The dissection of topography into ridges and valleys sets the scene for all manner of processes — physical, chemical and biological — that operate on Earth’s surface. How do these processes interact to set the scale of this dissection? Although many other aspects of landforms seem to be scale-invariant, there are plenty of instances in which our own eyes tell us that ridges and valleys are uniformly spaced (Fig. 1) — that there is a fundamental scale to landforms. This impression can be confirmed quantitatively.

For more than a century, geomorphologists have recognized that valley spacing is probably governed by a transition from hillslope (unchannelled) soil transport to channelled stream incision. Hillslope soil transport acts in a diffusive manner and tends to fill in incipient channels cut by stream flow, and competition between these two processes has long been thought to determine the scale of landscape dissection. Much progress has been made, but no general theory with demonstrably predictive power has emerged — until now, that is, for Perron et al. (page 502 of this issue) show that the wide variation in ridge–valley spacing can be explained by a simple model of this competition in a certain class of landscape.

From a scaling analysis of a statement of the conservation of mass, in previous work Perron et al. derived a non-dimensional quantity, akin to a value called the Péclet number, that gauges the competition between soil creep and channel incision. Their numerical simulations demonstrated that this non-dimensional quantity does indeed, in principle, govern valley spacing.

In their latest paper, Perron et al. test this model against observations using newly available, high-resolution topographic data that reveal a tenfold variation in valley spacing among five field sites. To define a simple, testable hypothesis, they restrict their analysis to ‘low-relief, soil-mantled’ landscapes, where soil creep and stream flow are the dominant processes controlling sediment transport and erosion. For these cases, their model and their scaling analysis predict that valley spacing scales with the ratio of the intensity of soil creep to the intensity of channel incision (D/K in their notation), but interestingly not with the actual erosion rate — a prediction in close agreement with previous theoretical work. Perron et al. have developed a new method that allows the D/K ratio to be estimated directly from topographic data. They find a more than 60-fold variation in D/K among the field sites in different climatic and geological settings that correlates strongly with independently measured valley spacing in a manner consistent with model predictions.

But what sets the ratio of intensities of soil creep and channel incision (D/K)? Both the denominator and the numerator in this ratio are known, qualitatively, to depend in various ways on substrate properties, climate, hydrology and biota. However, the linkages among these factors as they co-evolve are notoriously complex. As yet no theory exists to predict how D/K should vary with climate or rock type, and new data are needed to guide fresh thinking.

Nonetheless, despite some scatter, the data used in this study do provide some clues. They suggest that weaker rocks and drier climates are associated with closely spaced valleys (channel incision dominant), whereas stronger rocks and wetter climates are associated with widely spaced valleys (soil creep dominant) (Fig. 2). These findings are striking, in two respects.

First, although it is the less robust indication, the hint of a climatic control is interesting because the direct dependence of the intensity of channel incision on run-off intuitively implies the opposite trend — that wetter climates would be associated with lower D/K and more closely spaced valleys. However, greater vegetative cover and increased soil disturbance by vegetation or animals can reduce run-off while accelerating soil creep.

Second, the tenfold difference in D/K ratio, and associated fivefold difference in valley spacing, between two of the field sites — Dragon’s Back and Gabilan Mesa (Fig. 1) — is surprising. The sites are separated by only about 100 kilometres, experience a similar climate and are cut into the same moderately consolidated sedimentary rocks. These rocks seem to be slightly weaker at Dragon’s Back, consistent with the general trend between rock strength and valley spacing. Dragon’s Back is also slightly drier, and this climatic difference

Figure 1. Uniformity in ridge–valley spacing. This is Gabilan Mesa, California, one of the five ‘low-relief, soil-mantled’ sites that provided data for Perron and colleagues’ analysis. The valleys are cut into moderately consolidated sediments, with the distance between them being about 160 metres.
Cellular control in two clicks

Jason A. Burdick

If complex tissues are to be engineered, synthetic materials will be needed that provide cells with precisely located molecular cues. A method that attaches such cues to specific areas of a gel could be the answer.

Contrary to popular belief, George Washington’s dentures weren’t made of wood — they were actually made of ivory and gold. As with many other materials that have been used in biological systems, ivory and gold are relatively inert, and simply provided mechanical support for their intended application. Although giving biomaterials only a supporting role restricts their applications, it has nevertheless led to the development of a range of clinically useful materials (such as bone cements) and implantable devices (such as fixation plates for holding fractured bones in place). But what is really needed are biologically active materials that interact with and signal to surrounding cells and tissues.

Of particular interest are materials that can both track and manipulate the local three-dimensional arrangement of cells. Such an achievement would have been unimaginable just a few years ago, yet it is exactly what has been reported by DeForest et al.1 in Nature Materials. Using cell-compatible reactions, the authors first encapsulate cells in hydrogels — water-swollen polymer networks — and then introduce precisely targeted molecules into the gels to either monitor or alter the cells’ behaviour. Hydrogels are especially attractive as media for cell culture because they provide a tissue-like, three-dimensional environment in which cells can flourish.

The past couple of decades have seen an explosion of work in which engineers and biologists have collaborated to find ways of assembling cells, molecules and scaffold materials, with the ultimate goal of growing biological tissues1. These efforts are leading to new therapies, but progress has been slow, especially in producing tissues that consist of several cell types or that lack the capacity to

Figure 1 | Clicking into place. DeForest et al.1 have developed a method for monitoring or controlling the behaviour of cells at user-defined sites within a hydrogel (a water-swollen, polymeric network). a. The gel is prepared from its monomers in the presence of cells using a ‘click’ reaction, so that the cells become encapsulated in the gel. The crosslinks of the polymer network incorporate a reactive chemical group. b. When irradiated with light, the chemical group reacts in a second click reaction with molecules that contain thiol (SH) groups; these molecules act as signals that monitor or dictate the behaviour of the encapsulated cells. In the example shown, light is shone through a mask, so that only groups in the illuminated regions react. Once incorporated into the gel, the signal molecules cause the cells to change shape.

Figure 2 | Tentative interpretation of geological and climatic influences on valley spacing. According to theory, valley spacing in low-relief, soil-mantled landscapes is set by the ratio between hillslope transport (soil creep) intensity and channel incision intensity4–7. Perron and colleagues’ provide a successful test of theory, and their data contain further hints about the underlying controls exercised by the substrate and climate: weaker rocks and (less certainly) drier climates seem to lead to a dominance of channel-incision processes and more closely spaced valleys.

is associated with a change from semi-arid grassland to oak savannah. Could these small differences be sufficient to explain the fivefold difference in valley spacing, or are other factors at play? Much remains unknown about the complex controls on the intensity of soil creep and channel incision. But the work by Perron and colleagues’ will encourage further investigation because their ratio seems to set the fundamental length scale in landscapes, and fundamental length scale in landscapes, and process acting on the land surface.

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2. Perron, J. T., Kirchner, J. W. & Dietrich, W. E.