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STRUCTURAL HIERARCHIES

Simple geometry in complex organisms

Graham Scarr*

60 Edward Street, Stapleford, Nottingham NG9 8FJ, United Kingdom

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Summary Many cultures throughout history have used the regularities of numbers and patterns as a means of describing their environment. The ancient Greeks believed that just five archetypal forms — the 'platonic solids' — were part of natural law, and could describe everything in the universe because they were pure and perfect. The formation of simple geometric shapes through the interactions of physical forces, and their development into more complex biological structures, supports a re-appreciation of these pre-Darwinian laws. The self-assembly of molecular components at the nano-scale, and their organization into the tensegrities of complex organisms is explored here. Hierarchies of structure link the nano and micro realms with the whole organism, and have implications for manual therapies.

Introduction

Many cultures throughout history have used the regularities of numbers and patterns as a means of describing their environment. The ancient Greeks believed that just five archetypal forms — the 'platonic solids' — were part of natural law and could describe everything in the universe because they were pure and perfect (Figure 1) (Fuller, 1975, sec.820.00).

This platonic conception of nature persisted up until the mid nineteenth century when Charles Darwin published his revolutionary 'Origin of Species', ''After Darwin the whole lawful scheme was overthrown and organic forms came to be seen as contingent mutable assemblages of matter — 'clever artefact like contrivances' — put together gradually during the course of evolution primarily by natural selection for biological function'' (Denton et al., 2003). A recognition of natural patterns and shapes derived from physical laws seemed to reassert itself in 1917 when d'Arcy Thompson published his classic 'On Growth and Form' (Thompson, 1961), but in the scientific mainstream this remained little more than interesting. Using simple geometry to describe a complex organism is likely to generate a certain amount of skepticism, as esoteric and occult descriptions seem rather simplistic compared to modern scientific thinking. However, in 1928 Frank Ramsey proved that every complex or random structure *necessarily* contains an orderly substructure. His proof established the fundamentals of a branch of mathematics known as Ramsey theory, which is used to study the conditions under which order must appear, such as in large communication networks and the recognition of patterns in physical systems. The theory suggests that much of the essential structure of mathematics consists of extremely large

* Tel.: +44 115 9491753.
E-mail address: gscarr3@ntlworld.com

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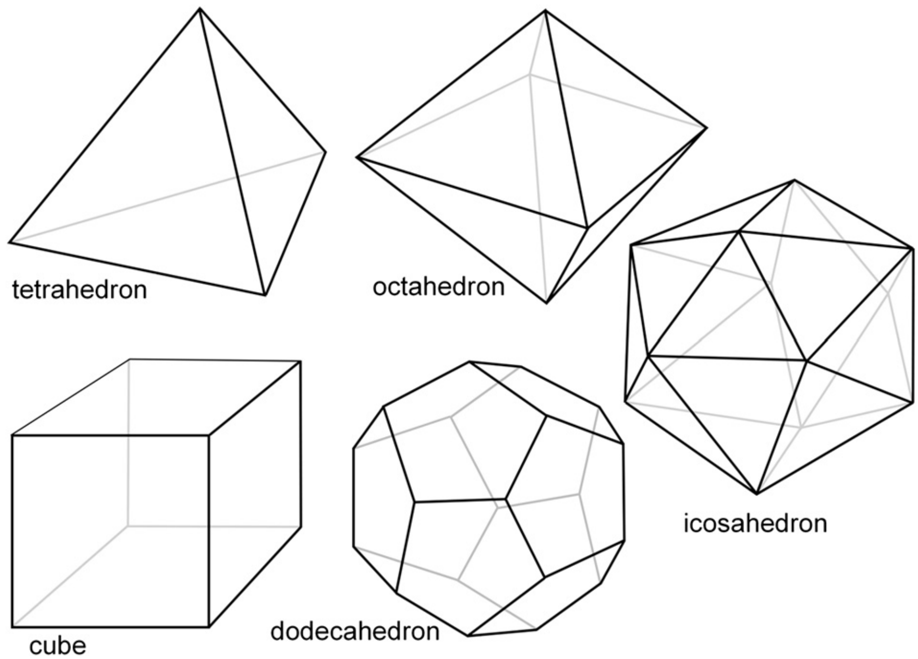

Figure 1 The five platonic solids.

numbers (with very complicated calculations) derived from problems which are deceptively simple (Graham and Spencer, 1990; Fuller, 1975, sec.227.00). From the perspective of the human body, Ramsey theory implies that simple shapes *might* form part of that underlying substructure, and an examination of how these could arise through the interactions of physical forces is presented. This supports recent research which reinstates physical law, and not natural selection, as the major determinant of biological complexity in the subcellular realm (Denton et al., 2003). The development of these shapes into more complex structures, and how they model biology, with implications for manual therapy then follows.

Simple geometry

One of the problems that nature seems to solve repeatedly is that of the most efficient ways of packing objects close together. A circle drawn on a piece of paper, i.e. in two dimensions (2D), demonstrates this. The circle encloses the largest area within the minimum boundary, which makes it a 'minimal-energy' shape (requiring the least amount of energy to maintain). Circles enclose space, as well as radiate out into it, as can be seen in a drop of oil floating on water, the growth of fruit mould, and the ripples in a pond. However, this efficiency is severely compromised when several circles are put next to each other as gaps are left in between (Figure 2). Other shapes, such as squares and triangles will both fill the space completely, but the proportion of area to boundary is not as good as with the circle. A square is inherently unstable; while triangles are very stable, even with flexible joints (Figure 3). Structures that are not triangulated can generate torque and bending moments at their joints, and must be rigidly fixed to prevent them from collapsing.

The best compromise between efficient space filling of the circle and stability of the triangle is the hexagon (Figure 2). Isolated hexagons are also liable to collapsing, but when several hexagons are packed together, they support each other as stresses balance at their 3-way

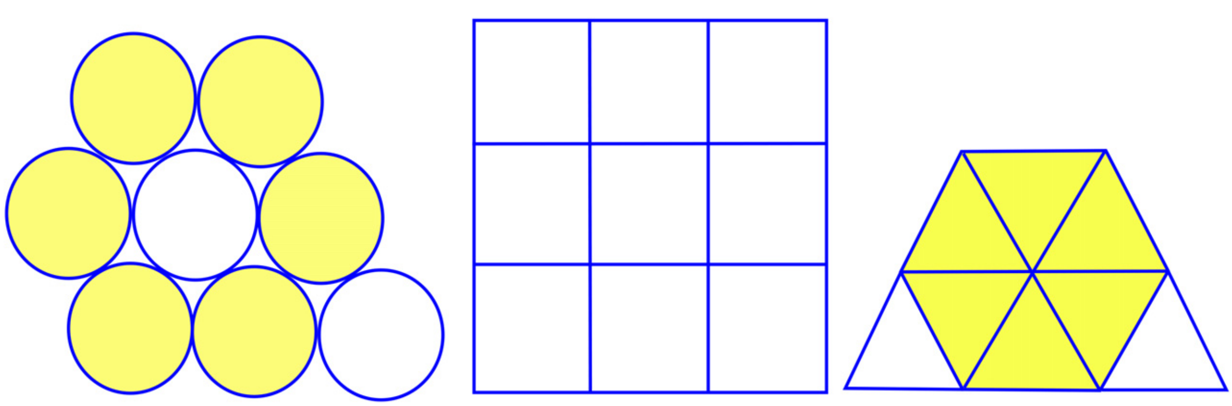

Figure 2 The tessellation of different shapes on a flat plane showing the appearance of the hexagon (shaded).