based vaccines should evaluate the amounts and distribution of both vector and insert responses in target tissues where HIV acquisition is known to occur.

Other research activities could be pursued to help clarify the roles of antivector responses in overall HIV vaccine efficacy. For example, nonhuman primate studies using empty vectors or vectors with non-HIV inserts as placebo controls could define the levels of antivector immunity and evaluate the effect on virus acquisition of this vector-related activation of $CD4^+$ T cells independent of an anti-HIV response. Also, the field could benefit from additional nonhuman primate studies. For example, the identification of biomarkers in primates that indicate increased risk of acquisition (*18*) could be valuable to monitor for risk in early-phase human studies.

A better understanding of mucosal immune responses to HIV vaccination is also needed. The timing, location, and number of mucosal biopsies that define the vaccine-induced gut immune responses need clarification. Understanding the influence of the mucosal microbiome on vaccination (*19*) and the impact specifically of the virome will be important. Particularly for Ad-based vectors, understanding components of risk related to the level of Ad exposure and persistence will be essential.

For non-HIV vaccine trials using vectors that induce strong T cell immunity that are conducted in regions with high HIV incidence, it may be important to monitor for HIV acquisition, depending on the target population. In such studies where the population may be at risk of HIV exposure, HIV incidence should be monitored at the end of the study and for an appropriate follow-up period.

The experience with rAd5-based HIV vaccines has shown that vaccine-induced protection likely reflects the balance between beneficial anti-HIV responses and deleterious effects of immune activation that increases the susceptibility of $CD4^+$ T cells to infection (see the figure). Among the spectrum of existing or planned vaccines, this phenomenon is likely unique for an HIV vaccine because the activated $CD4^+$ T cell is the very target for the virus. These observations should be taken into consideration in future HIV vaccine research endeavors and underscores the importance of maximizing the specific anti-HIV responses of such candidates.

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GEOPHYSICS

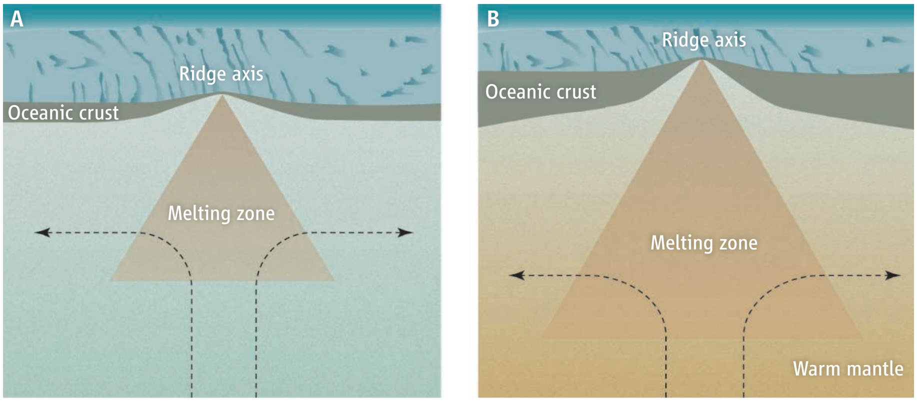
Inside Earth Runs Hot and Cold

Mid-ocean ridge volcanoes sample a mantle that varies in temperature and composition.

Katherine A. Kelley

The global mid-ocean ridge system is an interconnected network of volcanoes that produces the oceanic crust, which covers 70% of Earth's surface. The physical and chemical attributes of mid-ocean ridges, such as the depth of the volcanic ridge axis below the sea surface, the thickness of the oceanic crust created there, the composition of the erupted lava, and the way seismic waves interact with the mantle beneath the ridge, collectively reflect the properties of the mantle that melts to form the oceanic crust. On page 80 of this issue, Dalton *et al.* (*1*) explore relationships between global seismic wave velocities in the mantle beneath mid-ocean ridges and a global data set of ridge depth and lava chemistry (*2*). They find strong correlations between these three factors, ultimately linking the trends to a global mantle temperature variation of ~250°C.

Lavas erupted at mid-ocean ridges form as the mantle moves upward in response to tectonic plate movements at the surface. As the mantle ascends, it melts at a depth controlled partly by its temperature (*3*), such that hotter mantle will start melting deeper and produce more magma, ultimately leading to a shallower ridge axis and a thicker oceanic



Creating oceanic crust at mid-ocean ridges. As the mantle moves upward beneath mid-ocean ridges, it melts and creates a volcanic chain (ridge axis) that constructs the oceanic crust. (**A**) At cooler temperature, less melting takes place, the ridge axis is deep, and the oceanic crust is thin. (**B**) Higher temperatures enable more melting, creating a shallower axis and thicker crust.

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crust when compared with cooler mantle (see the figure). Hotter mantle also produces compositionally different lavas because it melts more, and seismic waves slow down when traversing hotter mantle. The seismic properties of the mantle beneath the ridge, the composition of the erupted lava, and the morphology of the ridge axis thus provide three independent sensors of mantle temperature. By compiling global-scale data sets, enabled through modern geoinformatics efforts (*4*, *5*), Dalton *et al*. show that the parameters of axial depth, lava composition, and seismic wave velocity covary globally, as expected from variations in mantle temperature.

Yet, temperature is not the only factor that controls the physical and chemical attributes of mid-ocean ridges. Other recent assessments of global-scale data sets have challenged a primary role for temperature variations (*6*). By taking different approaches to constraining axial depth and correcting lava compositions for the effects of crystallization within the crust, such studies argue that variations in mantle composition are the main control on axial depth and lava chemistry, with minor temperature variations (<50°C) (*6*).

By including the mantle seismic properties in their analysis, Dalton *et al*. suggest that temperature is indeed the primary factor. Higher mantle temperatures are expected to produce shallower ridge axes, lavas with lower sodium concentrations, and lower seismic wave speeds. How mantle composition relates to axial depth, lava composition, and seismic velocity, on the other hand, depends on how it is defined. For example, in (*6*) and (*1*), the mantle composition may vary globally as a function of how much it has melted previously, which influences its density and the composition and volume of magma it produces when melted but does not appreciably influence the speed of seismic waves that travel through it.

A key role, however, remains for mantle composition to determine the physical and chemical attributes of global mid-ocean ridges, because we know Earth's upper mantle is chemically heterogeneous. Compositionally distinct crustal materials from Earth's near-surface environment, such as marine sediments and oceanic crust, have been returned to the mantle through the subduction of tectonic plates at ocean trenches, enriching the mantle in elements such as volatiles (for example, H_2O and CO_2) that may influence mantle properties. The water content of the mantle affects the seismic velocities (*7*), as well as affecting the amount and composition of the crust produced by melting (*8*). A wetter mantle yields lower seismic velocities, thicker crust, and shallower ridge axes, similar to the effects of higher mantle temperature, but lava composition would define trends orthogonal to those found by Dalton *et al*. Similarly, trace quantities of carbon in the mantle could drive small amounts of melting at great depth beneath mid-ocean ridges (*9*), which may also influence seismic velocities and lava composition.

To what extent do water, carbon, and other compositional factors vary in Earth's mantle, and over what length scales? How are these variations expressed in the physical and chemical structure of modern mid-ocean ridges and the oceanic crust? Two potential paths forward involve global and local scale studies of the ridge system. Progress in constraining global-scale variations of H_2O and CO_2 in mid-ocean ridge lavas, and their mantle sources, lags behind our understanding of other elements. As global data sets and models of volatile element distribution develop, we may more fully resolve the competing effects of temperature and composition on global-scale geophysical and geochemical characteristics of spreading ridges. Smaller length scales of compositional heterogeneity in the mantle may also be poorly resolved by globally averaged data sets (*10*), requiring focused, local studies of the ridge system to access smaller-scale features.

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OCEANS

Not So Permanent El Niño

Paleoclimate data point to a warm tropical ocean with a clear east-west temperature gradient during the warm climates of the Pliocene and Miocene.

David W. Lea

Knowledge of the behavior of the tropical oceans under different climate conditions is important for understanding not only past climate change but also present and future global warming, especially given the recent finding that the cool state of the equatorial Pacific might be the cause of the current global warming hiatus (*1*). On page 84 of this issue, Zhang *et al*. evaluate the long-term evolution of tropical Pacific sea surface temperatures (SSTs) since 12 million years ago (*2*). They conclude that the equatorial Pacific was warmer during the Pliocene (5.3 to 2.6 million years ago) and late Miocene (12.0 to 5.3 million years ago) than it is today and that the temperature difference between the eastern and western tropical Pacific that is a fundamental characteristic of today's ocean was present (although somewhat smaller than it is today) during these warmer time intervals.

This view of the past tropical Pacific is strikingly different from the picture that has dominated paleoclimate thinking since 2005, when Wara *et al*. (*3*) argued that the tropical Pacific during the Pliocene was very different from that of today. In the present climate, the tropical Pacific is dominated by a distinct zonal gradient, with cool temperatures in the east and warm temperatures in the west (see the figure, panel A). Wara *et al*. reported Mg/Ca data showing that this gradient was nearly absent during the warmer climate of the Pliocene (see the figure, panel B). Because the equatorial zonal gradient slackens during El Niño events, the researchers called the Pliocene configuration a "permanent El Niño–like condition."

Since then, scientists have sought to understand the cause of the change, and in particular the observation that the Pliocene warm pool was no warmer than in preindustrial times, despite inferred higher atmospheric carbon dioxide concentrations in the Pliocene (*4*). Yet the warm pool is known

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