The Burning Issue

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trous consequences for the affected males. In many cases, they are born with raging autoimmune disease (*11*). Intriguingly, few if any of these patients carry a true null mutant (encoding a functionless form) of the *FOXP3* gene. The reason for this might be that the phenotype of such a mutant would be much more severe, resulting in the fetus not only developing autoimmunity, but also attacking the maternally derived portion of the placenta (the decidua). As a result, the affected fetus would cut off its own supply of nutrients and oxygen and thus might never see the light of day.

The data of Mold *et al*. suggest that hematopoiesis during fetal development occurs in waves, each generating distinct populations of T cells that may coexist for a period of time. T cells ($CD4^+$ subtype) originating from fetal liver HSPCs appear to have a propensity to adopt the fate of regulatory T cells ($Foxp3^+$), thereby biasing the fledgling immune system toward immune tolerance. As the source of hematopoiesis switches to the fetal bone marrow, the resulting effector T cell/regulatory T cell ratio gradually moves toward that found in adults. It will be interesting to examine whether the tendency of the early fetal immune system to promote tolerance is restricted to self antigens and noninherited maternal alloantigens, or whether it extends to foreign antigens encountered during development. The latter might have both beneficial and detrimental consequences on the immune system that reach far beyond pregnancy. Although the tendency toward tolerance might provide a window to educate the immune system not to respond to common allergens (*12*, *13*), it also provides an opportunity for exploitation by pathogens. Indeed, exposure of a fetus to malaria in utero, which leads to the accumulation of infected red blood cells in the placenta (placental malaria), results in the expansion of malaria-specific regulatory T cells. This might explain why children who have been infected as a result of placental malaria are more susceptible to subsequent malaria infections (*14*).

It remains to be resolved whether the fetal liver and adult HSPCs are distinct lineages, or whether the latter develops from the former (see the figure). A detailed analysis of the transcriptional profiles of these progenitor pools, in combination with an analysis of epigenetic modifications, should yield valuable information regarding their relationship.

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ATMOSPHERIC SCIENCE

The Burning Issue

Antarctic ice cores reveal a 650-year record of biomass burning in the Southern Hemisphere.

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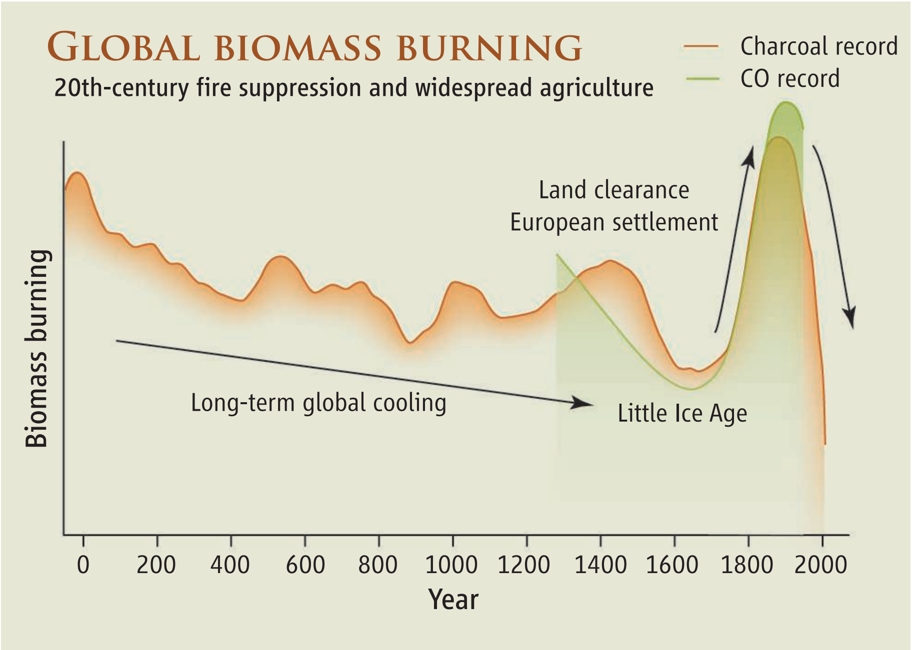
Fortunately for us, carbon monoxide (CO)—a toxic gas—is a very minor constituent of the atmosphere. It is produced by incomplete burning of fossil fuels and biomass (such as dry leaves and wood) and by the oxidation of methane and other volatile hydrocarbons in the atmosphere. On page 1663 of this issue, Wang *et al*. (*1*) present high-precision measurements, taken from air trapped in Antarctic ice, of how atmospheric concentrations of CO have changed over the past 650 years. Their findings offer a striking and surprising look at the history of fire in the Southern Hemisphere, and some hints at future global fire trends.

In addition to CO concentrations, Wang *et al*. present the first record of changes in two stable isotopes—carbon-13 (^{13}C) and oxygen-18 (^{18}O)—which they use to estimate how much of the CO came from burning biomass. This is a notable feat, consid-



Burning history. Hypothesized causes of major long-term trends in global biomass burning, based on a synthesis of sedimentary charcoal records (orange) (*4*) and analyses of carbon monoxide trapped in Antarctic ice (green) (*1*).

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Burning out. Studies of the recent history of fire, like this blaze in a California forest in 2009, suggest that total global biomass burning is now lower than at any time in the past 2000 years.

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ering the small amounts of air trapped in ice, the tiny amount of CO in the air (35 to 55 parts per billion), and the even smaller amounts of heavy isotopes in CO. A striking pattern emerged. Biomass burning declined steadily from the 1300s through the 1600s, in parallel with cooling that occurred from the Medieval Warm Period to the Little Ice Age. Then, some combination of warming and human activity drove a rapid increase in biomass burning, which peaked in the late 1800s before abruptly declining to a historic low in the present.

Wang *et al.*'s results add to a small but growing literature on the global history of fire. Studying fire from an "earth system" perspective is a relatively immature field, despite its enormous importance for carbon cycling, atmospheric composition, and human welfare (*2*). Until very recently, there were no large-scale data on fires, apart from records kept by firefighting agencies in a few countries. Two developments have changed that situation: the availability of data on active fires and burned areas from remote-sensing satellites (*3*) and the assembly of charcoal abundance records from stratified sediments (*4*). The remote-sensing data provide detailed information on the spatial patterns and interannual variability of fires. The stratigraphic records reveal longer-term regional trends. Researchers have also obtained evidence of long-term fire trends from the ^{13}C content of atmospheric methane (*5*), which is disproportionately influenced by changes in the frequency and extent of fires.

Wang *et al.*'s "top-down" observations dramatically confirm the recent history of global fire inferred from "bottom-up" charcoal records (*4*). Marlon *et al.* (*4*) show that a similar pattern, including the recent abrupt decline, was common to different regions of both hemispheres. The most plausible explanation for the decline is that it was a side effect of the spread of European-style intensive cropping and grazing, which dramatically reduced both fuel loads and connections between fire-prone habitats, inhibiting both the initiation and the spread of fires.

To bridge the gap between the uppermost ice-core measurements and the present day, Wang *et al.* include one crucial data point based on direct atmospheric measurements, and several more derived from firn air (firn is the mixture of air and snow that eventually consolidates to become ice). These data confirm that there has been a strong downward trend of biomass burning since the peak in the late 19th century and are consistent with the charcoal record (*4*).

These findings challenge some of the myths that abound in the fire literature. None is more persistent than the perception that fires are caused mainly by human activities. People start fires, it has been reasoned; therefore, in earlier times, when there were fewer people, there must have been less burning. This faulty assumption underlies several attempts, some of which are cited by Wang *et al.*, to reconstruct changes in the composition of the atmosphere during the industrial era. The evidence, however, shows the opposite. In southern Africa, for instance, researchers using remote-sensing observations have found a negative relationship between human population density and burned area, with fire decreasing as population increases (*6*). And despite the high media profile of "deforestation fires" in places like Indonesia and Brazil, research demonstrates that these fires are spatially restricted and subject to strong climate control (*7*); total biomass burning during recent decades has been lower than at any time during the past 650 years (*1*) or even the past 2000 years (*4*). Climate change, on the other hand, has had a major impact—as shown in the long decline in biomass burning in response to natural global climate changes of the past millennium, which researchers believe had an amplitude of no more than a few tenths of a degree. It is reasonable to expect that future climate change will greatly increase the risks of wildfire (*2*), especially if the global mean temperature increases by several degrees (*8*–*10*) as suggested by many projections.

This new perspective on the recent history of fire brings both good news and bad. If biomass burning on a large scale is controlled mainly by climate, then this is bad news for Smokey the Bear (the U.S. advertising icon who says that "only you can prevent forest fires"). The good news is that, if we can predict fire risks by using process-based models (*11*–*13*), we should be able to reduce fires through land use and fuel management. This approach, however, will require a major shift of policy emphasis toward avoiding conditions that favor the spread of fire (*10*).

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