

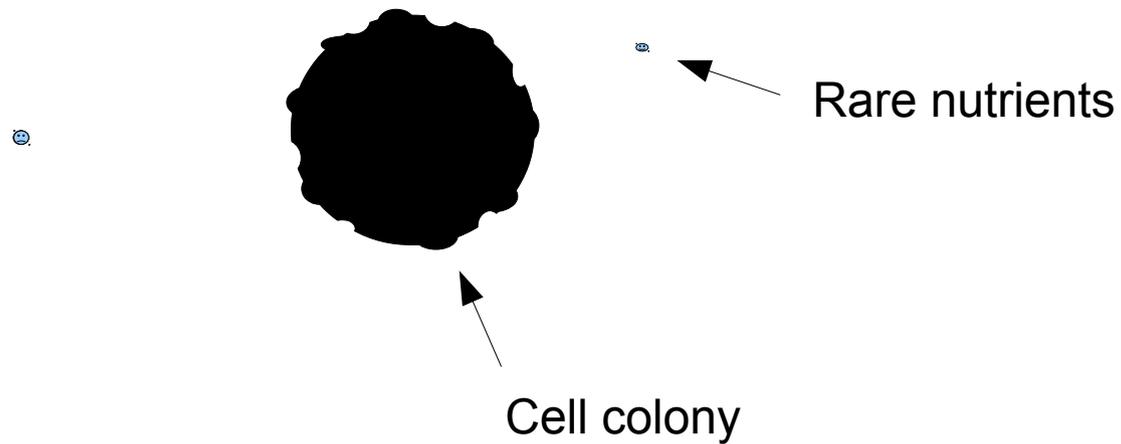
Lecture 2:

Sources of anisotropic growth

Again, these slides contain all of the text and important images, but not all of the simply illustrative images (for copyright reasons).

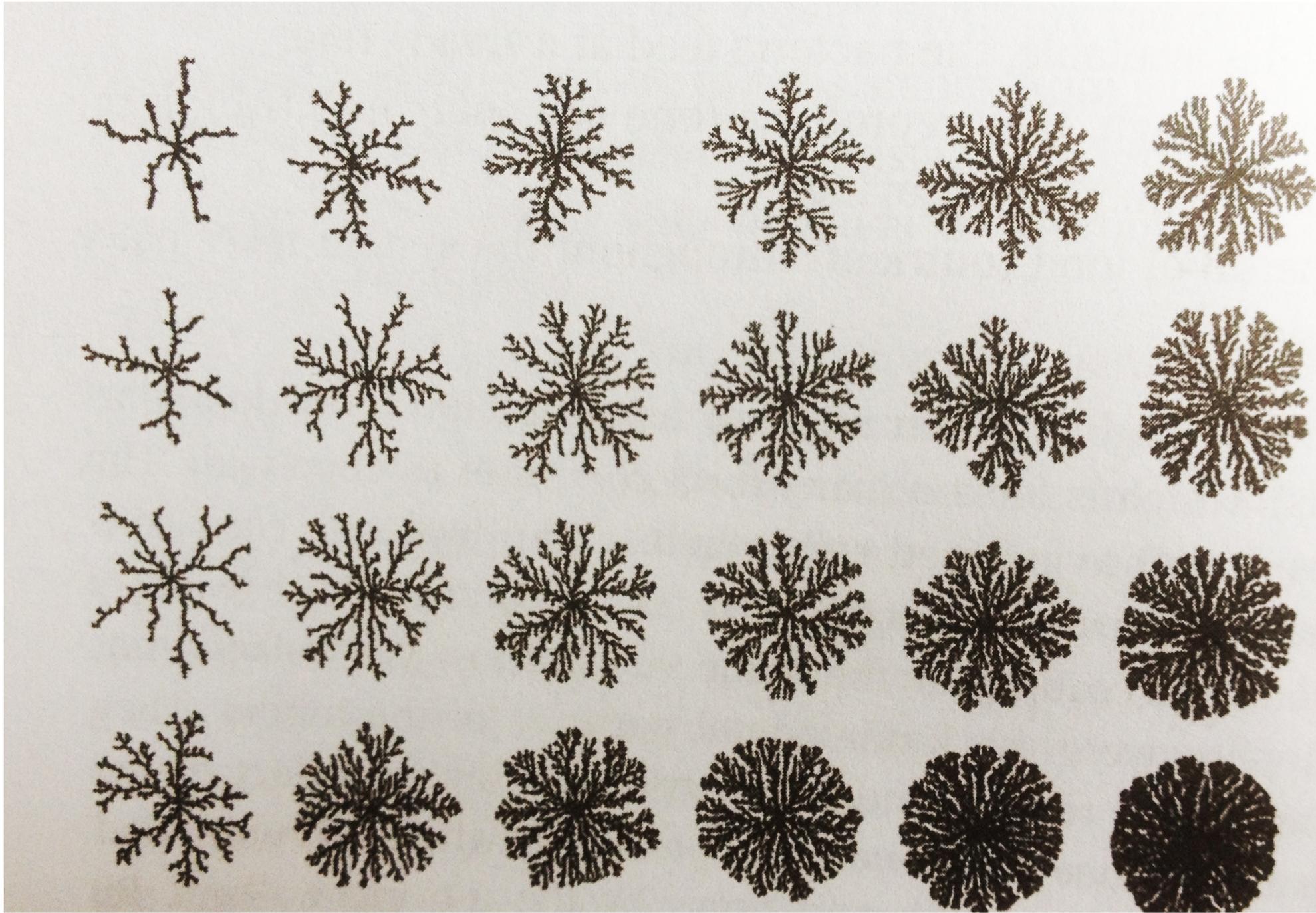
Environmental control of growth can directly drive morphogenesis.

Consider a colony of cells whose growth/proliferation is limited by availability of diffusible nutrients:



(low) ----- Nutrient availability ----- (high)

(high) ----- agar stiffness ----- (low)



B. subtilis

Directional cell division:

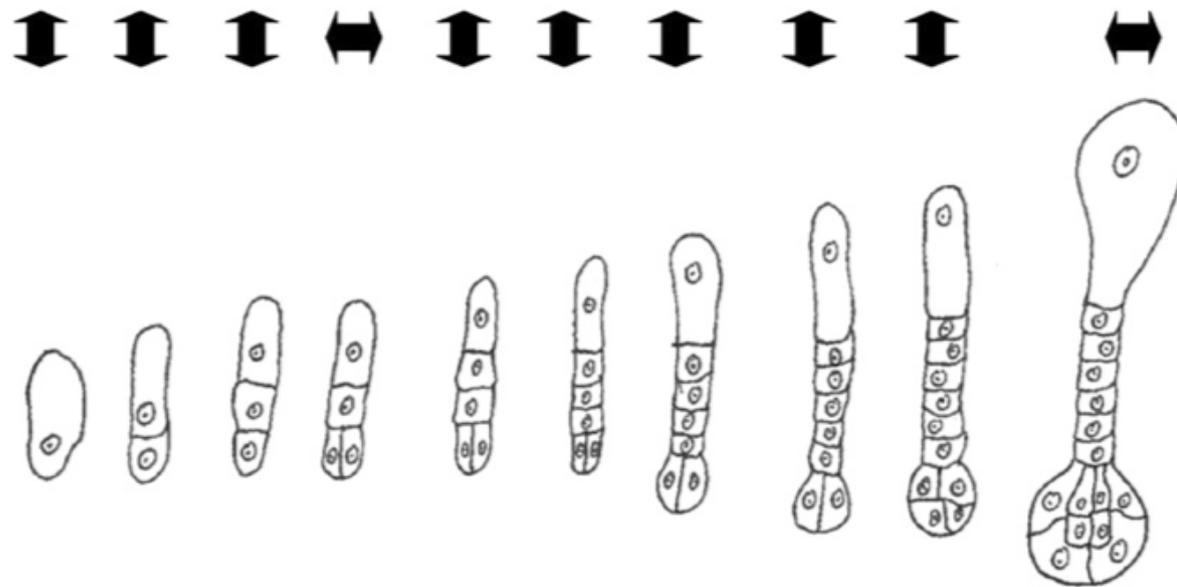
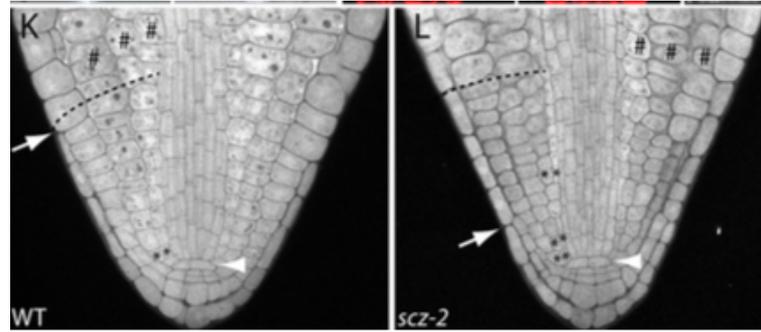
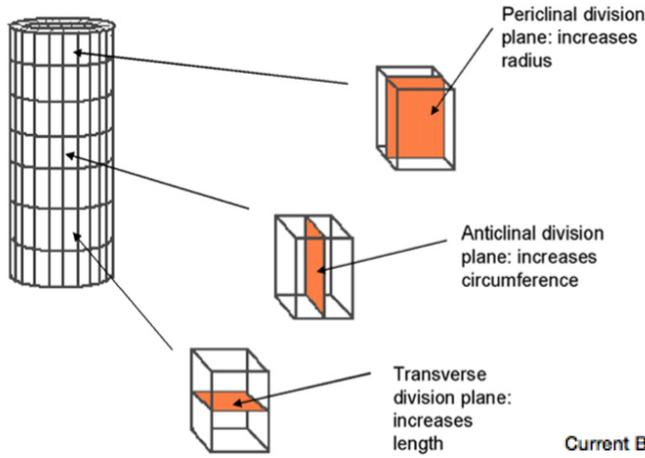
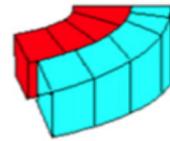


FIGURE 23.14 The succession of orientated cell divisions in the early development of the embryo of *Capsella bursa-pastoris* ('Shepherd's purse'): the orientation of each cell division is shown by the arrow above it, in the top of the diagram. Based on Fahm.⁴⁰

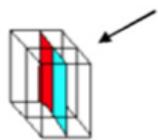


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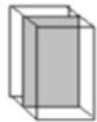
Wild type



Several anticlinal divisions



Single periclinal division

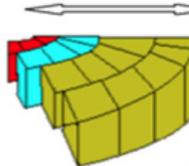


Daughter of initial cell

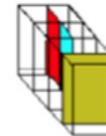


SCHIZORIZA mutant

Extra girth due to **extra cells**



These cells switch to anticlinal division and differentiate normally



Extra cells continue to divide



Extra periclinal divisions create **extra layers of cells** before differentiation takes place



FIGURE 23.16 Altered planes of cell division in the *schizoriza* mutant.

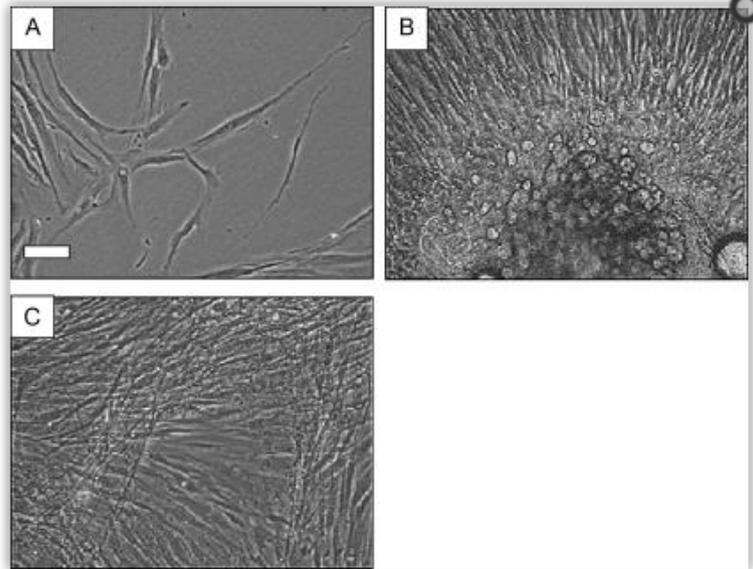
Hertwig's rule: (In the absence of over-riding factors) Cells orientate their division planes in the direction that will reduce mechanical stress in tissues.

Crowding of cells can also orientate expansion

Contact guidance in human dermal fibroblasts
is modulated by population pressure

Jennifer Sutherland, Morgan Denyer, and Stephen Britland

Uncrowded:
random

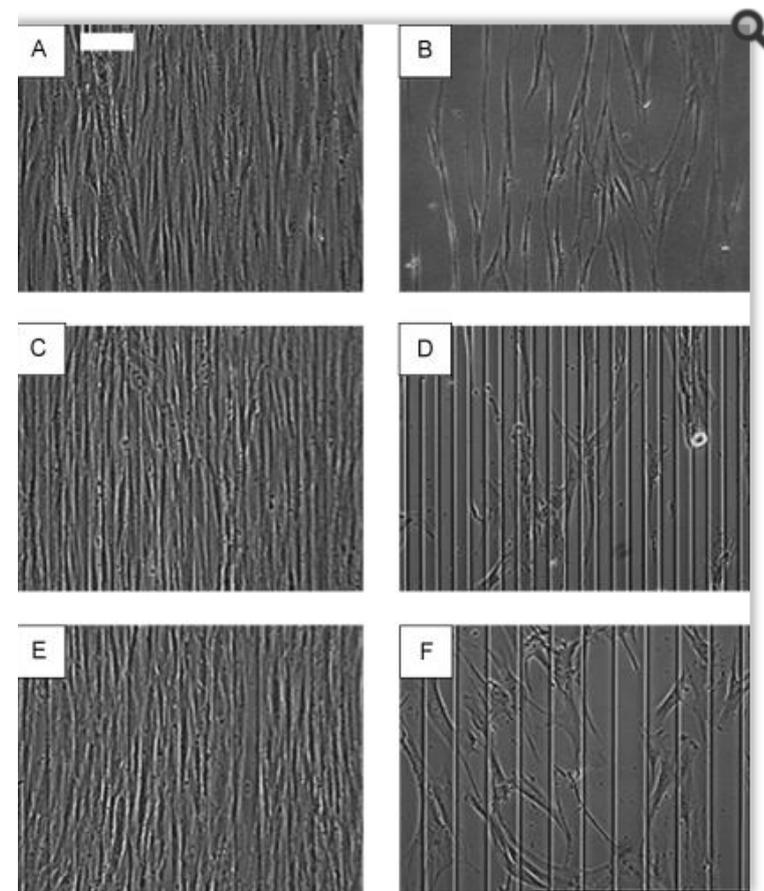
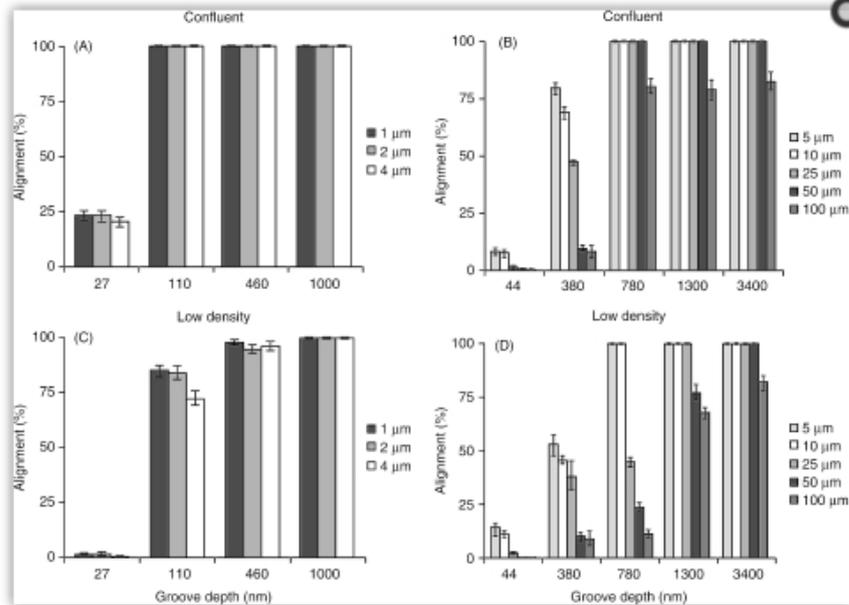


Crowded,
cued: radial

Crowded,
uncued:
orientated
domains

But it's not just physical crowding: cells become more sensitive to patterned substrates (grooves) if crowded.

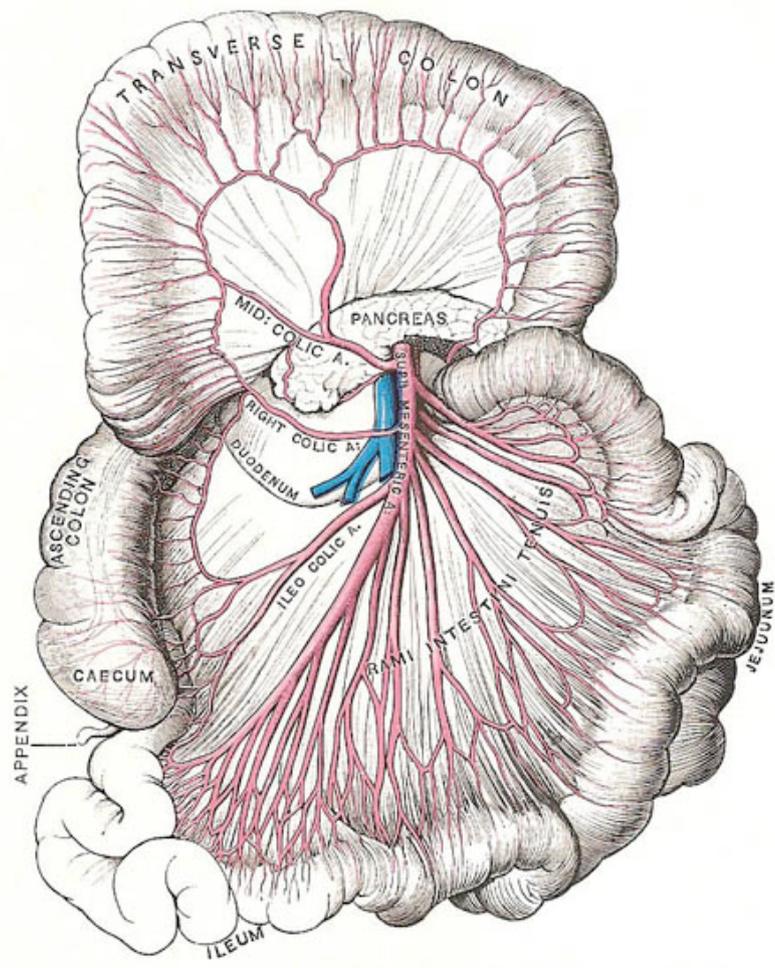
Fig. 2



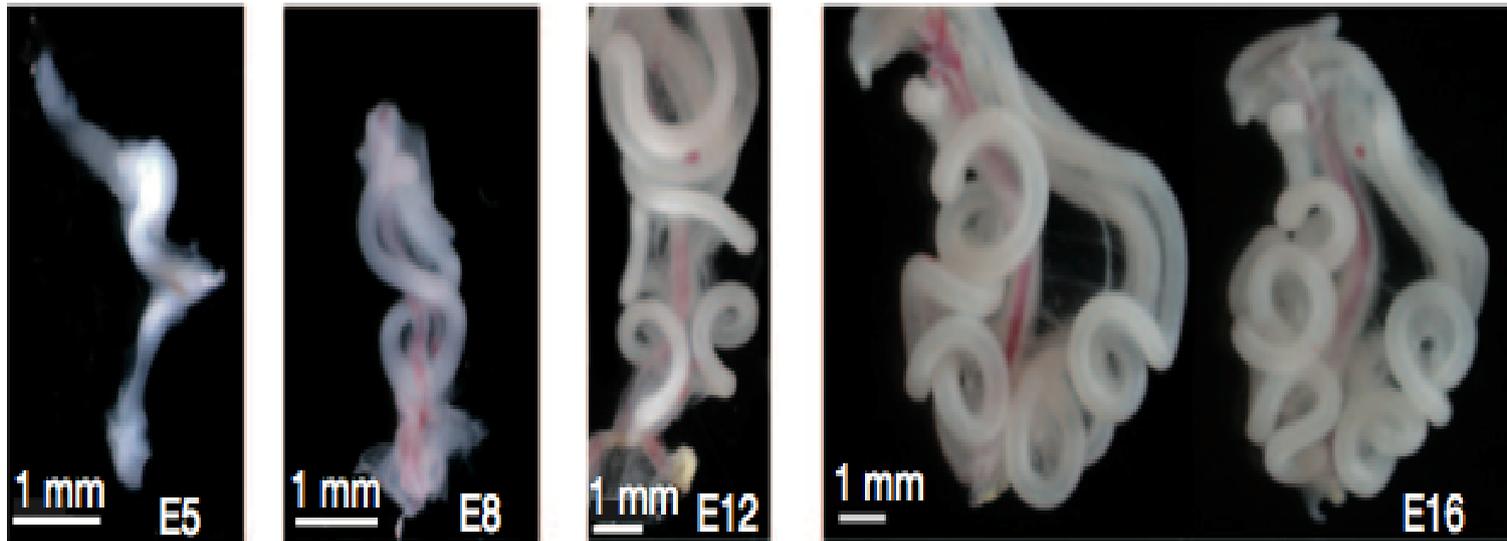
Line graphs illustrating the proportion of cells aligned to the underlying linear substratum microtopography within low-density and confluent cultures. Graphs A and B represent confluent cultures, C and D low-density cultures, and each displays alignment data for cells cultured on sets of grooves of increasing pitch and also increasing depth. Population pressure can be seen to exert maximum influence on alignment of cells on narrower grooves with depths between 380 and 1300 nm. On the narrowest grooves most cells in low-density cultures were insensitive to gratings 27 nm depth, but at confluence 25% of cells were aligned to the substratum.

The effect of growth in complex tissues

The gut is connected to the rest of the body via a mesentery:

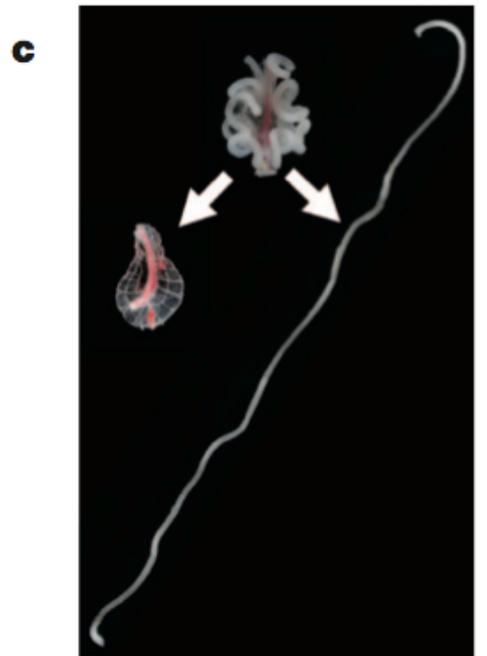


These are pictures of developing bird guts... they make loops.

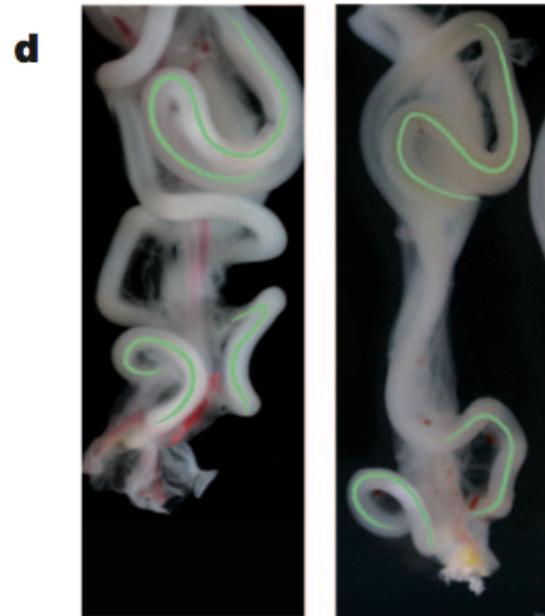


On the growth and form of the gut

Thierry Savin^{1†*}, Natasza A. Kurpios^{2†*}, Amy E. Shyer^{2*}, Patricia Florescu¹, Haiyi Liang^{1†}, L. Mahadevan^{1,3,4,5,6,7}
& Clifford J. Tabin²

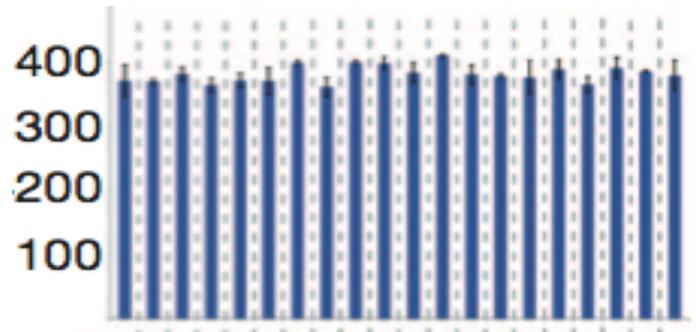


Mesentery removed *in vitro*

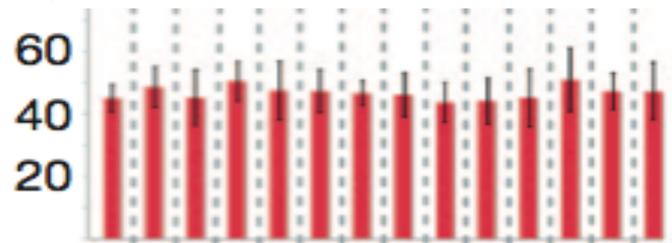


With mesentery Partial mesentery
removal *in ovo*

Without the mesentery, curving fails.

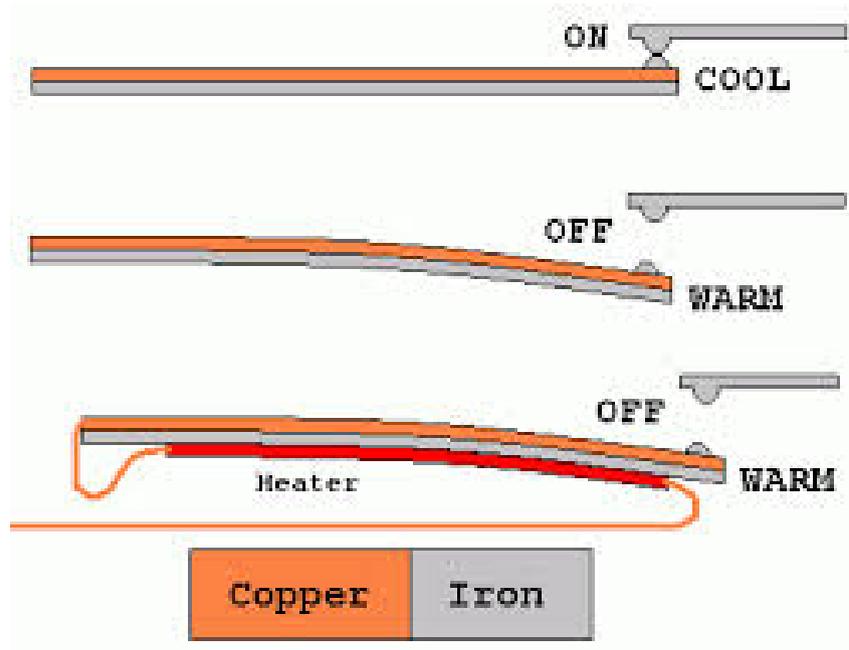


Proliferation in gut



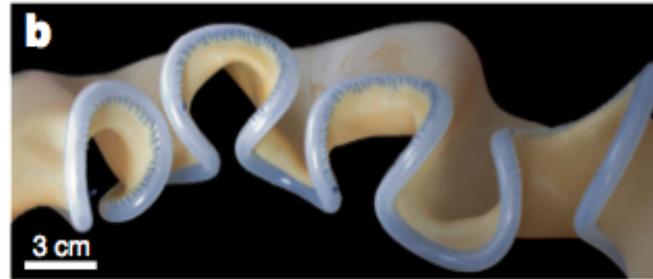
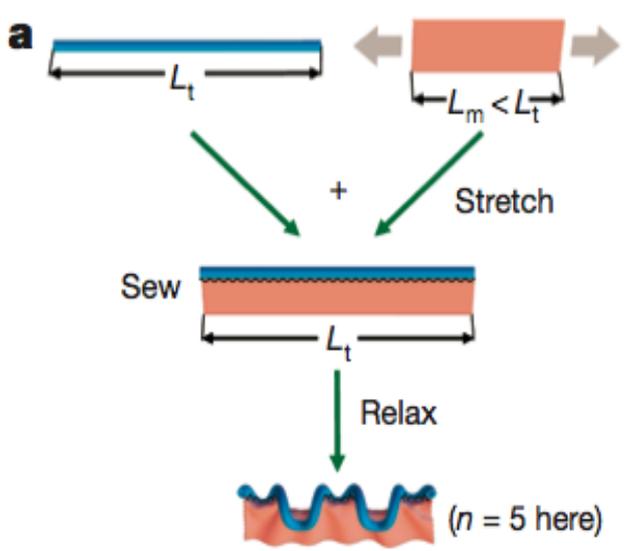
Proliferation in mesentery

Idea: does the gut loop because it tries to grow faster than the mesentery will let it?

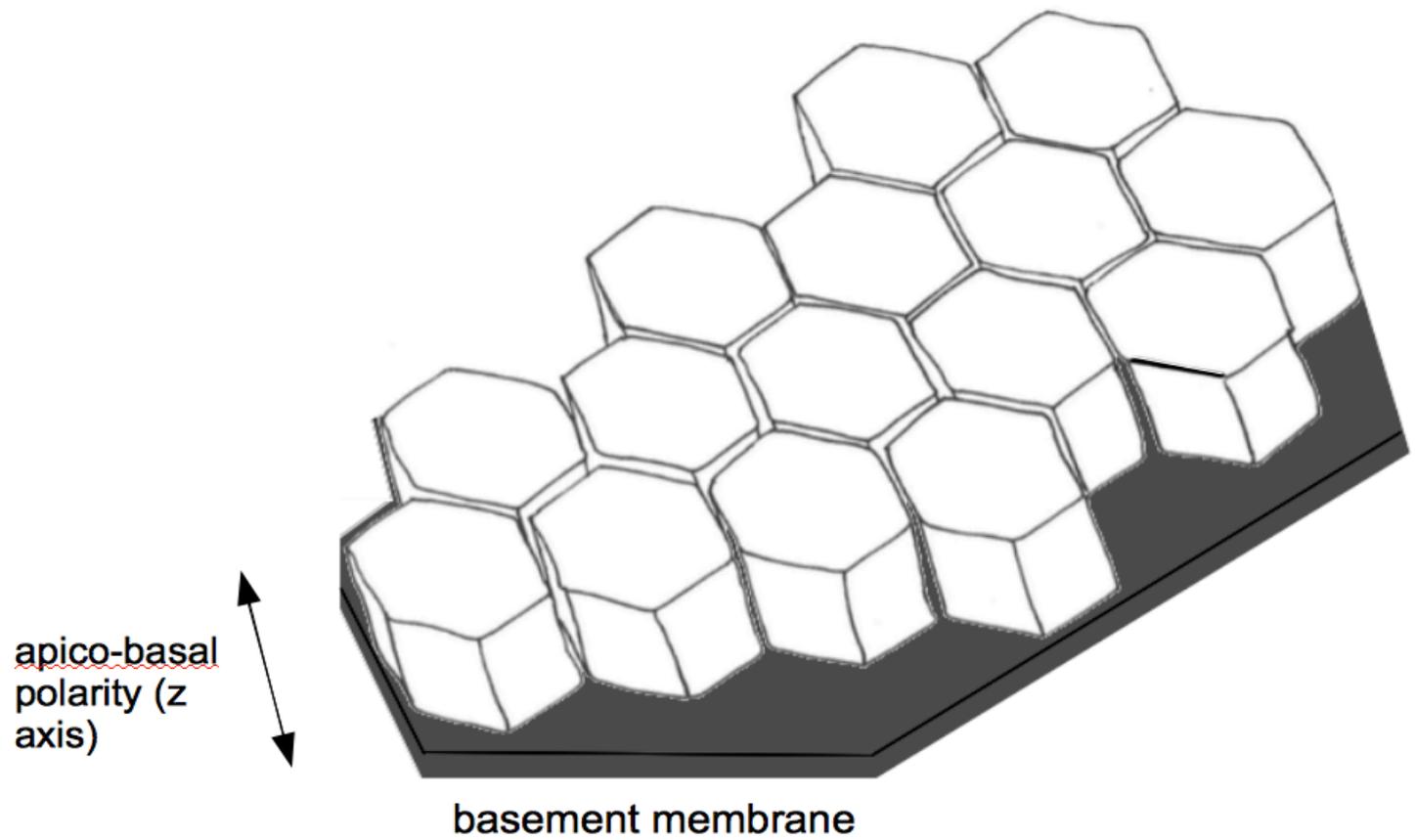


tube

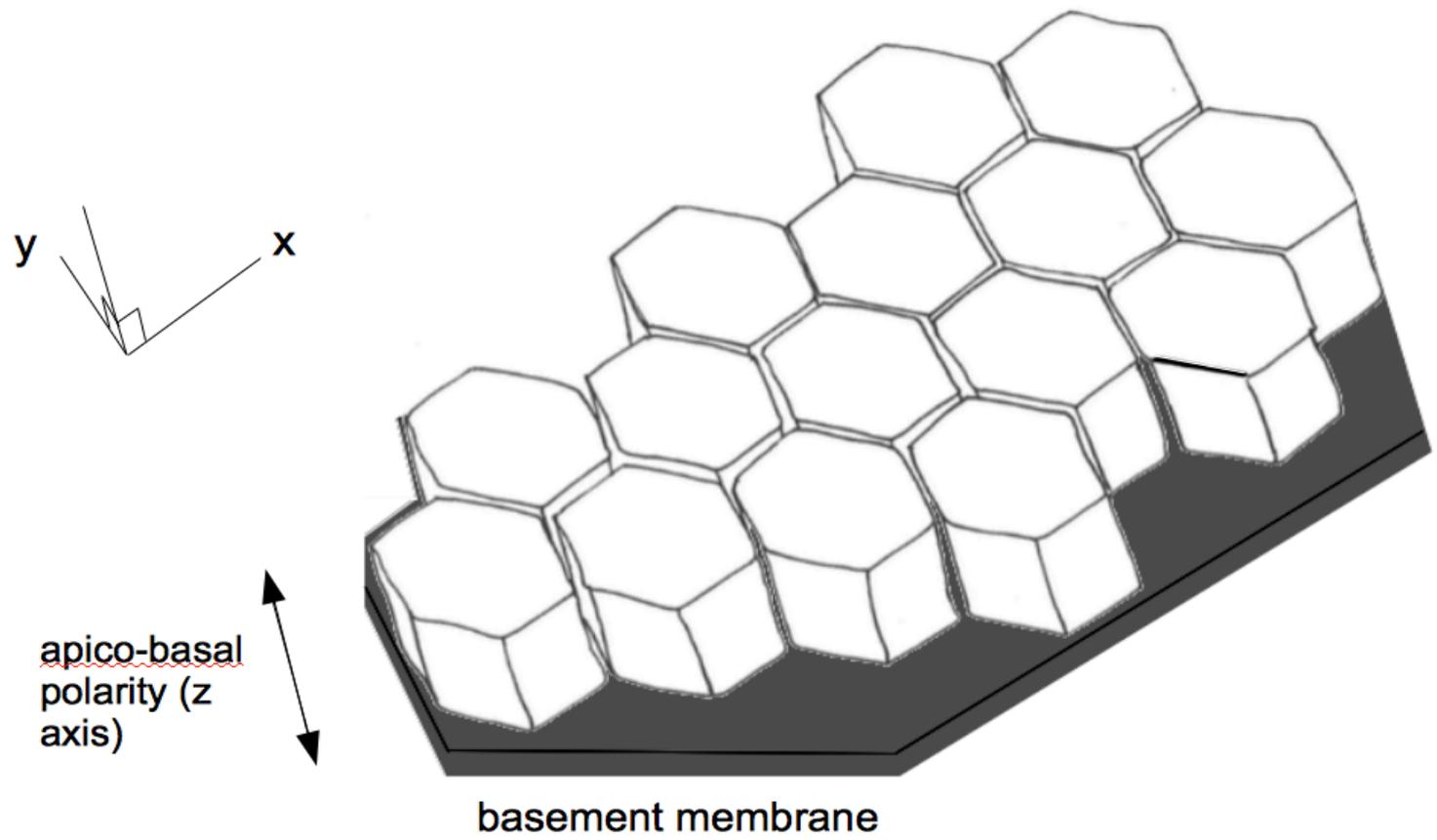
rubber



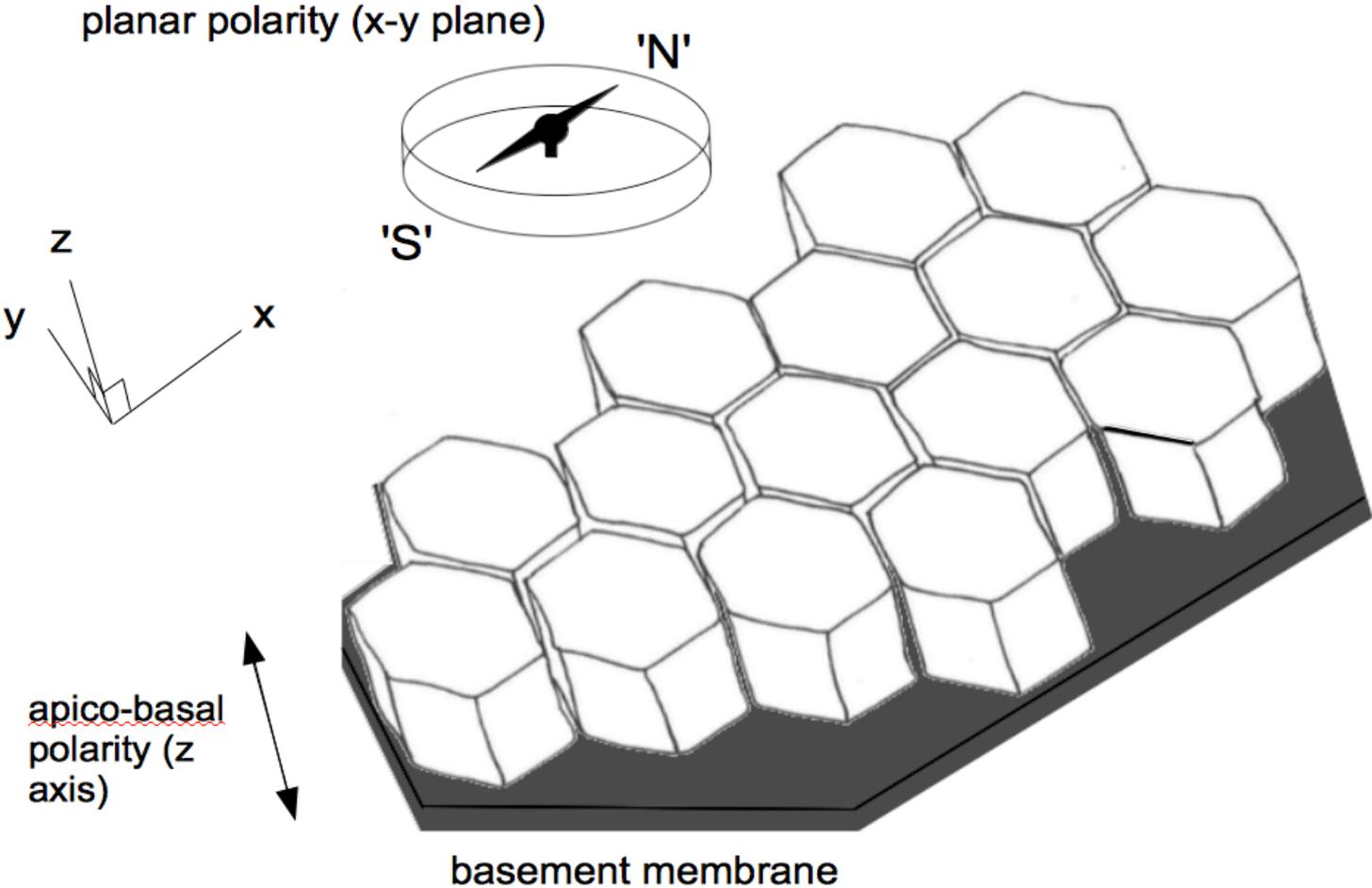
Planar cell polarity on cell sheets

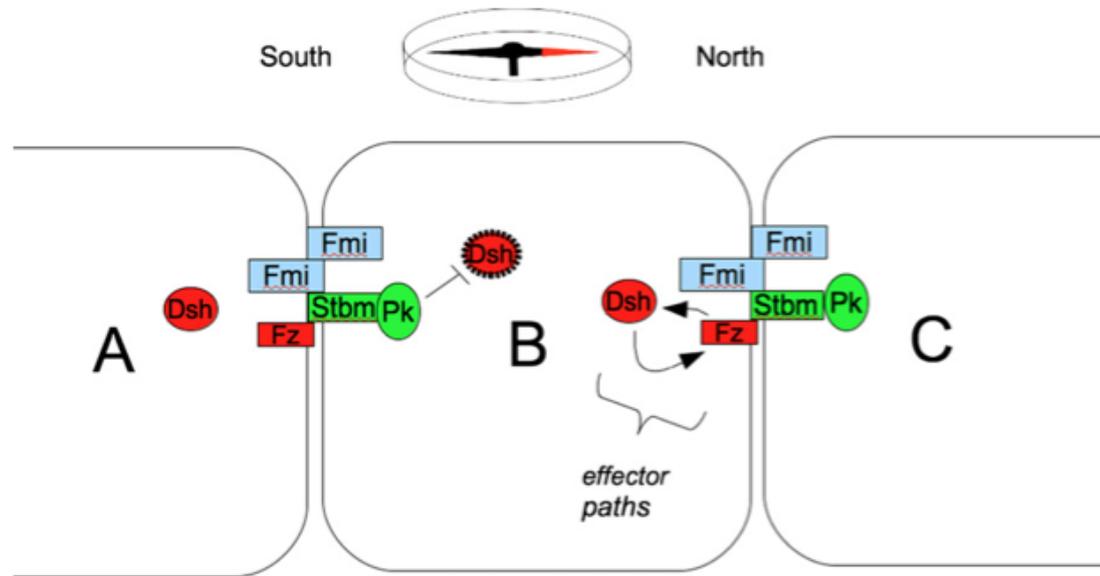


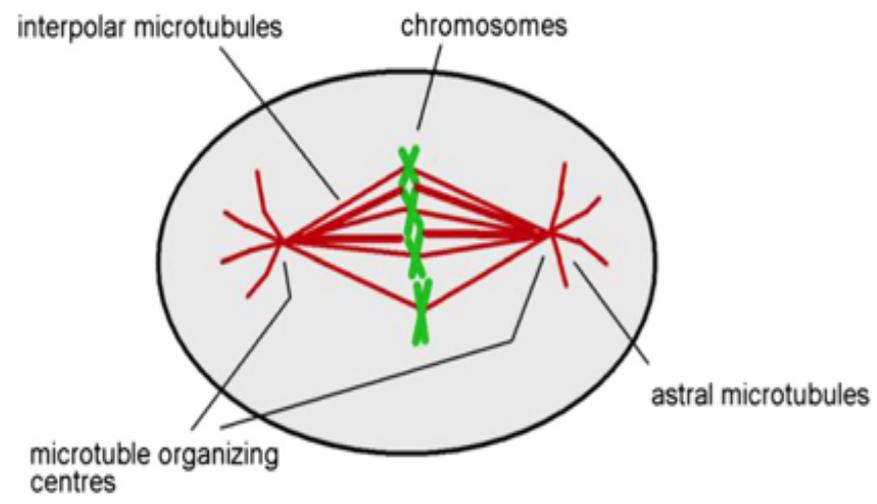
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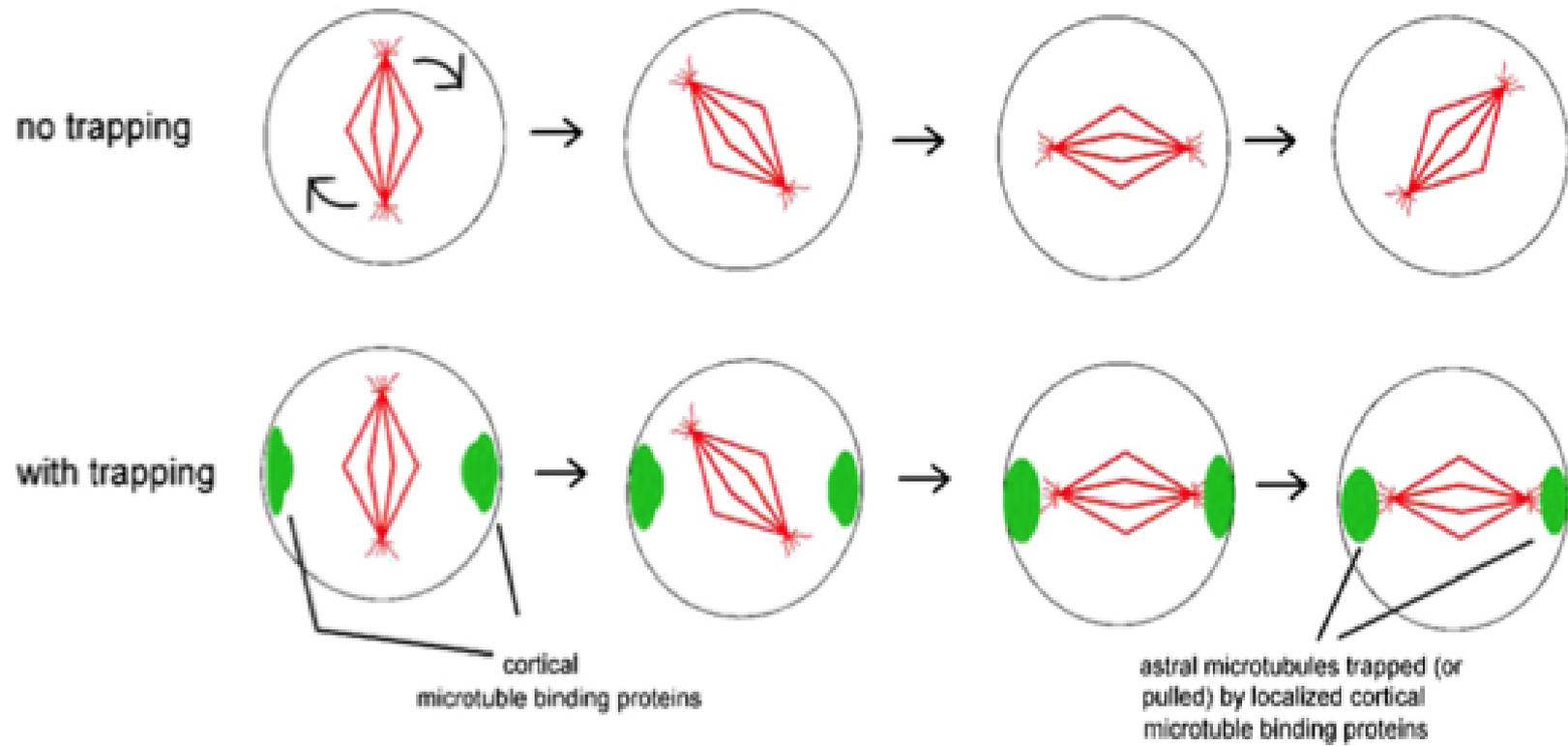


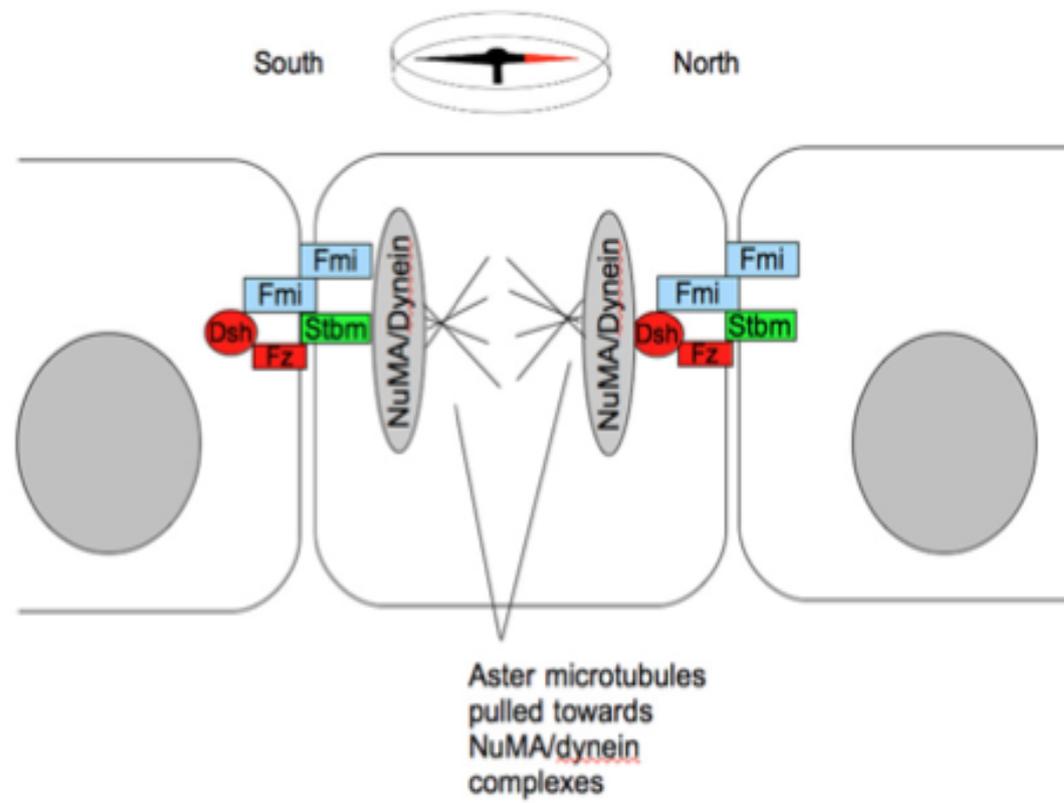
Planar cell polarity on cell sheets

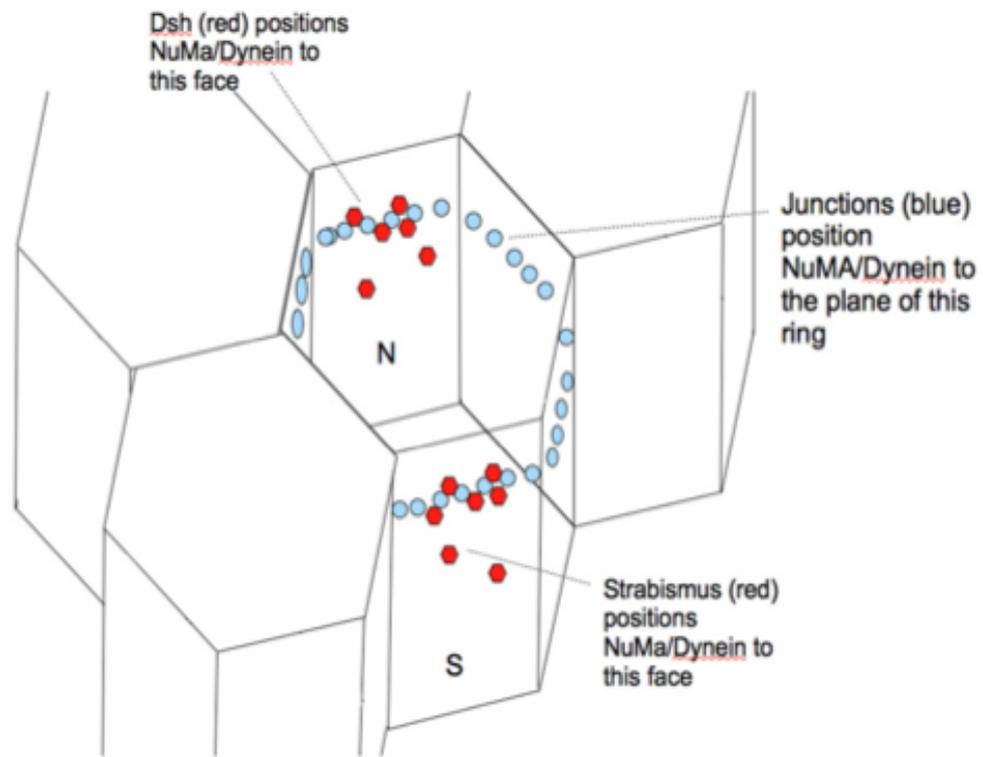




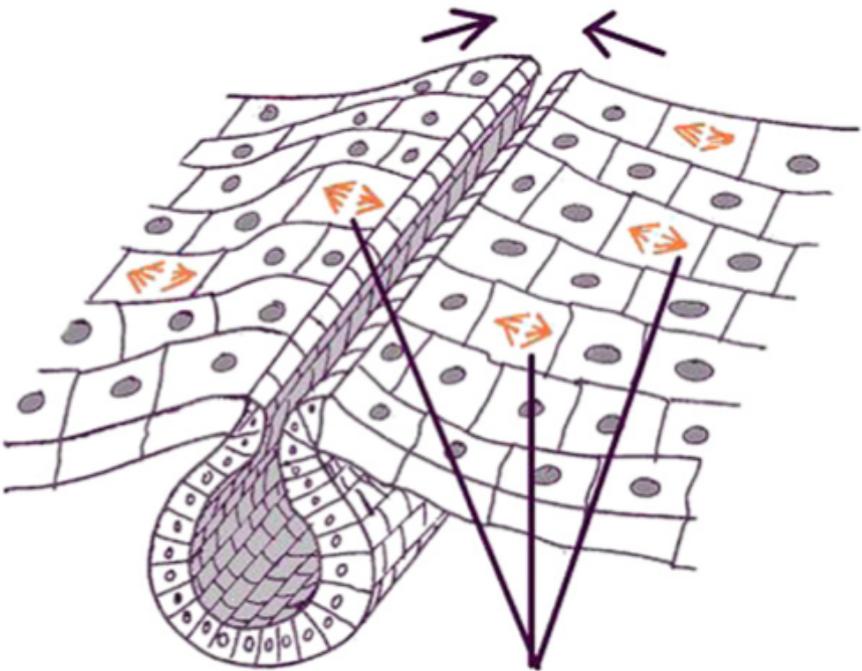








lips of forming neural tube pushed together



oriented mitoses

MEDICAL IMAGE WARNING

The sealing up of the edges of the tube, and its separation from the ectoderm, sometimes fails (e.g. spina bifida and anencephaly).

The sealing up of the edges of the tube, and its separation from the ectoderm, sometimes fails:

Next time: body-scale growth control.