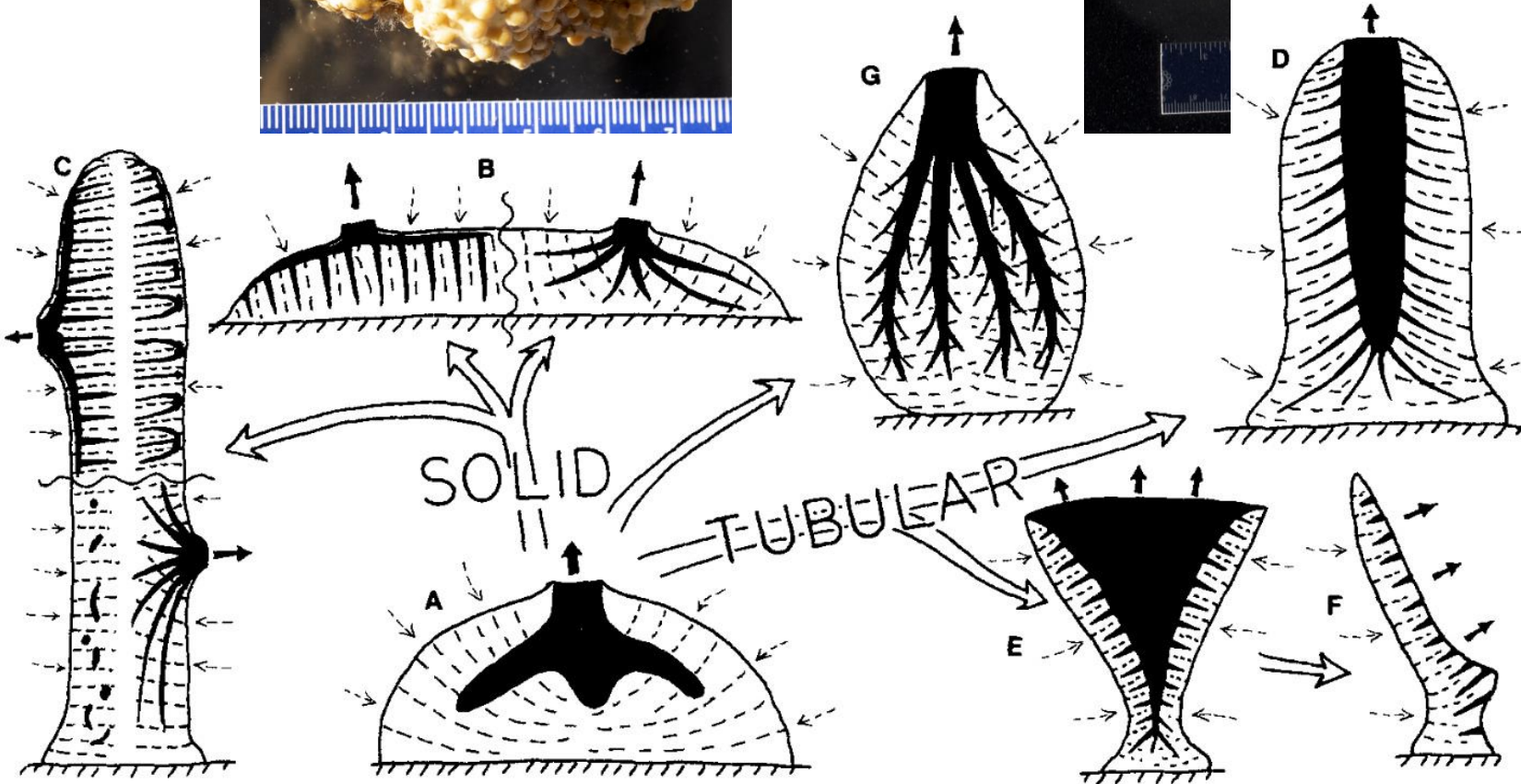
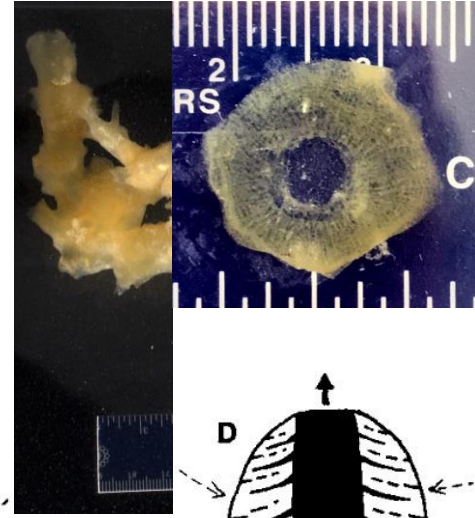
REISWIG, 1975

Sponges as Soft Matter

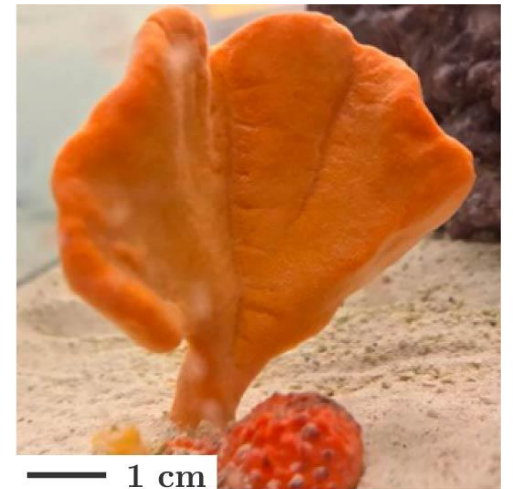


REISWIG, 1975

Sponges as Soft Matter

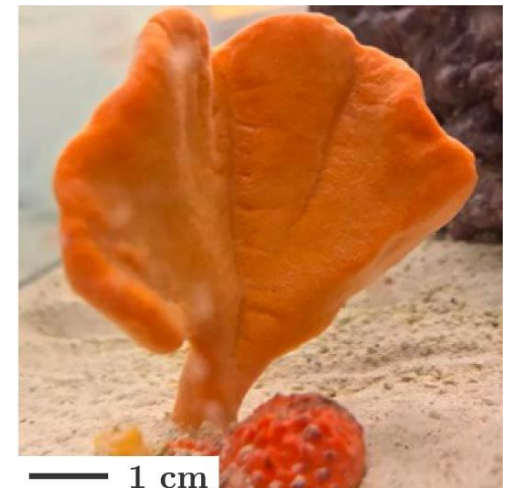
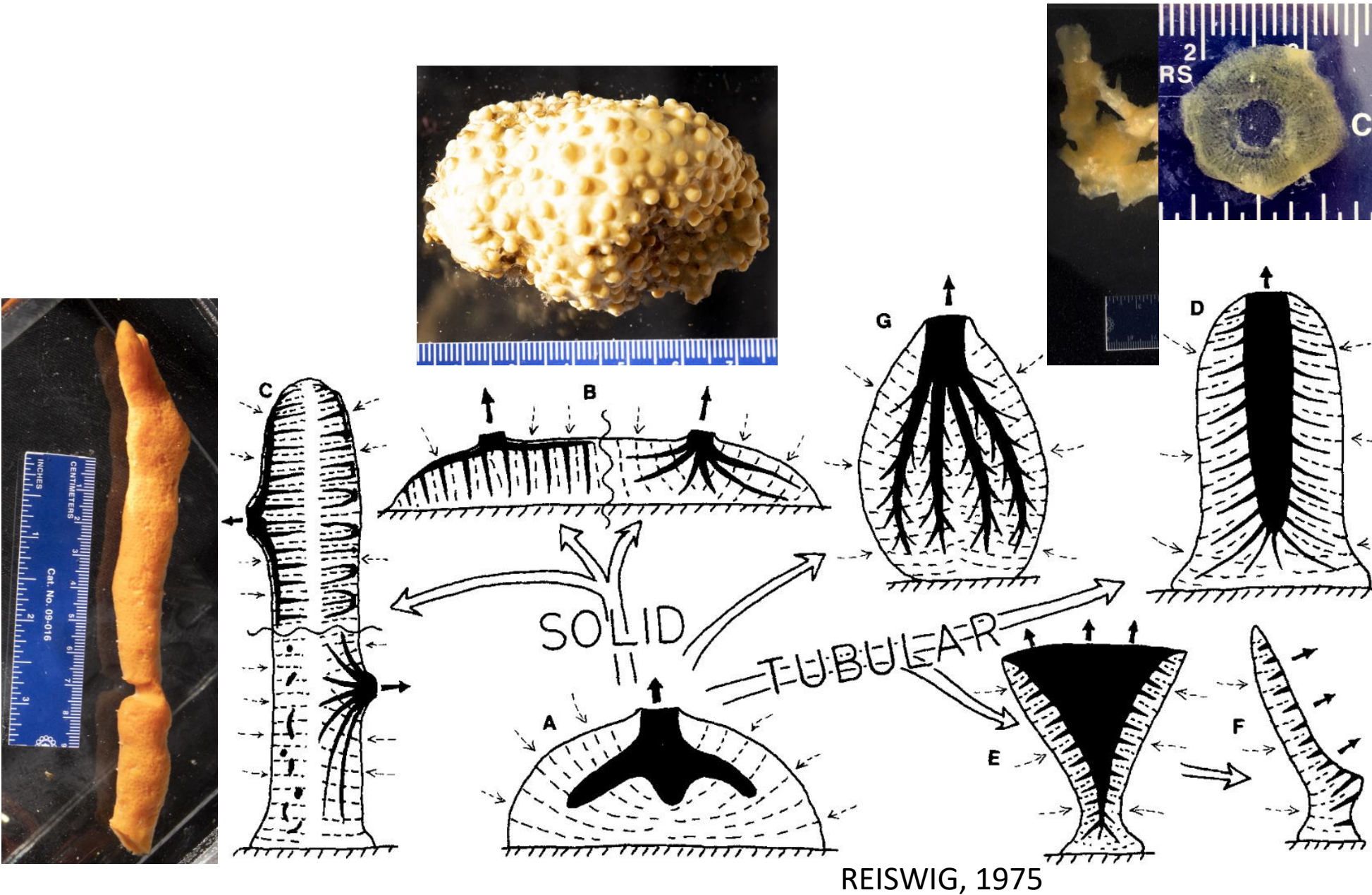


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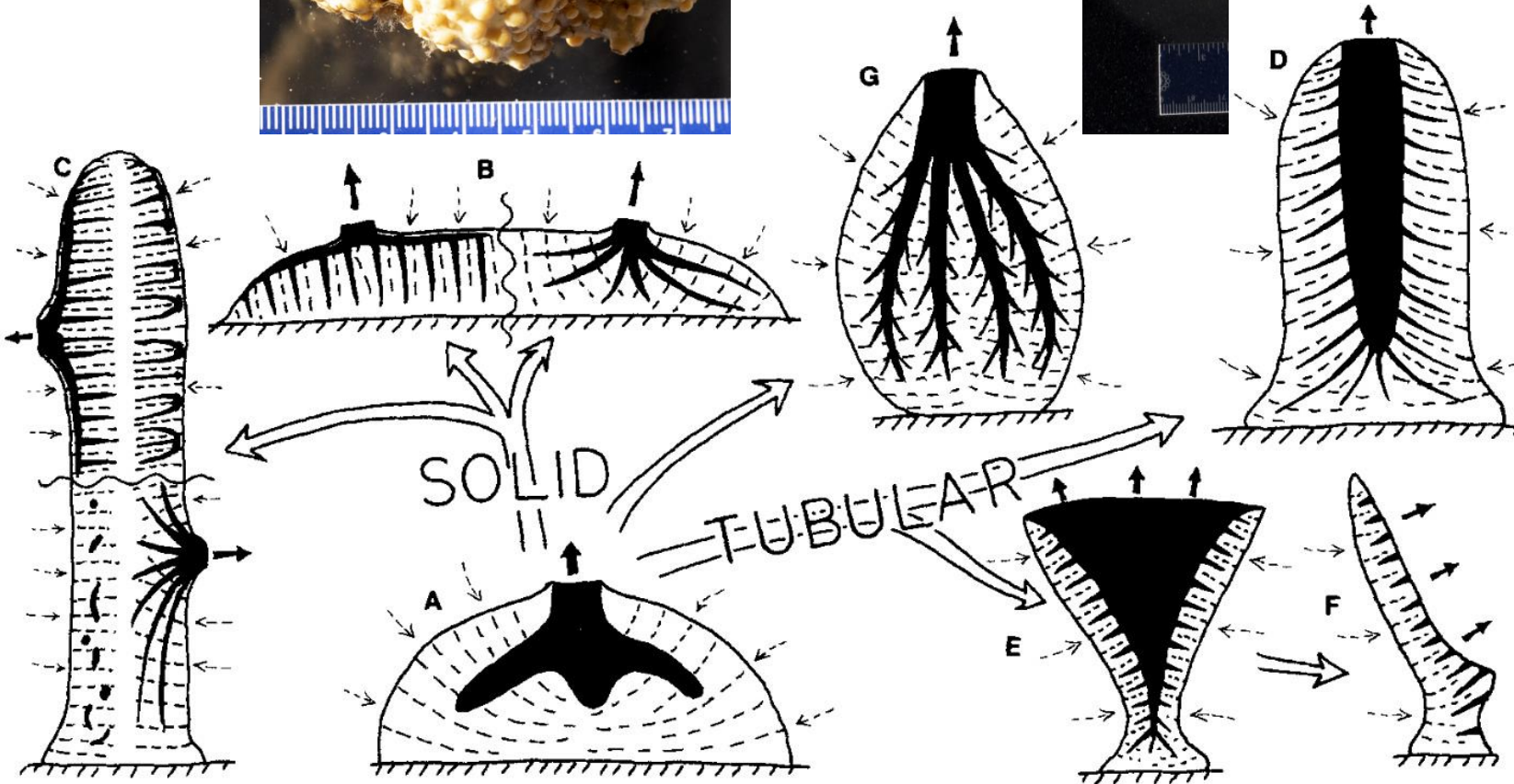
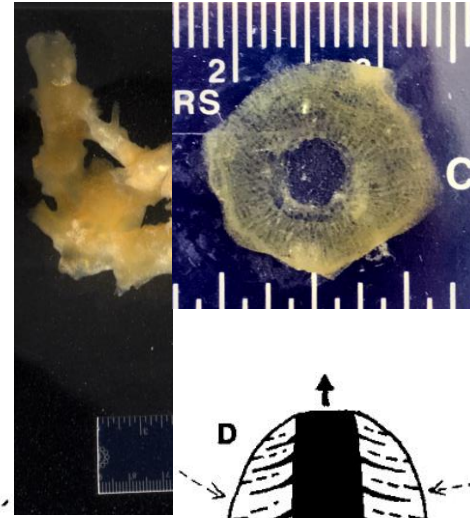


Sponges as Soft Matter

- Porous tissue specialized for filtering

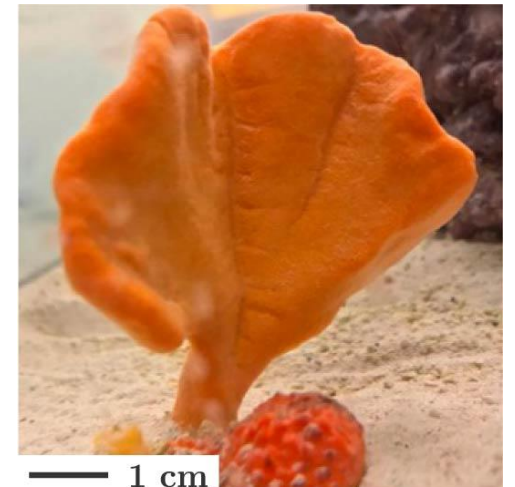


Sponges as Soft Matter

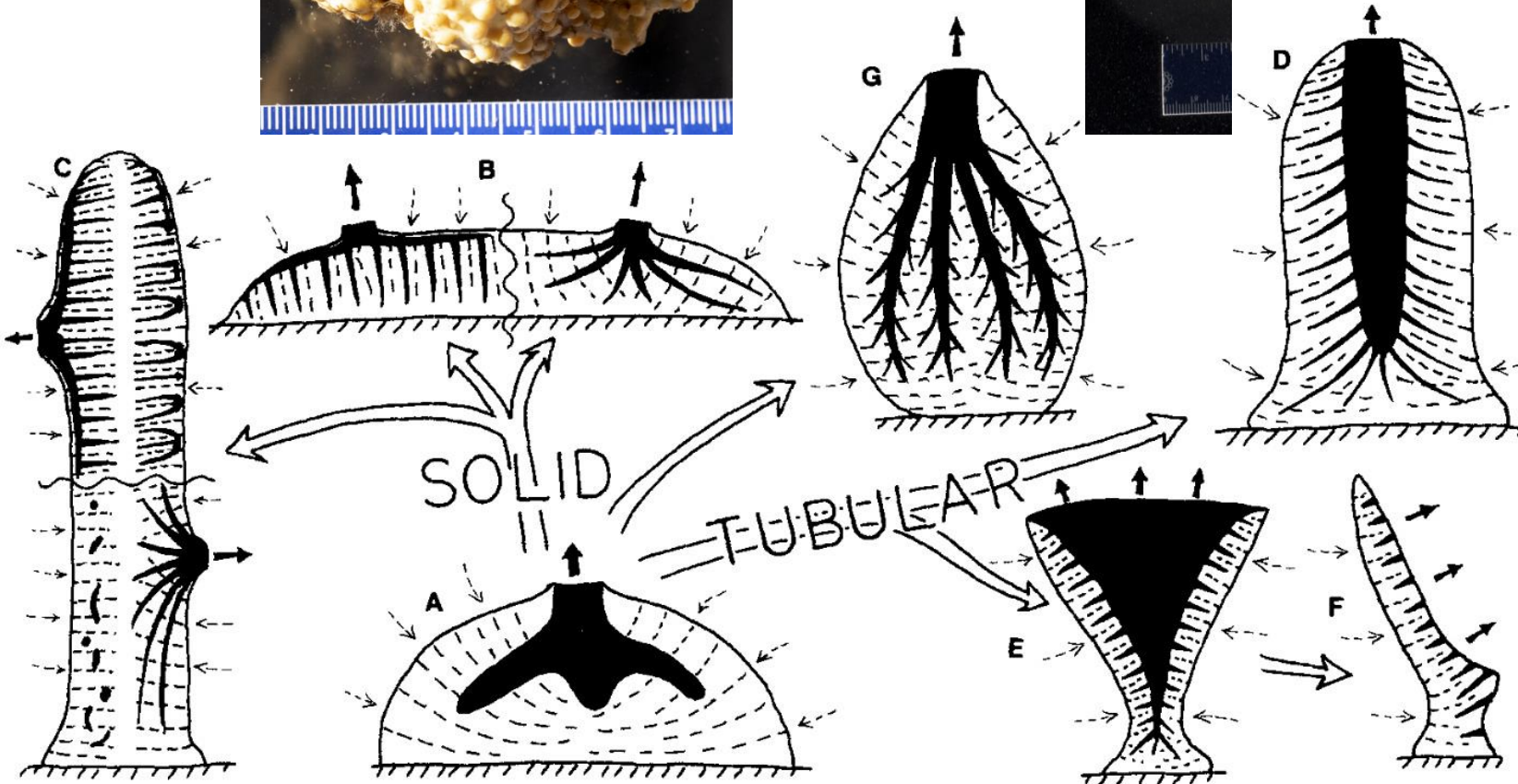
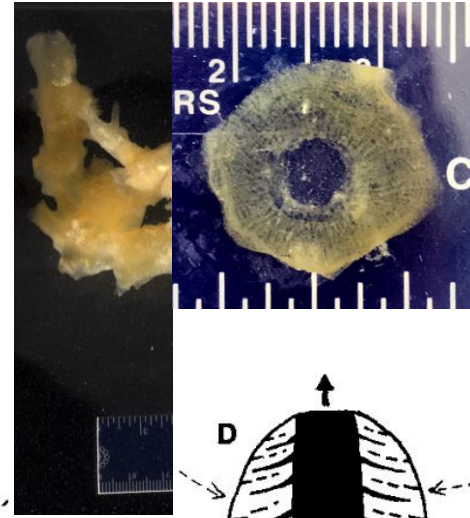


REISWIG, 1975

- Porous tissue specialized for filtering
- Two types of collagen: one sheet-like (related to type IV), and one fibrillar (related to type XIII)

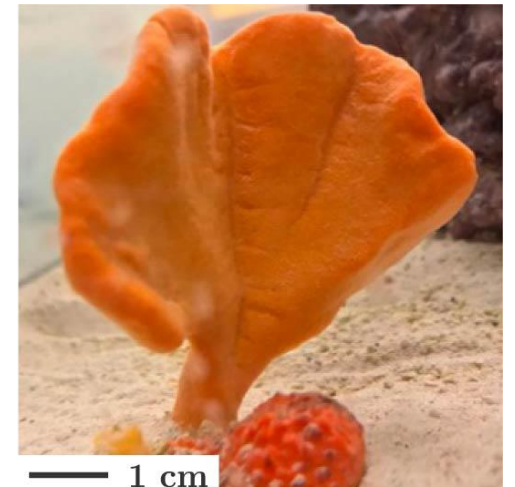


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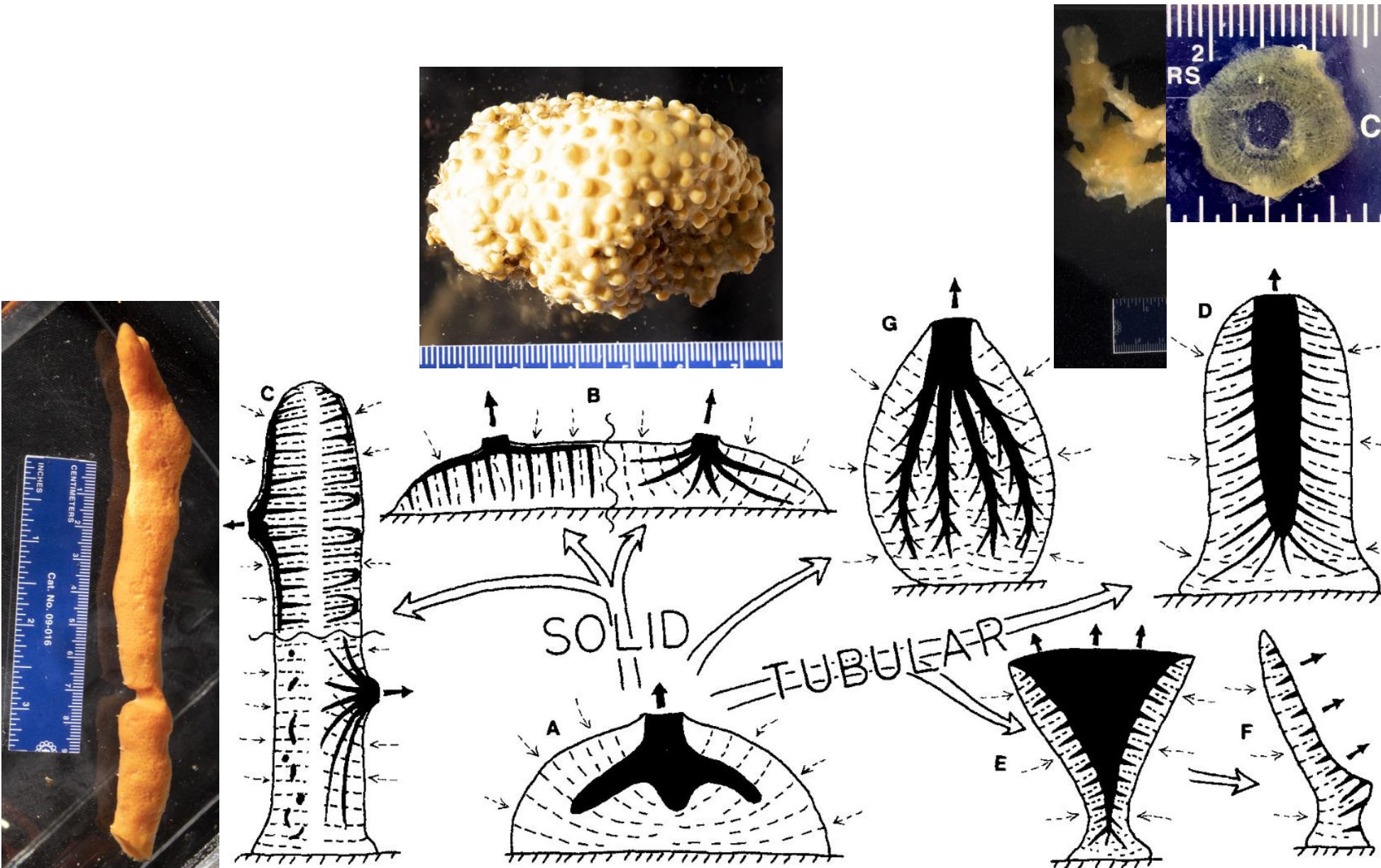


REISWIG, 1975

- Porous tissue specialized for filtering
- Two types of collagen: one sheet-like (related to type IV), and one fibrillar (related to type XIII)
- Cells (~10 types)

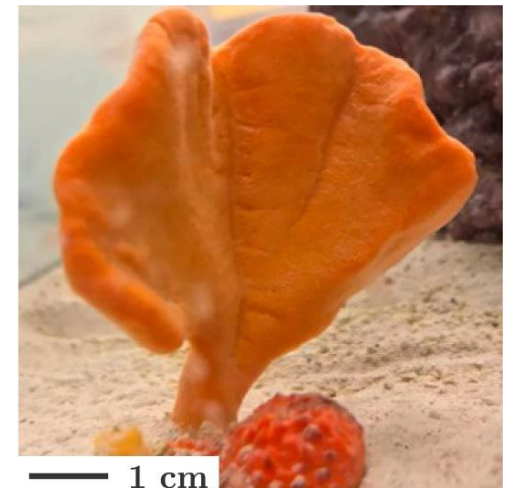


Sponges as Soft Matter

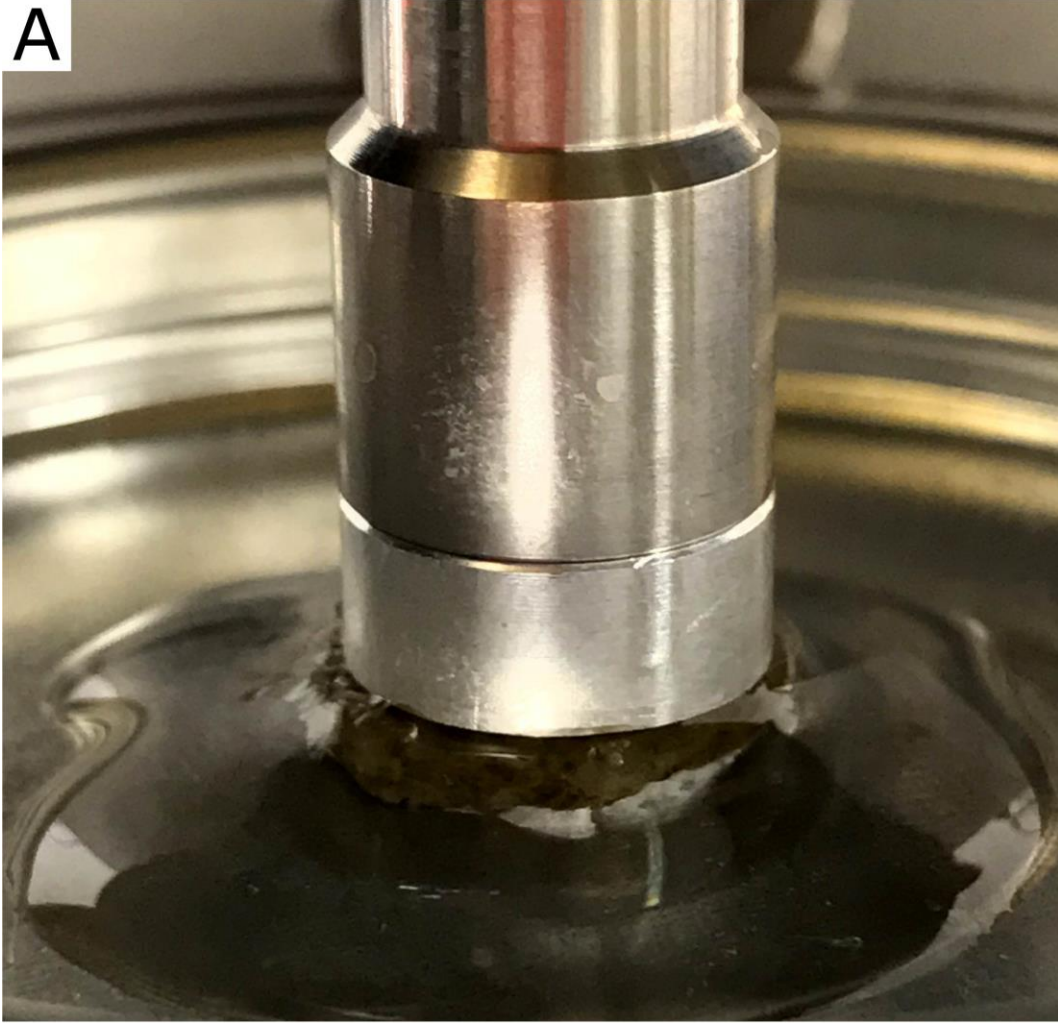


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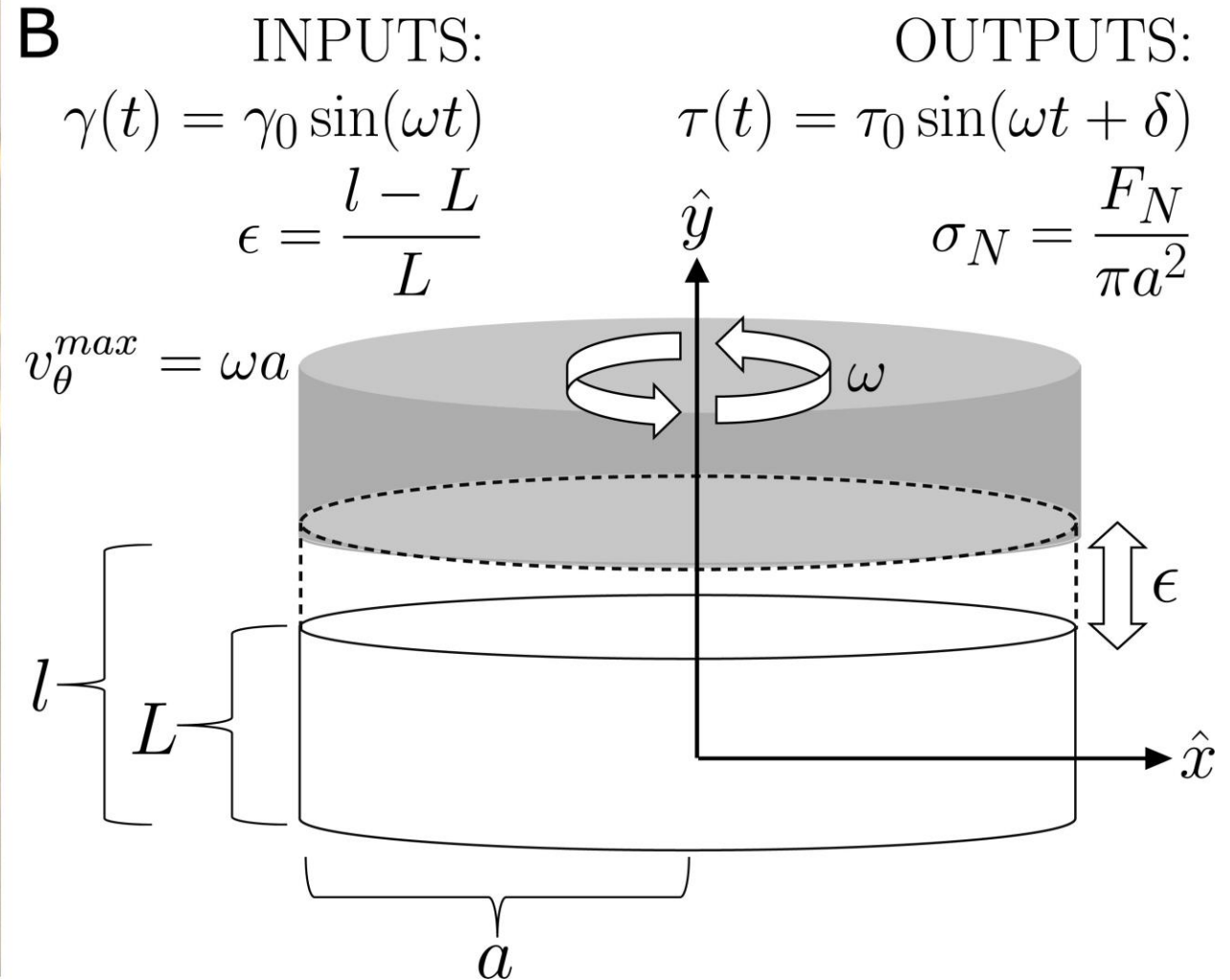
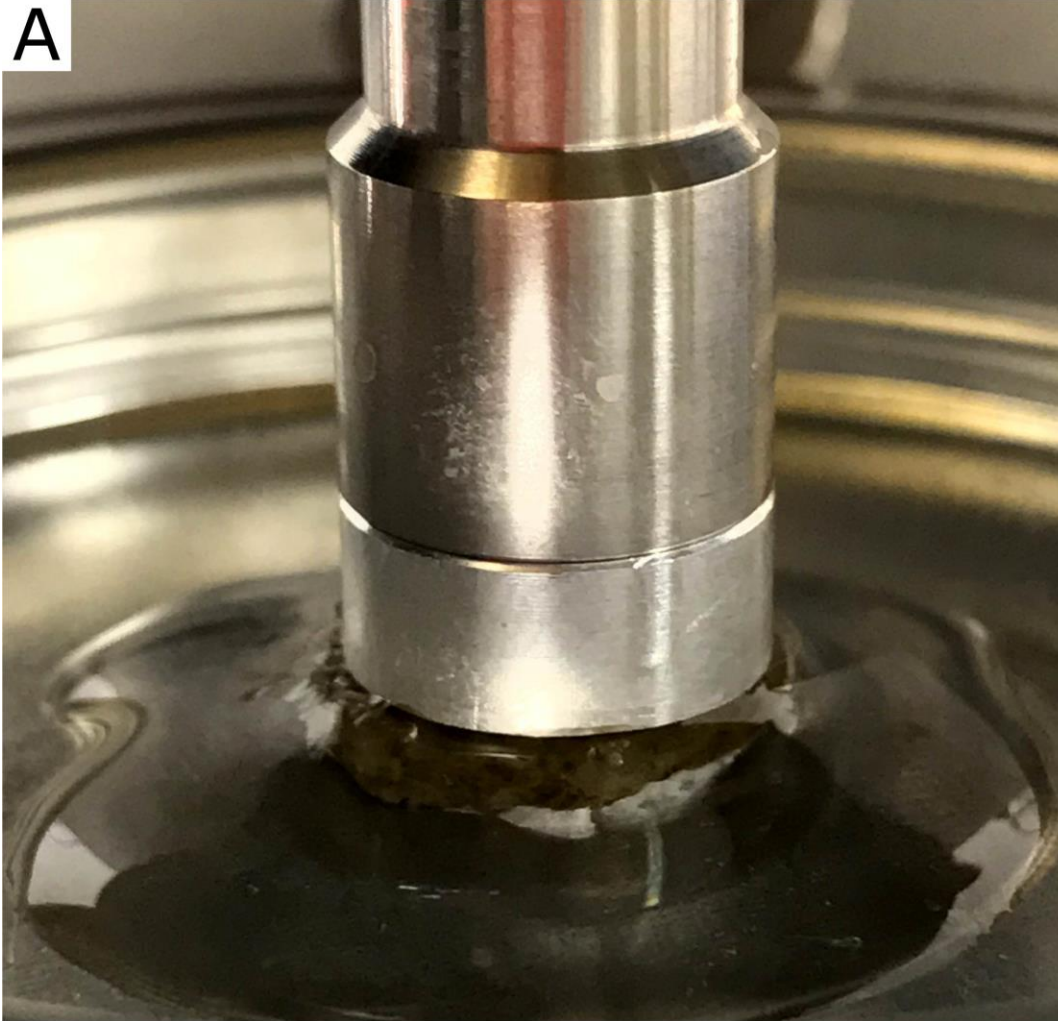
- Porous tissue specialized for filtering
- Two types of collagen: one sheet-like (related to type IV), and one fibrillar (related to type XIII)
- Cells (~10 types)
- Stiff inclusions, the spicules



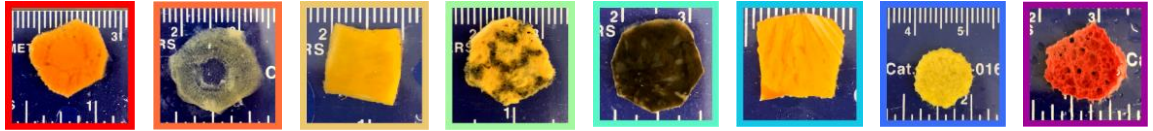
The Rheometer: Soft Matter's Atom Smasher



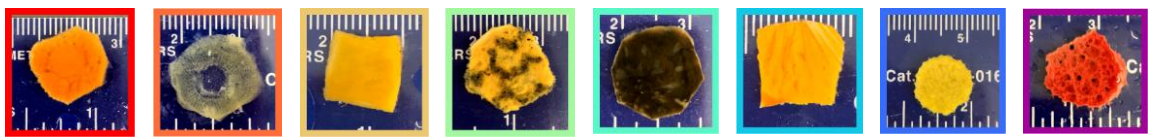
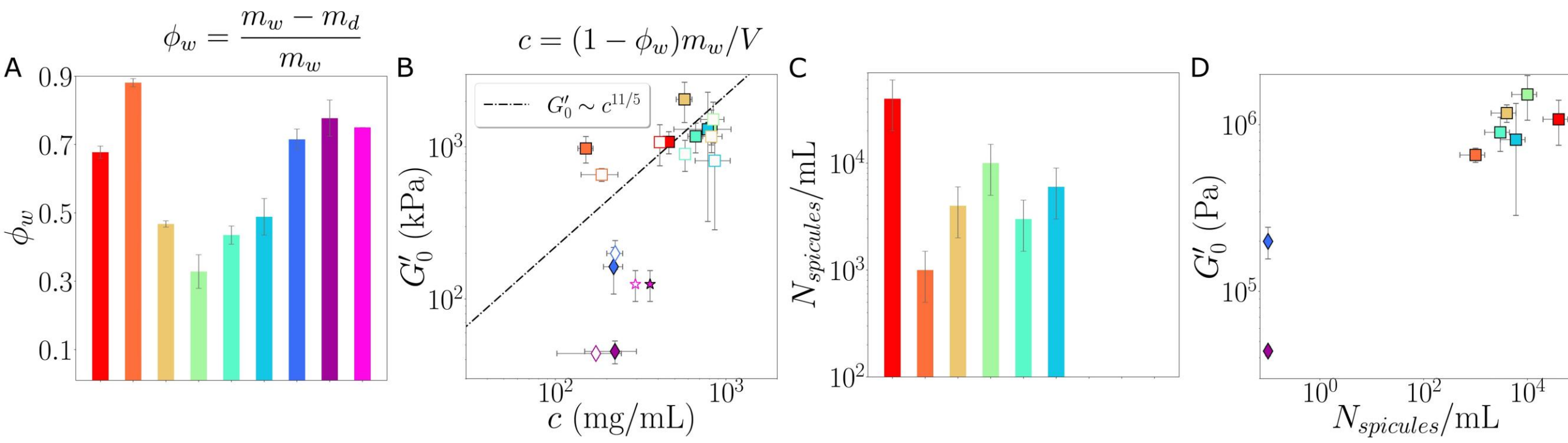
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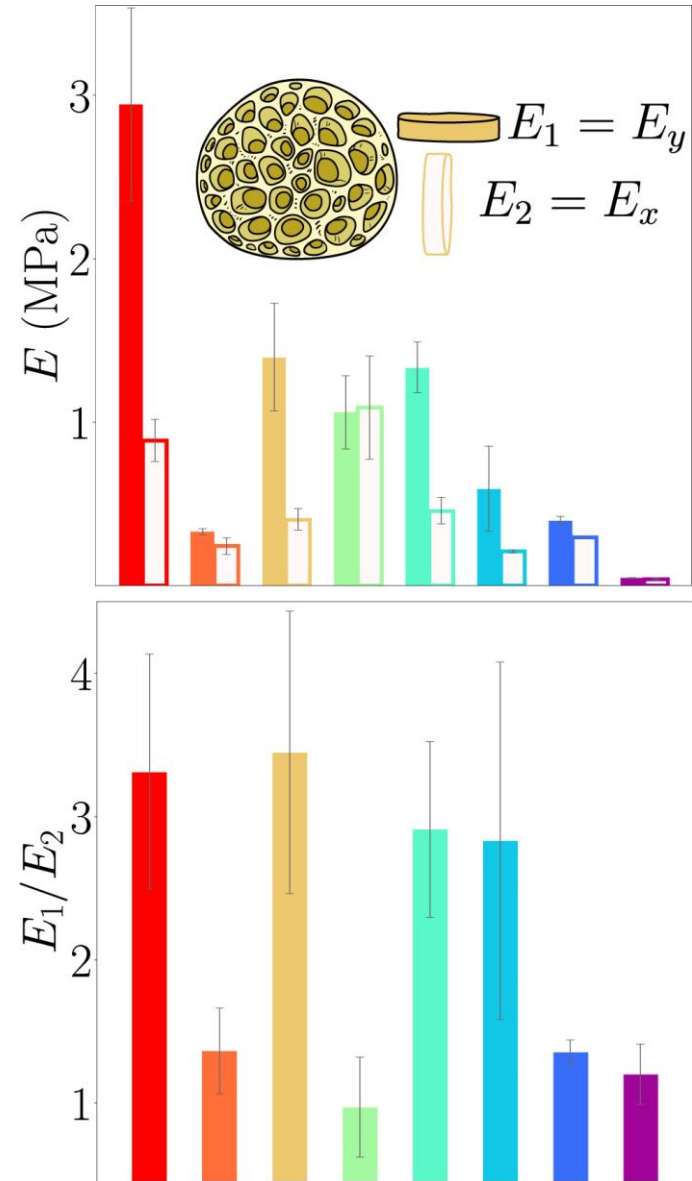
Shear rigidity scales with semi-flexible protein concentration and spicule volume fraction in a diverse set of eight common species



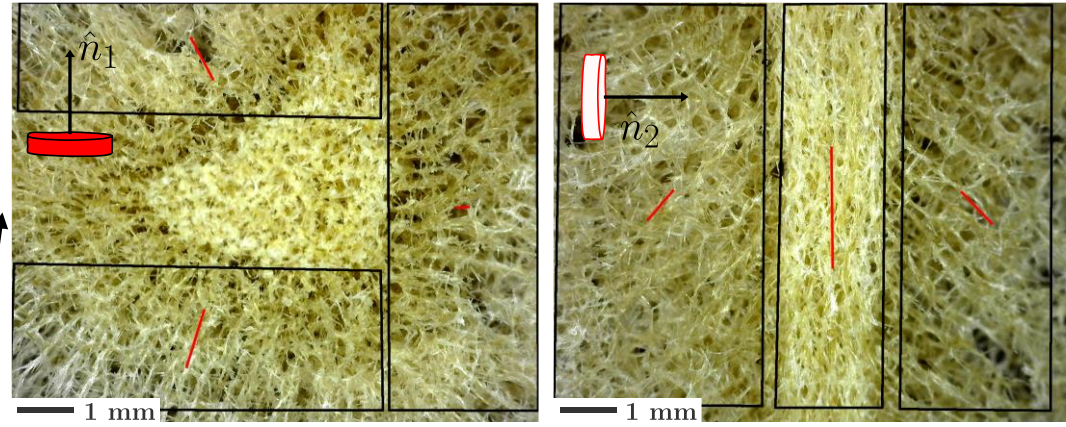
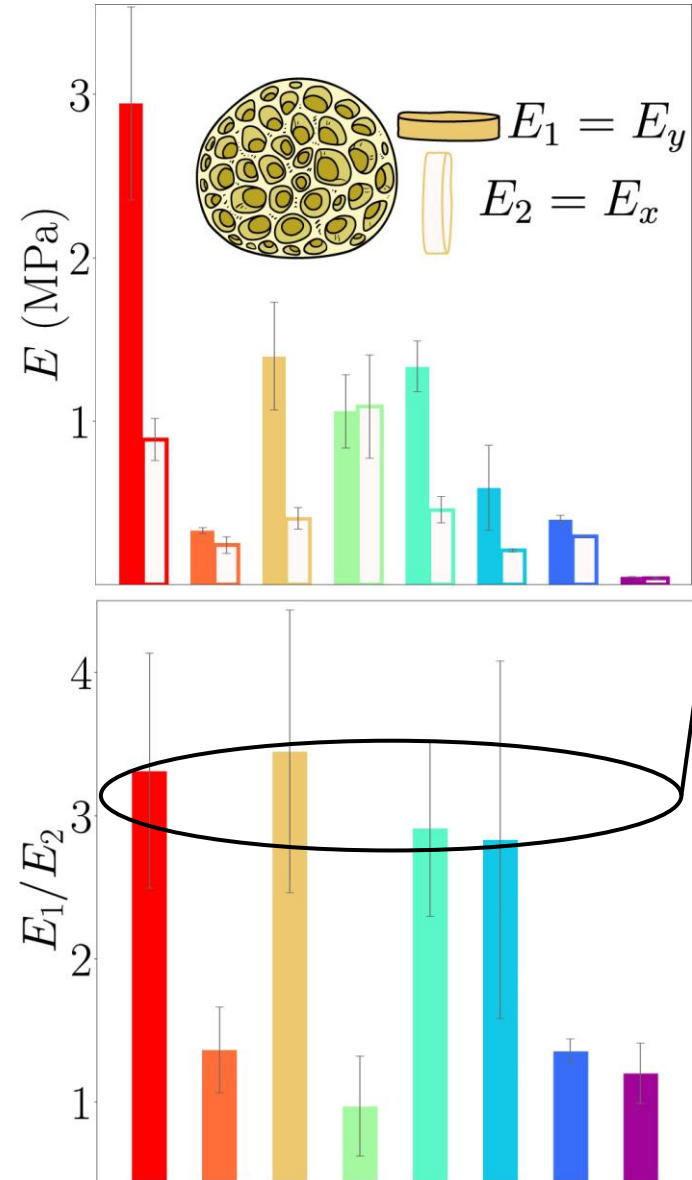
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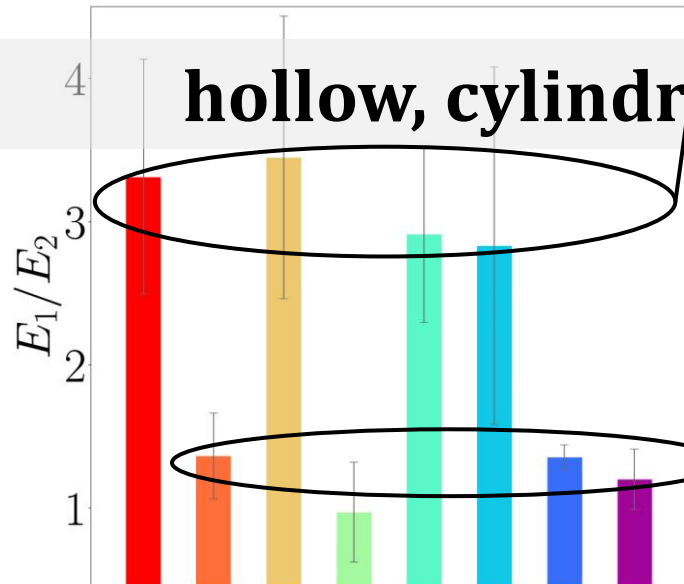
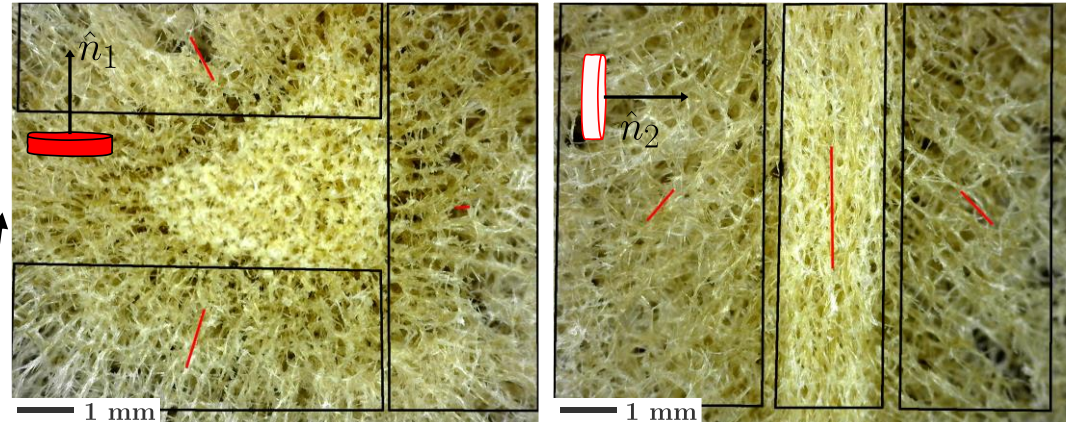
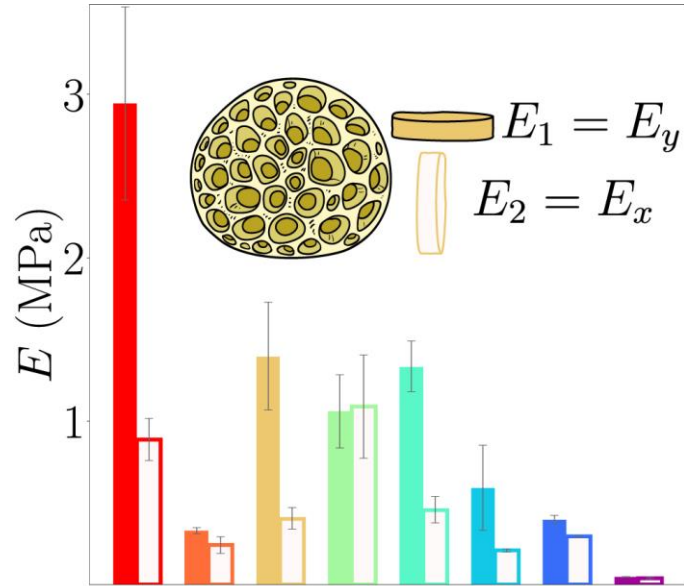
We find solid, cylindrical and spherical sponges have orthotropic tissue



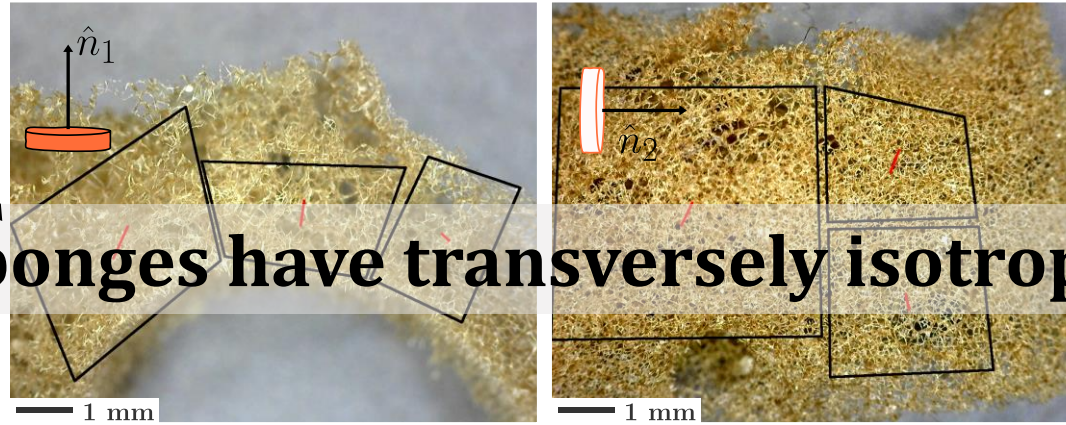
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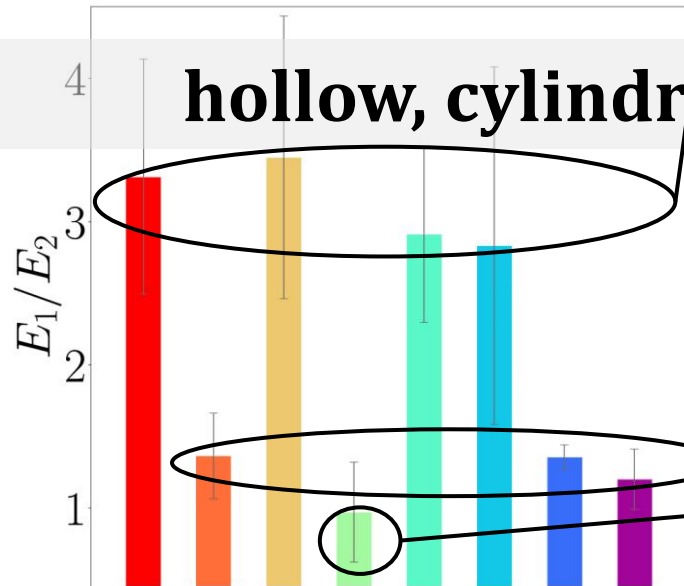
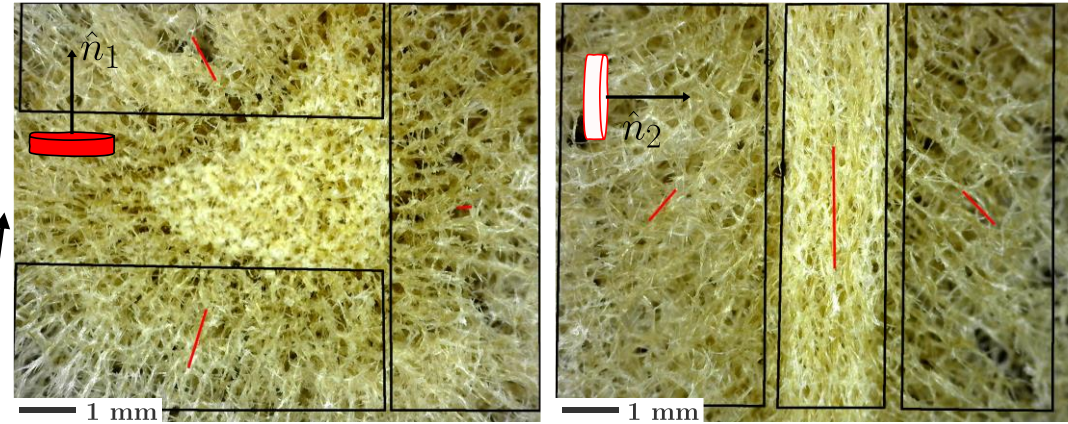
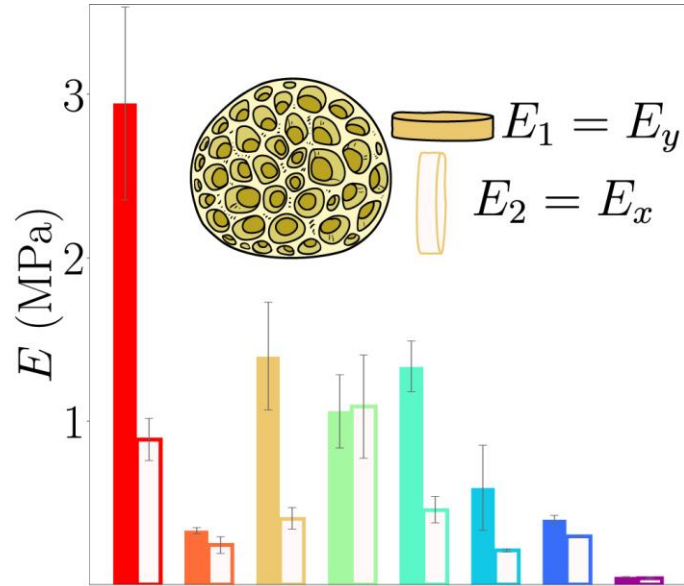
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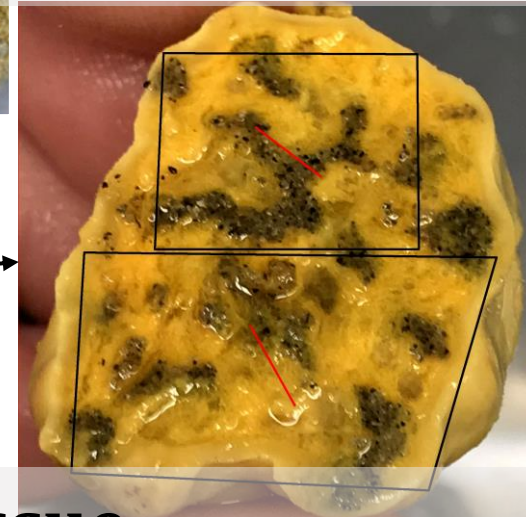
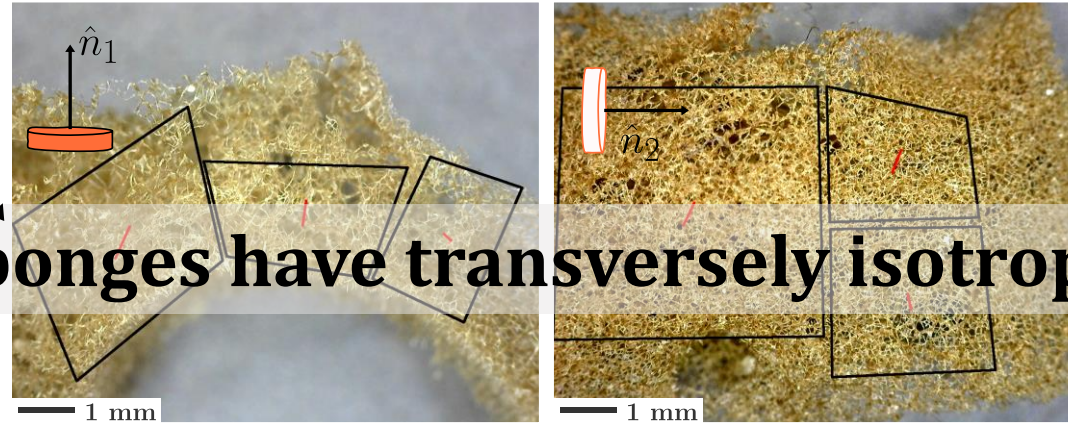
hollow, cylindrical sponges have transversely isotropic tissue



We find solid, cylindrical and spherical sponges have orthotropic tissue

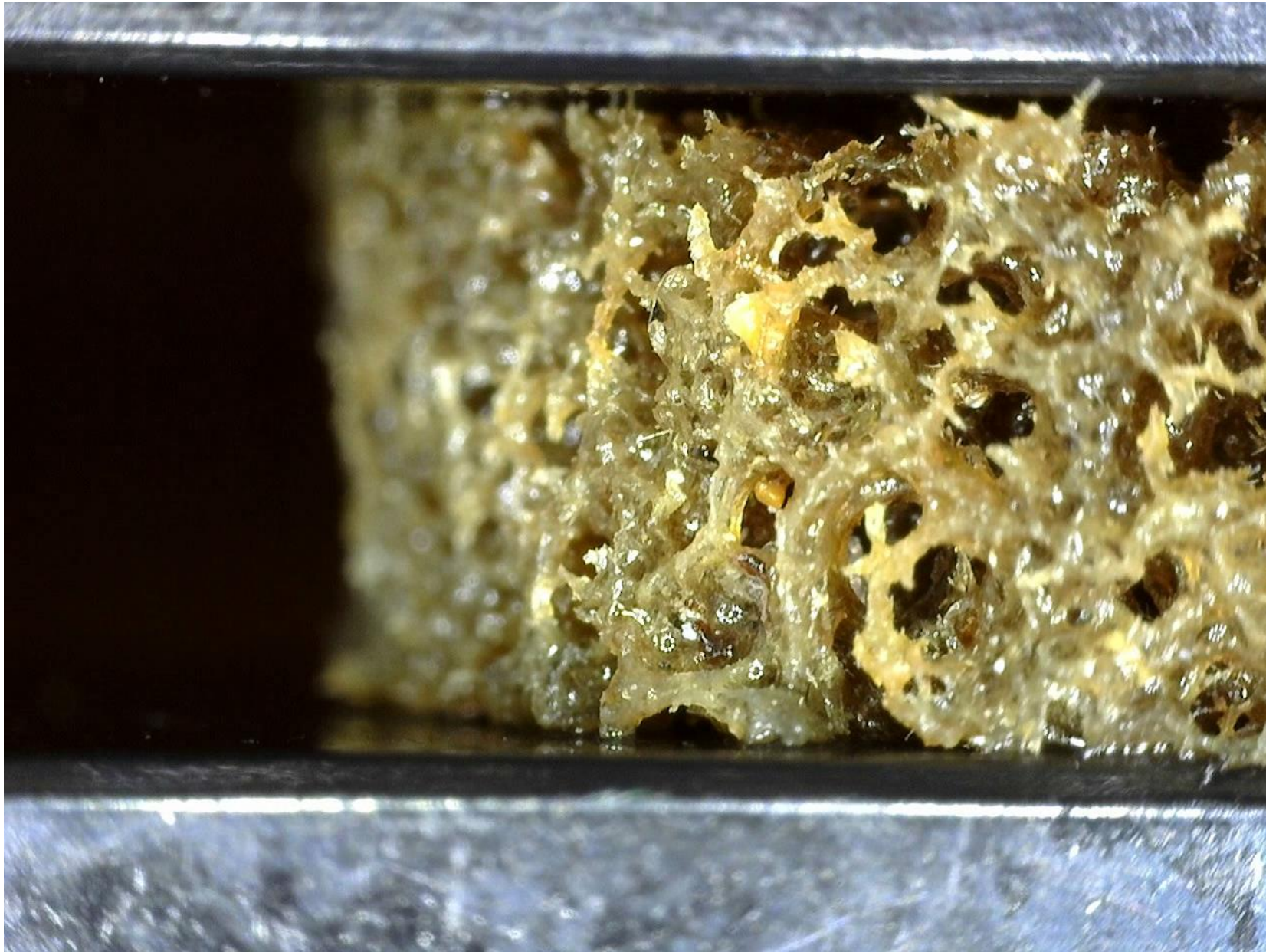


hollow, cylindrical sponges have transversely isotropic tissue

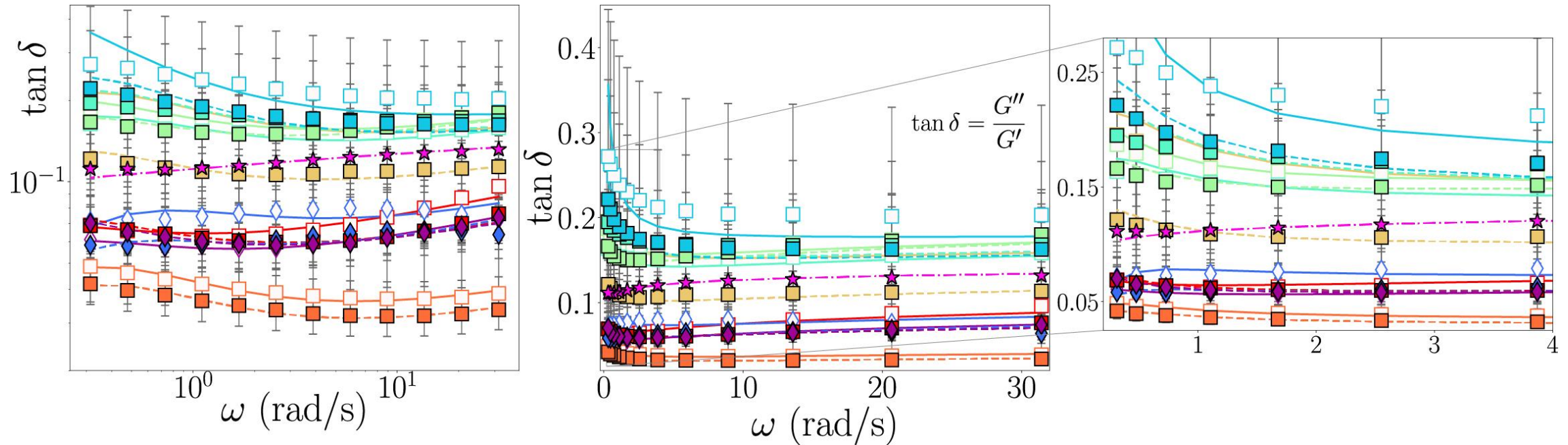


and solid amorphous sponges have isotropic tissue

Sponges Are Also Auxetic!

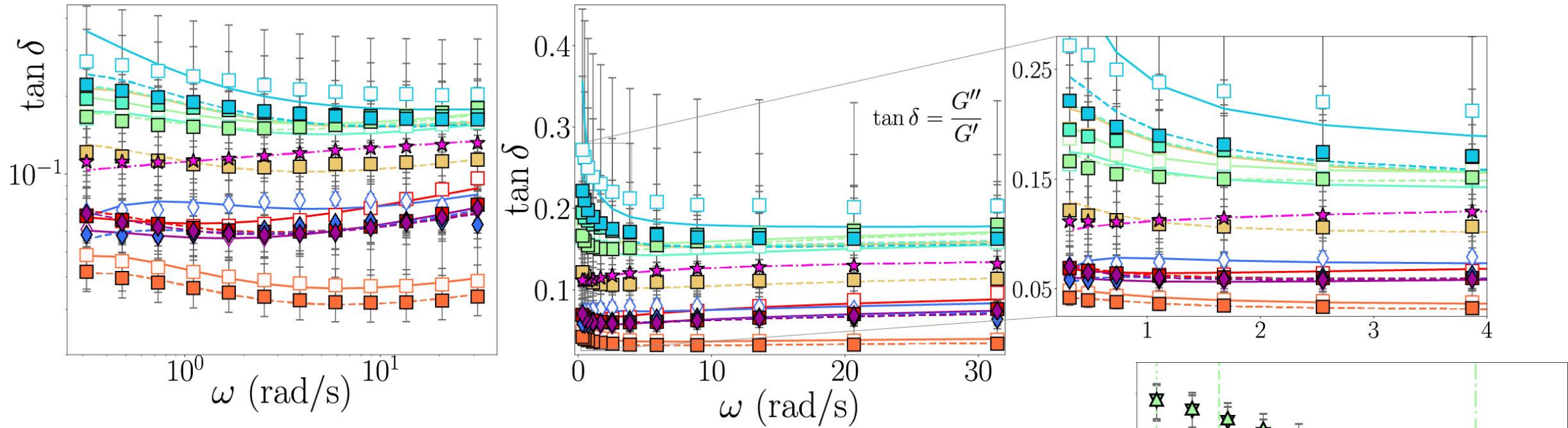


Linear and nonlinear viscoelasticity suggests tuning of $\{\omega, \gamma_0\}$, particularly in dense and disordered, isotropic tissue sponges

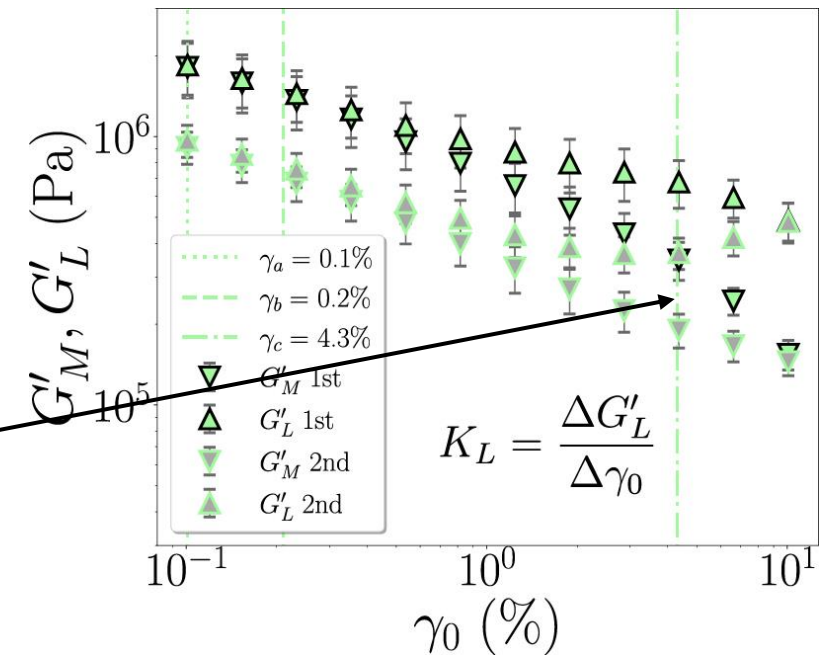


- non-monotonic frequency sweeps

Linear and nonlinear viscoelasticity suggests tuning of $\{\omega, \gamma_0\}$, particularly in dense and disordered, isotropic tissue sponges



- non-monotonic frequency sweeps
- non-monotonic strain sweeps but only after pre-conditioning!



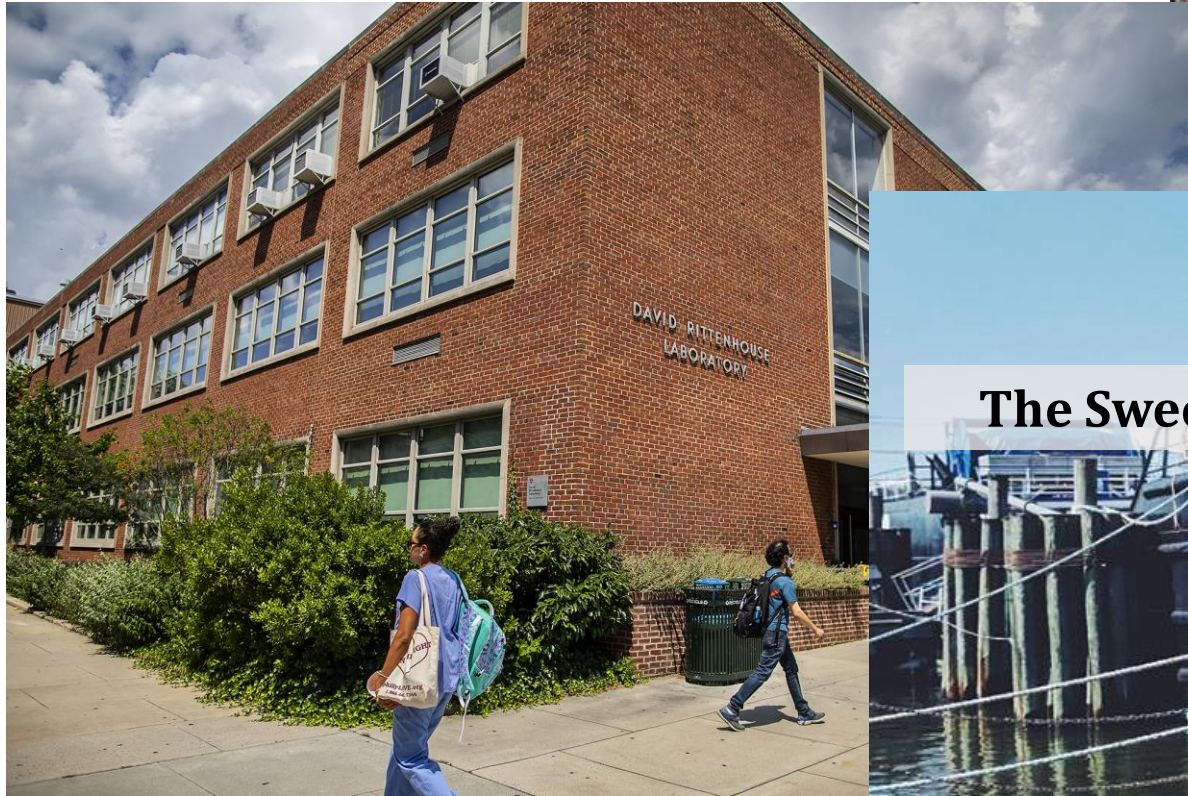
In conclusion

- Sponge bodies are composed of heterogeneous tissue highly specialized for filtering
- Different growth forms are achieved by tissue mechanical strategies such as orthotropy
- Auxeticity is a possible route to a cellular mechanobiological response
- A maximum dissipation at some frequency and strain amplitude implies tunability / memory

A freshwater sponge I found recently at an inlet of Owasco Lake in Upstate New York



Acknowledgements



The Janmey Lab



The Sweeney Lab