control are mediated by their impact on prefrontal–striatal circuitry. Indeed, preclinical studies have started to clarify the molecular mechanisms that modulate prefrontal–striatal communication during risky decision-making (1/7). For example, in the prefrontal cortex of rodents, dopamine D1 receptor signaling mediates working memory in a nonlinear fashion such that performance is degraded not only during insufficient (aging) but also during excessive (acute stress) transmission. Similarly, in the striatum, dopamine D2 receptor signaling relates to performance through an inverted U-shape function, because both suboptimal as well as supraoptimal dopamine signaling can lead to maladaptive excessive or deficient risk-taking, respectively.

The finding by Ersche et al. that decreased connectivity in the right inferior frontal lobe is linked to poor self-control has clinical implications, for it provides a potential biomarker that can be targeted for interventions to strengthen it. Indeed, several childhood and adolescent interventions can improve executive function and self-control, although studies have not yet assessed whether they strengthen fronto-striatal connectivity. In more general terms, a deeper, endophenotype-based understanding of personality traits that can promote resiliency and their degree of malleability may help prevent adverse trajectories such as those leading to substance use disorder or other conditions with underlying deficits in self-control.

References

10.1126/science.1218170

CLIMATE CHANGE
Marching in Near Lock-Step
Donald T. Rodbell

Over the past ~100,000 years, intervals of gradual climate cooling have repeatedly been followed by abrupt warming events. Collectively known as Dansgaard/Oeschger (D/O) cycles (1), these ~1500-year-long cycles are recorded in the oxygen isotope record of Greenland ice cores and in layers of iceberg-rafted sediments in the North Atlantic Ocean known as Heinrich layers (2) that record collapses of the Northern Hemisphere ice sheets. On page 570 of this issue, Kanner et al. (3) report a stunning new archive of the oxygen isotopic composition of tropical precipitation recorded in the deposits of Pacupahuain Cave (see the figure, panel A), located high on the eastern side of the Peruvian Andes, that matches the North Atlantic/Greenland records in striking detail. The results help to elucidate how climate change—both past and future—in one region of the globe may drive climate changes in far-flung regions.

The North Atlantic/Greenland record is based on ice and sediment cores that are tens to hundreds of meters in length, far longer than the 15-cm-long Peruvian speleothem studied by Kanner et al. (see the figure, panel B). But the diminutive Peruvian speleothem satisfies a critical prerequisite for close climate comparisons: precise radiometric age control. The calcium carbonate in caves is ideally suited to the uranium-thorium dating method, often yielding a higher age precision than any other dating method applicable to the time window in question; typical age uncertainties are less than ±1%. Indeed, this precision exceeds that of the proxy climate records from the North Atlantic/Greenland region that contain D/O cycles and Heinrich layers. Kanner et al. therefore suggest that their Peruvian archive can be used to improve the dating of the very records to which they are comparing.

Cave records from Northern Hemisphere sites have shown clearly that the climate patterns seen in the North Atlantic/Greenland records were followed at sites as far away as east central China and the northwestern Indian Ocean (4, 5). At these sites, the abrupt warmings that mark the end of D/O cycles are recorded as abrupt negative departures in oxygen isotope values—the opposite direction of the changes seen in the Greenland ice cores. Southern Hemisphere cave records show a somewhat more muted Northern Hemisphere influence, but the oxygen isotopic composition of cave calcite generally tracks in the same direction as the Greenland ice cores.

The key to understanding these differences lies in the climatic implications of isotopic shifts in precipitation. At high latitudes, the primary driver of the isotopic composition of precipitation is the temperature of condensation (6), with colder temperatures resulting in lower $^{18}O/^{16}O$ ratios in precipitation. At low latitudes, where atmospheric convection dominates, the main control on the isotopic composition of precipitation is the amount of precipitation, with greater convection driving increased precipitation and lower $^{18}O/^{16}O$ ratios, and vice versa.

Thus, warm events in the Greenland region correspond with wet events in the low latitudes of the Northern Hemisphere but dry events in the low latitudes of the Southern Hemisphere. The Pacupahuain Cave record shows this with greater fidelity than any other tropical Southern Hemisphere terrestrial record yet: It clearly shows 12 of the 13 major abrupt warming events that mark the end of D/O cycles between 16,000 and 50,000 years ago in Greenland as positive departures in the oxygen isotopic composition of cave calcite. Conversely, cooling of the North Atlantic Ocean during Heinrich events corresponds with increased precipitation over the Peruvian Andes and negative departures in the $^{18}O/^{16}O$ ratio of cave calcite. Several other climate proxy records have shown a close correspondence between the timing of Heinrich events and the advance of Peruvian glaciers (7) and expansion of Bolivian lakes (8), but until now no single tropical Southern Hemisphere record has recorded the complete sequence with such dating precision.

The interhemispheric precipitation seesaw evident in the network of cave records...
reflects changes in the vigor of the monsoons in response to variations in the position of the Intertropical Convergence Zone (ITCZ) over the oceans. The sea surface temperature gradient of the North Atlantic may affect the position of the ITCZ, thereby determining which hemisphere is to have a protracted interval of strong monsoons. A cold North Atlantic appears to cause a steep sea surface temperature gradient, a southward migration of the ITCZ, and an enhanced South American summer monsoon. Tropical cave records show that the monsoon seesaw has cycled dozens of times in the past ~50,000 years.

One of the curiosities of the precipitation seesaw is the degree to which it is controlled by temperature cycles in the North Atlantic/Greenland region, and the relatively minor role played by Antarctic temperature cycles. The latter preceed those in Greenland by 1500 to 3000 years (9). Kanner et al.’s precisely dated Pacupahuain Cave record may delineate the competing influence of the two poles. Over two intervals in which the influence of both poles can be seen in the record, the Northern Hemisphere appears to dominate. Speleothem records from caves at higher latitudes in the Southern Hemisphere could delineate the regions within which the influence of the South Pole is dominant. The large size of the region that has climatically marched in near lock-step with the North Atlantic illustrates the remarkable effectiveness with which atmospheric teleconnections can operate.

The universal thermodynamic functions of a superfluid formed from a fermion gas of strongly interacting lithium atoms have been measured precisely.

**References**


10.1126/science.1218365

---

**PHYSICS**

**Seeing the Superfluid Transition of a Gas**

**Wilhelm Zwerger**

An important characteristic of a superfluid is the critical temperature $T_c$, below which it forms from an ordinary fluid, but a more detailed understanding comes from measuring other thermodynamic and quantum-mechanical parameters. For systems in which the superfluid is created by pairing fermions (for example, the electron superfluid in superconductors), $T_c$ is often very low compared to another characteristic temperature of mobile fermions, their Fermi temperature $T_F$. Thus, superconductivity has not been observed at room temperature. On page 563 of this issue, Ku et al. (1) present precise measurements of thermodynamic quantities of an ultracold gas of lithium-6 atoms—fermions—with strong attractive interactions that explicitly show the superfluid transition through changes in the compressibility and the heat capacity. The absolute temperatures here are on the order of only 100 nK, but this Fermi gas provides an example of a high-temperature superfluid: No other system has ever been observed with a transition temperature as high as ~16% of $T_F$. Scalled to the density of electrons in metals, $T_F$ would occur far above room temperature.

In classical physics, no phase transitions occur within the gas phase itself. The situation is quite different in quantum physics. Indeed, Einstein showed in 1925 that even a gas of noninteracting particles can undergo a transition to a quite unusual gaseous phase, a Bose-Einstein condensate (BEC), provided that the particles obey Bose statistics (any number of particles can occupy the same quantum state). The realization of this transition with ultracold gases in the sub-microkelvin regime in 1995 opened up a new and still expanding field of atomic and molecular physics (2, 3).

Atoms that obey Fermi statistics (in which only one particle can occupy a quantum state), like lithium-6, undergo a transition to a condensate phase by forming composite particles that act like bosons. For this to happen, interactions are necessary. In the simplest case, a weak attraction arises between two fermions of opposite spin. As realized by Bardeen, Cooper, and Schrieffer (BCS) in 1957 (4), this attraction can be arbitrarily weak. The resulting $T_c$ is typically less than 1% of $T_F$. Stated differently, the pair size in this weak coupling limit is much larger than average interparticle spacing—by an order of $10^3$ in conventional superconductors. Within the volume occupied by a single pair, there are thus about a billion other ones.

The BCS theory of fermionic superfluids has proven to be widely applicable. Beyond conventional superconductors, it describes...