It is not yet clear what the precise cellular mechanisms are, in humans or other animals, that generate novel and separate neuronal firing patterns (the composition of electrical impulses that neurons discharge when excited by a stimulus) for images that share a striking number of common features. However, the mechanisms require that neuronal firing is initially not strongly influenced by the large number of visual features that are shared between similar images (*12*). It also remains to be determined whether neuronal processes that accentuate differences between sensory inputs in humans could be mechanistically related to those that select new, random neuronal firing patterns for spatial locations in rodents.

If such strong pattern separation is not available in other cortical architectures of the brain, it could be one of the defining processes that make the hippocampus and its connected regions in the medial temporal lobe essential for automatically recording detailed memories in humans and other mammals. It will therefore be important to address whether any related separation of sensory inputs also occurs outside of the medial temporal lobe, although such processes might be more difficult to identify if they are not bound to novelty signals in the same way as in the hippocampus. Conversely, it will be important to find how pattern separation and novelty signals might be integrated in the dentate gyrus and CA3 and across the entire medial temporal lobe to give rise to memory for detailed differences but still let us see the big picture. Although these questions are challenging to address even in animal models, the findings of Bakker *et al*. have paved the way for a new category of imaging studies that can investigate neuronal network mechanisms in the human brain.

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ATMOSPHERIC CHEMISTRY

Rethinking Ozone Production

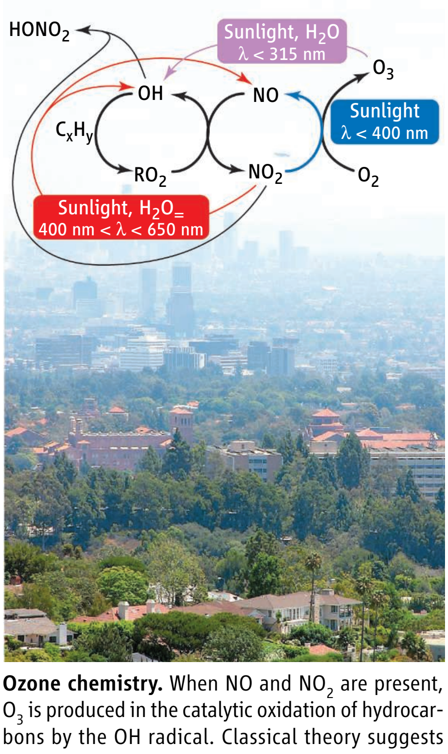
Paul O. Wennberg[1] **and Donald Dabdub**[2]

Laboratory data suggest that atmospheric models are missing a source of hydroxyl, which plays a central role in tropospheric ozone production.

More than a hundred million people live in cities that fail to meet international standards for air quality. Efforts to improve conditions in these urban areas have usually focused on reducing emissions of reactive hydrocarbons (such as unburned gasoline vapors), nitrogen oxide free radicals (NO and NO_2, together known as NO_x), and primary and secondary sources of particulate matter (such as diesel smoke and sulfur dioxide). Control strategies have changed over time in response to evolving understanding about atmospheric photochemistry and the impact of urban emissions on air quality downwind of cities (*1*, *2*). The results reported by Li *et al.* on page 1657 of this issue (*3*) may require another rethinking of these control strategies.

There are three essential ingredients for producing ozone, O_3, in urban atmospheres: sunlight, NO_x, and hydrocarbons (see the first figure). Ozone production chemistry is initiated when hydroxyl free radicals, OH, are produced from water vapor. Classical theory suggests that the O-H bond in water is broken by excited-state oxygen atoms produced in the photolysis of ozone. In the atmosphere, OH oxidizes hydrocarbons to produce peroxy radicals, RO_2 (where R is a hydrogen atom or carbon-containing fragment). In the presence of NO_x, the RO_2 radicals convert NO to NO_2; subsequent photolysis of NO_2 yields O_3. When sufficient amounts of NO are available, the chemistry is catalytic: For each OH produced from water, many hydrocarbons can be oxidized and large amounts of ozone produced. However, when NO_2 levels become high, the loss of OH to nitric acid, $HONO_2$, slows the reactivity, and the rate of ozone production drops. As a result, in many cities, including Los Angeles, ozone levels are generally higher on weekends, when NO_2 levels are lower due to the lack of truck traffic.

Li *et al.* add another level of complexity to the story. In laboratory experiments, they show that excited-state NO_2 (denoted NO_2*) may also break the O-H bond in water, yielding OH and HONO. NO_2* is produced in the atmosphere when NO_2 absorbs sunlight between 400 and 650 nm. Li *et al.* find that for typical urban conditions, 1 in 10,000 of the NO_2* molecules produced reacts with H_2O to produce OH and HONO. Despite this low efficiency, the rate of OH production from NO_2* in urban atmospheres can be comparable to the classical OH source (ozone photolysis). The amount of OH produced from NO_2*



Ozone chemistry. When NO and NO_2 are present, O_3 is produced in the catalytic oxidation of hydrocarbons by the OH radical. Classical theory suggests that the chemistry is initiated when OH is produced after the photolysis of ozone in the presence of water vapor (purple). Li *et al*. find that the O-H bond in water can also be broken by excited-state NO_2 (red). This chemistry increases the amount of OH and thus O_3 production.

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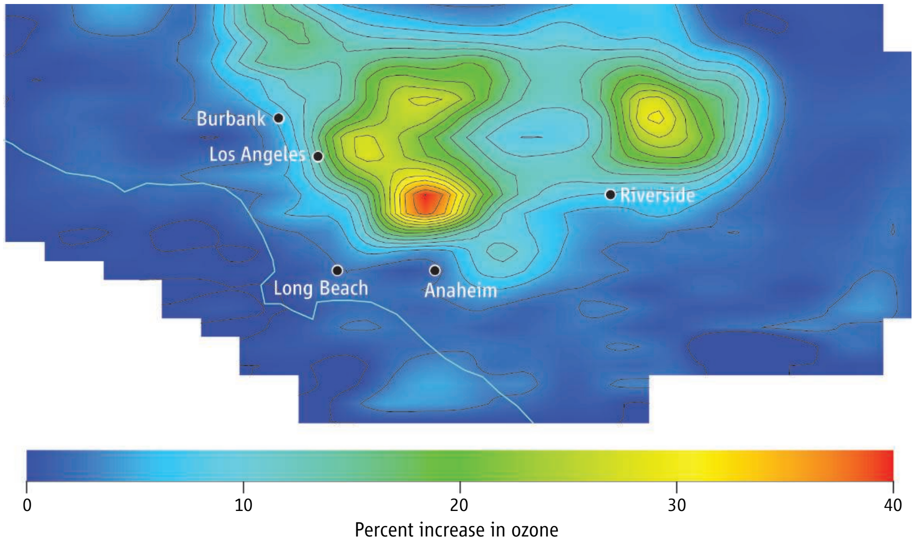
[1] California Institute of Technology, Pasadena, CA 91125, USA. E-mail: wennberg@caltech.edu [2] Department of Mechanical and Aerospace Engineering, University of California at Irvine, Irvine, CA 92697, USA. E-mail: ddabdub@uci.edu



More pollution? Photochemical simulations for 27 to 29 August 1987 in the South Coast Air Basin of California were obtained with and without including the OH source from NO_2* described by Li *et al*. Shown are the percentage increases in ozone concentrations in the afternoon due to the NO_2* chemistry.

scales linearly with the amount of NO_2 in the atmosphere. The net result is that the calculated ozone production rate is higher. In addition, the maximum ozone production rate occurs at higher NO_x concentrations.

We have performed model simulations of air quality in the Los Angeles basin for a typical summer smog episode (*4*, *5*) both with and without the NO_2* source of OH. With the NO_2* source, ozone concentrations are calculated to be much higher throughout the city, with increases of up to 55 parts per billion; percentage increases in ozone concentrations are as high as 30 to 40% (see the second figure). The most affected area is downwind of the city, near Riverside, where NO_x is most abundant. Aerosol levels are also affected, especially near Riverside, where small particle concentrations (diameter <2.5 μm) increase by 20 μg/m^3.

Our simulations that include the NO_2* OH source generally overestimate the observed distribution of O_3 in Los Angeles. Is it possible that the rate constant reported by Li *et al.* is too large? Perhaps. Following a suggestion by Paul Crutzen that the reaction of NO_2* with H_2O might be important, Crowley and Carl studied this chemistry a decade ago (*6*). They found that the rate of the reaction with H_2O was more than an order of magnitude slower than determined by Li *et al*. When we used this slower reaction rate in our model, we obtained a smaller, but still significant, air quality impact: Ozone concentrations increase by up to 10 parts per billion and the small-particle concentration by up to 10 μg/m^3.

The experimental approach used by Li *et al*. differs slightly from that used by Crowley and Carl, but it seems unlikely that this alone explains the different findings. We find no obvious problem with either study. Given the potential importance of this chemistry and the high sensitivity of atmospheric models to the reaction of NO_2* with H_2O, further investigation is clearly needed.

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MATERIALS SCIENCE

Who Wins the Nonvolatile Memory Race?

New memory concepts may lead to computer systems that do not require a lengthy start-up process when turned on.

G. I. Meijer

The semiconductor industry has long sought a high-density, high-speed, low-power memory device that retains its data even when the power is interrupted. Therefore a concept called resistance-change memory, in which a change in how easily current can flow through a material is exploited to store a memory bit, has recently sparked scientific and commercial interest. Can this concept surpass the performance of state-of-the-art devices?

DRAM (dynamic random-access memory), which is omnipresent in today's computers, must be powered continuously to keep its memory state. So-called flash memory, on the other hand, is nonvolatile, but this advantage comes at the price of a slow write speed and a limited number of write/erase cycles. Flash memory therefore cannot be used in a computer's main memory, which must frequently be rewritten. Instead, flash technology is restricted to applications that require neither high speed nor unlimited endurance, such as solid-state hard disks and storage media for digital cameras and cellular phones. Nonetheless, flash memory represented about a third of the US$ 60 billion memory market in 2007.

Traditional memory technologies are rapidly approaching miniaturization limits as the industry moves toward memory cells with 22-nm lateral features projected for 2016 (*1*). The reason is that they are based on charge storage—and it becomes increasingly difficult to reliably retain sufficient electrons in these shrinking cells. Magnetic and ferroelectric random-access memories, which are currently used in niche markets, share this struggle with scaling. Or, to adapt the famous quote from

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IBM Research, Zurich Research Laboratory, CH-8803 Rüschlikon, Switzerland. E-mail: inm@zurich.ibm.com