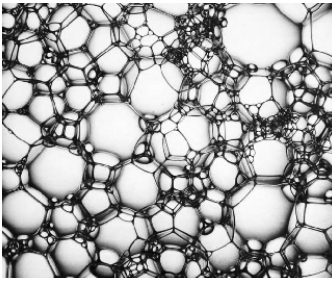
Form and Symmetry: Art and Science
Buenos Aires Congress, 2007

SOAP OPERA WHEN ART AND SCIENCE MEET IN SOAP FILMS AND FOAMS

WIEBKE DRENCKHAN

Name: Wiebke Drenckhan (b. Belzig, Germany 1977)
Address: Laboratoire de Physique des Solides d'Orsay, Université Paris-Sud 11/CNRS, France
E-mail: drenckhan@lps.u-psd.fr (website: www.maths.tcd.ie/~wiebke)
Fields of interest: Physics of soft and complex materials (science cartooning).
Awards: University Price 2000 (Canterbury University, Christchurch, New Zealand)
Publications and/or Exhibitions: W. Drenckhan (2006) "Bubble crawling in Dublin", the "Mathematical Tourist" column in Mathematical Intelligencer 28(4):39-42
W. Drenckhan (2005) "Ireland beats Scotland by 0.3%", Europhysics News 36(3):101/102
W. Drenckhan and D. Weaire (2004), "Some confluences of art and science in the physics of foams", Journal of ISIS - Symmetry, 1-4:54-57
Foam sculpture on the campus of Trinity College Dublin, Ireland (with Prof. D. Weaire and D. Grouse)
Monthly Science cartooning and illustrations for the Physik Journal and Europhysics News

Abstract: *Follow me into the dazzling world of soap films and foams, where art and science meet regularly as faithful companions. Colors of breathtaking purity are generated by interference of light at the thin liquid films, embodying simultaneously stunning beauty and important scientific information. In the same material, fundamental principles of energy minimization shape films and bubbles in intricate ways which provide not only scientific insight into the consequences of nature's desire to optimize – but also elegant role models for architecture and design by being simultaneously efficient and beautiful. Let us build a foam, step by step, moving from its fundamental ingredient – the soap film – towards increasing complexity; pausing for a little while here and there to see how art, science, mathematics, biology and architecture meet naturally at each level of this bubbly material.*



An artist's glance into a dishwashing foam by Dubliner Michael Boran.

1 SOAP FILMS

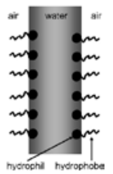


Figure:1

In order to turn ordinary water into a liquid that can make stable films or bubbles one needs to add chemicals like soap. This is because cleaning products contain schizophrenic molecules which have a head that loves water ("hydrophil") and a tail that hates water ("hydrophobe"). As a consequence, these molecules gather at the gas/liquid interface (Fig. 1), from where they avoid that films get too thin and break. They are also responsible for the beautifully chaotic swirling motion observed in the skin of soap bubbles.
The films are generally so thin that light is reflected in a peculiar way 's, which generates the purest colours known in nature. Each film thickness "paints" a particular colour, which helps physicists and physico-chemists to understand the behaviour of thin liquid films and which can paint magnificent abstract landscapes, as captured by Irish photographer Tim Durham (Fig. 2).

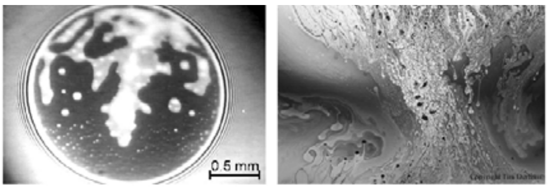


Figure:2

Such thickness variations also help physicists to gain insight into turbulent flows behind obstacles in very "flat" systems, such as our atmosphere or the oceans, which cover the earth in "quasi-two-dimensional" layers. In order to simulate this, they stick various objects into fast flowing soap films. The kitchen knife of physicist Martin Rutgers generated a particularly stunning pattern of interlinked vortices (left of Fig. 3). Similarly beautiful patterns are seen by physicists who try to understand how soap films oscillate in a sound wave (right of Fig. 3). They make rather peculiar kind of drums as liquid is re-distributed in the film in perfectly symmetric patters which depend on the frequency of the sound wave (Boudaoud 1999).

Figure 3: "Rutgers' blade", a kitchen knife in a flowing soap film generates magnificent patterns (left, www.maartenrutgers.org). So does a sound wave, which oscillates the two dishwashing films on the right at ~1kHz (Elias 2007).

2 LEAVING FLATLAND

Make a loop of wire that you bend in intricate ways, put it in dishwashing liquid and pull it out carefully. What you will see is that the wire is spanned by a thin liquid film which bends elegantly to accommodate its frame. For each shape of wire there is generally only one shape that the film can take, which is prescribed by nature's desire to optimise (Boys 1959, Weaire 1999). What is optimised here is the area of the film because a gas/liquid interface is physically speaking "energetically expensive". Such soap films are therefore called "minimal surfaces" and as such they are practical realisations of a whole branch of mathematics. Their elegant forms have not only artistically inspired architects such as Otto Frei or Fosters and Partner in designing the Olympia Stadium in Munich (left of Fig. 4) or the giant roof of the Great Court British Museum in London, respectively (the latter being the largest covered public square in Europe). The distribution of tension in these surfaces is so optimal that large roofs can be stabilized just with a few anchor points. Giant soap films have even made it on the stage in a performance against anti-personal mines by S. Gampert and coworkers in 2006 in Geneve, Switzerland."Directed" by the physicist Francois Graner, the 5 m high soap films reminded simulatenously of the beauty of life and its fragility.

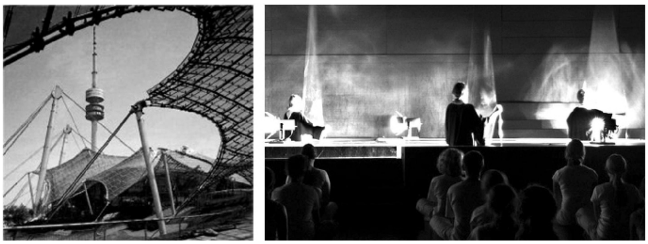


Figure:4

3 BUBBLE JUGGLE

Figure:5

A similar principle of energy minimisation governs soap bubbles – with the additional condition, that the volume of each bubble needs to be conserved. As a result, if we stick bubbles of equal volume together, they self-order in patterns which have many equivalents in natures. An example is shown in Fig. 5, where (dishwashing) bubbles self-order in a tube, forming the same hexagonal lattice and phylotactic pattern on the tube surface as is found in pine cones, pine apples or cacti. In the same spirit, bubbles in funnels can reproduce the arrangements of sunflower seeds (Drenckhan 2004).

Figure: 6

The question of how bubbles of equal size order – or how we can partition space into equal volumes such that the interfacial area is minimized – has been at the heart of scientific debates for centuries. The current best in this prestigious race was established by Dublin's physics professor D. Weaire and R. Phelan in 1994 (Fig. 6, Weaire 1994), which caused great excitement and has ever since inspired artists and architects. For example, a formation of 4500 giant Weaire-Phelan bubbles form ARUP'S award winning "Water Cube" (right of Fig. 7), the aquatic centre currently built in Beijing for the Olympic Games 2008. Much closer to Weaire's home, a giant statue of a 43 m high "bubble man" (left of Fig. 7) will be built by sculptor Anthony Gormley in the river Liffey in Dublin. People may wonder, though, whether this is an homage to Weaire's achievements or to the creamy froth that crowns the country's national drink.

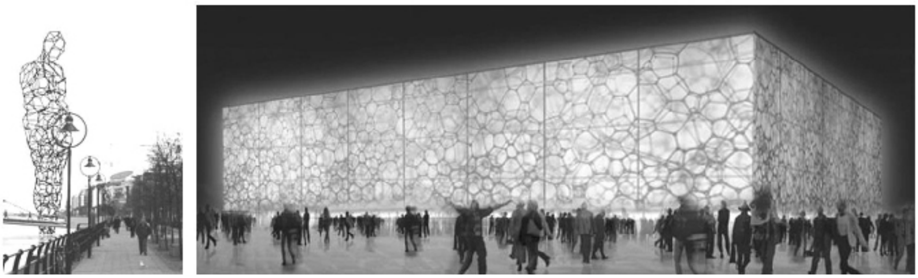


Figure 7: (Left) A 43 m high bubble man will be built by sculptor Anthony Gormley in the river Liffey in Dublin, Ireland. (Right) ARUP's award winning "Water Cube", the aquatic centre for the Olympic Games in 2008 in Beijing, consist of 4500 giant Weaire-Phelan bubbles.

References

Boudaoud, A., Y. Couder, et al. (1999). "Self-adaptation in vibrating soap films." Physical Review Letters 82(19): 3847-3850.

Boys, C. V. (1959). Soap bubbles: their colours and the forces which mold them, Gannon Distributing Co.

Drenckhan, W., D. Weaire, et al. (2004). "The demonstration of conformal maps with two-dimensional foams." European Journal of Physics 25(3): 429-438.

Elias, F., S. Hutzler, et al. (2007). "Visualisation of sound waves using regularly spaced soap films." European Physical Journal 28: 755.

Weaire, D. and S. Hutzler (1999). The Physics of Foams. Oxford, Clarendon Press.

Weaire, D. and R. Phelan (1994). "A counterexample to Kelvin's conjecture on minimal surfaces." Philosophical Magazine Letters 69: 107-110.