population and regression of the tumour.

The CSCs in squamous tumours that Beck *et al.* studied were predominantly in niches closely associated with the underlying endothelial cells. Leukaemia and brain-tumour stem cells are also often found side by side with vascular cells[7]. There is strong evidence that CSCs 'read' factors released by neighbouring endothelial cells and that these factors are necessary for CSC maintenance (paracrine communication)[8,9], perhaps working in synergy with the autocrine signalling through CSC-derived VEGF to sustain tumour stemness (Fig. 1).

These findings raise several interesting questions. For instance, heterogeneous populations of CSCs have been described[3] in squamous-cell carcinomas that have comparable tumour-promoting potential but different proliferation rates. CSC heterogeneity is also evident in leukaemias and in solid tumours such as lung carcinomas[10,11]. Are different CSC subtypes localized close to the vascular niche? Do other tumour types rely on the VEGF autocrine loop? Does Nrp1 act alone or does it cooperate with different primary VEGF receptors? One might also ask whether CSCs are equally dependent on autocrine VEGF and on communicating with neighbouring endothelial cells for their self-renewal, and whether VEGF is still as important in the later stages of cancer as it is in the initial stages.

Developing strategies that precisely target the self-sustaining mechanism of CSCs — rather than blanket prevention of angiogenesis — might be therapeutically useful. One adverse side effect of anti-angiogenic cancer therapies is the deprivation of oxygen in tumours, which paradoxically enhances their metastatic potential[12]. Therapies that preferentially inhibit VEGF signalling in CSCs — for instance by preventing interaction between Nrp1 and VEGF — might selectively prevent stem-cell self-renewal without creating pro-metastatic oxygen shortage. Although most of the vascularly secreted paracrine factors that affect CSC self-renewal are yet to be identified, blocking their activity might also selectively eliminate CSCs with little anti-angiogenic effect. Beck and colleagues' promising findings warrant further investigation into the molecular mechanism and therapeutic potential of blocking the autocrine VEGF/Nrp1 loop. ■

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MATERIALS SCIENCE

Deft tricks with liquid crystals

Some biological macromolecules can control their own assembly into elegant hierarchical structures. Synthetic supramolecules are catching up fast, promising new advances for optical and biomedical materials. SEE LETTER P.364

IVAN I. SMALYUKH

Liquid crystals are widely used in electro-optics, photonics, sensors, artificial muscles and even in laboratory modelling of the early Universe[1–3]. But even these applications are nowhere near as complex and important as the use of liquid crystals in biological systems, where they underpin the organization of both soft and hard tissues. On page 364 of this issue[4], Chung *et al.* borrow an ingenious trick from biology to produce highly structured biomimetic materials from liquid crystals. Their discovery of how to fine-tune the assembly of such complex structures from identical building blocks could help to accelerate the large-scale fabrication of new functional materials.

The simplest liquid crystals are typically rod-like molecules that spontaneously orient along a common direction while flowing under shear or gravity[1]. The chirality (handedness) of such molecules and their various degrees of positional ordering introduce a plethora of different phases that have unique combinations of order and fluidity. Biological tissues often resemble crystalline structures or liquid-crystal flow patterns frozen in time[5], but the physical origins of their organization are not well understood. The synthetic templating of biomimetic structures by Chung *et al.*[4] provides valuable insight into these processes.

The authors use a rod-shaped bacteriophage (a virus that specifically infects bacteria), known as M13, as their starter building block. They dip-coat plates in dispersions of unoriented anisotropic phage particles while tuning the concentration and speed of extraction of submerged glass substrates, so that, as the water evaporates, the particles concentrate at the triple contact line of water, glass and air (Fig. 1a). The particles are carried to the meniscus by capillary flow to maintain the contact angle by replenishing the fast evaporative water losses near the pinned contact line. Such flows are ubiquitous in everyday life and cause, for example, the 'coffee-ring' stains in drying drops[6,7]. As the concentration increases, the phage particles spontaneously align and form different phases (Fig. 1b,c). When the contact line recedes while the substrate is being extracted, the liquid-crystal structures become further enriched by flows and by the action of capillary forces, and are then imprinted in the structure of the ensuing film (Fig. 1d).

By changing the speed of plate extraction and the initial concentration of phage particles, Chung *et al.* obtain highly controlled structures that mimic various liquid-crystal phases, as well as complex patterns generated by the combined effects of confinement geometry, flow and the receding contact line. The patterns closely resemble those seen in some biological tissues[2], supporting the idea that such tissues are 'frozen' liquid crystals[5].

The discontinuous receding and pinning of the contact line are important. Phage particles spontaneously align parallel to a pinned contact line to maximize their overall translational and rotational entropy in the wedge-shaped meniscus region. This gives rise to liquid-crystal phases that depend on concentration[7], yielding both uniform and twisted structures that minimize the elastic energy of liquid crystals confined in the wedge-shaped menisci (Fig. 1b,c).

The receding of the contact line as a result of pulling the substrate exerts 'combing' forces, which act on anisotropic particles at the fluid–air interface to minimize the surface-tension energy[8]; these forces tend to align the rods along the receding direction. As the contact-line dynamics are discontinuous and dependent on pulling speed, the interplay of these antagonistic entropic/elastic and combing effects provides a simple means to control the biomimetic self-assembly of a host of complex structures (Fig. 1d). The authors[4] show

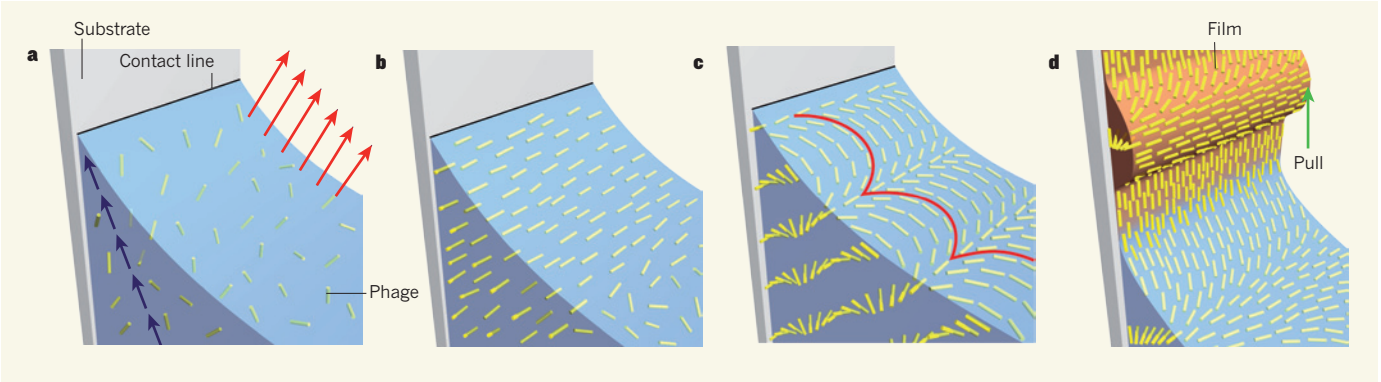

Figure 1 | Self-assembly of liquid-crystal structures. Chung *et al.*[4] have grown films in a single-step process in which substrates are dipped in and out of suspensions of rod-like particles (phage viruses) in water. **a**, When a glass substrate is withdrawn from a suspension, rapid water evaporation (red arrows) occurs at the contact line formed at the interface of the suspension, the substrate and the surrounding air. This evaporation, coupled with the need for the contact angle between the surface of the water and the substrate to be maintained as the substrate is withdrawn, causes capillary flow (blue arrows) that replenishes water at the contact line and carries particles to the meniscus. **b**, Particles concentrated at the meniscus spontaneously form a 'nematic' liquid crystal in which the particles align with the contact line. **c**, Interactions between highly concentrated particles promote their assembly into twisted, helical structures. The wedge-shaped geometry of the suspension just below the contact line causes the particles to form features called Bouligand arches (red lines). **d**, The discontinuous receding of the contact line as the substrate is withdrawn (green arrow), and rapid water evaporation at the line, promote the mechanical imprinting of self-organized liquid-crystal patterns into the film that forms as particles are deposited on the substrate.

that this process can yield biomimetic films that have pigment-free structural colours. These structured films are of interest for use as reflectors and filters, for providing periodic patterns for applications in unconventional diffraction gratings, and for controlling mechanical properties of artificial materials that resemble those of tissues found in nature.

In conventional liquid crystals, such as those used in mobile-phone displays, these structures would be unstable in the absence of external fields, relaxing to the ground state of the corresponding phases. In the set-up used by Chung *et al.*, however, water drying and the corresponding loss of fluidity imprint the liquid crystals into the biomimetic morphology of thin structured films. Contact-line pinning and discontinuous receding are usually evident during natural water drying at menisci and during droplet motion under gravity, offering clues to the origins of many forms of natural materials and tissues.

This type of biomimetic self-templating could extend the scope of application of many powerful fabrication techniques based on liquid-crystal self-organization and dip-coating[9–11]. As liquid-crystal behaviour is not restricted to rod-shaped particles, new liquid-crystal phases may be discovered in dispersions of particles that have low symmetry. It will be of great interest, both from a fundamental viewpoint and for potential applications, to explore how the approach taken by Chung *et al.*[4] can be extended to dispersions of particles of varying composition, shape, rigidity and size, as well as to composite dispersions comprising different types of particles.

Biomimetic self-templating has the potential to be used to engineer tissues to acquire sophisticated structure, to investigate links between liquid-crystal self-organization and morphogenesis[12] and to fabricate metamaterials, photonic crystals and organic photovoltaics, adding to an already impressive list of applications. ■

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ASTROPHYSICS

Stars acquire youth through duplicity

The origin of unusually hot stars in a sparse cluster has been attributed to their being members of binary systems rather than stellar collisions. This prompts a rethink of how stars merge when they collide. SEE LETTER P.356

CHRISTOPHER TOUT

Stars in dense clusters were mostly born at the same time, but a few seem to be much younger. The origin of these oddly young stars, which are known as blue stragglers, has been attributed to collisions between stars in the dense stellar environment or to the accretion of matter from a close companion. On page 356 of this issue, Geller and Mathieu[1] examine current companions to blue stragglers and establish that the mass-transfer origin is prevalent in a sparse star cluster known as NGC 188.

Two properties of any star — its brightness, or magnitude, and colour — can be easily measured. If a star's distance is known, its luminosity can be calculated from its magnitude. Its colour is due to its temperature. In a plot of luminosity against temperature, known as a Hertzsprung–Russell diagram, stars lie in specific regions (Fig. 1). The most populous area is known as the main sequence, in which the hottest blue stars are the brightest and the