Edited by

JOHN BROCKMAN

Editor of *This Idea Must Die*

"A lavish cerebral feast."
–*The Atlantic*

Know This

Today's Most Interesting and Important Scientific Ideas, Discoveries, and Developments

EDGE.ORG *Presents Original Ideas from "the World's Finest Minds"*[*]:

Jared Diamond, Steven Pinker, Carlo Rovelli, Frank Wilczek, Alison Gopnik, Freeman Dyson, Martin Rees, Jonathan Haidt, Rebecca Newberger Goldstein, *and more "Very, VERY smart people"*[†]

[*]*The Guardian* [†]Boing Boing

Contents

Preface
The *Edge* Question

> Scientific topics receiving prominent play in newspapers and magazines over the past several years include molecular biology, artificial intelligence, artificial life, chaos theory, massive parallelism, neural nets, the inflationary universe, fractals, complex adaptive systems, superstrings, biodiversity, nanotechnology, the human genome, expert systems, punctuated equilibrium, cellular automata, fuzzy logic, space biospheres, the Gaia hypothesis, virtual reality, cyberspace, and teraflop machines. . . . Unlike previous intellectual pursuits, the achievements of the third culture are not the marginal disputes of a quarrelsome mandarin class: they will affect the lives of everybody on the planet.

You might think that the above list of topics is a preamble for the *Edge* Question of 2016, but you would be wrong. It was a central point in my essay, "The Third Culture," published twenty-five years ago in the *Los Angeles Times*, September 19, 1991. The essay, a manifesto, was a collaborative effort, with input from Stephen Jay Gould, Murray Gell-Mann, Richard Dawkins, Daniel C. Dennett, Jared Diamond, Stuart Kauffman, and Nicholas Humphrey among other distinguished scientists and thinkers. It proclaimed that "the third culture consists of those scientists and other thinkers in the empirical world who, through their work and expository writing, are taking the place of the traditional intellectual in rendering visible the deeper meanings of our lives, redefining who and what we are," and it continued:

> What traditionally has been called "science" has today become "public culture." Stewart Brand writes that "Science is the only

news. When you scan through a newspaper or magazine, all the human interest stuff is the same old he-said-she-said, the politics and economics the same sorry cyclic dramas, . . . even the technology is predictable if you know the science. Human nature doesn't change much; science does, and the change accrues, altering the world irreversibly." We now live in a world in which the rate of change is the biggest change.

Science has thus become a big story, if not *the* big story: News that will stay news.

This is evident by the continued relevance today of the scientific topics in the 1991 essay, all of which were in play before the Web, social media, mobile communications, deep learning, Big Data. Time for an update. . . .

WHAT DO YOU CONSIDER THE MOST INTERESTING RECENT [SCIENTIFIC] NEWS? WHAT MAKES IT IMPORTANT?

The online response this year is just shy of 200 contributions: Here is the news, sifted by those who often make it.

John Brockman
Publisher, Edge

Human Progress Quantified

Steven Pinker
Johnstone Family Professor, Department of Psychology;
Harvard University; author, *The Sense of Style*

Human intuition is a notoriously poor guide to reality. A half-century of psychological research has shown that when people try to assess risks or predict the future, their heads are turned by stereotypes, memorable events, vivid scenarios, and moralistic narratives.

Fortunately, as the bugs in human cognition have become common knowledge, the workaround—objective data—has become more prevalent, and in many spheres of life observers are replacing gut feelings with quantitative analysis. Sports have been revolutionized by *Moneyball*, policy by *Nudge*, punditry by *538.com*, forecasting by tournaments and prediction markets, philanthropy by effective altruism, the healing arts by evidence-based medicine.

This is interesting news, and it's scientific news because the diagnosis comes from cognitive science and the cure from data science. But the most interesting news is that the quantification of life has been extended to the biggest question of all: Have we made progress? Have the collective strivings of the human race against entropy and the nastier edges of evolution succeeded in improving the human condition?

Enlightenment thinkers thought this was possible, of course, and in Victorian times progress became a major theme of Anglo-American thought. But since then, Romantic and counter–Enlightenment pessimism have taken over large swaths of intellectual life, stoked by historical disasters such as the World

Wars and by post-1960s concerns with anthropogenic problems such as pollution and inequality. Today it's common to read about "faith" in progress (often a "naïve" faith), which is set against a nostalgia for a better past, an assessment of present decline, and a dread of the dystopia to come.

But the cognitive and data revolutions warn us not to base our assessment of *anything* on subjective impressions or cherry-picked incidents. As long as bad things haven't vanished altogether, there will always be enough to fill the news, and people will intuit that the world is falling apart. The only way to circumvent this illusion is to plot the incidence of good and bad things over time. Most people agree that life is better than death, health better than disease, prosperity better than poverty, knowledge better than ignorance, peace better than war, safety better than violence, freedom better than coercion. That gives us a set of yardsticks by which we can measure whether progress has actually occurred.

The interesting news is that the answer is mostly yes. I had the first inkling of this answer when quantitative historians and political scientists responded to my answer to the 2007 *Edge* question ("What Are You Optimistic About?") with data sets showing that the rate of homicides and war deaths had plummeted over time. Since then, I have learned that progress has been tracked by the other yardsticks. Economic historians and development scholars (including Gregory Clark, Angus Deaton, Charles Kenny, and Steven Radelet) have plotted the growth of prosperity in their data-rich books, and the case has been made even more vividly in Web sites with innovative graphics, such as Hans Rosling's *Gapminder*, Max Roser's *Our World in Data,* and Marian Tupy's *HumanProgress.*

Among the other upward swoops are these. People are living longer and healthier lives, not just in the developed world but globally. A dozen infectious and parasitic diseases are extinct or moribund. Vastly more children are going to school and learning to read. Extreme poverty has fallen worldwide from 85 to 10 percent. Despite local setbacks, the world is more democratic than ever. Women are better educated, marrying later, earning more, and in more positions of power and influence. Racial prejudice and hate crimes have decreased since data were first recorded. The world is even getting smarter: In every country, IQ has been increasing by three points a decade.

Of course, quantified progress consists of a set of empirical findings; it is not a sign of some mystical ascent or utopian trajectory or divine grace. And so we should expect to find some spheres of life that have remained the same, gotten worse, or are altogether unquantifiable (such as the endless number of

apocalypses that may be conjured in the imagination). Greenhouse gases accumulate, fresh water diminishes, species go extinct, nuclear arsenals remain.

Yet even here, quantification can change our understanding. "Eco-modernists" such as Stewart Brand, Jesse Ausubel, and Ruth DeFries have shown that many indicators of environmental health have improved over the last half-century, and that there are long-term historical processes—such as the de-carbonization of energy, the dematerialization of consumption, and the minimization of farmland—that can be further encouraged. Tabulators of nuclear weapons have pointed out that no such weapon has been used since Nagasaki, testing has fallen effectively to zero, proliferation has expanded the club only to nine countries (rather than thirty or more, as was predicted in the 1960s), seventeen countries have given up their programs, and the number of weapons (and hence the number of opportunities for thefts and accidents and the number of obstacles to the eventual goal of zero) has been reduced by five-sixths.

What makes all this important? Foremost, quantified progress is a feedback signal for adjusting what we've been doing. The gifts of progress we have enjoyed are the result of institutions and norms that have become entrenched in the last two centuries: reason, science, technology, education, expertise, democracy, regulated markets, and a moral commitment to human rights and human flourishing. As counter–Enlightenment critics have long pointed out, there's no guarantee that these developments would make us better off. Yet now we know that in fact they *have* left us better off. This means that for all the ways in which the world today falls short of utopia, the norms and institutions of modernity have put us on a good track. We should work on improving them, rather than burning them down in the conviction that nothing could be worse than our current decadence and in the vague hope that something better might rise from their ashes.

Also, quantified human progress emboldens us to seek more of it. A common belief among activists is that any optimistic datum must be suppressed lest it lull people into complacency, and instead one must keep up the heat by wailing about ongoing crises and scolding people for being insufficiently terrified. Unfortunately, this can lead to a complementary danger: fatalism. After being told that the poor might always be with us, that the gods will punish our hubris, that nature will avenge our despoliation, and that the clock is inexorably ticking down to a midnight of nuclear holocaust and climatic catastrophe, it's natural to conclude that resistance is futile and we should party while we can. The empowering feature of a graph is that it invites you to identify the forces pushing a curve up or down,

and then to apply them to push it farther in the same direction.

Doing More with Less

Freeman Dyson
Theoretical physicist; author, *Dreams of Earth and Sky*

One of the scientific heroes of our time is Pieter van Dokkum, professor in the Yale Astronomy Department and author of a recent book, *Dragonflies*. The book is about insects, illustrated with marvelous photographs of dragonflies taken by van Dokkum in their natural habitats. As an astronomer, he works with another kind of dragonfly. The Dragonfly Telephoto Array consists of ten 16-inch refractor telescopes arranged like the compound eye of a dragonfly. The refracting lenses are coated with optical surface layers designed to give them superb sensitivity to faint extended objects in the sky. For faint extended objects, the Dragonfly array is about 10 times more sensitive than the best large telescopes. The Dragonfly is also about 1,000 times cheaper. The ten refractors cost together about $100,000, compared to $100 million for a big telescope.

Dragonfly recently discovered forty-seven “ultra-diffuse” Milky-Way-sized galaxies in the Coma cluster, more than were expected from computer models of galactic evolution. Each galaxy is embedded in a halo of dark matter whose mass can be determined from the observed velocities of the visible stars. The galaxies have about 100 times more dark mass than visible mass, compared with the ratio of 10 to 1 between dark and visible mass in our own galaxy. The Dragonfly observations reveal a universe with an intense fine-structure of dark-matter clumps, much clumpier than the standard theory of Big Bang cosmology had predicted.

So it happens that a cheap small telescope can make a big new discovery about the structure of the universe. If the cost-

effectiveness of a telescope is measured by the ratio of scientific output to financial input, Dragonfly wins by a large factor. This story has a moral. The moral is not that we should put all our money into small telescopes. We still need big telescopes and big organizations to do world-class astronomy. The moral is that a modest fraction of the astronomy budget, perhaps as much as a third, should be reserved for small and cheap projects. From time to time a winner like Dragonfly will emerge.

The “Specialness” of Humanity

Kurt Gray
Assistant professor of psychology, University of North Carolina, Chapel Hill

“Then the Lord God formed the man of dust from the ground and breathed into his nostrils the breath of life, and the man became a living creature.”—Genesis 2:7

Humans have always been convinced of our own specialness, certain that we sit at the center of the universe. Not long ago, we thought ourselves to be God’s favorite creation, placed on a newly created Earth, which was orbited by all other celestial bodies. We believed that humans were fundamentally different from other animals and possessed intelligence that could never be duplicated. Those ideas made us feel comfortable and safe and so were easy to believe. But they were wrong.

Copernicus and Galileo revealed that the Sun, not the Earth, lay at the center of the solar system. Charles Lyell revealed that the Earth was much older than previously thought. Darwin revealed that humans were not fundamentally different from other animals. Each of these scientific discoveries challenged our presumed specialness. Of course, even if people were just apes with large frontal cortices, at least we could claim that humans are part of a very special club—that of living creatures. We marvel at the beauty

of life, the diversity of plants, animals, insects, and bacteria. Unfortunately, one recent theory undermines the specialness of all life.

The MIT physicist Jeremy England has suggested that life is merely an inevitable consequence of thermodynamics. He argues that living systems are the best way of dissipating energy from an external source: Bacteria, beetles, and humans are the most efficient way to use up sunlight. According to England, the process of entropy means that molecules that sit long enough under a heat lamp will eventually structure themselves to metabolize, move, and self-replicate—i.e., become alive. Granted, this process might take billions of years, but in this view living creatures are little different from other physical structures that move and replicate with the addition of energy, such as vortices in flowing water (driven by gravity) and sand dunes in the desert (driven by wind). England's theory not only blurs the line between the living and the nonliving but also further undermines the specialness of humanity. It suggests that what humans are especially good at is nothing more than using up energy (something we seem to do with great gusto)—a kind of specialness that hardly lifts our hearts.

J. M. Bergoglio's 2015 Review of Global Ecology

Stuart Pimm
Doris Duke Professor of Conservation Ecology, Duke University; author, *The World According to Pimm*

The year 2015 saw the publication of an impressive *tour d'horizon* of global ecology. Covering many areas, it assesses human impacts on biodiversity, the subject that falls within my expertise. Like all good reviews, it's well documented, comprehensive, and contains specific suggestions for future research. Much of it has a familiar feel, although it's a bit short on references from *Nature* and *Science*. But that's not what makes this review news. Rather, it's because it reached a well-defined 1.2 billion people, plus uncountable others—putting the citation statistics of other recent science stories in the shade. The publication is "On Care for Our Common Home," and its author is better known as Pope Francis.

How much ecology is there in this? And how good is it? Well, the word "ecology" (or similar) appears eighty times, "biodiversity" twelve, and "ecosystem" twenty-five. There's a 1,400-word section on the loss of biodiversity—the right length for a letter to *Nature*.

The biodiversity section starts with a statement that Earth's resources "are also being plundered because of short-sighted approaches to the economy, commerce and production." It tells us that deforestation is a major driver of species loss. It explains that a diversity of species is important as the source of food, medicines, and other uses, and that "different species contain genes which could be key resources in years ahead for meeting human needs and regulating environmental problems." A high rate of extinction

raises ethical issues—in particular, the idea that our current actions limit what future generations can use or enjoy.

We learn that most of what we know about extinction comes from studying birds and mammals. In a sentence that E. O. Wilson might have written, it praises the small things that rule the world: "The good functioning of ecosystems also requires fungi, algae, worms, insects, reptiles and an innumerable variety of microorganisms. Some less numerous species, although generally unseen, nonetheless play a critical role in maintaining the equilibrium of a particular place." There is no point in a complete catalog, but this short list exemplifies its insights and comprehensiveness. Knocking pieces from any complex system—in this case, species from ecosystems—can have unexpected effects.

Technology has benefits, but Bergoglio eloquently rejects unbridled technological optimism: "We seem to think that we can substitute an irreplaceable and irretrievable beauty with something which we have created ourselves." We not only destroy habitats, but we fragment those that remain behind. The solution is to create biological corridors. He continues: "When certain species are exploited commercially, little attention is paid to studying their reproductive patterns in order to prevent their depletion and the consequent imbalance of the ecosystem."

Whereas there has been significant progress in establishing protected areas on land and in the oceans, there are concerns about the Amazon and the Congo (the last remaining large blocks of tropical forest) and about replacing native forests with tree plantations, which are so much poorer in species. Overfishing and discarding large amounts of bycatch diminish the oceans' ability to support fisheries. Human actions physically damage the seabed across vast areas, radically altering the composition of the species living there. The section ends with a statement that might have come from a Policy Forum in *Science*, arguing as it does for increased effort and funding:

> Greater investment needs to be made in research aimed at understanding more fully the functioning of ecosystems and adequately analyzing the different variables associated with any significant modification of the environment. Because all creatures are connected, each must be [conserved], for all . . . are dependent on one another. . . . This will require undertaking a careful inventory of [species] with a view to developing programmes and strategies of protection with particular care for safeguarding species heading towards extinction.

The biodiversity section would make an outstanding course

outline for my graduate course in conservation. Its coverage is impressive, its topics of global significance. Its research is strikingly up-to-date and hints at active controversies.

The encyclical includes lengthy sections on pollution, climate change, water, urbanization, social inequality and its environmental consequences, both the promise and threat of technology, intergenerational equity, policies both local and global. All these topics would appear in a course on global ecology. But this is not why its publication made news. Rather, it's an incontestable statement of the importance of science in shaping the ethical choices of our generation—for Catholics and non–Catholics alike. It asks all religions and all scientists to grasp the enormity of the problems that the science of ecology has uncovered and to seek their solutions urgently. The author deserves the last word—and it is a good one—on how we should do that:

> Nonetheless, science and religion, with their distinctive approaches to understanding reality, can enter into an intense dialogue fruitful for both. Given the complexity of the ecological crisis and its multiple causes, we need to realize that the solutions will not emerge from just one way of interpreting and transforming reality. . . . If we are truly concerned to develop an ecology capable of remedying the damage we have done, no branch of the sciences and no form of wisdom can be left out, and that includes religion and the language particular to it.

Leaking, Thinning, Sliding Ice

Laurence C. Smith
Professor and Chair, Department of Geography; professor, Department of Earth, Planetary, and Space Sciences, UCLA; author, *The World in 2050*

Recently the *New York Times, Wall Street Journal, Los Angeles Times,* and other prominent news outlets around the world have been granting an abnormally high level of media coverage to scientific news about the world's great ice sheets. The news conveyed is not good.

Through unprecedented new images, field measurements, and modeling capabilities, we now know that Greenland and Antarctica, remote as they are, have already begun the process of redefining the world's coastlines. More than a billion people—and untold aspects of our economies, ecosystems, and cultural legacies—will be altered, displaced, or lost in the coming generations.

Five studies in particular commanded especial attention. One showed that the floating ice shelves ringing Antarctica (which do not affect sea level directly but do prevent billions of tons of glacier ice from sliding off the continent into the ocean) are thinning, their bulwarking ability compromised. Another, through the use of drones, satellites, and extreme field work, found pervasive blue meltwater rivers gushing across the ice surface of Greenland. A major NASA program called Oceans Melting Glaciers, or OMG, showed that the world's warming oceans—which thus far have absorbed most of the heat from rising global greenhouse-gas emissions—are now melting the big ice sheets from below, at the

undersides of marine-terminating glaciers. A fourth study used historical air photographs to map the scars of 20th-century deglaciation around the edges of the Greenland ice sheet, showing that its pace of volume loss has accelerated. A fifth, a long time-horizon study, used advanced computer modeling to posit that the massive Antarctic ice sheet may disappear altogether in coming millennia, should we choose to burn all known fossil-fuel reserves.

That last scenario is extreme. But if we choose to bring it to reality, the world's oceans would rise an additional 200 feet. To put 200 feet of sea-level rise into perspective: The entire Atlantic seaboard, Florida, and the Gulf Coast would vanish from the United States, and the hills of Los Angeles and San Francisco would become scattered islands. Even 5 or 10 feet of sea-level rise would change or imperil the existence of coastal populations as we currently know them. Included among these are major cities like New York, Newark, Miami, and New Orleans in the U.S.; Mumbai and Calcutta in India; Guangzhou, Guangdong, Shanghai, Shenzen, and Tianjin in China; Tokyo, Osaka, Kobe, and Nagoya in Japan; Alexandria in Egypt; Haiphong and Ho Chi Minh City in Vietnam; Bangkok in Thailand; Dhaka in Bangladesh; Abidjan in Côte d'Ivoire, Lagos in Nigeria, and Amsterdam and Rotterdam in the Netherlands. The risk is not simply of rising water levels but also of the enhanced reach of storm surges (as illustrated by Hurricane Katrina and Superstorm Sandy); and of private capital and governments ceasing to provide insurance coverage for flood-vulnerable areas.

Viewed collectively, these studies and others like them tell us four things that are interesting and important.

The first is that ice sheets are leaky, meaning that it seems unlikely that increased surface melting from climate warming can be countered by significant retention or refreezing of water within the ice mass itself.

The second is that the pace of global sea-level rise, which has already nearly doubled over the past two decades (and is currently increasing approximately 3.2 mm/year, on average), is clearly linked to the shrinking ice volumes of ice sheets.

The third is that warming oceans represent a hitherto unappreciated feedback to sliding ice.

The fourth is that the process of ice-triggered sea-level rise is not only ongoing but accelerating. Many glaciologists now fear that earlier estimates of projected sea-level rise by the end of this century (about 1 foot if we act aggressively now to curb emissions, about 3.2 feet if we do not) may be too low.

Sea-level rise is real; it's happening now and is here to stay. Only its final magnitude remains for us to decide.

Glaciers

Robert Trivers
Evolutionary biologist; professor of anthropology and biological sciences, Rutgers University; author, *Wild Life: Adventures of an Evolutionary Biologist*

Glaciers throughout the world are melting at an unprecedented rate. Glaciers throughout the world will continue to melt at an unprecedented rate. Try living with an average sea level 5+ meters higher.

Our Collective Blind Spot

Jennifer Jacquet
Assistant professor of environmental studies, NYU; author, *Is Shame Necessary?*

Scientists and the media are establishing new ways of looking at who is responsible for anthropogenic climate change. This expanded view of responsibility is some of the most important news of our time, because whomever we see as causing the problem informs whom we see as obligated to help fix it.

The earliest phases of climate responsibility focused on greenhouse-gas emissions by country and highlighted differences between developed and developing nations (a distinction that has become less marked as China and India have become two of the top three emitters). Then, in the first decade of the 21st century, the focus, at least in the U.S., narrowed to individual consumers. However, this century's second decade has brought corporate producers into the spotlight, not only for their role in greenhouse-gas emissions but also for their coordinated efforts to mislead the public about the science of climate change and prevent political action.

Although we have traditionally held producers responsible for pollutants, as in the case of hazardous waste, a debate followed about whether it was fair to shift the burden of responsibility for greenhouse-gas emissions from demand to supply. New research revealing how some fossil-fuel companies responded to climate science has placed a greater burden on the producer. Since the late 1980s, when the risks of climate change began to be clear, some corporations funded efforts to deny climate science and worked to ensure the future of fossil fuels. Producers influenced public beliefs

and preferences.

One reason for the recent research into corporate influence is the growing number of disciplines (and interdisciplines) involved in climate research. While psychologists were some of the first to conduct headline-generating climate-related social science (which helps explain the focus on individual responsibility and preferences), researchers from other disciplines, like sociology and history of science, began documenting the role of corporations and a complicit media in the failure to act on climate change.

The mounting evidence for producer culpability has happened relatively quickly, but its timing remains embarrassing. Over the last two decades of the climate wars, scientists have been accused of being bad communicators, of emphasizing uncertainty, and of depressing and scaring people. I find none of these lines of argument particularly convincing. But the failure of researchers and the media, until recently, to neither see nor document industry's legerdemain as partly responsible for the stalemate over climate represents their (our) biggest failure on climate action. We might be able to blame corporate influence over politics and the media for the public-opinion divide, but that doesn't explain why researchers and journalists overlooked the role of corporations for so long. Now that we've recognized industry's important role in climate change, let's hope this doesn't regress into our collective blind spot.

Three De-carbo
Scientific Breakt

Bill Joy
Futurist; cofounder and former chief scientist, Sun Microsystems; Greentech Venture Capital Group and Partner Emeritus, KPCB

Climate change is an enormous challenge. Rapid de-carbonization of manufacturing, electricity generation, and transportation is critical and may become a crisis because of nonlinear effects. Last year brought not-widely-disseminated news of the commercial availability of three substantial scientific breakthroughs that can significantly accelerate de-carbonization.

1. **DE-CARBONIZING CONCRETE; COMMODITIZING CO_2**

   After water, concrete is the most widely used material in the world. The manufacture of Portland cement for use in concrete accounts for up to 5 percent of global anthropogenic emissions. A new "Solidia cement," invented by Dr. Richard Riman of Rutgers University, can be made from the same ingredients as Portland cement and in the same kilns, but at lower temperature, while incorporating less limestone, thus emitting substantially less CO_2 in its manufacture. Unlike Portland cement, which consumes water to cure, this new cement cures by consuming CO_2. Concrete products made from it have their CO_2 footprint reduced by up to 70 percent. Thousands of tons of the new cement have been manufactured, and 2015

brought news that large manufacturers are now modifying their factories to use it instead of Portland cement to make concrete. Its widespread adoption would multiply the demand for industrial CO_2 substantially, creating a strong economic incentive for CO_2 capture and reuse.

Previous attempts at introducing radically-low-carbon cements have all failed to scale, because they required raw materials that were not ubiquitous and expensive new capital equipment, and/or because of the large range of material properties required by regulation or for specific applications. Solidia cement overcomes these problems and offers lower cost and better performance. But rapid adoption in an existing infrastructure has to be simple. In this case, only a single step of the manufacturing process—to cure with CO_2 rather than water—has to change.

Can we similarly expect to reduce the CO_2 footprint of other high-embodied-energy materials, such as steel and aluminum, while reusing the existing infrastructure? A decade-long search found no suitable candidate breakthroughs, so these de-carbonizations may unfortunately require a much slower process of redesigning products to use lower-embodied-energy materials like structural polymers and fibers.

2. **SCALABLE WIND TURBINES FOR DISTRIBUTED WIND**

More than a billion people, mostly in rural areas in the developing world, lack access to a reliable grid and electricity; it matters greatly whether they will get electricity from renewables or fossil fuels. Wind turbines today are the cheapest renewable but only in very large multi-megawatt Utility-Scale units unsuitable for distributed generation. At smaller sizes, the performance of existing wind-turbine designs degrades substantially. A new type of shrouded wind turbine, invented by Walter Presz and Michael Werle of Ogin Energy, saw its first multi-unit deployment at Mid-Scale (100kW-rated range) in 2015. This new turbine's shroud system pumps air around the turbine so that it is efficient at both Mid- and Small-Scale sizes and at lower wind speeds, thus supporting distributed generation and microgrids.

A recent analysis shows Utility-Scale Wind the cheapest renewable, with unsubsidized cost at about $80/MWh, Solar PV at about $150/MWh; conventional Mid-Scale Wind is $240/MWh—too expensive to make a substantial contribution. The new shrouded turbines provide electricity

at half the cost of the conventional Mid-Scale turbines today and will be cost-competitive with Utility-Scale Wind when they are in volume production.

We need to deploy enormous amounts of renewables to fully de-carbonize electricity generation and enable the necessary decommissioning of most of the existing fossil-fuel-consuming generating equipment. Wind can be deployed extensively much more quickly, safely, and cheaply than the often proposed scale-up of nuclear energy, and can be combined with grid storage such as batteries to make it fully dispatchable. If we get serious about de-carbonization, Small- and Mid-Scale turbines can be quickly scaled to high-volume production using existing manufacturing infrastructure, much as was done for materiel during WW II. Having cost-effective wind at all scales complements Solar PV and, with grid storage, completes a portfolio that can further accelerate the marked trend toward renewables.

3. **ROOM TEMPERATURE IONIC ELECTROLYTE FOR SOLID STATE BATTERIES**

Current lithium-ion batteries use a flammable liquid electrolyte and typically incorporate materials that further increase fire danger. Most contain expensive metals, like lithium, cobalt, and nickel. Last year brought publication of the existence of a new polymer electrolyte invented by Michael Zimmerman of Ionic Materials—the first solid to have commercially practical ionic conductivity at room temperature. The polymer is also inherently safe, self-extinguishing when set on fire. It creates a chemical environment substantially different from that of a liquid, supporting novel and abundant cathode materials, like sulfur (which is high-capacity, light, and inexpensive) and new and inexpensive metal anodes, thereby supporting multivalent species, like Zn2+. Many desirable battery chemistries, infeasible with liquid electrolytes, are newly possible.

This scientific breakthrough, shown only in the 2030s on most battery-industry roadmaps, has long been desired because solid batteries can be much cheaper and safer and store more energy. Solid polymer batteries can be manufactured using mature and inexpensive scale-manufacturing equipment from the plastics industry.

Fifteen percent of global CO_2 fossil-fuel emissions come from wheeled transportation. India and China’s fleets will grow substantially in the years ahead; whether energy for

these additional vehicles is provided by renewables or fossil fuels will make a significant difference in global emissions. Low-cost, safe, and high-capacity batteries can greatly accelerate the electrification of transportation and these fleets beyond the current modest projections.

In the 21st century, we need to stop combusting fossil fuels. Electrochemistry—both better batteries and fuel cells—has far greater potential than is generally realized and can displace most combustion.

There are other gas- and liquid-based technologies we can hope to convert to solid-state to reduce their CO_2 impact—such as cooling, which generally uses a liquid-gas phase transition today. I hope the future brings news of a solid-state cooling breakthrough that, like the above technologies, can be quickly taken to scale.

Juice

James Croak
Artist

In one hand you're holding a gallon of gasoline weighing 6 pounds, in the other a 3-pound battery; now imagine them containing equal energy. Spoiler alert: They already can. The most exciting and far-reaching scientific advance is the dramatic increase in electric-battery density, allowing it to displace gasoline and solving the problems of night electricity, vehicle range, and becalmed windmills.

Electric-car range increases about 9 percent per year and has reached a point where one can imagine round-trips that don't involve a flatbed. But the public was startled in 2011 when a seven-figure prize was claimed from Green Flight Challenge, which had offered it to an aircraft that could fly 200 miles in under two hours with a passenger, using less than a gallon of fuel. Three planes competed—two electric and one hybrid—with only the electric planes finishing within the allotted time. The winner averaged 114 mph on a plug-in electric plane *sans* a gas engine. This was a Tom Swift fantasy five years earlier, because the weight of the batteries was too much for the plane—even if they had been able to be crammed into fuselage. Their weight and size shrank, while the energy storage increased.

Battery density now peaks at about 250 watt-hours per kilogram, up markedly from 150 wh/kg a few years ago but still far below petroleum, which is 12,000 wh/kg. One company is about to release a 400 wh/kg, but batteries under development could pass the energy density of fossil fuels within a few years.

The most exciting and counterintuitive battery invented is the

lithium-air, which inhales air for the oxygen needed for its chemical reaction and exhales the air when finished. This should ring a bell: Gas engines inhale air and add a gas mist; the expanding air creates power but then expels an atmospheric sewer. The lithium-air battery is solid-state and exhales clean air. MIT has already demonstrated a lithium-air battery with densities of over 10,000 wh/kg.

Batteries need not have the energy density of gasoline in order to replace it. The physics of gasoline power are lame; only 15 percent of the energy in your tank powers the car down the highway; the rest is lost to heat, engine and transmission weight, friction, and idling. As a practical matter, batteries in the labs are already beyond usable energy density of fossil fuels, an energy density that results in a 500-mile range for an electric car with a modest battery and probably more for a small plane.

The second substantial change is that increased battery density has lowered both the size and cost of electrical storage, creating the bridge between intermittent wind and daytime photovoltaic energy, and the round-the-clock current demands of the consumer.

Windmills produce prodigious electricity during a good blow but bupkis when becalmed; the batteries provide steady current until a breeze appears. A new battery installation at the Elkins, West Virginia, windfarm keeps the 98-megawatt turbines as a constant part of the overall grid supply, with pollutant-free electricity and the reliability of a conventional fossil-fuel plant.

Also, fossil-fuel plants run at higher capacity than needed, in case of a spike in demand. A new megawatt battery installation in the Atacama Desert of Chile brought stability to the grid and a reduction in fuel usage.

The hoped-for green revolution is suddenly here, improbably due to the humble battery. A century ago, there were more electric cars on the road than gasoline cars. Very soon, we will be back to the future.

A Call to Action

Hans Ulrich Obrist
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The publication in 2015 of a paper by Mark Williams *et al.* titled "The Anthropocene Biosphere"* provides more evidence that the changes wrought upon the climate by human civilization are set to produce a sixth mass extinction. According to one of the paper's co-authors, geologist Peter Haff, we have already entered a period of fundamental changes that may continue to alter the world beyond our imagination. All of us can provide anecdotal evidence of the shifts in our environment. In December I received a call from a friend in Engadin, Switzerland, where Nietzsche wrote *Thus Spoke Zarathustra;* at an altitude of 2,000 meters, there was no snow. Meanwhile, in Hyde Park, the daffodils were blooming.

As the artist, environmentalist, and political activist Gustav Metzger has been saying for years, it is no longer enough just to talk about ecology: We need to create calls to action. We must consider the potential for individual and collective agency to effect changes in our behavior and develop adaptive strategies for the Anthropocene age. To quote Metzger, we need "to take a stand against the ongoing erasure of species, even where there is little chance of ultimate success. It is our privilege and our duty to be at the forefront of the struggle." We must fight against the disappearances of species, languages, entire cultures; we must battle the homogenization of our world. We must understand this news as part of a broader continuum. The French historian Fernand Braudel advocated the *longue durée*, a view of history which relegates the historical importance of "news events" to a place

beneath the grand underlying structures of human civilization. Extinction is a phenomenon belonging to the *longue durée* of the Anthropocene, the symptoms of which we are beginning to experience as news. By connecting the news to the *longue durée*, we can formulate strategies to transform our future and avert the most catastrophic extinction scenarios. By understanding the news, we can act upon it.

Art is one means by which we reimagine existing paradigms to accommodate new discoveries, the thread connecting the now to the past and future, the thread linking news events to the *longue durée*. Art is also a means of pooling knowledge, and it is, like literature, news that *stays* news. When Shelley stated that "poets are the unacknowledged legislators of the world," he meant something like this: that writers and artists reimagine news in ways that change how we perceive the world, how we think and act.

Among my great inspirations is Félix Fénéon, a fin-de-siècle French editor (and the first publisher of James Joyce in France), art critic (he discovered and popularized the work of Georges Seurat), and anarchist (put on trial, he escaped prosecution after famously directing a series of barbs at the prosecutor and judge, to the jury's great entertainment). Fénéon was a master of transformation. He transformed the news into world literature via his series of prose poems. In 1906 he was the anonymous author of a series of three-line news items published in *Le Matin* which have since become famous. Those brief reports adapted stories of contemporary murder and misery into prose poems that will last forever. Lawrence Durrell's *Alexandria Quartet* transformed the Copernican breakthroughs of Einstein and Freud into fiction. By translating events that are ephemeral and local in their initial impact into that which is universal and enduring, we can make news into culture.

John Dos Passos gave lasting form to events that seemed characterized by a fleeting immediacy. In his *U.S.A.* trilogy, Dos Passos pioneered new styles of writing that sought to capture the experience of living in a society overwhelmed by the proliferation of print media, television, and advertising. In his "newsreel" sections, the author collages newspaper clippings and popular song lyrics; elsewhere he pursues his experiments in what he called the "camera eye," a stream-of-consciousness technique that attempts to replicate the unfiltered receptivity of the camera—which makes no distinction between what is important and what is not. Later this material is transformed into stories. According to the filmmaker Adam Curtis, the *U.S.A.* trilogy identifies

> the great dialectic of our time, which is between individual experience and how those fragments get turned into stories, . . .

> [W]hen you live through an experience you have no idea what it means. It's only later, when you go home, that you reassemble those fragments into a story. And that's what individuals do, and it's what societies do. It's what the great novelists of the 19th century, like Tolstoy, wrote about. They wrote about that tension between how an individual tells the story of an event themselves, out of fragments, and how society then does it.

The Lebanese-American poet, painter, novelist, urbanist, architect, and activist Etel Adnan speaks about the process of transformation as the "beautiful combination of a substratum that is permanent and something that changes on top. There is a notion of continuity in transformation." In her telling, transformation describes the relationship between the *longue durée* of history, current news events, and action that can transform the future. She shows us how dialogue can produce new strategies that can preserve difference and help act against extinction, while also acknowledging that change is inevitable. If we are to develop radical new strategies to address one of the most important issues of our time, then we must go beyond the fear of pooling knowledge among disciplines. If we do not pool knowledge, then the news is just news: Each new year will bring reports of another dead language, another species lost. While writing this text, I received an email in the form of a poem from Etel Adnan which expresses this beautifully:

> ***WHERE DO THE NEWS GO?***
>
> *News go where angels go*
> *News go into the waste-baskets of foreign embassies*
> *News go in the cosmic garbage that the universe has become*
> *News go (unfortunately) into our heads.*

A Bridge Between the 21st and 22nd Century

Koo Jeong-A
Conceptual artist

Aristotle discussed magnetism with Thales of Miletus. Oriental medicine refers to the meridian circles and was treating by using the magnetic field before the invention of the acupuncture needle in the Iron Age. As the Italian philosopher Benedetto Croce wrote, “All history is contemporary history.” The magnet’s cryptographic character—relevant in the computer network, medical devices, and space expeditions through electromagnetic fields that link multiple cultural devices in our saturated era—as a decorous bridge between the 21st and the 22nd century, will still innovate. Far from extreme division, magnet-espoused technology would make peace in our world.