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xTech Futures:
BioTech

Bringing new life to people, products, and the planet

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INTRODUCTION

PREFACE

From macro to micro

This same time last year, our team of technologists published our first ***xTech Futures*** report. Its aim was to broaden the aperture of our annual ***Tech Trends*** report, creating room to talk about the xTechs—or exponential technologies beyond infotech—likely to change the way our world works and lives.

Our first *xTech Futures* report chronicled advancements in space technologies. In many ways, it was an exploration of the macro—the buzzing ecosystem of satellites, assets, and space stations above us.

This year's report focuses less on the macro, more on the micro. Less on what rests above us, more on what lies within us: biotech.

It would be easy to think of advancements in biotech as only relevant to PhDs in lab coats. But the truth is that if your company employs people, delivers products, or is geographically located on planet Earth, biotech is relevant for you and your business.

Although generative artificial intelligence (AI) has taken center stage as the mother of all efficiencies, we would posit that there's no more efficient system than Mother Nature herself. Name a more perfectly orchestrated machine than the human body, or a more effective form of compute than the brain.

Compiling this report led to humility. Despite how far humanity has come (and boy, have we come far), people still have much to learn from nature. Now, we're finally paying attention, in a way that's radically reshaping our industries and ways of being.

Instead of just taking inspiration from nature, we're harnessing it. Creating and building with biology so that we can design a better future not just for ourselves, but for all those who follow.

An exciting world awaits.

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WHY BIOTECH? WHY NOW?

From humanity's earliest days, the grace and efficiency of the natural world has propelled our advancement. Our awe of nature led us to harness fire, domesticate animals, and eventually decode the very fabric of life itself—DNA.

Modern biotech represents nothing short of a miracle in human ingenuity. Today, we find ourselves at a critical turning point, as monumental as the shift from analog to digital computing. The digital evolution of the 1940s, led by Alan Turing and others, brought about the first digital computers, characterized by their ability to store and process large amounts of data quickly and accurately. This breakthrough brought us the personal computer, the modern data center, the internet, and the mobile phone. The revolution came gradually at first, then all at once.

Much like the early years of computing, applications of new genomic technologies were once unclear. By the early 1900s, scientists became proficient in identifying and describing proteins, tissues, and DNA—an arcane yet critical foundation. Then, in the 1950s, Watson and Crick helped discover DNA's famed double-helix structure, and with it, the understanding that DNA was the fundamental information storage and processing mechanism for life. This discovery birthed an inspiring premise: If we can understand the code to life, then we can repair it, and eventually heal the entire body.

Our new understanding ushered in discoveries such as polymerase chain reaction (PCR), restriction enzymes, and the operon, which gave us lifesaving synthetic human insulin and Bt-corn, the varietal that now accounts for more than 90% of the corn grown in the United States[1]. Such early biotech inventions were on par with the creation of the microprocessor or integrated circuit, which enabled rapid invention and improvement of digital computers. And today's latest advancements in biotechnology, like CRISPR-enabled gene editing and prime editing, are no less impactful than the advent of generative AI. Our relationship to the natural world can now be engineered, not just received as is.

From a cost accessibility standpoint, biotech and genomics are moving faster than digital did in the 1980s or '90s. The falling cost of sequencing a human genome—from about US$14 million in 2005 to less than $1,000 today, —has even outpaced Moore's Law.[2]

The analogy between biology and information technology is not merely a metaphor. It is a reality that reflects the fundamental nature of life as information. Just as digital information can be stored, processed, and transmitted by computers, biological information can be stored, processed, and transmitted by living cells. And biotechnologists can now use that information to chart a predictable, programmable path to new products.

The scientific method was once solidified as a rigorous, evidence-based process for humans to make and re-make discoveries

about the natural world. But now, AI breakthroughs like the AlphaFold model can predict the molecular structure of many forms of life, saving hundreds of millions of years in research experiments, and trillions of dollars.[3] We're living through an era where the scientific method itself is being disrupted, as scientists across the world no longer have to start from scratch to solve the world's toughest puzzles.

In the chapters ahead, we will explore this inflection point in biotech access and opportunity. The modern biotech landscape has come to represent a wide swath of innovations such as rapidly engineered lifesaving therapeutics, ecological replacements for traditional textiles, and biological enzymes that dissolve plastic waste, to name just a few.

We are not just being inspired by biology. We are engineering with biology itself. The spectrum of products and technologies on the next page demonstrates just a sample of the wide range of innovation we're seeing across the industry. Many of these innovations open up the market for new entrants and major players alike to revolutionize health care, leapfrog the competition, and restore the planet.

However, it is not just about the potential of what can be achieved, but also the urgency of the challenges we face—from climate change to global health crises, from food insecurity to resource scarcity. The solutions to these challenges may very well lie in our ability to leverage biotech effectively and responsibly—to work with nature, instead of against it.

As we embark on this journey into the era of biotech, we invite you to explore, engage, and envision. Those who are willing to delve into the micro, the science of biology, could one day harness the natural world itself to build a better future. The lab is prepared, and the microscope is waiting. What will you discover?

THE SPECTRUM OF BIOINSPIRED TECHNOLOGIES

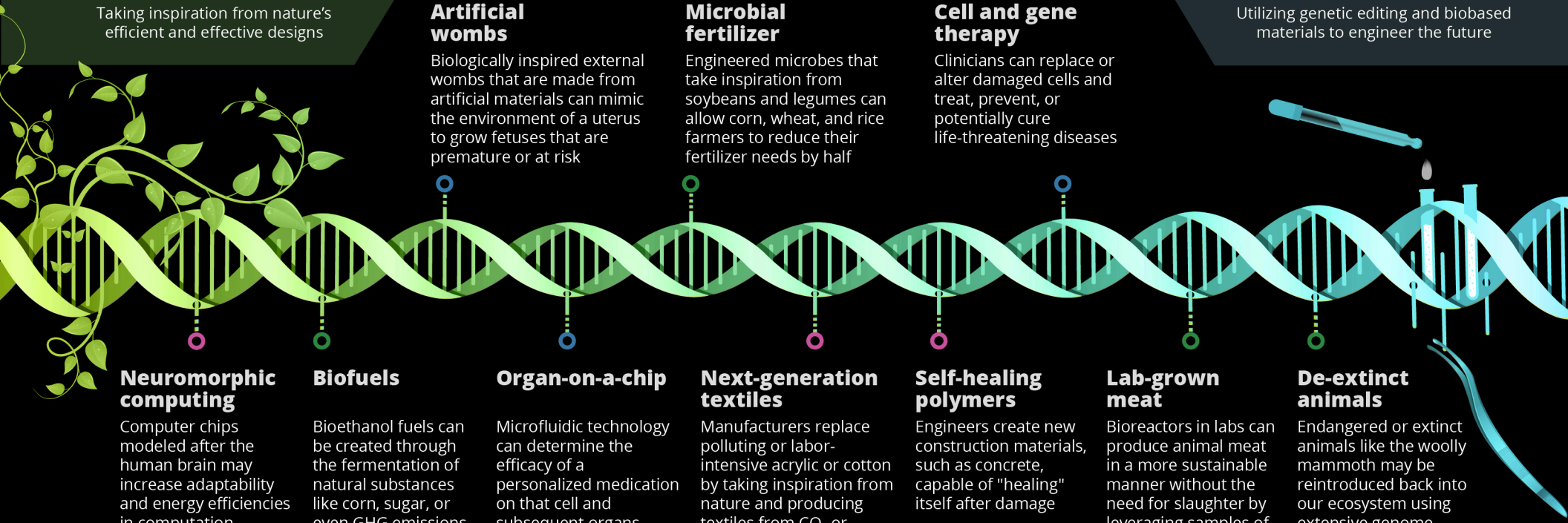
Biotechnology is helping us better build our products, plants, and animals with the blocks of life

BIOINSPIRED

Taking inspiration from nature's efficient and effective designs

BIOENGINEERED

Utilizing genetic editing and biobased materials to engineer the future



Neuromorphic computing

Computer chips modeled after the human brain may increase adaptability and energy efficiencies in computation

Biofuels

Bioethanol fuels can be created through the fermentation of natural substances like corn, sugar, or even GHG emissions

Artificial wombs

Biologically inspired external wombs that are made from artificial materials can mimic the environment of a uterus to grow fetuses that are premature or at risk

Organ-on-a-chip

Microfluidic technology can determine the efficacy of a personalized medication on that cell and subsequent organs

Microbial fertilizer

Engineered microbes that take inspiration from soybeans and legumes can allow corn, wheat, and rice farmers to reduce their fertilizer needs by half

Next-generation textiles

Manufacturers replace polluting or labor-intensive acrylic or cotton by taking inspiration from nature and producing textiles from CO_2 or organic inputs

Cell and gene therapy

Clinicians can replace or alter damaged cells and treat, prevent, or potentially cure life-threatening diseases

Self-healing polymers

Engineers create new construction materials, such as concrete, capable of "healing" itself after damage

Lab-grown meat

Bioreactors in labs can produce animal meat in a more sustainable manner without the need for slaughter by leveraging samples of an animal's stem cells

De-extinct animals

Endangered or extinct animals like the woolly mammoth may be reintroduced back into our ecosystem using extensive genome sequencing and genetic editing

Source: Deloitte analysis.

PEOPLE PRODUCTS PLANET

ABOUT THE REPORT

Our previous *xTech Futures* report was concerned with no less than rocket science. In this edition as well, we tackle advanced concepts at the cutting edge of science and technology. Breakthroughs that are en route to making blockbuster impacts on society. Our aim is to distill the complexities of biotechnology into digestible compounds of information that any reader can benefit from. Businesses across industries can take advantage of the opportunities of this exciting new field. To that end, while a majority of the examples we provide are US-based, the business opportunities previewed here will likely be available to organizations regardless of geographic boundaries.

To help you understand your organization's potential role in the emerging biotech economy, we structured this report into three chapters, as described here and shown in our **BioTech frontiers** framework.

PEOPLE

A path to longer, better lives for everyone could forever elevate the status quo for health and humanity.

PRODUCTS

Materials that were once shaped by the industrial revolution may now be transformed by the bio-industrial revolution.

PLANET

Biotech is blooming in the environment, reactively restoring and proactively preventing ecological damage.

Additionally, we have interspersed callouts throughout the report. Some of these introduce technologies, such as robotics, neurotech, and traditional IT, that intersect with biotechnology, while others illuminate the ethical considerations at stake in biological innovation.

INTERVIEWS WITH INDUSTRY EXPERTS

Some of our greatest insights came from speaking with leading industry experts. We'd like to thank the following individuals for their time and contribution:

Peter Diamandis, co-founder and executive chairman of Fountain Life; founder and executive chairman of XPRIZE Foundation

John Dobak, CEO of ClicBio and 10xBio

Mo Jain, founder and CEO of Sapient

Ben Lamm, founder and CEO of Colossal Biosciences

Chris Learn, senior vice president at Parexel

David Longo, CEO of Ordaos Bio

Gary Magnant, general partner at Formation Venture Engineering

Megan Palmer, senior director of public impact at Ginkgo Bioworks

Reshma Shetty, co-founder, COO, and president of Ginkgo Bioworks

Didier Toubia, co-founder and CEO of Aleph Farms

Ajay Verma, general partner at Formation Venture Engineering; CEO of Twilight Neuroscience

Ron Voglewede, group director of sustainable retail at Walmart

Steve Winitsky, vice president at Parexel

BioTech frontiers

People

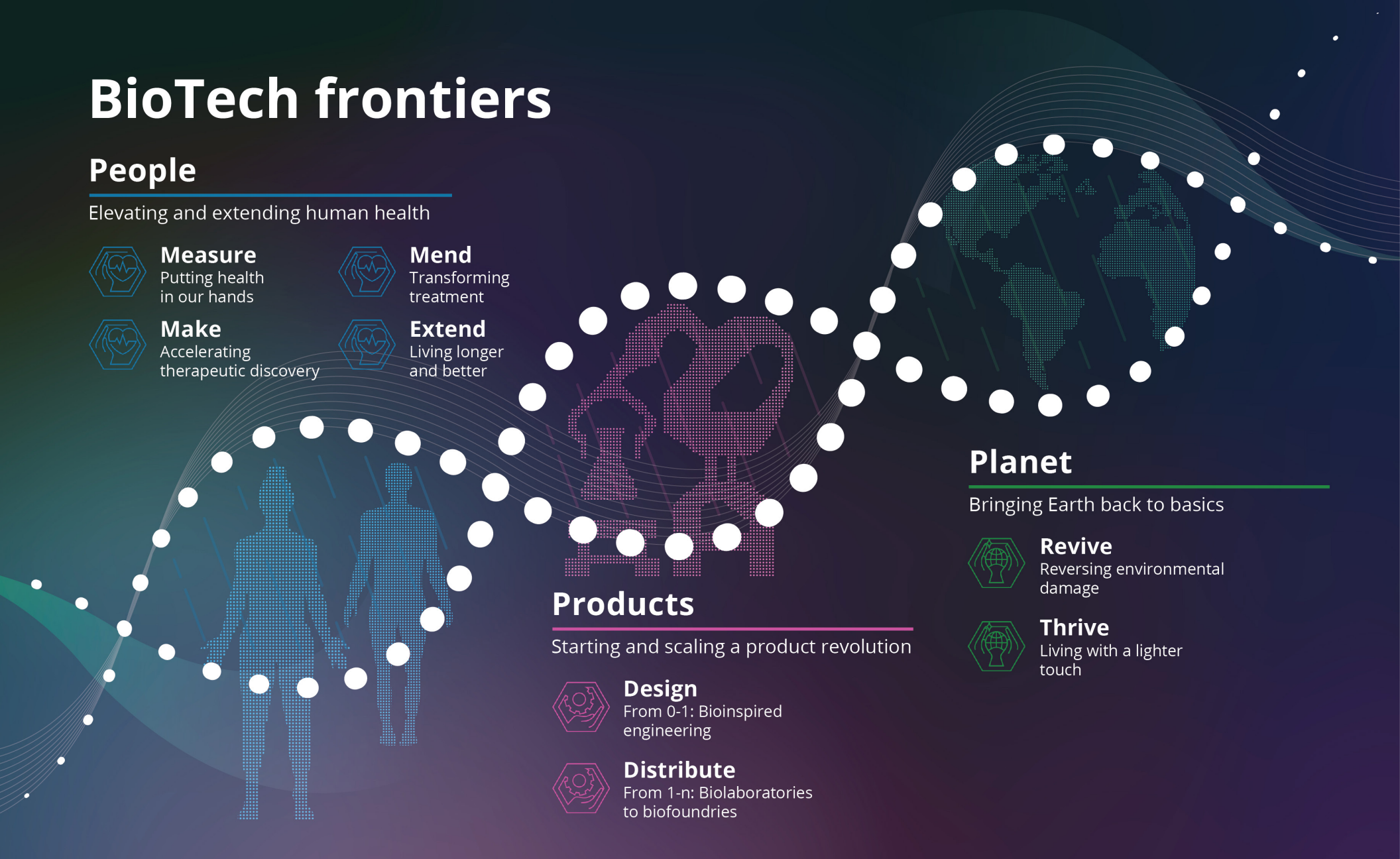
Elevating and extending human health

Measure
Putting health in our hands

Mend
Transforming treatment

Make
Accelerating therapeutic discovery

Extend
Living longer and better



Products

Starting and scaling a product revolution

Design
From 0-1: Bioinspired engineering

Distribute
From 1-n: Biolaboratories to biofoundries

Planet

Bringing Earth back to basics

Revive
Reversing environmental damage

Thrive
Living with a lighter touch

PEOPLE

Elevating and extending
human health

PEOPLE

ELEVATING AND EXTENDING HUMAN HEALTH

At the turn of the 20th century, a newborn baby could expect to live an average of 32 years, depending on where they were born.[4] Pernicious bacterial infections endangered infants and young children and an influenza pandemic would soon sweep the globe, killing more than 50 million people.[5] Diseases like cancer remained mysterious and untreatable, and the double helix structure of deoxyribonucleic acid (DNA) wouldn't be discovered by Crick, Watson, and Franklin for another five decades.

Fast-forward just over a century and the landscape of human health is nearly unrecognizable in comparison. Antibiotics, chemotherapy, and vaccines, among myriad other inventions, emerged and scaled. Researchers sequenced the human genome, discovered and distilled insulin, and developed magnetic resonance imaging (MRIs). Babies born in 2024 benefit from these innovations to the tune of extra decades, with life expectancy reaching up to 80.[6] Today, we regard strep throat, a disease that killed around one-fifth of those infected prior to antibiotics, a minor inconvenience.[7] In the future, we may look at cancer the same way.

Biotechnology is the hero of this story. It enables humans to measure health with deeper understanding, make a new set of tools to discover and deliver treatments, and mend issues in our own DNA through revolutionary genetic-editing capabilities. This newfound agency mirrors a broader technology-enabled transformation happening across health care, from the individual patient and provider to the whole population. Ultimately, today's breakthroughs could extend our tomorrows, empowering us to live longer and better.

MEASURE
Putting health in our hands

Health care is under construction. The convergence of groundbreaking innovation and seismic sociocultural shifts (not to mention global pandemics) is beginning to reframe how consumers view and experience their health care journeys. One of the most significant is a pivot to a more distributed model of care. To avoid a trip to the hospital or clinic, patients are leveraging emerging technologies, ranging from AI to wearables to at-home testing tools, to actively take control of their health. The tired adage, "an apple a day keeps the doctor away" has morphed into a massive consumer and services market where now an app a day keeps the doctor away.

This new era is fueled in part by the proliferation of cheap and accurate sensors and supercharged by rapid advancements in AI and machine learning. Around 60% of US consumer households already own wearable devices like smartwatches, and skin-based sensors in those wearables enable users to gather complex health metrics at home.[8] Electrocardiograms (ECGs), sleep quality, and hormone levels are all examples of measurements made accessible through wearables that would've previously required hospital visits.[9] And because small changes in heart rate and skin temperature can indicate when the body is fighting off an infection, these devices also have the power to assess disease before someone even feels symptomatic (when used in collaboration with a medical professional).[10]

On top of staying informed, patients also need answers when symptoms strike. Fortunately, accurate diagnostic tests are increasingly available. Just as the first at-home pregnancy test served as "a private little revolution any woman can easily buy at her drugstore,"[11] new classes of tests are expanding to encompass thousands of illnesses and empower patients. Whether it's a urine monitor capable of evaluating metabolism or a "smart pill" that detects gut inflammation, the possibilities extend beyond and beneath surface level.[12]

The influence of our traditional "sick-care" health system is diminishing, and a "well-care" system of early detection and prevention is beginning to replace it. The global at-home testing market reflects this exciting potential, valued at over $16 billion in 2021 and expected to grow at an estimated compound annual growth rate (CAGR) of 10.5% through 2031.[13] That expansion includes both tests for infections, such as wearable breath sensors capable of detecting COVID-19, and tests for traditionally under- or undiagnosed conditions, such as endometriosis.[14]

Together, these emerging technologies and systems are driving health care toward a new paradigm: The individual patient has access to continuous health data. Individuals can receive personalized recommendations, and public health professionals can anticipate the next pandemic-scale event. However, not

all of that data is intuitive, and many would be rightfully concerned about the privacy implications of gathering so many inputs. Finding the right balance between providing actionable, contextual insight and overwhelming patients with unnecessary information or data monitoring is a critical challenge. As Mo Jain, CEO of the biomarker discovery organization Sapient, explains, "Generating more data is not the end goal; the end goal is generating more insights that can be acted on."[15]

NEURAL INTERFACES
Thinking is the new doing

Although wearables today mostly refer to watches and armbands, in the future we'll increasingly utilize data collected from our brains via headsets, ear pods, and other devices. Brain-computer interfaces, or BCIs, have been studied since the 1960s, when researchers attempted to control simple devices like lightbulbs using brain signals. In the modern day, uses have expanded to more complicated operations like speech decoding, mental-state classification, and brain-to-brain communication. As more viable technology is developed, the market for these futuristic devices is predicted to grow to US$6.2 billion by 2030, with applications in health care, entertainment, communication, and gaming, among others.[16]

MAKE
Accelerating therapeutic discovery

Even the best preventive measures are not guaranteed to keep us healthy all the time, and many of us may require lifesaving treatments at some point. Fortunately, the way that we discover and develop therapeutic drugs is supercharging every step of a drug's journey from lab to bedside, making the phrases "too little" and "too late" relics of an earlier era.

The journey of better therapeutics begins with advanced computation tools, such as generative AI, that can analyze biology at breakneck speed. Consider the change in how we understand proteins. These critical molecules, often thought of as macronutrients, can also be used by the body to neutralize foreign substances and fight off infection, making them crucial inputs to pharmaceuticals.[17] Harnessing a new protein requires understanding its structure, which is notoriously hard to predict due to the sheer number of possible combinations.[18] But now, revolutionary deep learning models such as AlphaFold are achieving what was previously impossible. AlphaFold can identify complex relationships among large datasets and predict the structures of most forms of biological life, thereby transforming the typical drug discovery process.[19] Subsequent efforts, such as Salesforce Research's Progen Model—an AI language model trained on the largest protein database available—are producing novel protein designs that could be more effective in delivering drugs to infected cells.[20]

Once treatments are identified, they begin the long and arduous path through clinical trials. The cost per approved drug made

by major pharmaceutical companies is around US$2.3 billion, a staggering sum that accounts for many failed compounds (on average, 70% of drugs don't make it to market).[21] Fortunately, a combination of in silico (computer simulations) and in vitro (lab-based experiments) testing techniques stand ready to cut into this mountain of risk, as shown in the infographic on the next page.

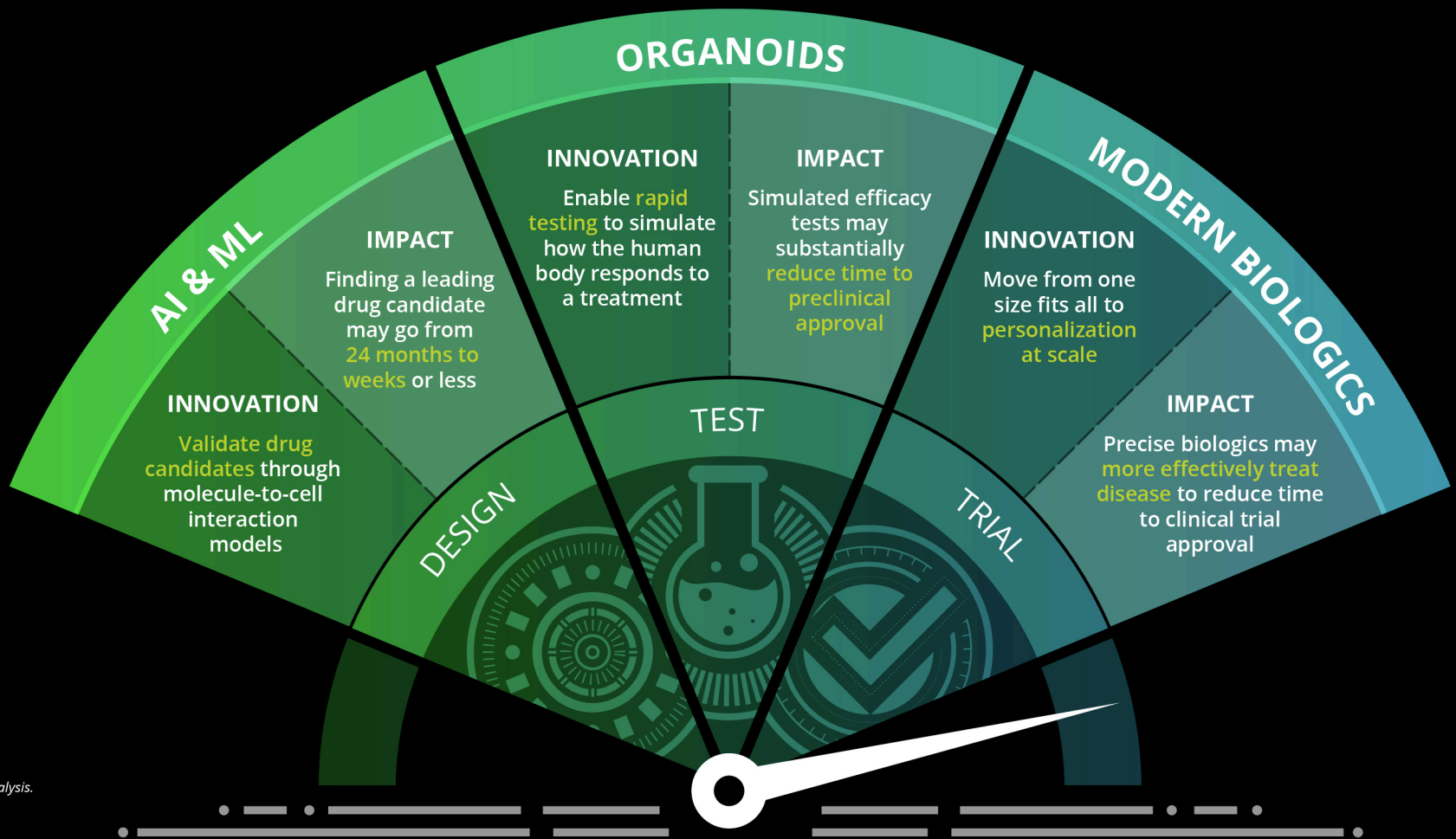
One day, quantum computers could rapidly simulate complex biomolecular interactions to de-risk new compounds and drastically compress the 13-year drug development timeline.[22] Even now, an AI tool called inClinico has demonstrated nearly 80% accuracy in predicting the probability of success in phase 2 and 3 clinical trials, which generally cost tens of millions of dollars.[23] With better predictions and digital twin simulations, companies can restrict their investments to the clinical trials that have the highest degree of confidence. Altogether, integrating AI across the entire drug development process could cut down on time to market by 40%.[24]

In vitro testing of therapeutics has also proven beneficial for studying diseases and even simulating human testing. Notably, organ-on-a-chip technology (which leverages microfluidics) mimics the environment within our organs and tests drugs on specific cell populations without a human trial.[25] Organoids, miniaturized three-dimensional versions of human organs that are derived from a few cells of organ tissue, also offer a promising window for testing therapeutics. Since organoids mimic the key facets of a full human organ, they can offer insight into complex biological processes like menstruation and enable more personalized medicine.[26]

As drugs are discovered and refined through advancements in computation and simulation, the efficiency of drug production is poised to greatly improve. The next stage, then, is ensuring these breakthrough treatments are successful

ACCELERATING DRUG DEVELOPMENT

Advancements across IT and biotech are making drug development more effective and efficient than ever before



Source: Deloitte analysis.

once delivered to patients. Even with the robust simulations at our disposal, no two patients are the same, but personalization at scale is now possible through the advent of modern biologics. These drugs, derived organically instead of chemically produced, use new understanding of genome and protein sequencing to better target their treatments to disease.[27]

Finally, for this progress to continue, safety should be of utmost importance to biotech companies that seek to impact human health. David Longo, the CEO of drug design company Ordaos Bio, emphasizes, "The power of AI allows us to design drugs with idealized properties. That has to include making drugs safer by avoiding off-target issues and development liabilities."[28]

MEND
Transforming treatment

Beyond accelerating the treatments we already have, scientists are now broaching entirely new frontiers of medicine. Synthetic biology, a term often used in parallel with biotechnology, aims to create new biological systems or redesign existing ones. New therapies in this field can engineer our very genetic material to be more resilient or study our body's blueprint to develop more targeted treatments.

GENE EDITING

Twenty years beyond the first partially complete sequencing of the human genome in 2003, scientists can now reliably manipulate the genome.[29] Fueled by innovations like CRISPR-Cas9 that simplify genetic editing, our understanding is now being translated into treatments that rewrite our genetic code and our perception of the term "incurable."[30]

For instance, the FDA recently approved a gene therapy, known as Casgevy, to treat the life-threatening condition of sickle cell disease. The treatment extracts the patient's own cells, edits out the mutation that causes red blood cells to take on a sickle shape, and then reinfuses those cells back into the patient. Following treatment—of a disease previously considered near incurable—93.5% of patients were free from a serious sickle cell event for at least 12 consecutive months.[31]

Novel uses of CRISPR's gene-editing capabilities are further fortifying the body against diseases that have evaded medical cures. Prime editing, best compared to the "search and replace" function in digital documents, can directly write new genetic information into a specific DNA site for a broad range of therapeutic applications.[32] This technique is also being used to engineer improvements in chimeric antigen receptor (CAR) T-cells, a targeted immunotherapy that turns the immune system's attackers (T-cells) into guided missiles, leading to improvements in patients who haven't responded to other therapies for years.[33]

According to doctors Chris Learn and Steve Winitsky, of Parexel's Cell and Gene

Therapy Center of Excellence, "Gene editing may foundationally reset the practice of medicine. It is the ultimate goal for treating all kinds of diseases."[34]

NANOTECH IN MEDICINE

Good things come in small packages

Nanomedicine and nano-delivery systems are a relatively new science where miniscule materials are used to diagnose or deliver therapeutic agents to specific targeted sites.[35] These advancements could allow for more precise, lower dosages to patients—ultimately leading to lower drug toxicity and treatment burden.[36] The global nanotechnology drug delivery market size is expected to grow from US$95 billion in 2022 to US$308 billion in 2032.[37]

RNA THERAPIES

While the double helix of DNA is broadly familiar, its single-stranded companion, ribonucleic acid (RNA), has only recently debuted on the mainstage of popular science. The COVID-19 pandemic accelerated the introduction of RNA-based therapies to the market, especially the mRNA (messenger RNA) vaccine that can send detailed instructions to the body's cells to fight disease. Going forward, RNA therapies are poised to usher in a new era of targeted treatments for afflictions ranging from cancer to ALS.[38]

Today's mRNA vaccines are faster and easier to produce than traditional vaccines as well, thanks to the ability to scale production using standardized components (akin to a biotech-inspired assembly line).[39] These exciting possibilities are driving significant market interest as more than 115 pharmaceutical companies are now developing mRNA assets.[40]

TARGETED THERAPIES

With the advent of all these new therapies, the natural question for many is whether cancers can be defeated as well. Longo of Ordaos Bio shares, "The average cancer patient lives about six years following

diagnosis. If we can develop and roll out innovations that beat the speed of the disease, we can greatly benefit patients."[41]

New tools, similar to debugging software, enable us to find genetic markers affiliated with a cancer and then direct the immune system to eliminate those flaws. Antibody-drug conjugates (ADCs), for example, leverage the immune system's existing targeting system, antibodies, to deliver powerful drugs directly to cancer cells. Radiopharma, the long-standing treatment of radioactive drugs for cancer patients, has progressed to delivering radiation directly to cancer cells, significantly reducing the risks and side effects of traditional chemotherapy.[42] Given the new possibilities, Point Biopharma, a radiopharmaceutical startup, was recently acquired by Eli Lilly for US$1.4 billion, while Ratio Therapeutics, another startup, is partnering with Bayer AG to develop treatments capable of accurately locating tumors and destroying cancerous tissue.[43]

Clearly, the scientific community has made enormous progress in fighting diseases that have long plagued humanity. At each critical juncture, new discoveries and treatment methodologies (e.g., mRNA vaccines) have led to important changes in the vitality of human life. And now, we're also making progress in understanding the actions and medicines we can take throughout our lives to increase longevity.

RESPONSIBLE GENETIC MODIFICATION

The potential dangers of designer babies

In 2018, scientist He Jiankui announced that he had used CRISPR-Cas9 to genetically modify the embryos of twin babies, making them resistant to HIV.[44] A global uproar among the scientific and civilian world promptly ensued, sparking immense and ongoing debate about the ethics of using genetic modification tools to alter human embryos. Consider the issues of inequality and access, as such treatments would be prohibitively expensive and only available to the rich. Not to mention, incorrect gene editing could result in disease or unintentionally create new genetic diseases that would be passed down. The ability to modify a human being's genetic code is revolutionary, but we must be cautious, intentional, and ethical in our collective global approach.

EXTEND

Living longer and better

Our bodies function like well-oiled automobiles, requiring regular maintenance and checkups, and, on occasion, replacement parts. The parallels extend back for decades. Annual physicals were introduced just a few years before annual car safety inspections in 1949—both designed to keep their subjects running better for longer—and well-kept machines and bodies can now reach far beyond the life expectancies of years past. Moving forward, instead of just trying to reach a certain mileage or life expectancy, say 80 years, we're trying to reach that milestone with *less maintenance required*.

ROBOTIC EXOSKELETONS

Supporting humanity as we age

An exoskeleton is a wearable, integrated structure that supports the body, in place of or in addition to the internal skeleton. While they are now used primarily for rehabilitation, there are emerging use cases in industrial and military settings. Case in point: Lockheed Martin's Onyx, a 20-pound wearable robotic suit made of carbon fiber and titanium, that uses predictive AI and sensors to reduce strain on muscles and joints, boosting efficiency and safety in a range of professions such as firefighting.[45] Exoskeletons could one day empower many of us to stay able-bodied for longer, increasing well-being and mobility even in advanced age.

As Peter Diamandis, co-founder and executive chairman of Fountain Life, Inc., has claimed, "The two largest business opportunities on the planet today are AI and longevity."[46] To that end, Diamandis founded a US$101 million competition, known as the XPRIZE Healthspan, to "revolutionize the way we approach human aging."[47] Though many early longevity solutions aren't affordable for the masses, improving accessibility and equity is a market imperative: Health inequities today account for approximately US$320 billion in annual healthcare spending in the US, and could eclipse US$1 trillion in annual spending by 2040 if left unaddressed.[48]

Thankfully, researchers are making progress on spreading the benefits of longevity technologies. Recent advancements in our understanding of aging are allowing us to better decipher the body's opaque journey from birth to death. For example, companies like InsideTracker are marketing solutions to track biological age, scoring how efficiently your body is aging against chronological age.[49]

Scientists are building on this knowledge and market opportunity to combat aging through three increasingly involved vectors: lifestyle changes, preventive treatments, and antiaging drugs.

LIFESTYLE CHANGES AND TRACKERS

As diet and fitness optimization become increasingly accessible, the resulting cultural shift is feeding consumer interest in mass-market biotechnology. Bestselling authors like Peter Attia—who makes viral claims that exercise is the most potent pro-longevity "drug,"—are contributing to a market for digital fitness trackers (as referenced in the *Measure* section above) that could surpass US$93 billion in 2024.[50] Meanwhile, green powder brands like Athletic Greens that promise cellular repair are just one facet of a burgeoning worldwide health food market that is also growing year over year.[51]

PREVENTIVE CARE

The second vector of longevity seeks to prevent or reduce the impact of commonly fatal diseases, such as heart disease, type 2 diabetes, and Alzheimer's disease, through advances in research. Science magazine named the development of GLP-1 agonists, medications that can help manage

type 2 diabetes and obesity, as its 2023 breakthrough of the year.[52] John Dobak, CEO of ClicBio and 10xBio, agrees: "If you want to have a big impact on heart disease, strokes, and cancer, you need to learn how to treat obesity."[53] While there are still unknowns, the popularity of GLP medication is inarguable—more than a fifth of Americans have already asked their doctor for the drug Ozempic.[54]

Alzheimer's disease does not yet have a similar breakthrough, but new immunotherapy approaches could improve quality of life for the elderly. Like other dementias, Alzheimer's is caused by a buildup of toxic proteins around nerve cells that leads to inflammation. Ajay Verma, CEO of Twilight Neuroscience, seeks to understand why natural immunity protects some people from this toxic protein buildup while failing in others.[55] His company is leveraging technologies developed to address the COVID-19 pandemic and emerging links between infections, vaccination status, and dementia to develop a precision approach that can clear out toxic proteins. According to Gary Magnant, general partner of Formation Venture Engineering, which backs Twilight, the goal is to "create low-cost immune monitoring and vaccination approaches that can broadly help prevent the age 50 and up population from developing dementia."[56]

ANTIAGING DRUGS

The final combat strategy against aging lies in the search for a one-pill solution, or a pharmaceutical "fountain of youth," that can address multiple ailments. For instance, Metformin, a drug that controls glucose release from the liver, has been preliminarily found to slow aging and increase life expectancy by improving the body's responsiveness to insulin and antioxidants.[57] Similarly, Rejuvant, a drug aimed at winding back the biological clock, claims to achieve an eight-year reduction in biological aging after seven months of use (on average).[58] Finally, senolytic drugs are being developed to target and kill senescent cells, which secrete inflammatory molecules that injure tissue as a person ages.[59]

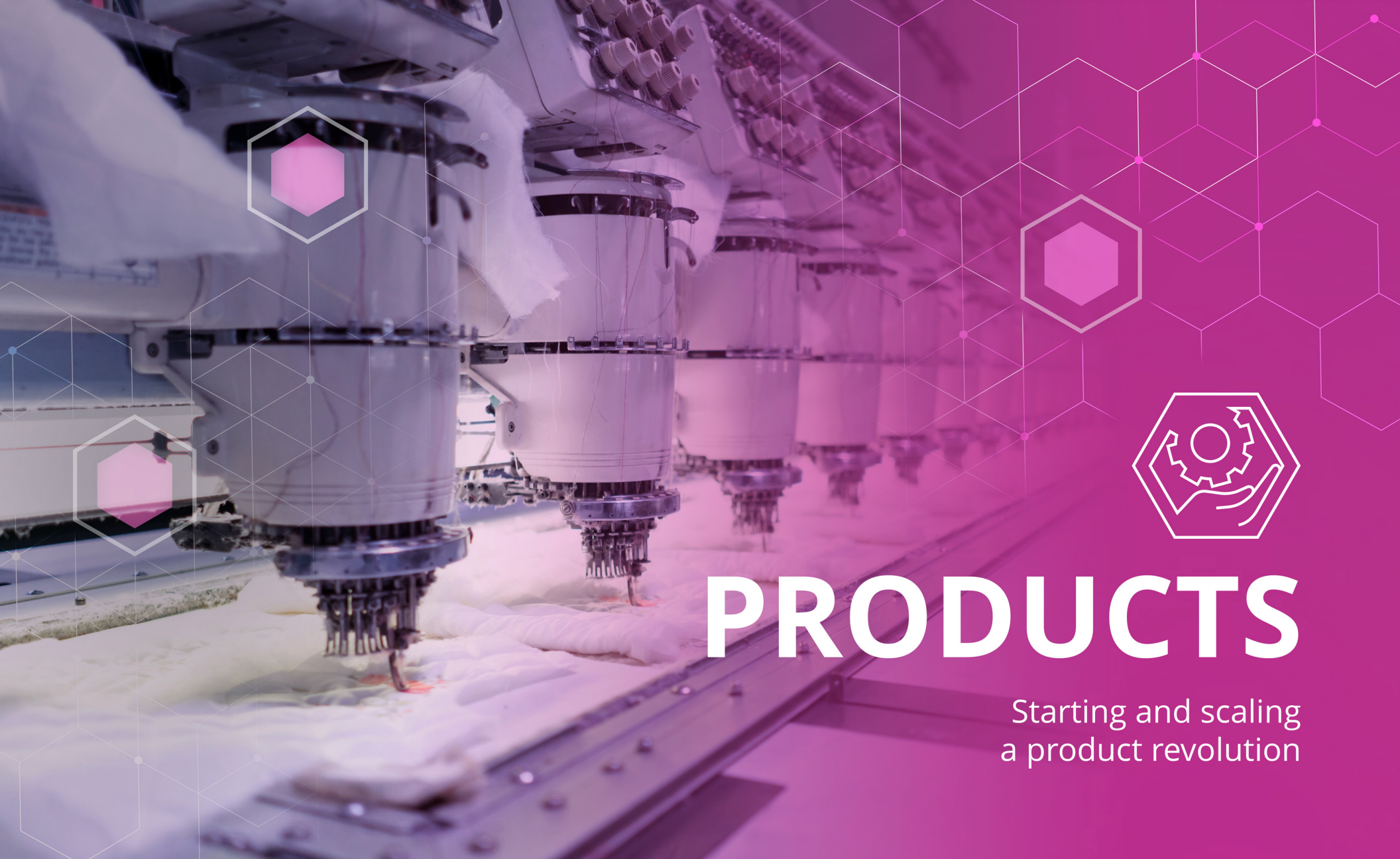
The collection of breakthroughs now at our fingertips could lead to a future where the average life expectancy jumps from 80 to 90, a result of improved health equity.[60] An increase of healthy living, enabled by these biotech innovations, could not just extend lives but also expand economies, meaning companies across industries should be paying attention to what's to come. As Diamandis of Fountain Life states, "One healthy year added onto the average life expectancy in the US is worth US$38 trillion for the global economy."[61]

FINAL THOUGHTS

The World Health Organization recognizes the right to health as a fundamental human right. Yet, we live in a world where health is not distributed fairly. Some struggle to secure the most basic care for preexisting conditions, while others live comparatively unburdened and unscathed. Some face an uphill battle against preventable issues, while others are resigned to the losses of their genetic lottery. Human health need not stay this way. Fortunately, the companies mentioned in this chapter are still just scratching the surface of opportunities to address health outside hospitals.

Biotechnology innovations can hold the pen in rewriting our prevailing narrative on health equity, to change the story from one of disparity to one of shared prosperity. In the future, early and accurate data-informed diagnoses can be accessible at our fingertips; rigid statements of incurability can be broken open by gene editing; and personalized, efficient therapeutics can be prescribed widely. Just as advancements in computing have democratized our global access to knowledge, so, too, can advancements in biotechnology and AI democratize our access to health services. Organizations that recognize the opportunity could have an outsized impact in meeting the needs of future consumers.

Reaching this ideal will likely require great feats of technology advancement and industry reorganization. The good news is that our journey is already well underway: New markets like wearables have already become a staple of buying behavior. Biotechnology is also forging forward to redefine the way we build our products and live on our planet, meaning that every single business can be affected. As you read the following chapters, keep in mind that human health is inextricably tied to innovations that reduce plastics, microbes that heal our soil and oceans, and industrialization that becomes fully carbon-neutral. Indeed, as people, products, and planet are increasingly intertwined, biotechnology improves the health of all three.



PRODUCTS

Starting and scaling
a product revolution

PRODUCTS

STARTING AND SCALING A PRODUCT REVOLUTION

Unbeknownst to many, biology has consistently inspired industrial innovation. The first airplanes were inspired by the effortless glide of birds. Olympic swimsuits were built to imitate the membranes of dolphin and shark skin for optimal fluid dynamics.[62] From biology, we've learned time and again how to use the diverse forms and functions of living organisms to create novel designs, materials, and processes for everyday products.

In the past, humans relied primarily on natural raw materials (e.g., wood and cotton), but in the age of industrialization, we introduced—and increasingly have come to rely on—synthetic and engineered materials (e.g., laminate and nylon). Biotechnology advancements are now bringing these two strands together. We're starting to see materials that are both *engineered* and entirely *natural* (e.g., synthetic spider silk, as shown in the infographic below) thanks to our nascent abilities to reproduce biological materials on our own terms. As these innovations trickle into everyday life, we're not only benefiting from gains in efficiency and effectiveness, but as we detail in the next chapter on Planet, we're also engineering a healthier planet for future generations.

Biotechnology does, however, face a challenge in achieving scale. For scientific breakthroughs to make the long journey from laboratory to consumer homes, we need better ways to produce and distribute innovations to all. After all, Henry Ford's assembly line arguably had a greater impact than the Model T it produced. Adaptable systems are thus needed to test and manufacture biology-based products on a large enough scale to drive economic impact and open the chapter on a new type of industrial revolution—one where biology graduates from inspiration to accelerant.

DESIGN

From 0–1: Bioinspired engineering

As Ron Voglewede, group director of sustainable retail at Walmart, says: "Nature does things better and more efficiently than the machines we've made in the past. Look at the energy efficiency of the hummingbird. Biology is just better."[63] From design inspiration to reengineering of organic materials, biotechnology is enabling product designers and manufacturers—across industries like plastics, textiles, and even construction—to emulate nature's efficiency, sustainability, and adaptability.

Consider the food plastics industry, an immense US$450+ billion market.[64] Food

packaging traditionally uses plastic because it is cost-effective and provides protection from pathogens, but the toxins in plastic can be hazardous to human health.[65] Bioinspired packaging materials, on the other hand, can be equally cost-effective and protective, but even safer for human health. For example, scientists inspired by the water-repellent lotus leaf have coated starch fibers with naturally occurring stearic acid (a fat-based water repellent) to create biodegradable packaging. Such efforts could one day significantly reduce the need for plastic and plastic-based toxins.[66]

Biotechnology also ventures a step beyond bioinspiration to fully reengineer natural materials for consumer products. Organizations in the apparel industry, which accounts for 10% of greenhouse gas emissions from human activity (more than aviation and shipping combined), seek to engineer such alternatives for common textiles.[67] For instance, the San Francisco-based startup Rubi Laboratories uses plant enzymes to capture and convert carbon dioxide, taken from sources like textile manufacturing facilities, to produce viscose, the third most used textile fiber worldwide.[68] The resulting material aims to be fully carbon-negative, water-neutral, and naturally biodegradable.[69]

Similarly, Keel Labs, a series A startup in North Carolina, was inspired by seaweed's ability to absorb carbon dioxide. The company created a bio-based fabric that uses 70 times less water than cotton and completely eliminates pesticide use. In contrast, the cotton industry requires US$2 billion to US$3 billion in pesticides annually.[70] Furthermore, Lululemon recently launched its first product utilizing plant-based nylon, a sustainable and recyclable alternative to a historically problematic material.[71]

Another key use case for bioengineering is in construction materials, where innovation is sorely needed. Whether due to natural erosion or poor quality standards, the global market for concrete repair is growing each year.[72] In addition, the production of cement, a key input to concrete, accounts for roughly 8% of global greenhouse gas emissions.[73]

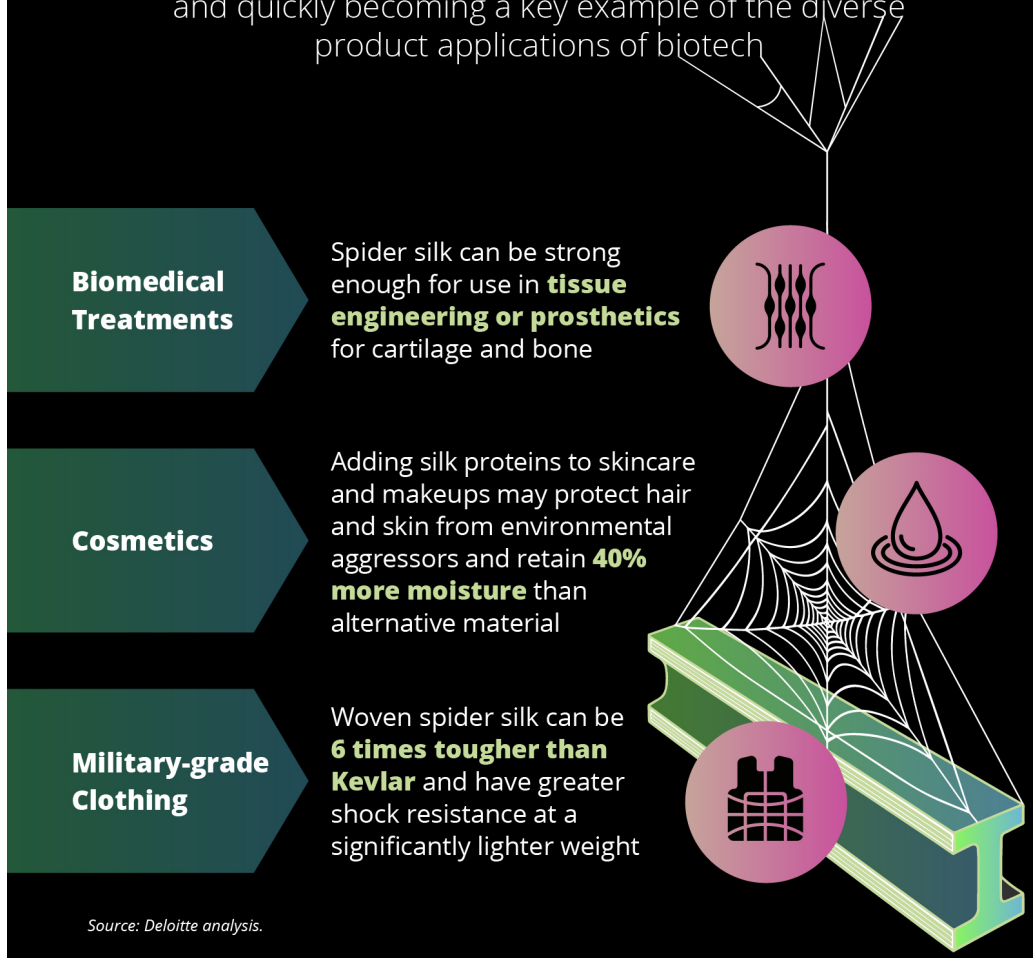
Companies like Biomason and Fortera mitigate these concerns through biomineralization, the natural process by which living organisms produce minerals, like coral or our own skeletons. Instead of burning limestone to make cement, biomineralization allows these companies to grow concrete bricks (using microbes to bond together crushed rocks) that last longer and require zero carbon emissions.[74] These bricks, embedded with self-healing polymers that can seal their own cracks, may forge the resilient buildings of the future.[75]

The plethora of revolutionary bioengineering concepts indicates a future where materials can be far more energy-efficient, cost-effective, and resilient than traditional alternatives. For that reason, the biocement market is projected to grow at a 37% CAGR in the coming years, while the bioplastics market could grow at more than 18%.[76] Zooming out, the US National Institute of Standards and Technology (NIST) estimates the overall biomanufacturing economy to be more than US$1.3 trillion, indicating an immense scale of opportunity.[77]

The momentum for biotechnology-based advancements in materials and products is geared to make a significant impact on our industries, but only once we develop economies of scale. After all, one tree is beneficial, but a forest sustains life.

SYNTHETIC SPIDER SILK

Once notoriously difficult to produce, synthetic spider silk is 5 times stronger than steel by weight and quickly becoming a key example of the diverse product applications of biotech



Source: Deloitte analysis.

BIOCOMPUTERS

Computing with the power of the brain

Biocomputers, composed of hard silicon and soft brain tissue, attempt to combine the performance of computers with the energy efficiency, plasticity, storage, and parallel processing capabilities of the human brain.[78] For example, Melbourne-based startup Cortical Labs is working on a product named Dishbrain, a semi-biological computer chip with approximately 800,000 lab-grown human and mouse brain cells in its electrodes.[79] The computer system learned to play Pong in less than five minutes, thanks to a training system that rewarded the cells with predictable stimuli.[80]

DISTRIBUTE

From 1–n: Biolaboratories to biofoundries

Consider the journey of a famous biological product: Alcohol, the happy discovery of Neolithic humans who left rice, honey, and grapes in the bottom of a clay pot, where they turned into a fermented beverage.[81] As its popularity increased, alcohol evolved from a culturally specific beverage with experimental production processes to a globally consumed drink requiring large-scale operations, major distilleries, and standardized distribution. A similar advancement is underway that could change the face of bioproduction.

Today's biolaboratories—experimental settings that slowly transform scientific breakthroughs into biotech products—are graduating to biofoundries that can accelerate bioproduction. In these settings, robust automation and analytics (i.e., precise robotics, computer-aided design, and AI), are combined to speed up tedious lab work and engineer entire biological systems. In turn, this enables scientists to develop a new range of products from biofuels to cosmetics to pharmaceuticals.[82]

"In the way that many companies shifted to cloud servers for superior performance and lower cost, biotechnology companies are now outsourcing their research and development to biofoundries," says Ginkgo Bioworks COO Reshma Shetty.[83] The US National Science Foundation plans to deploy US$50 million to US$70 million in research grants toward the further development of biofoundries, like Solugen and Ori Biotech, that can reduce multiyear manufacturing timelines and cut the cost of goods by 50%.[84]

Another key aspect of the shift to scale is fermentation facilities. Now that scientists can genetically modify the microorganisms in fermentation (e.g., yeast and bacteria), a bevy of new use cases has opened. For instance, Givaudan, a leading Swiss fragrance company, is looking into "nature-friendly" fermented substitutes for the ingredients in its cosmetics.[85] And California-based UPSIDE Foods recently sold the first cultivated chicken (also a product of fermentation) in America in July 2023.[86]

In light of these exciting possibilities, pilot and full-scale fermentation capacity needs to grow quickly to keep pace with demand.

If only 10% of global meat consumers were to switch to lab-grown alternatives, the demand would still be 50,000 times more than the capacity of all global fermentation facilities.[87] The market for cultivated meat is expected to grow by nearly 15% annually over the next decade.[88]

Such demand for bioengineered products is likely to grow well into the future, especially if consumer sentiment, sustainability, and profit march hand in hand. Companies that want to take advantage of this trend should consider building bioproduction infrastructure today or partnering with contract development manufacturing organizations (CDMOs) that already have infrastructure and expertise. After a long period of experimentation and discovery, the biotechnology industry is making a marked shift from working to working at scale—and early movers are poised to benefit.

FINAL THOUGHTS

When we think of biotech as a whole, we tend to think about how advances in tech can bolster our biology, as we discussed in our previous chapter on *People*. But the inverse is just as interesting: Our understanding of biology can ameliorate our technology and its resulting products.

The newfound powers of biotech are ushering in an era where bioproduction could scale to industrial levels. Soon, even the most cautiously invested organizations, whose chief concerns are to increase product quality, lower costs, and deliver competitive services, are likely to join the growing trend. With this in mind, Walmart is exploring new bio-sustainable alternatives up and down the supply chain.[89] The myriad products we take for granted may increasingly be created and enhanced with biological understanding, bringing them closer into harmony with the natural world. As we'll discuss in the following chapter, *Planet*, the biotech revolution is poised to reverse the ecological harms of the industrial revolution. The world-renowned architect Frank Lloyd Wright once said, "Study nature, love nature, and stay close to nature. It will never fail you." His words increasingly ring true.


PLANET
Bringing Earth
back to basics

PLANET

BRINGING EARTH BACK TO BASICS

In Greek lore, Pandora is sent down to Earth with a box she must never open. Of course, the story is told because she breaks the rule. Various evils of the world fly out of the box to populate Earth, and realizing what she's done, Pandora slams the box shut. Scholars of mythology tend to recognize the box as a symbol of knowledge, its opening as a loss of innocence. When applied to commerce, the box is industrialization, and chief among its evils is the ecological harm unleashed over the past few centuries.

In 2023, global average carbon dioxide levels set a new record high: 419.3 parts per million, marking a 50% increase since the Industrial Revolution that scaled our use of coal.[90] The resulting climate warming has wreaked havoc on our ecosystems, communities, and existing industrial infrastructure. It's no surprise that we're in need of restorative solutions.

Biotechnology affords us a surprising second chance. It supercharges existing organisms to heal the damage done by industrialization, while also empowering humanity to cause less harm in the coming years, through new modes of production and consumption. Advancements once relegated to science fiction, such as plastic-eating bacteria and plants that communicate their needs, are now poised to meaningfully impact the commercial market. In that sense, biotechnology may be humanity's greatest collaboration to date with the natural world.

REVIVE

Reversing environmental damage

An infusion of life may be the best treatment for the planet's damaged ecosystems. Bioremediation, the use of living organisms to remove pollutants and heal the environment, is fast gaining traction and was estimated to reach a market of at least US$180 billion in 2023.[91] Organizations and labs in the field are innovating technologies across multiple areas of planetary importance, as shown in the infographic below: air, biodiversity, soil, and water.

SUSTAINABLE FUTURES THROUGH BIOTECHNOLOGY

Healing nature with nature

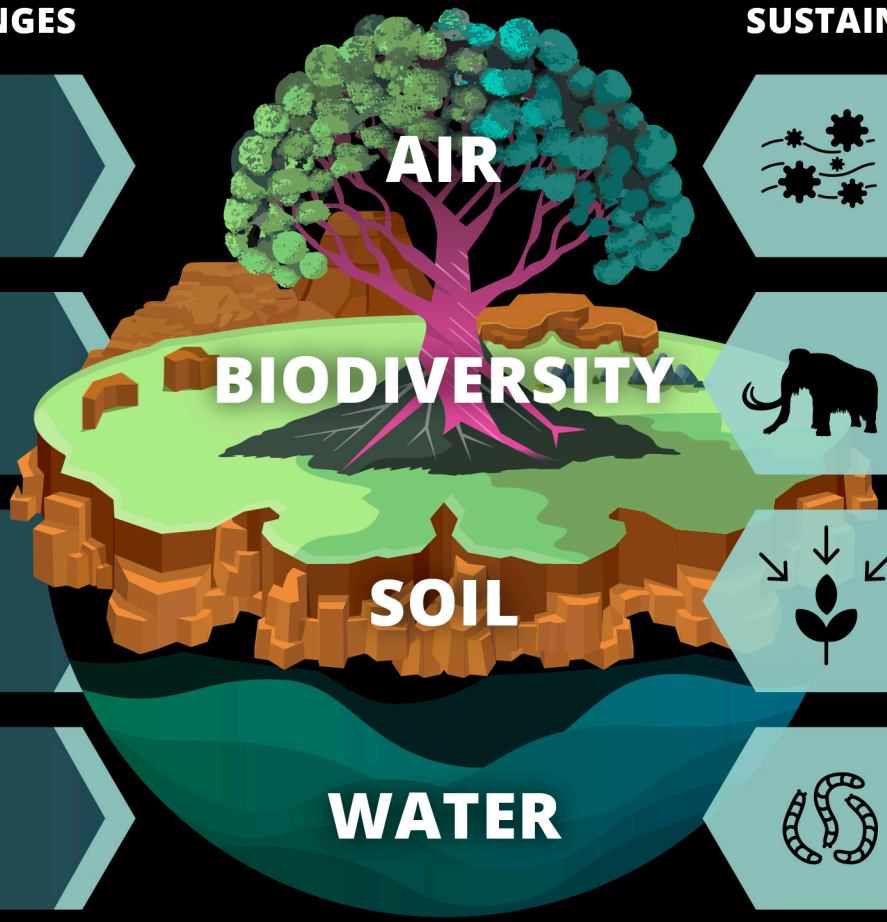
ENVIRONMENTAL CHALLENGES

Global energy-related CO_2 emissions reached a new high of more than **36.8 billion tons** in 2022

Species extinction rates today are estimated to be **1,000-10,000x higher** than natural rates

More than **10 million soil sites** are contaminated worldwide, with over 50% polluted by heavy metals

8 million pieces of plastic pollute the ocean every day



SUSTAINABLE BIOTECH SOLUTIONS

Engineered microorganisms can convert air and greenhouse gas into natural biomaterials

Biological de-extinction methods can restore crucial species, like the woolly mammoth, with the added resilience needed to survive in today's world

Hyperaccumulator plants can absorb lead and other hazardous metals in the soil to reduce pollution

Genetically engineered "superbugs" can be leveraged to eat plastic in marine environments

Source: Deloitte analysis.

AIR

Fresh air and a clear ozone layer won't just make for a healthier world to live in; they're also an economic necessity. According to the World Bank, the current estimated cost of health damage caused by air pollution amounts to US$8.1 trillion each year.[92] Fortunately, biotechnologists are tackling this problem with the planet's natural defense against pollution.

Genetically enhanced plants can catalyze cleaner air by reducing harmful pollutants in the atmosphere and lowering greenhouse gases. For example, the Paris-based startup Neoplant has engineered a common houseplant to be 30 times more efficient in capturing air pollution within homes.[93] Similarly, Green City Solutions employs moss to create an air filter that can absorb as much pollution as hundreds of trees.[94] Other companies take this one step further by creating helpful material with the byproducts captured from pollution.

Newlight Technologies takes waste substance from the air and converts it into a biodegradable plastic that can be used for furniture or packaging, while Windfall Bio produces microbes that can eat harmful methane and transform it into organic soil nutrients.[95]

BIODIVERSITY

The diversity of different plant and animal species is critical for maintaining adequate food, shelter, and medicine for our population. Due to environmental decline, scientists estimate that 200 to 2,000 species go extinct every year—1,000 to 10,000 times higher than natural extinction rates.[96] Technology can be a crucial fix for this issue in two avenues: First, to save endangered species, and second, to reintroduce extinct species back into our ecosystem.

When it comes to endangered species, the last two northern white rhinos are critical to save, but both are female.

Thanks to biotechnology, scientists from the BioRescue consortium hope to revive the species by using in vitro fertilization (IVF) to implant preserved northern white rhino embryos into a surrogate southern white rhino mother.[97] The BioRescue team is also collaborating with the company Colossal Biosciences to edit the DNA of their preserved embryos, restoring genetic diversity to produce the most accurate and viable samples possible.[98]

Colossal Biosciences is also a key player in the challenge of reintroducing extinct species back into our ecosystem. It aims to bring back a genetically enhanced version

of the woolly mammoth, one that can adapt to the current planet and resist viruses that plague today's Asian elephants.[99] Similarly, scientists at the SUNY College of Environmental Science and Forestry aim to revive the virtually extinct American chestnut tree, with the addition of a wheat gene to ensure that it will not meet the same fungi-driven extinction of its first lifetime.[100]

SOIL

Similar to the research around plastic-eating bacteria, scientists are now using plants known as hyperaccumulators to clean sites contaminated with lead, cadmium, and other hazardous metals.[101] For instance, in areas with low agricultural yields due to the presence of nickel in the soil, the company Botanickel has placed plants that can absorb the pollutant without additional harm to the environment. Once these plants are harvested, the nickel can then be separated out and processed into stainless steel.[102]

Allied Microbiota, on the other hand, has opted for a smaller scale and created a microbial product, ThermO+, which can break down challenging contaminants such as chlorinated compounds, petroleum products, and dioxins, cleaning the soil faster and cheaper than traditional methods.[103]

WATER

By 2050, plastic pollution in the ocean is expected to outweigh the collective mass of all fish in the ocean.[104] Since saltwater organisms can't break down plastic, the garbage we've dumped into our seas could remain there forever.

However, researchers at North Carolina State University have identified a possible solution. The plastic-eating bacteria known as *Ideonella sakaiensis* cannot survive in marine environments, but the gene responsible for its biodegrading enzymes can be extracted and inserted it into bacteria that flourish in salt water. Once research is complete, the anticipated impact of introducing plastic-eating bacteria to oceanic pollution could be monumental.[105] Similarly, the company Allonnia genetically engineers microorganisms to break down harsh chemicals and potential carcinogens that have leaked into and contaminated groundwater.[106]

Clearly, biotechnology offers hope. We can restore parts of nature that have been damaged by human activity and even engineer nature itself to be more resilient. But human activity will not cease anytime soon. In order for the potential gains detailed above to be meaningful, biotechnology also needs to ensure we can live on Earth with a lighter impact and bring us back into harmony with a planet we've taken for granted.

THRIVE
Living with a lighter touch

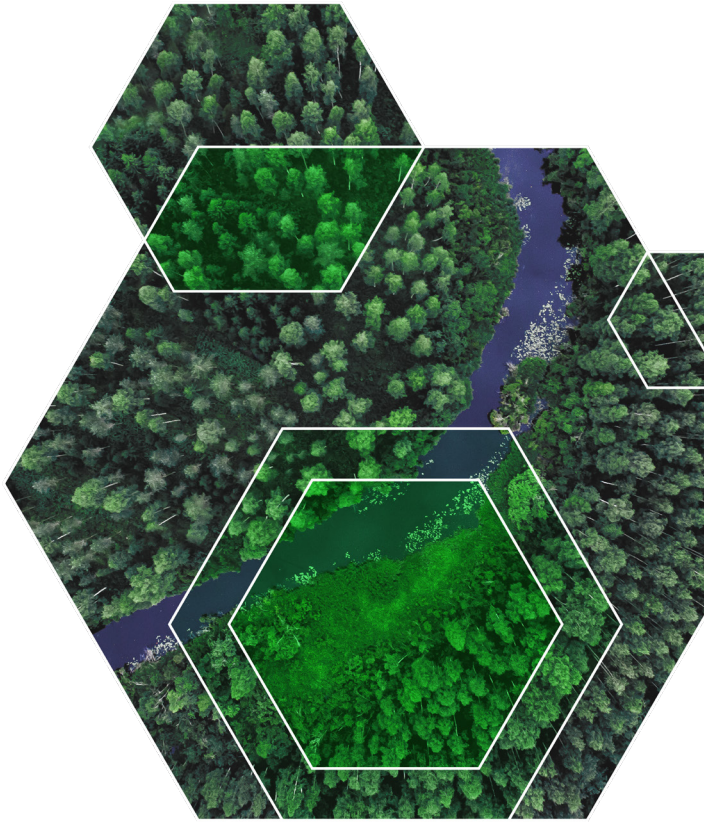
Imagine if we had both the foresight and tools to minimize the environmental impact of industrialization in the first place. Instead of seeking to heal the Earth, we could focus on preserving it. As stewards of the Earth, we can now tread softer as we fuel ourselves and our machines.

FOOD FOR OURSELVES

Agriculture requires enormous resources to feed a growing human population. The first step to reducing this burden is to limit the harmful substances we currently rely on to protect and grow crops: pesticides and nitrogen fertilizers. For example, Robigo, a startup spun out of MIT, engineers microbes that can neutralize disease outbreaks which would normally inflict 20% to 40% crop loss.[107] Additionally, Boston-based Joyn Bio is genetically enhancing a microbe that would allow corn, wheat, and rice farmers to cut their nitrogen fertilizer in half and decrease their greenhouse gases emissions.[108]

We can also engineer crops themselves to be more resilient. In 2020, Argentina approved the world's first drought-tolerant wheat for cultivation and consumption, which enabled the country to stabilize production and revenue.[109] On the other hand, the company InnerPlant grows plants that can communicate their needs with farmers. The startup, backed by John Deere, uses genetic circuits to create plants that glow when exposed to negative stimuli, such as a pathogen or a lack of water, so that farmers can take corrective action before it's too late.[110]

Moving forward, we may need to diversify our sources of animal proteins and fats, opting to originate our meals from animal cells as opposed to farms. According to Didier Touba, the CEO of cultivated meat company Aleph Farms, "Today's



food system is sensitive to shocks such as COVID-19, war, or extreme climate events. Diversifying our sources of foods with cultivated meat can have a great contribution to food security and the resilience of the food system."[111] Indeed, cell-cultured food (as referenced in the *Products* chapter) greatly lowers the environmental cost of meat production, in which just cattle alone cause nearly 10% of global greenhouse gas emissions.[112] Investors recognize these advantages, as alternative meat and fish companies have raised more than US$2 billion to date.[113]

RESPONSIBLE AGRICULTURE

Playing with your food

The role of genetically modified organisms (GMOs) in agriculture, when wielded with the right degree of risk management, could be nothing short of transformative. This is perhaps best exemplified by the grain varietal known as golden rice, which is genetically enhanced with beta carotene, a compound that turns into vitamin A when ingested. In affluent countries, this essential vitamin can be found in fortified cereals, multivitamins, and other nutrient-dense foods, but in emerging economies, vitamin A deficiencies claim lives and stunt the growth of children. Golden rice had the potential to rescue millions from Vitamin A deficiency but became mired in regulatory and political hurdles.[114] Today, it serves as a reminder that societal considerations are crucial to any discussion of GMOs within agriculture.

ENERGY FOR OUR MACHINES

While we fuel ourselves with food, we need sustainable energy sources to fuel everything else in our lives, from our cars to our heating systems to our factories. Identifying new and better fuels is an ongoing and challenging process, but candidates like biobutanol and others are being actively tested. For example, Virgin Atlantic successfully completed a long-haul flight between London's Heathrow International Airport and New York City's John F. Kennedy International Airport using sustainable aviation fuel (SAF), but SAF costs three to five times as much as traditional jet fuel.[115] As Shetty of Ginkgo Bioworks shares, "Most fuel molecules are still not cost-effective to make with biological production unless you have the right regulatory policy. [In contrast], we are really good at extracting oil and have spent a lot of money and decades doing so."[116]

Still, progress is being made, such as the budding partnership between LanzaTech, a startup focused on carbon capture, and the US National Renewable Energy Laboratory (NREL), which aims to apply machine learning and genome engineering to optimize fuel production.[117] LanzaTech's bacteria-based technology has already produced more than 40 million gallons of ethanol and offset 200,000 metric tons of carbon dioxide.[118] Along those lines,

a research team from Fujian Agriculture and Forestry University in Fuzhou, China, recently unveiled a rapid-charging battery enhanced with microbial fuel cells that can break down organic matter or agricultural waste to generate electricity.[119]

Others are developing sustainable methods for mining the scarce metals that fuel our electronics. Biomining (or bioleaching) is the process of using microorganisms to extract critical metals from deposits, pollution sites, or even electronic waste. Boulder, Colorado–based Jetti Resources and Auckland, New Zealand–based Mint Innovation are just two examples of companies using biomining to stall environmental damage and improve upon traditional mining practices for copper and gold, respectively.[120] Considering that both companies have raised healthy venture funding, it's possible that solutions like biomining can scale to help us meet energy demand while simultaneously caring for our planet.

FINAL THOUGHTS

Addressing the growing problems of climate change, pollution, and extinction is a multilevel challenge, requiring an active approach to reviving the Earth and a proactive approach to living more sustainably. Biotechnology offers the potential for both and beyond, as humans strive to come back into sync with nature. This sentiment is summed up well by the founder of Colossal Biosciences, Ben Lamm, on what the future of biotechnology can bring: "I think that we will be able to truly integrate humanity and nature through technology. I think that will dwarf everything that humanity has accomplished thus far. It will dwarf the space race. I think it will dwarf computers, the first PCs. I think it will dwarf fire. I truly think that the merging of nature and humanity through the lens of synthetic biology will be the biggest transformative leap of the next couple hundred years."[121]

CONCLUSION

THE BIOTECHNOLOGY REVOLUTION IS HERE

Throughout this report, we've shown how the tendrils of biotech innovation are bound to intertwine with every industry, geography, and society. Just as the internet revolution caught the world by storm, making our existence more digital, the biotech revolution is now brewing, largely unnoticed, yet poised to create an equally thunderous shift.

This is not an obituary for software. Far from it. A glance at headlines dominated by artificial intelligence can put any such doubts to rest. Rather, advancements in software and biology stand poised to complement and compound each other, fanning the fire of innovation across industries.

But for all that the infotech and biotech industries share as regards their rapid growth trajectories, there are stark contrasts to consider. In the software universe, a prematurely dispatched product that is riddled with bugs or vulnerabilities is a rectifiable misstep. A quick fix to the code and the issue is resolved. Alas, speedy corrections are not a luxury we have in biotech.

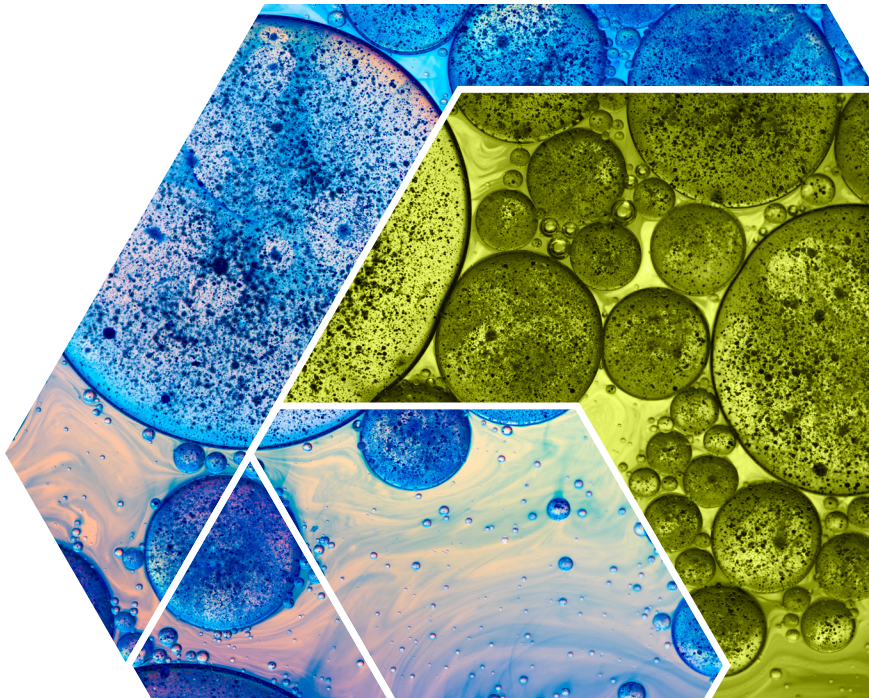
Once you have dispatched cells or manipulated DNA, there's no "Ctrl+Z" option available—no opportunity to debug at the speed of a keystroke. The need for precision and accuracy from the outset is paramount. It's this very reason that calls for responsible innovation and a deep-seated respect for the delicate equilibrium of nature.

Biotech shouldn't be regarded as a panacea to apply with reckless abandon, but rather as a powerful tool that demands prudent handling. "Move fast and break things," the

darling mantra of the tech industry, finds little resonance here. In the laboratory and clinical trial-laden business of biotech, the anthem might instead be, “Proceed with care and preserve balance.”

Imagine, then, a future where we harness this immense power responsibly and intentionally. A future where we extend human life and vanquish seemingly invincible diseases. A future where profitability coexists with, and even promotes, planetary well-being, and products contribute to the restoration of Earth’s natural balance. A future defined by a delicate dance of progress and preservation. This is the promise that biotech innovation holds—to challenge the status quo in ways that enable us to live better, richer lives, while also tending to the world that sustains us.

As we’ve established, each and every human enterprise—if it employs people, produces goods, or simply exists on this planet—has a role to play in shaping this future. The question that now lingers in the air is not if, but how, we all will contribute to this grand narrative. What will your role be?



ACKNOWLEDGMENTS

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As chief futurist with Deloitte Consulting LLP, Mike Bechtel helps clients develop strategies to thrive in the face of discontinuity and disruption. His NExT team researches the novel and exponential technologies most likely to have an impact on the future of business, and builds relationships with the startups, incumbents, and academic institutions creating them.

Prior to joining Deloitte, Bechtel led Ringleader Ventures, an early-stage venture capital firm he co-founded in 2013. Before Ringleader, he served as CTO of Start Early, a national not-for-profit focused on early childhood education for at-risk youth.

Bechtel began his career in technology R&D at a global professional services firm where his dozen US patents helped result in him being named that firm's global innovation director.

He currently serves as adjunct professor of corporate innovation at the University of Notre Dame.

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ENDNOTES

1. Samantha Watters, "Forty years of data quantifies benefits of Bt corn adoption across a wide variety of crops for the first time," University of Maryland College of Agriculture & Natural Resources, March 12, 2018.
2. Our World in Data, "Data page: Cost of sequencing a full human genome," part of the following publication: Max Roser, Hannah Ritchie, and Edouard Mathieu, "Technological change" (data adopted from National Human Genome Research Institute), 2023; Kris A. Wetterstrand, "The cost of sequencing a human genome," National Human Genome Research Institute, accessed May 2024.
3. Google DeepMind, "AlphaFold is accelerating research in nearly every field of biology," accessed May 2024.
4. Saloni Dattani et al., "Life expectancy," Our World in Data, 2023.
5. Jeffery K. Taubenberger, John C. Kash, and David M. Morens, "The 1918 influenza pandemic: 100 years of questions answered and unanswered," *Science Translational Medicine* 11, no. 502 (2019).
6. Centers for Disease Control and Prevention, National Center for Health Statistics, "New reports confirm U.S. life expectancy increased while drug overdose deaths remained stable in 2022," press release, March 21, 2024.
7. Dennis L. Stevens and Amy E. Bryant, "Severe group A streptococcal infections," in Joseph J. Ferretti, Dennis L. Stevens, and Vincent A. Fischetti (eds.) Streptococcus pyogenes: Basic Biology to Clinical Manifestations (Oklahoma City, OK: University of Oklahoma Health Sciences Center, 2016–).
8. Michael Steinhart, Susanne Hupfer, and Jagadish Upadhyaya, "Healthy holidays: Wearables and health data may tip the scales toward better nutrition," Deloitte Insights, December 8, 2022.
9. Peter Francis Mathew Elango et al., "Dry electrode geometry optimization for wearable ECG devices," Applied Physics Review 10, no. 4 (2023); Steinhart et al., "Healthy holidays: Wearables and health data may tip the scales toward better nutrition"; Andrew Paul, "A new noninvasive patch could monitor a vital hormone," *Popular Science*, October 5, 2023.
10. University Hospitals, "Smart watches hold promise to detect disease and improve health," *Science of Health* blog, September 8, 2022.
11. Pagan Kennedy, "Who made that home pregnancy test?," New York Times, July 27, 2012.
12. Victoria Song, "Withings wants you to pee on its latest device," The Verge, January 3, 2023.; Elizabeth A. Thomson, "A smart pill to track IBD," MIT Technology Review, January 4, 2024.
13. Valuates Reports, "At-home testing market to grow USD 45,582.24 million by 2031 at a CAGR of 10.5%," press release, January 17, 2023.
14. H. Ceren Ates and Can Dincer, "Wearable breath analysis," *Nature Reviews Bioengineering* 1 (2023): pp. 80–82.; DotLab, "Science," accessed May 2024.
15. Interview with Mo Jain, founder and CEO of Sapient, January 25, 2024.
16. SkyQuest Technology Consulting Pvt. Ltd., "Brain-computer interface market set to soar past USD 6.18 billion by 2030," press release, January 19, 2024.
17. University of Washington, Institute for Protein Design, "What is protein design?," accessed May 2024.
18. EMBL's European Bioinformatics Institute (EMBL-EBI), "What is the protein folding problem?," accessed May 2024.
19. Google DeepMind, "AlphaFold is accelerating research in nearly every field of biology," accessed May 2024.
20. Laura Kurtzman, "AI technology generates original proteins from scratch," University of California San Francisco, January 26, 2023.
21. SandboxAQ, "AI simulation," accessed May 2024; Deloitte, "Pharma R&D return on investment falls in post-pandemic market," press release, January 6, 2023.
22. SandboxAQ, "AI simulation."
23. Johns Hopkins Bloomberg School of Public Health, "Cost of clinical trials for new drug FDA approval are fraction of total tab," press release, September 24, 2018; Alex Aliper et al., "Prediction of clinical trials outcomes based on target choice and clinical trial design with multi-modal artificial intelligence," *Clinical Pharmacology & Therapeutics* 114, no. 5 (2023): pp. 972–80.
24. Matej Mikulic, "AI usage in drug discovery: Time and cost savings worldwide 2023," Statista, December 13, 2023.
25. Mohammad Rabiee et al., "Microfluidic devices and drug delivery systems," in Michael R. Hamblin and Mahdi Karimi (eds.), *Biomedical Applications of Microfluidic Devices* (Cambridge, MA: Elsevier Academic Press, 2021), pp. 153–86.
26. Saima Sidik, "Tiny faux organs could crack the mystery of menstruation," MIT Technology Review, August 18, 2023.
27. Thomas Morrow and Linda Hull Felcone, "*Defining the difference: What Makes Biologics Unique*," Biotechnology Healthcare 1, no. 4 (2004): pp. 24–9.
28. Interview with David Longo, CEO of Ordaos Bio, January 16, 2024.
29. Eric Green, "The human genome sequence is now complete," National Human Genome Research Institute, April 7, 2022.
30. Thomas Gaj et al., "Genome-editing technologies: Principles and applications," *Cold Spring Harbor Perspectives in Biology* 8, no. 12 (2016): a023754; Your Genome, "What is CRISPR-Cas9?," accessed May 2024.
31. US Food and Drug Administration (FDA), "FDA approves first gene therapies to treat patients with sickle cell disease," press release, December 8, 2023.
32. Jeff Schmerker, "Prime editing: Here's what you need to know," Integrated DNA Technologies, April 21, 2021.
33. American Association for Cancer Research, "First-ever car T-cell therapy approved in U.S.," *Cancer Discovery* 7, no. 10 (2017); Alexander Dimitri, Friederike Herbst, and Joseph A. Fraietta, "Engineering the next-generation of CAR T-cells with CRISPR-Cas9 gene editing," *Molecular Cancer* 21, no. 78 (2022).
34. Interview with Chris Learn and Steve Winitsky, senior vice president and vice president at Parexel, February 12, 2024.
35. Jayanta Kumar Patra et al., "Nano based drug delivery systems: Recent developments and future prospects," *Journal of Nanobiotechnology* 16, no. 71 (2018).
36. GlobalData, "Leading innovators in drug delivery nanoparticles for the pharmaceutical industry," Pharmaceutical Technology, November 7, 2023.
37. Global Market Insights (GMI), *Nanotechnology-based drug delivery market size and share*, July 2023.
38. Herra Grajo Mendoza, "The golden era of RNA-based therapeutics," UC Davis Biotechnology Program, May 22, 2023.
39. Catherine Clifford, "How the Moderna Covid-19 mRNA vaccine was made so quickly," CNBC, updated July 9, 2021.
40. Kim Ribbink, "From the fringes to the forefront—the mRNA ERA has taken hold of pharma," PharmaVoice, April 22, 2022.
41. Interview with David Longo, CEO of Ordaos Bio, January 16, 2024.
42. National Cancer Institute (NCI), "Radiopharmaceuticals: Radiation therapy enters the molecular age," October 26, 2020; George Sgouros et al., "Radiopharmaceutical therapy in cancer: Clinical advances and challenges," *Nature Reviews Drug Discovery* 19 (2020): pp. 589–608.
43. Bill McColl, "Eli Lilly buys Point Biopharma to boost its cancer-fighting therapies," Investopedia, October 3, 2023; Ratio Therapeutics, "Ratio Therapeutics launches to discover and drive early clinical development of best-in-class targeted radiopharmaceuticals for treatment of cancers," press release, June 10, 2022.
44. Henry T. Greely, "CRISPR'd babies: Human germline genome editing in the 'He Jiankui affair'," Journal of Law and the Biosciences 6, no. 1 (2019): pp. 111–83.
45. Bree Watson, "Power move: Forging the future of endurance-boosting technology," Pegasus (Fall 2019).
46. Interview with Peter Diamandis, co-founder and executive chairman of Fountain Life; founder and executive chairman of XPRIZE Foundation, February 28, 2024.
47. XPRIZE Healthspan, "Healthy aging made possible," accessed May 2024.
48. Andy Davis et al., "US health care can't afford health inequities,". Deloitte Insights, June 22, 2022.
49. Domenique Riedel, "What is Innerage 2.0?," InsideTracker, July 15, 2023.
50. Peter Attia and Bill Gifford, *Outlive: The Science and Art of Longevity* (New York, NY: Harmony, 2023); Statista, "Digital fitness & well-being – worldwide," accessed May 2024.
51. Market Reports World, *Global green powder market 2023 by manufacturers, regions, type and application, forecast to 2029*, August 13, 2023; M. Shahbandeh, "Functional and natural health food market value forecast worldwide 2023–2033,' Statista, May 22, 2024.
52. Jennifer Couzin-Frankel, "Science's 2023 breakthrough of the year: Blockbuster weight loss drugs show promise for a wider range of health benefits," Science 382, no. 6676 (2023).
53. Interview with John Dobak, CEO of ClicBio and 10xBio, February 1, 2024.
54. Andrea Curry, "Ozempic in America: What's the real impact? A survey reveals details," *The Intake*, March 28, 2023.
55. Interview with Ajay Verma, CEO of Twilight Neuroscience and general partner at Formation Venture Engineering, January 17, 2024.
56. Interview with Gary Magnant, general partner at Formation Venture Engineering, January 17, 2024.
57. Robert H. Shmerling, "Is metformin a wonder drug?," Harvard Health Publishing, April 8, 2024.
58. Oleksandr Demidenko et al., "Rejuvant®, a potential life-extending compound formulation with alpha-ketoglutarate and vitamins, conferred an average 8 year reduction in biological aging, after an average of 7 months of use, in the TruAge DNA methylation test," *Aging* 13, no. 22 (2021): pp. 24485–99.

59. J. L. Kirkland and T. Tchkonia, "Senolytic drugs: From discovery to translation," Journal of Internal Medicine 288, no. 5 (2020): pp. 518–36.

60. Andy Davis et al., "How employers can spark a movement to help us live longer and healthier lives," Deloitte Insights, June 20, 2023.

61. Interview with Peter Diamandis, co-founder and executive chairman of Fountain Life; founder and executive chairman of XPRIZE Foundation, February 28, 2024; Andrew J. Scott, Martin Ellison, and David A. Sinclair, "The economic value of targeting aging," *Nature Aging 1* (2021): 616–23.

62. J. D. Allen, "The proof is in the physics: Olympic 'sharkskin' swimsuits outperform shark skin," WSHU Public Radio Group, June 28, 2016.

63. Interview with Ron Voglewede, group director of sustainable retail at Walmart, February 2, 2024.

64. Fortune Business Insights, *Food packaging market size, share, trends, and growth*, updated May 20, 2024.

65. Shipra Pandey, Kajal Sharma, and Venkat Gundabala, "Antimicrobial bio-inspired active packaging materials for shelf life and safety development: A review," *Food Bioscience 48* (2022): 101730.

66. Jie Cai et al., "Hydrophobic interface starch nanofibrous film for food packaging: From bioinspired design to self-cleaning action," *Journal of Agricultural and Food Chemistry 69*, no. 17 (2021): pp. 5067–75.

67. Christine Ro, "Can fashion ever be sustainable?," BBC, March 10, 2020.

68. Haje Jan Kamps, "Green is the fashion flavor of the week with Rubi Labs' materials made from captured CO2," TechCrunch, February 16, 2022.

69. Rubi Laboratories homepage, accessed May 2024.

70. Keel Labs homepage, accessed May 2024; *Modern Dane*, "Why cotton is called the world's dirtiest crop," June 1, 2019; World Wildlife Fund (WWF), "Farmed Seaweed," accessed May 2024.

71. Karen Laird, "Partnership Lululemon, Genomatica yields first bio-nylon products," Sustainable Plastics, April 24, 2023

72. Spherical Insights LLP, "Global concrete repair mortars market size to worth USD 5.10 billion by 2032 | CAGR of 3.84%," press release, January 28, 2024.

73. Johanna Lehne and Felix Preston, *Making concrete change: Innovation in low-carbon cement and concrete*, Chatham House, updated December 14, 2020.

74. John Cumbers, "Concrete has a dirty little secret. Can biology solve it?," Forbes, May 16, 2022; Biomason homepage, accessed May 2024.

75. Jeffrey Moore, "The chemistry of self-healing polymers," Royal Society of Chemistry, August 31, 2005; Chris Woodford, "Self-healing materials," *Explain that Stuff*, last updated July 6, 2023.

76. Grand View Research, *Self-healing concrete market size and share report*, accessed May 2024; Grand View Research, *Bioplastics market size, share and growth analysis report*, accessed May 2024.

77. Douglas Thomas, "The U.S. biomanufacturing economy: Value added, supply chains, cost, sustainability, and efficiency," National Institute of Standards and Technology (NIST), June 23, 2023.

78. Lena Smirnova et al., "Organoid intelligence (OI): The new frontier in biocomputing and intelligence-in-a-dish," *Frontiers in Science* 1 (2023).

79. Cortical Labs homepage, accessed May 2024.

80. Pallab Ghosh, "Lab-grown brain cells play video game Pong," BBC, October 12, 2022.

81. Rod Phillips, "A brief history of alcohol," TED, January 2020.

82. Nathan Hillson, "Building a global alliance of biofoundries," *Nature Communications* 10, no. 2040 (2019); Paul Freemont et al., "These 'biofoundries' use DNA to make natural products we need," World Economic Forum, October 28, 2019.

83. Interview with Reshma Shetty co-founder, COO, and president of Ginkgo Bioworks and Megan Palmer, senior director of public impact at Ginkgo Bioworks, February 26, 2024.

84. Fraiser Kansteiner, "Robots, automation and pod factories: How cell and gene therapy makers are catching production up to speed," *Fierce Pharma*, July 26, 2021; US National Science Foundation (NSF), "NSF 23-585: BioFoundries to Enable Access to Infrastructure and Resources for Advancing Modern Biology and Biotechnology (BioFoundries)," May 10, 2023.

85. Givaudan, "Biotechnology: Making innovative ingredients with love for nature," accessed May 2024.

86. Lisa S. Benson and Joel L. Greene, *Cell-cultivated meat: An overview*, Congressional Research Service Report No. R47697, September 19, 2023.

87. Eben Bayer, "For bio manufacturing to scale, it has to think outside the tank," Forbes, July 25, 2022.

88. Research and Markets, "The cultured meat market: Global and regional analysis, 2024–2033 – Global market projected to soar to $3.81 billion by 2033, fueled by sustainable advantages and growing consumer demand," press release, March 8, 2024.

89. Interview with Ron Voglewede, group director of sustainable retail at Walmart, February 2, 2024.

90. Rebecca Lindsey, "Climate change: Atmospheric carbon dioxide," Climate.gov, April 9, 2024.

91. BCC Publishing, *Bioremediation: Global markets and technologies to 2023*, March 2019.

92. World Bank, The Global Health Cost of PM2.5 Air Pollution: A Case for Action Beyond 2021 (Washington, D.C.: World Bank, 2022).

93. Neo PX, "Neoplants," accessed May 2024.

94. Green City Solutions homepage, accessed May 2024.

95. Renée Cho, "How synthetic biology can help the environment," State of the Planet, Columbia Climate School, August 14, 2019; Windfall Bio homepage, accessed May 2024.

96. WWF, "Well... this is the million dollar question. And one that's very hard to answer," accessed May 2024.

97. Dina Fine Maron, "World's first IVF rhino pregnancy could save near-extinct animals," National Geographic, February 1, 2024.

98. BioRescue, "Colossal Biosciences joins BioRescue in its mission to save the northern white rhino from extinction," news release, September 19, 2023.

99. Colossal Laboratories & Biosciences, "De-extinction," accessed May 2024.

100. Ferris Jabr, "A new generation of American chestnut trees may redefine America's forests," Scientific American, March 1, 2014.

101. Ekta Bhattacharya and Suparna Mandal Biswas, "First report of the hyperaccumulating potential of cadmium and lead by Cleome rutidosperma DC. With a brief insight into the chemical vocabulary of its roots," *Frontiers in Environmental Science 10* (2022).

102. Aperam & Econick, "Using plants to extract nickel from soil and then turning that nickel into stainless steel may sound like science fiction, but that's exactly what Botanickel is doing," press release, February 10, 2023.

103. Allied Microbiota homepage, accessed May 2024.

104. Center for Biological Diversity, "Ocean plastics pollution," accessed May 2024.

105. Lina Zeldovich, "The superbug that devours ocean plastic," Nautilus, October 9, 2023.

106. John Cumbers, "Breakthrough bio-ingenuity banishes cancer-causing 'forever chemical' found in drinking water," Forbes, May 22, 2023.

107. Robigo, "Robigo secures $10M seed round to protect crops from untreatable diseases," press release, updated May 4, 2023.

108. Catherine Clifford, "Joyn Bio aims to solve the world's fertilizer problem with microbes," CNBC, May 18, 2022.

109. Emma Kovak, and Dan Blaustein-Rejto, "The world's first genetically engineered wheat is here," The Breakthrough Institute, April 4, 2022.

110. InnerPlant homepage, accessed May 2024.

111. Interview with Didier Toubia, CEO of Aleph Farms, March 21, 2024.

112. Naoki Nitta and Grist, "Quitting cows could have big environmental impacts, but it's harder than it sounds," *Scientific American*, November 7, 2023.

113. CB Insights Market Map, "Cultured meat," accessed May 2024.

114. Ed Regis, "The true story of the genetically modified superfood that almost saved millions," Foreign Policy, October 17, 2019.

115. Virgin Atlantic, "Virgin Atlantic flies world's first 100% Sustainable Aviation Fuel flight from London Heathrow to New York JFK," press release, November 28, 2023; Chris Kjelgaard, "The Sustainable Aviation Fuel pricing challenge," AvBuyer, January 25, 2024.

116. Interview with Reshma Shetty co-founder, COO, and president of Ginkgo Bioworks and Megan Palmer, senior director of public impact at Ginkgo Bioworks, February 26, 2024.

117. Brooke Van Zandt, "NREL launches synthetic biology project to advance biofuel discovery technologies with LanzaTech, Northwestern, and Yale," National Renewable Energy Laboratory (NREL), January 31, 2023.

118. David Salazar, "This company ferments industrial carbon emissions into useful products," Fast Company, March 2, 2023.

119. Wiley, "Research team develops fast-charging hybrid microbial fuel cell and CO2 electrolyzer based on formic acid," Tech Xplore, October 31, 2023; Wilgince Apollon, "An overview of microbial fuel cell technology for sustainable electricity production," *Membranes* 13, no. 11 (2023): p. 884.

120. CB Insights, "Mint Innovation," accessed May 2024; Jetti Resources homepage, accessed May 2024; Mint Innovation homepage, accessed May 2024.

121. Interview with Ben Lamm, founder and CEO of Colossal Biosciences, March 1, 2024.

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