Views

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BIOTECHNOLOGY

Genome Gambits

New genetic tools can do tremendous good—if we use them carefully.

My dad loved to hike in the rain forests near our home on the Big Island of Hawaii, often to hunt for mushrooms with Don Hemmes, his colleague at the University of Hawaii. The goal of these trips was not to harvest mushrooms but to photograph them for a research project that Hemmes was leading. When I accompanied them, I was always struck by the incredible diversity of the mushrooms we found. Having learned a little about genetics in school, I wondered what kinds of DNA changes were responsible for these organisms' range of colors, shapes, and sizes. And how could we figure out such molecular signatures?

Fast-forward 30-odd years, and it's become routine to sequence the entire genomes of organisms, and to interpret that information to reveal the underlying causes of observable traits. A simple and effective technology for making precise changes to those genomic sequences, developed by harnessing a system that bacteria use to fight viral infections, has exploded into widespread use (see "Engineering the Perfect Baby," page 26). The technology, called CRISPR, relies on a programmable DNA-cutting enzyme called Cas9, together with its guide RNA, to let scientists alter the genetic information within cells, tissues, and whole organisms. Scientists have used it to generate new strains of wheat, to cure a genetic disease in the livers of adult mice, and to produce altered fungal cells capable of efficient biofuel synthesis. The CRISPR-Cas9 technology has opened up a world of research opportunities that were inconceivable just three years ago. The technology will benefit humanity in many ways.

There's also a growing appreciation of the risks involved. CRISPR-Cas9 technology can, as an example, be used to alter the DNA in germ cells or embryos, resulting in permanent changes to the genetic makeup of every differentiated cell in a resulting organism—and to that organism's progeny. The system is so efficient that genetic changes it introduces could become self-propagating. Such applications could be employed to cure genetic disease in humans or to limit the fitness of disease-carrying organisms—but the intricacies of genetic interaction mean those uses could also have unintended consequences, perhaps triggering other diseases.

Research is needed to understand the utility and risks of CRISPR-Cas9 in cells including human germ cells, as well as the risks inherent in any human clinical applications that might be possible in the future. We should research the ramifications of using genome engineering to control organisms, such as mosquitoes, that can spread malaria or dengue fever. While we should embrace this technology, scientists also must come together to guide peers and regulators as to its responsible use.

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ENERGY

Peace Through Grids

How smart energy policy can ease conflicts.

When I served as the chief technical specialist for renewable energy and energy efficiency at the World Bank, one project I found especially interesting was the construction of an electricity highway between the rich geothermal energy

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fields of the Rift Valley in Kenya through the Lake Turkana plains—where the best wind resource identified to date in Africa was recently mapped—to newly constructed hydroelectric facilities in Ethiopia. Not only are these indigenous renewable energy resources largely untapped, but the policy tools to build markets for clean energy are often most effective in poor, power-starved nations.

Roughly 1.5 billion people around the world live without electricity today, so these kinds of projects should be a priority for international development (see "Lake Kivu's Great Gas Gamble," page 34). But such projects have ramifications well beyond energy. They represent a major opportunity to use some of our greatest infrastructure investments to build peaceful, prosperous, and coöperative regional economies. The grid is the greatest engineering achievement of the 20th century, and yet we've given very little thought to building partnerships through shared energy commerce. This has to change.

Critical opportunities now exist to build coöperative regional economies and address the global climate crisis. One example can be found in South Sudan, the world's newest nation, where old ethnic tensions, exacerbated by potential oil and gas wealth, have disrupted an already fragile process of nation building. But if investors could connect South Sudan to the emerging East African Power Pool, the country could disengage from its tense relationship with Sudan and cheaply power the local economy—in a place where less than 2 percent of the population now has electricity.

Kosovo, the poorest nation in Europe, has been a battleground over a proposed coal-fired power plant. Kosovo happens to have significant resources in wind, biomass, and hydropower, much of which would most efficiently be developed jointly with Albania. This approach would make the coal plant—a pollution-belcher six kilometers from the capital city—an unnecessary anachronism. Kosovo and Albania recently announced that they will integrate their power markets, a step that could unleash the region's impressive solar energy resources to work closely with bioenergy and distributed hydropower.

Nations linked by energy commerce—and in particular clean, local energy—are far less likely to enter into hostilities than those that see each other only as regional rivals. That's why governments seeking to build strong international partnerships would do well to make transmission diplomacy and development a centerpiece of foreign policy. Such efforts would greatly aid energy access globally and make clean energy the technology of choice for a new wave of investments.

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COMPUTING

Better Architecture

Computers are overdue for the fundamental changes they could soon get.

Computer architectures aren't laws of physics. They're man-made interfaces designed to harness raw resources, such as billions of transistors, for a range of useful computational tasks.

When our computing needs and tasks change—as they inevitably will over the decades—it becomes increasingly awkward to express programs through the original architecture. And yet that's where we find ourselves—adhering to an ossified architecture that imposes constraints and slows our technological progress.

Today's architectures are more than half a century old. In the 1940s, electronic computers became reprogrammable, with data and instructions (a.k.a. software) stored in memory and passed to a central processing unit (CPU) for computation. This architecture evolved slightly over time but remained fundamentally the same.

The vast majority of computing devices today are connected to the Internet, making them vulnerable to remote attack. Our data centers demand the type of strong security—including isolation and tracking of data—that classic architectures were never designed to support.

That's one reason computing architectures must evolve. A system being developed by Hewlett-Packard, known as the Machine (see "Machine Dreams," page 48), uses electronic components called memristors to store and process information—offering more powerful ways to handle large amounts of data—together with silicon photonic components that allow data to be processed at very high speeds using light. HP's researchers are also developing a new operating system, Machine OS, to make the most of this new architecture.

Reinvention like this doesn't solve all our problems. In some cases it creates new ones. The consistent architecture of IBM's System 360 in the 1960s and 1970s ensured that buyers of early models could upgrade their machines and feel confident that the programs they were already using would continue to work. Can a new architecture evolve without forcing every program to evolve with it?

Probably. Since the days of the System 360, compilers and program translators—tools that allows software to run on a different architectures—have matured substantially. We'll need to make the most of such tools if we hope to loosen our ties to legacy architectures and allow computers like the Machine to thrive.

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