

SOME CONFLUENCES OF ART AND SCIENCE IN THE PHYSICS OF FOAMS

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Publications and/or Exhibitions:

- Related to science:

Drenckhan, W., Cox, S., and Weaire, D. (2004) The demonstration of conformal maps with two-dimensional foams, *European Journal of Physics*, Vol. 25, 429-438.

Drenckhan, W. (2004) *Stability and Motion of Foams and Films in Confined Geometries*, PhD Thesis, University of Dublin, Trinity College

- Related to "arts":

Regular illustrations for *European Physics Journal*, monthly Cartoons for *Physik Journal*.

Abstract: *Art and science present two faces of human culture that reflect each other in many ways. Those of us seeking a topic which links (rather than simply reflects) both faces naturally, find much of their desire satisfied in the dazzling beauty and elegance of soap bubbles and foams; a subject which has attracted scientists, artists and children (see cartoon by the author) alike over hundreds of years. The simple principle of minimisation of surface energy governing their geometry and topology, leads to the origin of a plethora of scientifically relevant and artistically beautiful patterns - most of which have counterparts in nature. At the heart of this presentation lies a simple question: How to arrange cells of equal volume such that their interfacial area is minimized? In the search to answer some of its aspects we bring together fields as versatile as mathematics, physics, biology, architecture and arts.*



1 INTRODUCTION

Books such as “Structure in Nature is a Strategy for Design” (Pearce 1980) have advocated the deployment of the structures that are encountered in science. Not only does this strike a resonance with the natural world, but the structures themselves may be in some sense optimal, for nature always optimises.

One class of such structures is that which derives from the minimisation of surface energy, and is found in nature everywhere: in bubbles, foams, emulsions, ecological territories, plant cells (Ball, 2001; Weaire et al., 1999). They divide up two or three-dimensional space in an optimal way, with boundaries that are generally curved and meet at equal angles. They will be our subject here, and we will present some startling artistic manifestations of them.

2 MINIMAL SURFACES AND PATTERNS IN FOAMS

At the heart of this presentation lies a very simple question: How to arrange cells of equal volume such that their interfacial area is minimized? Posing this question for various boundary conditions, has given researchers sleepless nights over hundreds of years. An analytic answer for two dimensions has only been established very recently by Hales (2001), confirming on 22 Pages what the bees have known all along by building their “honeycombs” (Fig. 1 (a)). Fig. 1 (b) shows a photograph of a soapy honeycomb generated by trapping bubbles of equal volume between two parallel glass surfaces. Light reflections generate an interesting graphic effect.



Figure 1: (a) Honeycomb made by bees. (b) Honeycomb made by physicists: bubbles of equal volume are trapped between two glass surfaces. The artistic pattern is a result of light being reflected at the gas/liquid interface.

The problem becomes scientifically and artistically more interesting, when the surfaces trapping the bubble mono-layer are angled or curved. If appropriate surfaces are chosen, the patient experimentalist is rewarded with watching beautiful patterns emerge, which turn out to represent conformal transformations of the honeycomb under particular circumstances. The only conformal pattern with translational symmetry (Fig. 2 (a)) has been dubbed “Gravity’s Rainbow”. Its significance in the field of pattern formation was

established by Rothen's and Pieranski's (1996) work on magnetic steel balls subjected to gravity. Pieranski enjoys an artistic outlook on his work, having created among other images the one shown in Figure 2 (b) - which predicted the pattern we found many years later without being aware of his vision. In a private communication he recently wrote:

"I'm glad that the gravity's rainbow has revealed its secrets to somebody else. When, by accident, I saw it for the first time emerging from the chaotic arrangement of tiny steel balls submerged in the magnetic field, I was taken over by its beauty. [...] Find enclosed a primitive computer graphics I created many years ago [Fig. 2 (b)]. Then, it was just a vision. Now, you made the vision real."

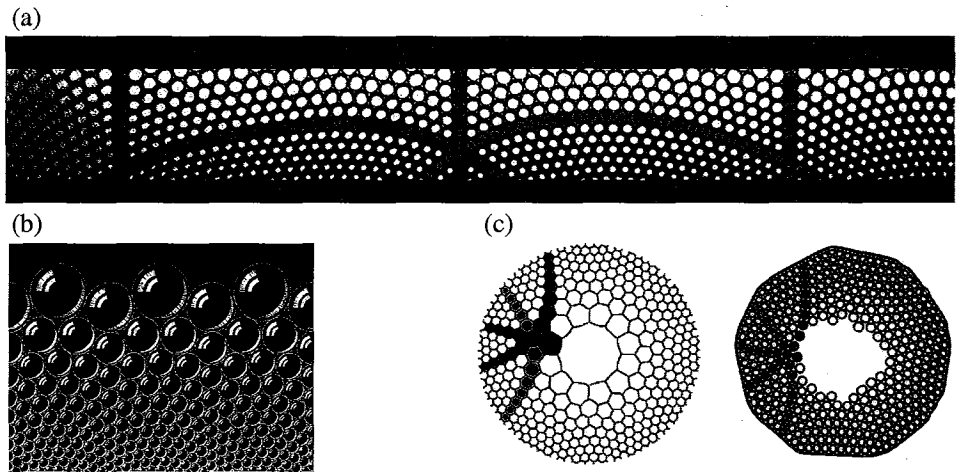


Figure 2: Conformal transformations of the honeycomb with (a) translational symmetry and (c) rotational symmetry, generated with soap bubbles between non-parallel surfaces. Coincidentally, (a) reproduced an artistic vision P. Pieranski expressed a few years ago in (b).

In an attempt of finding the optimal packing in three dimensions scientists are still racing each other, their race horses being ever faster computers. One of these, saddled with the powerful Surface Evolver by K. Brakke (1996), brought Weaire and Phelan (1999) 0.2 % ahead of the to that date unbeaten Kelvin structure (Fig. 3 (a)).

Originally proposed as a building, we have transformed a section of the Weaire-Phelan structure into a sculpture (Fig. 3 (b)) for our university campus. Among its many sculptures by famous artists, ours is going to be the first one made by scientists. Some may like to consider this a symbolic - if not desperate - outreach...

Modern materials and computers have opened up a wide vista of opportunities for architects. Rigid rectangularity has already been replaced by curved or angular forms, although restricted university budgets may call for simple boxes.

Minimal surfaces and patterns can provide inspiration for new structures that do not only look natural and appropriate, but satisfy the requirements of stability by invoking analogies to systems like foams or plant cells.

In this spirit, the Weaire-Phelan structure has recently left the world of pure scientific relevance by having become a vital and artistically stunning ingredient of the architectural design of the “Water Cube” (Fig. 3 (c)) – a magnificent swimming pool for the Olympic Games 2008 in Beijing, China. This building has a wonderfully ingenious and complex construction, but still within the overall constraint of a rectangular building, which perhaps reflects the necessary form of its principal swimming pool. Future buildings, however, are likely to combine intriguing internal structures with more expressive external forms. In this process, scientists should not stand back and admire (or condemn) such designs, but offer inspiration, suggestions and directions. Fractals, quasicrystals, catastrophes, minimal forms... Our repertoire is formidable, and remains to be exploited!



Figure 3: (a) The Weaire-Phelan structure. (b) Model of the sculpture for the campus of Trinity College Dublin, originally proposed as a design for a building. (c) The “Water Cube” swimming centre for the Olympic Games 2008 in Beijing, China. The Walls are made of the Weaire-Phelan structure (Image courtesy of ARUP).

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