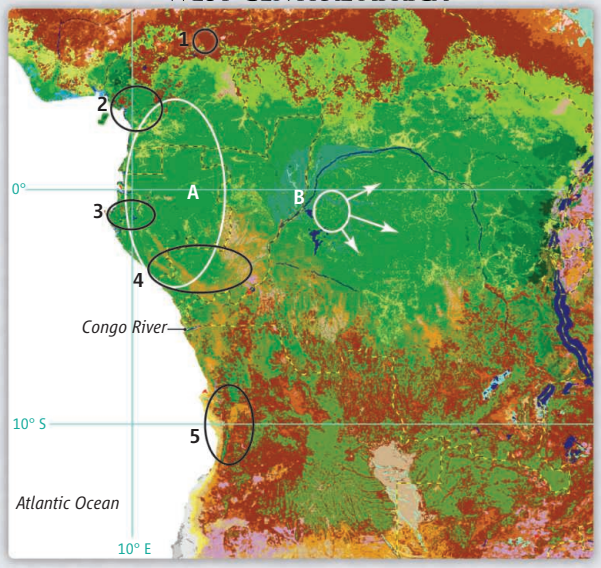


1 ~3000 years ago: submontane semideciduous forest changes to savannah
2 2500 to 2700 years ago: disturbed rainforest, pioneer trees, patches of savannah
3 2500 to 2400 years ago: mature rainforest replaced by secondary forest
4 3000 to 2500 years ago: grasslands extend at swampy and forested sites
5 3700 to 2000 years ago: two-step decrease of forest, extension of savannah

A time of change. Pottery styles from late Neolithic and iron-age cultures nearer the coast (area A) may have been a precursor of the earliest pottery, dated 2500 to 2100 years ago, found in the inner Congo Basin (area B) (*3*). Results reported by Bayon *et al*. suggest that this expansion of agriculturists may have been partly responsible for extensive changes in the rainforest between ~3700 and 2500 years ago (numbers 1 to 5) (*5*–*7*). Satellite-derived vegetation map of Central Africa from (*12*). Forest in green, forest-savannah mosaic in light green, woodland in brown, grassland in yellow, agriculture in pink.

with other proxies for continental temperature and precipitation.

Second, they measured hafnium (Hf) and neodymium (Nd) isotopes. Both the Nd and the Hf isotopic composition of rocks are determined by magmatic processes in the upper continental crust and depend on the rock source, but Hf isotopes are additionally changed by weathering of silicates. By comparing the isotopic composition of these trace elements in marine sediments, changes in silicate weathering can be deduced. Bayon *et al*. find that the Hf isotopic composition was relatively low during the Last Glacial Maximum (~20,000 years ago) and increased during deglaciation, whereas the Nd isotopic composition remained constant.

The results from both weathering proxies can be explained by changing climate, except for the period between 3000 and 2000 years ago. During the African rainforest crisis of the first millennium B.C.E., both proxies show that weathering increased despite reduced precipitation and constant temperatures.

Hence, although climate played a role in the rainforest crisis, it cannot have been the only factor. The explanation may lie with human activities, which may have had a strong impact on the forest through slash-and-burn agriculture and/or cutting trees for iron smelting (*1*). If so, then the next task will be to differentiate the relative impacts of human land-use effects and climatic influences.

The results of Bayon *et al*. also caution against using the tropical forest development of past millennia as a direct indicator of the West African monsoon. The climatic interpretation of the rainforest crisis invokes a shift in the yearly migration pattern of the Intertropical Convergence Zone to explain aridity and seasonality in West Central Africa (*5*–*7*). However, if only part of the forest change is climatically induced, any inferences using this forest decline will overestimate the aridification and increased seasonality of the past 3000 years.

References

1. G. Bayon *et al*., *Science* **335**, 1219 (2012); 10.1126/science.1215400.
2. K. Bostoen, *J. Afr. Hist.* **48**, 173 (2007).
3. H.-P. Wotzka, *Studien zur Archäologie des Zentralafrikanischen Regenwaldes, Africa Praehistorica 6* (Heinrich-Barth-Institut, Cologne, Germany, 1995).
4. C. Assi-Kaudjhis *et al*., *Geo-Eco-Trop* **34**, 1 (2010).
5. A. Vincens, G. Buchet, M. Servant, ECOFIT Mbalang Collaborators, *Clim. Past* **6**, 281 (2010).
6. A. Vincens *et al*., *J. Biogeogr.* **26**, 879 (1999).
7. A. Ngomanda *et al*., *Quat. Res.* **71**, 307 (2009).
8. A.-M. Lézine, *Quat. Res.* **32**, 317 (1989).
9. P. Hoelzmann *et al*., in *Past Climate Variability Through Europe and Africa*, R. W. Battarbee *et al*., Eds. (Springer, Dordrecht, Netherlands, 2004), pp. 219–256.
10. J. Lebamba, A. Vincens, J. Maley, *Clim. Past* **8**, 59 (2012).
11. J. W. H. Weijers *et al*., *Science* **315**, 1701 (2007).
12. A Land Cover Map of Africa. European Commission, Joint Research Centre, 2003. See http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php.

10.1126/science.1219903

Downloaded from www.sciencemag.org on April 4, 2012

CELL BIOLOGY

Embryonic Clutch Control

A molecular clutch couples actin-based contractions to changes in cell shape that drive morphogenesis.

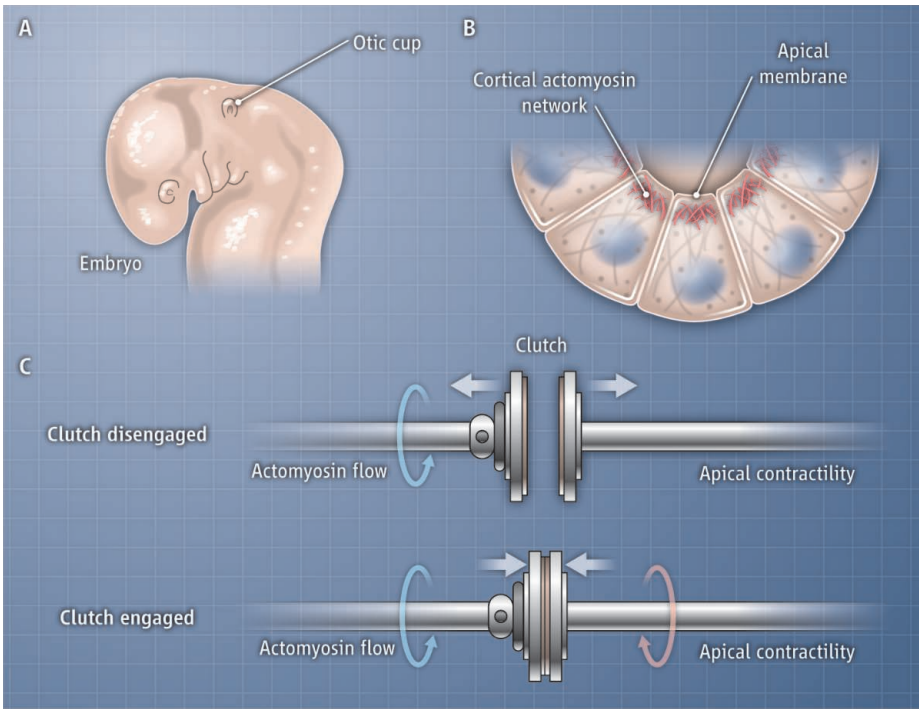
William Razzell[1] and Paul Martin[1,2]

All embryos, from worms to humans, are shaped during development by morphogenetic steps that tug, bend, fold, and sculpt epithelial sheets into forms that resemble, or are the precursors of, the final adult structure (*1*). Most of these changes are the consequence of constrictions of the apical surfaces of epithelial cells that are powered by pulsatile contracting cytoskeletal (actomyosin) networks. On page 1232 of this issue, Roh-Johnson *et al*. (*2*) show that, just as in a car where the power of the engine is linked to forward movement by means of a clutch, clutch control is also the rate-limiting step for contracting cells in tissues.

One of the best-studied examples of apical constriction driving morphogenetic episodes is gastrulation in the fly *Drosophila melanogaster*, in which a strip of approximately 1200 epithelial cells buckles inward and invaginates to internalize the presumptive mesoderm of the embryo (*3*). Variations of this process drive gastrulation in all organisms, as well as other morphogenetic events such as neural tube formation in vertebrates (*4*), which gives rise to the brain and spinal cord, and to formation of the optic and otic vesicles, which develop into the human eye and inner ear, respectively (see the figure). Concerted apical constrictions of cells are generated by the assembly and contractility of actomyosin networks composed of myosin II molecules that tug on actin filaments (*5*). These networks are linked to the plasma membrane by adherens junctions, protein complexes that also weld one cell to its neighbor (*6*). Live imag-

[1]School of Biochemistry, Faculty of Medical and Veterinary Sciences, University of Bristol, Bristol BS8 1TD, UK. [2]School of Physiology and Pharmacology, Faculty of Medical and Veterinary Sciences, University of Bristol, Bristol BS8 1TD, UK. E-mail: william.razzell@bristol.ac.uk; paul.martin@bristol.ac.uk

Published by AAAS



Cell apical constrictions during embryonic morphogenesis. (**A**) Concerted apical constrictions in epithelial sheets drive invaginations to form structures such as the otic cup from which the human inner ear derives. (**B**) Constricting cells become wedge-like to drive many morphological movements. (**C**) As in a car, the engine (actomyosin flow) during gastrulation can run without output. Only when the clutch is engaged and the motor is directly linked to the effector (apical plasma membrane) can there be movement of the apical membrane.

ing of the fly embryo has revealed the pulsatile and ratchet-like nature of cell contractions during gastrulation and other morphogenetic processes, with periods of shrinkage and resting before another round of contraction (*5*, *7*). This contractile machinery is exquisitely responsive to mechanical cues from neighboring cells and tissue; gentle probing with a needle can trigger actomyosin assembly and drive epithelial invagination (*8*); similarly, disrupting adherens junctions, which changes tissue tensions, can alter the polarity of apical constrictions (*9*). The presumption has been that the regulatory step for apical constrictions is determined by when and where cells assemble and contract their actomyosin networks.

Roh-Johnson *et al*. challenge and extend this idea through a series of elegant studies in the worm *Caenorhabitis elegans*. In this model organism, two neighboring endodermal precursor cells (Ea and Ep) constrict their apical surfaces and ingress beneath the surface during gastrulation. The authors followed actomyosin network dynamics in these cells by tracking fluorescently tagged myosin II and, concomitantly, measured changes in the shape of the apical membrane. They observed that myosin moves centripetally toward the center of the cell at a constant pace, whereas the apical cell surface initially shrinks slowly, or not at all. At early stages, actomyosin flow (the engine) runs for several minutes before any cell constriction actually happens. Only later does myosin movement occur in unison with the movement of "contact zones" (adherens junctions). After a transitional period of "slippage," the flow of actomyosin is only later efficiently coupled to constriction of the apical cell surface. The authors observed very similar mechanisms operating during *Drosophila* gastrulation, and it might now be feasible to live image and observe whether the same is true for vertebrate embryos, too (*10*).

What explains the initial lack of linkage between actomyosin flow and cell shrinkage? Roh-Johnson *et al*. suggest that a "molecular clutch" engages the myosin II engine with the apical membrane so that actomyosin contractility can drive shrinkage of the apical cell surface. Because cortical tension generated within the apical actomyosin network increased only a little after clutch engagement, constriction of the apical plasma membrane must reflect a change in efficiency of the link between actomyosin and contact zones.

Clutch control of myosin flow is not an entirely novel concept. In the migrating neural growth cone, the actomyosin engine is continually running, but only when positive guidance cues are received does a region of lamellae engage the clutch and extend forward (*11*). What are the benefits to having a clutch during morphogenesis? It may be easier to synchronize the start of a morphogenic event if the engines of all the participating cells are already running and clutch engagement is the rate-limiting step. Indeed, Roh-Johnson *et al*. observed that cells "rev" their actomyosin engines at least once or twice before the first sign of cell contraction is seen. It might also be easier to subtly respond to local cues (for example, the faltering contraction by a neighboring cell) by slightly altering the degree of engagement of the clutch—as one might when starting a car on hills of different inclines—than by crudely switching the engine on or off.

What is the molecular basis of this clutch and how is it regulated? Roh-Johnson *et al*. show that disruption of the small GTP-binding protein Rac, or of various components of adherens junctions (cadherin and the catenins), disengages actomyosin flow from cell contractions in the worm embryo. Further clues may come from observing the altered linkage between actomyosin contractions and the generation of tissue tension in fly embryos that harbor mutations in either of two key transcription factors, snail and twist (*9*). Or, possibly clutch machinery is regulated by a factor called folded gastrulation, a diffusible signal that synchronizes cell constrictions during fly gastrulation (*12*). Perhaps the ezrin-radixin-moesin family of proteins, which both transduces signals in the cell as well as links actomyosin with the plasma membrane (*13*), is a potential candidate for clutch proteins. We can now shift attention slightly away from the engine and unravel how the clutch works although, as those who drive manual transmission cars can attest, clutches are not always the easiest of gadgets to get to grips with.

References

1. J. M. Sawyer *et al*., *Dev. Biol.* **341**, 5 (2010).
2. M. Roh-Johnson *et al*., *Science* **335**, 1232 (2012); 10.1126/science.1217869.
3. M. Leptin, *Dev. Cell* **8**, 305 (2005).
4. S. L. Haigo, J. D. Hildebrand, R. M. Harland, J. B. Wallingford, *Curr. Biol.* **13**, 2125 (2003).
5. A. C. Martin, M. Kaschube, E. F. Wieschaus, *Nature* **457**, 495 (2009).
6. V. Koelsch *et al*, *Science* **315**, 384 (2007).
7. J. Solon, A. Kaya-Copur, J. Colombelli, D. Brunner, *Cell* **137**, 1331 (2009).
8. P.-A. Pouille, P. Ahmadi, A.-C. Brunet, E. Farge, *Sci. Signal.* **2**, ra16 (2009).
9. A. C. Martin, M. Gelbart, R. Fernandez-Gonzalez, M. Kaschube, E. F. Wieschaus, *J. Cell Biol.* **188**, 735 (2010).
10. Y. Yamaguchi *et al*., *J. Cell Biol.* **195**, 1047 (2011).
11. L. Bard *et al*., *J. Neurosci.* **28**, 5879 (2008).
12. R. E. Dawes-Hoang *et al*, *Development* **132**, 4165 (2005).
13. A. L. Neisch, R. G. Fehon, *Curr. Opin. Cell Biol.* **23**, 377 (2011).

10.1126/science.1220388

CREDIT: C. BICKEL/*SCIENCE*

Downloaded from www.sciencemag.org on April 4, 2012

Published by AAAS