somebody [else] born today, 30 years from now, is completely unimaginable." From sonograms to wedding photographs and the Social Security Death Index, digital records mark nearly every milestone in our lives. And, because storage is plentiful and cheap and the information never decays, those records don't disappear.

Palfrey believes companies should be required to disclose—either in plain English or on an icon resembling a nutritional label—what they do with the information they collect. "What is it that you collect and store about me?" he would ask. "Is it only what I put in, or is it my browsing habits? Do you share [data] with any third parties? How long do you keep all of [it]?" He also advocates updating the copyright code and making social-networking sites such as Facebook more, though by no means entirely, accountable for their users' actions. He generally shies away from sweeping policy measures, such as banning social networks altogether. "Kids will find some other digital public in which to live their lives," he reasons. "You can just keep banning them, but it's 'whack-a-mole.'"

He fears that keeping kids off line would stifle the creativity he sees springing up all over the Web. In amateur videos on YouTube and in blogs, he sees a popular movement toward what he calls "semiotic democracy," which refers to the way each person watching a television show interprets it differently. Digital tools, Palfrey claims, take this a step further: instead of simply supplying meaning to someone else's show, anyone with a digital camera can make his or her own.

Palfrey points to parents and educators, rather than legislators, as children's best guides to the often hazardous terrain of the digital world. But parents and educators, to be effective, must engage with that world and understand how young people behave in it. For instance, while conducting a survey of study habits, Palfrey was unable to find a single digital native whose first step, when assigned a research paper, was toward a library. Instead, students typed their topic into a Google search bar, scrolled down to the reference in Wikipedia (an online encyclopedia edited by its readers), read the entry, and then followed the links to learn more. "The only variant I've heard to that," says Palfrey, "is typing en.wikipedia.org and going straight to Wikipedia." Whether or not Wikipedia is a credible source, teachers need to know that their students consult it before they can present alternatives.

Palfrey hopes that digital natives eventually become creators of on-line content, rather than simply consumers. Shooting and posting a video, or writing a comment on a message board, he argues, is a way of reaching out to an audience that potentially numbers in the millions. "If in fact kids over time find that they can have more of an impact on their society by virtue of what they can do through these new media...I think that leads to a more active form of democratic participation," he says—looking forward to a time when those who choose to be born digital regularly make, unmake, and remake the information world they live in.

~PAUL GLEASON

JOHN PALFREY BLOG:
http://blogs.law.harvard.edu/palfrey

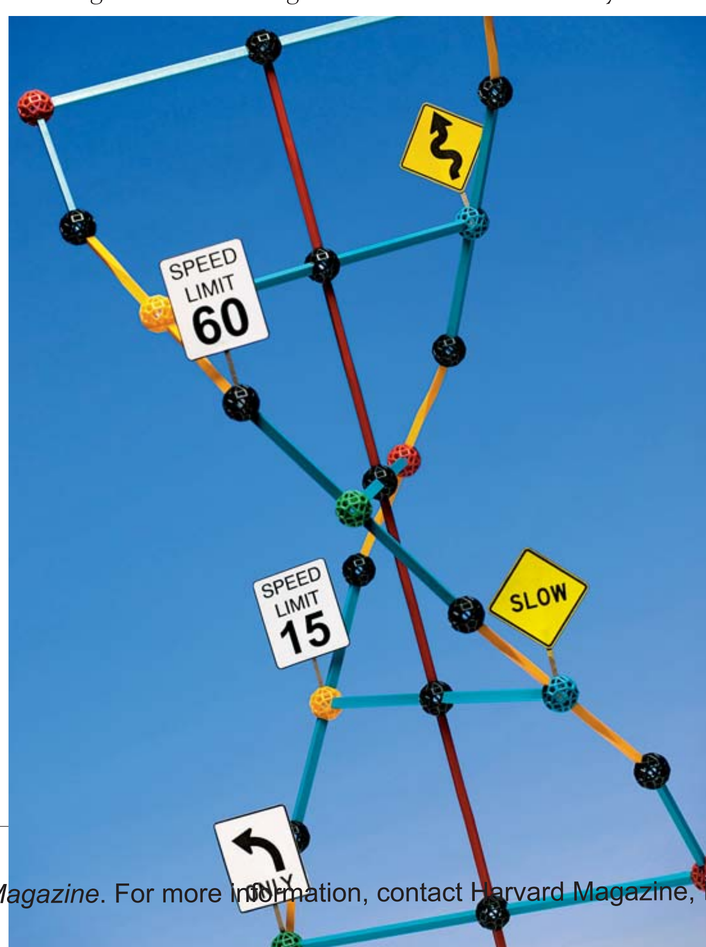
CHECKS ON CHANGE

Life's Speed Limit

Mutation is the engine of evolution: organisms would not be able to evolve new characteristics if their DNA did not randomly acquire small changes. But mutations can also be dangerous. If too many life-threatening mutations appear too quickly, an entire species could face extinction. Now a group of Harvard scientists has calculated the number of mutations that can appear in any organism's genome in each generation without threatening a population's survival. And because this "speed limit" on genetic change arises from fundamental properties of molecules, the limit is the same for the simplest viruses and the most complex plants and animals.

The study, which appeared recently in *Proceedings of the National Academy of Sciences*, links two lines of scientific research: the detailed investigation of the physical properties of proteins, and the broader study of evolutionary change. DNA serves as a template for building proteins, which are the primary actors in the cells of organisms. Professor of chemistry and chemical biology Eugene Shakhnovich, the study's lead author, says that a great deal is known about the three-dimensional properties of proteins and how their shape affects their function. "The next step," he explains, "is to understand how the proteins' shape affects the behavior of organisms," including their survival and evolution.

His team, led by research associate Konstantin Zeldovich, focused on a key property of proteins: their stability. Some mutations in



Photograph by Stu Rosner

DNA affect the way proteins fold into three-dimensional structures. Critical proteins must be structurally stable for an individual organism to survive; on a population level, if too many individuals die out because their proteins are unstable, a species risks extinction.

To find the limit on mutations per genome per generation, the team modeled a range of possible stabilities for proteins essential to life. Employing a diffusion equation, widely used in physics, they calculated the balance point at which too many proteins become unstable for a population to survive. The answer they came up with: six mutations per generation.

Shakhnovich notes that this absolute speed limit illustrates why organisms that have very large genomes, such as mammals, must mutate very slowly: it is far more difficult to ensure that fewer than six mutations occur in a genome with billions of potential mutation sites than in one with several thousand. In fact, he says, most organisms operate far below the theoretical speed limit because they have developed elaborate error-correction systems to *ensure* that mutations occur only rarely.

Some diseases, on the other hand, thrive by operating near the fundamental limit of mutation. Viruses, and particularly RNA viruses like HIV, have relatively high mutation rates; only by changing their proteins constantly can they evade their host's immune system. Certain bacteria speed their evolution by shutting down their error-correction systems. Cancer cells grow and spread by mutating more quickly than normal cells.

The six-mutation rule has real-world applications. Certain therapies already take advantage of such limits by drastically *boosting* mutation rates in order to kill their targets: radiation therapy to treat cancer, for example. At the same time, the low mutation rate that allows complex organisms to support large, stable genomes limits their ability to adapt quickly in response to new conditions, as a virus or bacterium would. Global warming, for instance, may pose a particular threat to those species that evolve slowly—and Shakhnovich's team is trying to understand in more detail how the need to maintain a stable genome affects the speed at which organisms can adapt to environmental change.

~COURTNEY HUMPHRIES

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SEXUAL CIRCUITRY

When Minnie Turns Mickey

If males are from Mars and females from Venus, as self-help author John Gray memorably suggested, sex hormones usually get the blame for placing them so far apart. Scientists have long believed that exposure to hormones close to birth and during puberty organize and activate neural circuits to trigger *or* suppress male or female behavior.

But surprising findings in the lab of Higgins professor of molecular and cellular biology Catherine Dulac, published last summer in the journal *Nature*, offer a profoundly new way to think about how male and female brains develop. Working with postdoctoral fellow Tali Kimchi and Jennings Xu '08, Dulac discovered that sex-specific behaviors in mice switch on and off at the command of the vomeronasal organ (VNO), a collection of non-olfactory sensory receptors located in the nasal septa of mice and other mammals.

The VNO allows mice to