Reversible processes make the thermodynamicist’s life simpler, but the experiments can require a lot of waiting. In 1997, Jarzynski derived a remarkable equality that relates the work done in irreversible processes to the equilibrium, or reversible, free energy difference of the system, no matter how far from equilibrium the irreversible paths might go. The catch, however, is that the more irreversible the paths measured, the larger the number of trials that must be performed to achieve a reasonable standard deviation. Lipphardt et al. (p. 1832; see the Perspective by Egolf) now report an experimental verification of Jarzynski’s equality, based on hundreds of stretches of a single molecule of RNA between its folded and unfolded conformations.

Closing the Loop in Neuroprosthetic Control

Neuroscientists have tried to control the movement of prosthetic arms or hands by signals from motor cortex neurons. These studies have largely been open-loop, in that subjects could not see the movement that was commanded by their cortex. Taylor et al. (p. 1829; see the Perspective by König and Vershure) developed a closed-loop paradigm in which subjects have visual feedback of their brain-controlled movements and found that movement tasks could be performed with much higher accuracy. The pool of motor neurons from which recordings were made also retained their directional selectivity during training. This finding enables brain-controlled virtual movements with nearly the same accuracy, robustness, and speed as normal arm movements.

Colloidal Control of Fluid Flow

In microfluidic systems a number of tools have evolved to control the flow and mixing of the fluid streams. Most of these, however, depend on some intrinsic property of the fluids and surfaces, such as electrokinetic pumping, or combinations of hydrophilic and hydrophobic surfaces. Terray et al. (p. 1841; see the Perspective by Burns) add a generic set of tools to the toolbox, by showing that colloidal particles can be used to create pumps and valves with dimensions of just a few micrometers. The pumps are controlled by an optical trap, which cycles through a preprogrammed pattern to control each colloidal particle that makes up the pump. The valves can be either passive or actively controlled with optical trapping.

Off in a Shot

Scanning probe methods should make it possible to map out the full series of steps that occur during the desorption of molecules from surfaces. However, desorption often occurs at temperatures where molecular diffusion is rapid, especially when recombination of species precedes desorption, and these diffusion events obscure the picture. Dürr et al. (p. 1838) used a single-shot laser pulse to locally heat hydrogen molecules on a Si(001) surface to accelerate desorption but not diffusion of nearby sites. During conventional heating of this system, the pair of hydrogen atoms that escaped came from the same dimer, and the two dangling silicon orbitals formed a π-like bond. However, after the laser-pulse experiment, the dangling bonds were paired on adjacent dimers. Desorption may be occurring through an interdimer reaction, which would now agree with known mechanisms for the adsorption process.

And in Brevia ...

An analysis of molecular data by Paxinos et al. (p. 1827) indicates that the nene, or Hawaiian goose, lost much of its genetic diversity during the expansion of the Polynesian population on the islands.

Getting a Grip on Stem Cells

A stem cell’s microenvironment, or niche, is important, both for localizing the stem cell as well as for providing cues for replenishing the stem cell supply or directing the cell down a specific developmental pathway. Song et al. (p. 1855) examined how germline stem cells in the Drosophila ovary are maintained in their niche. E-cadherin-mediated cell adhesion is involved in recruiting the germline stem cells to the niche and anchoring them to the neighboring cap cells, thus keeping the germline cells from differentiation. Similar adhesion mechanism may exist in other stem cell microenvironments.

Big Bad Flood Basalts

The Siberian Traps flood basalt province in Russia occurred near the Permian-Triassic boundary, and this volcanism, which would have released gases such as sulfuric acid and carbon dioxide, could account for the major extinctions during this period. Reichow et al. (p. 1846; see the Perspective by Renne) determined the age and chemistry of borehole samples of basalts from the western Siberian Basin and found that the western basalts correlate with the Siberian Traps flood basalt province to the east. This new correlation doubles the extent and thus the potential environmental impact of the Siberian flood basalts.

From Sulfide to Ore

Economically valuable concentrations of copper (Cu) and gold (Au) ore deposits are produced by hydrothermal alteration of intermediate to acidic, silica-rich igneous rocks. Halter et al. (p. 1844) used highly sensitive mass spectrometry to measure the concentrations of Cu and Au in primary melt inclusions in minerals from the Bajo de la Alumbrera Mine in Argentina. These results indicate that the metals were initially concentrated in a sulfide melt and then released and concentrated in the ore deposits by secondary hydrothermal alteration.

Can’t Leaf Without Them

The shape of plant leaves has been of value in considering the evolutionary relationships between plants. Simple and complex
leaves, without and with lobes and divisions, are found through multiple plant taxa. Bharathan et al. (p. 1858; see the cover) have analyzed the expression of KNOXI homeobox genes in the shoot apical meristems from plants of a variety of taxa. The pattern of KNOXI expression is different in meristems that will give rise to primary simple and complex leaves. KNOXI expression patterns also reveal that some seemingly simple leaves are secondary evolutionary refinements of previously complex leaves.

Assessing CNS Axon Regeneration

Neurons of the central nervous system (CNS) are much less able to repair themselves after damage than are neurons of the peripheral nervous system. The causes might lie with the differences in environment and type of surrounding glia, or with the neurons themselves. Goldberg et al. (p. 1860; see the Perspective by McKerracher and Ellezam) have isolated retinal ganglion cells (RGCs), which form part of the CNS, from the rat to study their ability to regenerate axons. RGCs isolated from embryonic rats showed a much greater capability for axon regeneration than did RGCs from early postnatal rats. The diminishing capacity for axonal regeneration correlated with developmental times at which the RGC axons would normally have reached their targets and switched from axonal growth to dendrite elaboration. The switch in growth mode was not related to intrinsic cell age but, rather, arose from signals from neighboring retinal cells.

Animated Immunity

Our current understanding of the complex cellular interactions required for immune responses has come largely from in vitro manipulation or from snapshots of events within fixed tissues. Three reports now describe real-time analysis of immune cell responses within living tissues (see the Perspective by von Andrian). Using two-photon technology to compare migration of T and B cells within organized lymphoid tissue, Miller et al. (p. 1869; X) observed that T cells roam considerably further and at faster rates than B cells. This explorative behavior shifted toward focused clustering upon inclusion of antigen. Stoll et al. (p. 1873) used modified single-photon confocal imaging to investigate interactions of naïve T cells with antigen on dendritic cell (DC) in lymph nodes. Extended periods of connection, with the formation of immune synapses and eventual departure of activated T cells, were observed in the presence of antigen-loaded DCs. Bousso et al. (p. 1876) used two-photon imaging to study thymocyte interactions with thymic stromal cells in a reaggregated thymic organ culture. Recognition events that resulted in positive selection of thymocytes promoted thymocyte motility and increased the duration of thymocyte–thymic stromal cell contacts.

Form But No Function

Lymphatic vessels have been detected within tumors by immunostaining, but the role of these structures in tumor cell metastasis has been debated. Applying rigorous functional assays to a mouse model of metastasis, Padera et al. (p. 1883; see the Perspective by Gershenwald and Fidler) show that although the central regions of the tumors stain with molecular markers for the lymphatic system, the vessels there are nonfunctional. Metastasis appears to occur solely through lymphatic vessels at the tumor margin, a distinction that may have important implications for cancer therapy.

Oxygen in the Cell

The cellular response to oxygen—or the lack of it—is important in diseases such as cancer, cardiovascular disease, and stroke. Min et al. (p. 1886) have gained insight into an interaction that is key to this response by determining the structure at 1.85 angstroms resolution of a 20-residue peptide from the hypoxia-inducible transcription factor (HIF) bound to a von Hippel–Lindau tumor suppressor (pVHL)–ElonginB–ElonginC complex. The structure shows that hydroxyproline plays a central role in the specificity and affinity of the interaction and binds at a site in pVHL that is a hotspot for tumorigenic mutations. The structure could provide a basis for designing drugs that could help treat cardiovascular disease and stroke.