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Spiral and target patterns in bivalve nacre manifest a natural excitable medium from layer growth of a biological liquid crystal

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Nacre is an exquisitely structured biocomposite of the calcium carbonate mineral aragonite with small amounts of proteins and the polysaccharide chitin. For many years, it has been the subject of research, not just because of its beauty, but also to discover how nature can produce such a superior product with excellent mechanical properties from such relatively weak raw materials. Four decades ago, Wada [Wada K (1966) Spiral growth of nacre. Nature 211:1427] proposed that the spiral patterns in nacre could be explained by using the theory Frank [Frank F (1949) The influence of dislocations on crystal growth. Discuss Faraday Soc 5:48 –54] had put forward of the growth of crystals by means of screw dislocations. Frank's mechanism of crystal growth has been amply confirmed by experimental observations of screw dislocations in crystals, but it is a growth mechanism for a single crystal, with growth fronts of molecules. However, the growth fronts composed of many tablets of crystalline aragonite visible in micrographs of nacre are not a molecular-scale but a mesoscale phenomenon, so it has not been evident how the Frank mechanism might be of relevance. Here, we demonstrate that nacre growth is organized around a liquid-crystal core of chitin crystallites, a skeleton that the other components of nacre subsequently flesh out in a process of hierarchical self-assembly. We establish that spiral and target patterns can arise in a liquid crystal formed layer by layer through the Burton–Cabrera–Frank [Burton W, Cabrera N, Frank F (1951) The growth of crystals and the equilibrium structure of their surfaces. Philos Trans R Soc London Ser A 243:299–358] dynamics, and furthermore that this layer growth mechanism is an instance of an important class of physical systems termed excitable media. Artificial liquid crystals grown in this way may have many technological applications.

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