The thickness of the sheet can be varied from a one-octahedra-thick layer (n = 1) up to five-octahedra-thick layers (n = 5) by controlling the ratio of small MA to large BA cations. While studying single crystals (n ≤ 2) of these materials with time-resolved photoluminescence, the authors noted that excitons generated in the bulk of the crystals recombined quickly (see the figure). Yet, surprisingly, for crystals with n > 2, excitons that reached the edge of the crystal within a picosecond time scale encountered new electronic states, called layer-edge states (LESs). In these states, the separated charge carriers survive for a long time before recombining to reemit a photon. Consequently, for n > 2 2D perovskites, fabricating solar cells from polycrystalline films of crystal grain sizes smaller than the diffusion length of the excitons (10 to 100 nm) guarantees that a maximal number of excitons will reach LESs, and thus can be separated and collected efficiently. Indeed, the study observed very low PCEs for cells based on n = 1 and 2 (no LESs), and impressively high efficiencies as soon as n exceeded 2 (LESs present).

The discovery of LESs that protect charges from fast recombination in 2D perovskites is in stark contrast to 3D perovskite surfaces, which tend to be defective and riddled with undesirable trap states that prevent charge carriers from being collected. Additionally, from a fundamental physics and materials property standpoint, the precisely controlled quantum confinement of these 2D perovskites with LESs makes them ideal systems for studying the physics of highly confined free-carrier states—a situation that is difficult to replicate in other materials systems. The finding of Blancou et al. opens the possibility for engineering similar LESs in other members of the low-dimensional perovskite family; as such, a large group of materials that photovoltaic researchers mostly overlooked in the past now become prime competitors in optoelectronics, offering an expanded toolbox to remediate many of the impediments plaguing 3D perovskites. ■

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permutations of source materials could also be programmed to self-assemble. Several challenges lie ahead. The method requires a lot of effort to generate new dT staples, which may limit adoption. The DNA-protein hybrid shapes are genetically encoded but have not yet been shown to work in living organisms, unlike alternative RNA-based methods (9) and protein scaffolds (10) that have been used to control metabolic flux in vivo. It may be difficult in general to translate complex self-assembly methods to work in vivo, even though simple DNA nanostructures have been expressed and folded in bacteria (11).

On a positive note, the hybrid DNA–protein structures reported by Praetorius and Dietz do not rely on any ssDNA components, which might be a major advantage because custom ssDNA is typically difficult to produce in cells. It will be interesting to see what kinds of functionalization can be added to dT staples, especially because applications in cells may require careful regulation of expression and folding conditions. Fortunately, there will be no shortage of options to explore as molecular engineers get ever closer to biological-level sophistication and complexity.

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**ACTIVE MATTER**

**From chaos to order in active fluids**

Random flows in an active fluid become directional under confinement

By Alexander Morozov

There are few sights more spectacular than the swirling of a school of fish or a flock of birds that suddenly gives way to a directional motion. Arguably, our admiration is rooted in the surprise that individual organisms, capable of self-propulsion on their own, organize to move en masse in a coherent fashion. Coherent motion is common in a large class of biological and synthetic materials that are often referred to as active matter. Such materials consist of particles immersed in a fluid that can extract energy from their surroundings (or internal fuel) and convert it into directed motion. Living organisms, biological tissues, rods on a vibrated plate, and self-phoretic colloids are just a few examples (1). Similar to schools of fish and flocks of birds, active matter often exhibits random swirling motion (2–5) that until now was impossible to control or use. On page 1284 of this issue, Wu et al. (6) demonstrate that an active fluid can be manipulated to flow in a particular direction without any external stimuli by confining it in microchannels.

Active systems can display unusual properties that develop from the motion of their individual components. Enhanced diffusion of passive tracers added to active fluids (7), superfluid-like behavior of bacterial suspensions (8), and an ongoing debate about how to define the pressure inside an active fluid (9, 10) add to recent fascination with active matter across many disciplines. In physics, active systems act as a playground for developing new nonequilibrium methods applicable in situations in which usual statistical mechanics breaks down. In biology, it poses a fundamental question of what traits can be considered truly biological and what is emergent and caused by the activity of its constituents. In materials science, these fluids might be manipulated to per-
Editor's Summary

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