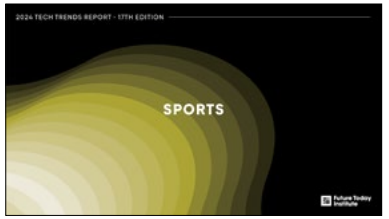
HEALTH CARE · MEDICINE

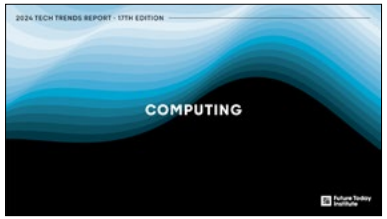
Future Today Institute

FUTURE TODAY INSTITUTE'S 2024 TECH TREND REPORT

Our 2024 edition includes nearly 700 trends, which are published individually in 16 volumes and as one comprehensive report with all trends included.

Download all sections of Future Today Institute's 2024 Tech Trends report at **http://www.futuretodayinstitute.com/trends.**





THE YEAR AHEAD: TECH SUPERCYCLE

The theme for our 2024 report is Supercycle. In economics, a "supercycle" refers to an extended period of booming demand, elevating the prices of commodities and assets to unprecedented heights. It stretches across years, even decades, and is driven by substantial and sustained structural changes in the economy.

We believe we have entered a technology supercycle. This wave of innovation is so potent and pervasive that it promises to reshape the very fabric of our existence, from the intricacies of global supply chains to the minutiae of daily habits, from the corridors of power in global politics to the unspoken norms that govern our social interactions.

Driving this seismic shift are the titans of technology and three of their inventions: artificial intelligence, biotechnology, and a burgeoning ecosystem of interconnected wearable devices for people, pets, and objects. As they converge, these three macro tech segments will redefine our relationship with everything, from our pharmacists to our animals, from banks to our own bodies. Future Today Institute's analysis shows that every technology—AR/ VR/ XR, autonomous vehicles, low Earth orbit satellites, to name a few—connects to the supercycle in some way.

The ramifications are stark and undeniable. As this tech supercycle unfurls, there will be victors and vanquished, those who seize the reins of this epochal change, and those who are swallowed whole. For business leaders, investors, and policymakers, understanding this tech supercycle is paramount.

In this 17th edition of FTI's annual Tech Trends report, we've connected the supercycle to the nearly 700 trends we've developed. Our research is presented across 16 technology and industry-specific reports that reveal the current state of play and lists of influencers to watch, along with detailed examples and recommendations designed to help executives and their teams develop their strategic positioning. The trends span evolutionary advancements in well-established technologies to groundbreaking developments at the forefront of technological and scientific exploration. You'll see emerging epicenters of innovation and risk, along with a preview into their transformative effects across various industries.

We've visually represented the tech supercycle on the report's cover, which is an undulating image reminiscent of a storm radar. Vertical and horizontal lines mark the edges of each section's cover. When all 16 section covers converge, the trends reveal a compounding effect as reverberating aftershocks influence every other area of technology and science, as well as all industries.

It's the convergence that matters. In isolation, trends offer limited foresight into the future. Instead, the interplay of these trends is what reveals long-term change. For that reason, organizations must not only remain vigilant in monitoring these evolving trends but also in cultivating strategic foresight—the ability to anticipate future changes and plan for various scenarios.

Our world is changing at an unprecedented rate, and this supercycle has only just begun.

Amy Webb
Chief Executive Officer
Future Today Institute

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02 Consumers Take Charge of Their Care

Increasingly sophisticated consumer-facing sensors and direct-to-consumer health care services are turning consumers into stewards of their own health.

03 Understanding How Our Brain Works

Translating brain signals into speech or re-creating images by measuring brainwaves are just two examples of milestones achieved in neuroscience in 2023.

04 Shifting to an Ecosystem Approach

Researchers and the medical community are turning their attention to ecosystems in our body (microbiomes) and our environment (holobionts) to analyze our overall health and make diagnoses.

05 Breakthrough Treatments for Major Diseases

Vaccines that shrink cancer tumors, an inverse vaccine that reverses multiple sclerosis, and an FDA-approved Alzheimer's treatment give hope for beating these diseases.

STATE OF PLAY

Advances in biotechnology, understanding of body ecosystems, and artificial intelligence are reshaping the global health landscape.

The fusion of technology with biology has led to remarkable advancements recently. Scientists have decoded aspects of brain function, enabling groundbreaking applications like brain-controlled mobility for paralysis and thought-to-speech conversion. These innovations, however, raise ethical concerns about privacy and mind reading and will need thorough regulatory guidelines to be explored safely. In health care, enhanced sensor technology is revolutionizing early disease detection and personal health monitoring. The shift toward more proactive, consumer-driven health care is complemented by promising developments in fighting noncommunicable diseases, such as potential vaccines for cancer and innovative gene therapies.

The study of various body microbiomes is revealing their significant impact on health and disease treatment, highlighting the complex interplay within our biological ecosystems and providing opportunity for new perspectives on treatments. In mental health, the worsening crisis is prompting the emergence of AI-driven digital health services as an alternative to traditional treatments, although their effectiveness and ethical implications are highly controversial. And climate change's far-reaching effects are continuing to strain population health, due to factors like the spread of disease-carrying insects and lifestyle adjustments in reaction to extreme weather. It is becoming increasingly apparent that public health strategies need to adapt to meet this rising challenge.

KEY EVENTS

MARCH 11, 2023

AI Reconstructs Brain Images
AI reconstructs images people see by analyzing functional magnetic resonance imaging (fMRI).

MAY 2023

Three-Parent Baby Born in UK
To prevent mitochondrial disease in the baby, DNA from a donor is added to that of the parents.

JULY 31, 2023

Electric DNA Manipulation
Scientists trigger insulin production in a cell through electrical signals.

AUGUST 23, 2023

Brain Signals Are Translated into Speech
A stroke patient talks through an avatar using implanted electrodes that translate brain signals.

SEPTEMBER 7, 2023

Synthetic Human Embryo
Scientists create a human embryo from stem cells without using sperm or eggs.

LIKELY NEAR TERM DEVELOPMENTS

CHALLENGES FROM ALL SIDES

The health care system is battling with increased needs for services, a rise in costs, disruption of supply chains because of geopolitical tensions, and an uptick in diseases based on worsening climate conditions. Technology is coming to the rescue but can only accomplish so much: A fractured data landscape, lack of infrastructure, and a lack of data ownership and sharing regulation make timely solutions unrealistic. On the other hand, increasingly sophisticated patients, thanks to powerful sensors on smart devices, are actively taking charge of their own health. As higher expectations for quality care rise by such patients, medical professionals need to deliver an all-encompassing, holistic approach to their services.

Rising Consumer Expectations

Consumers have increased access to information about their health, which will affect their expectations of routine examinations. Professional insights must exceed and incorporate the information available to the consumer directly, or services will be viewed as superfluous.

New Stakeholder Ecosystems

When health care moves to the sphere of the consumer, through smart devices or medical services administered in the home, new service needs that mimic those typically provided in a hospital arise. These can be digital (data analysis) or physical (food delivery, care, etc.).

Decreased Access, Quality in Care

Health care systems are struggling to provide sufficient care, especially in rural regions. Telemedicine offers potential support, but these areas often lack the required digital infrastructure and medical personnel allowed to reach them.

Fighting Misinformation

Social platforms have rolled back their COVID-19 content moderation policies and reduced staff in monitoring departments in recent rounds of layoffs. The increased amounts of AI-generated content will continue to challenge sharing accurate health communication.

Novel Health Threats

As the effects of climate change worsen, disease patterns will change globally: Respiratory illnesses will increase in areas exposed to smoke from wildfires, or vector-borne diseases will emerge in regions with rising temperatures.

Fight for Patient Data

Sensors from consumer-facing smart devices are becoming more precise and increasing the type of biological information they can collect. Health care providers need to ensure that they can access that data to provide adequate services to their patients.

11 MACRO SOURCES OF DISRUPTION

WHY HEALTH CARE & MEDICINE TRENDS MATTER TO YOUR ORGANIZATION

Adjusting to a Shifting Landscape

The separation between health care and wellness is becoming more and more fluid. Patients expect their care to be holistic, instead of an isolated look at medical diagnostics. To access the information from a person's daily life, including exercise habits, health care companies need to consider new partnerships.

Evolving Needs of Older Demographics

The aging population will require more health care, but their wellness needs to be taken into consideration as well. Right now, wellness mainly targets demographics up to middle age, but focusing on the needs of the elderly, and taking their tastes and lifestyles into consideration, will be a significant part of the market.

Conquering the Digital Divide

The shortage of medical personnel is especially palpable in rural regions where the necessary infrastructure for digital services does not exist to compensate for the lack of in-person access. Finding holistic solutions that include serving these affected communities will become increasingly important.

Prepare for Disruption from Big Tech

Big Tech has prioritized delivering medical services to the population, with each giant focusing on a different facet (e.g., cloud services, primary care, smart devices). Think about how the tech giants' extended involvement will affect relevant ecosystems, products, and services, and define if competition or collaboration are most beneficial.

Increased Cybersecurity Threats

Cyberthreats in the health care industry have exponentially increased over the last few years, and the trend is unlikely to reverse. Companies need to not only think about data security across their entire supply chain but also prepare for emerging threats, such as biomalware, that cross the digital/physical divide.

Fix-It Care

Consumers are more knowledgeable about their physical health and, increasingly, their mental health. They're more likely to self-diagnose and self-treat, and delay asking for help from a professional until conditions have progressed. Increasingly, doctors will need to "fix" treatment and measures that were self-prescribed, in addition to treating the actual ailment.

OPPORTUNITIES & THREATS

Threats

Hospital-at-home might alleviate the strain on the health care system, but it is not clear who is responsible when something goes wrong in the remote environment. The regulatory landscape needs to be sufficiently defined.

Bad actors often access a data ecosystem through a vendor at an unmonitored point in the supply chain. Ensure that you have visibility into not only your own data security but also of anyone exchanging data with you.

It's highly likely that Big Tech will create "walled gardens," making it difficult or impossible for any outside stakeholders to partake in their ecosystem. Companies that don't have their own data sets will be at a disadvantage.

As the cost of health care continuously rises, those that can afford it will opt for treatment in other countries with more modest fees or direct-to-consumer services. The number of patients opting for telehealth care will also increase as it becomes mainstream.

AI will misdiagnose conditions. Develop processes to double-check AI's actions to minimize harm. And get clarification on liabilities and relevant regulation before deploying any new technology.

Opportunities

Think about offering tangential products and services, including digital therapeutics, as the health care definition expands. They could be in the wellness, food and beverage, or continuous care sectors, as well as education or products such as apparel or hardware.

Increase your competitiveness by supporting your employees' health. Many traditional business-to-consumer entities are now shifting to business-to-business models, providing companies greater flexibility to think expansively about their benefits.

The shift to digitalized care will open up global markets. Look for ways to optimize your offerings to regional needs and ensure you are fulfilling regulatory requirements. New strategic partners in those markets might be needed.

Deepen the relationship with your customers to set the stage for expanded services in the future. Utilize existing customer data and explore how you can collect more of it so that you can broaden your opportunities for personalized services.

Rethink your product development processes, especially the manual ones. Investigate how emerging artificial intelligence technologies can speed up timelines. This will lower the risk of exploring the viability of new products.

INVESTMENTS AND ACTIONS TO CONSIDER

1

Responding to the evolution of the health care space will require new skills. Invest in reskilling or upskilling your workforce early, and hire new talent as needed to proactively design your path in this new landscape rather than having to respond to conditions after they have manifested.

2

Developing new technologies to keep a business competitive is often quite costly. Instead of focusing on acquisitions to build in-house capabilities, connect to an innovation hub that combines experts from public services, the research community, and the startup scene to save resources.

3

Adjust your products and services to cater to a more health-educated consumer. Think about how you can provide adjacent information and where your product sits within the bigger context of health and wellness. There might also be interest in complementary offerings that cater to more niche interest groups.

4

Clean up your data storage system to make sure it is standardized and can be synthesized with other relevant data sources. Simplify the infrastructure to facilitate easy data flows within your ecosystem and to outside providers, to become an attractive collaborator, minimize costs, and maximize the benefit your data provides.

5

Analyze your supply chain and consider nearshoring crucial links to avoid instability caused by geopolitical tensions. As customers increasingly expect higher degrees of personalization, and personalized care becomes more commonplace, local production will enable faster turnaround times and more nimble responses to custom demands.

6

Tech-enabled medical devices need continuous maintenance and software updates. Consider how you can ensure users' safety even beyond the existence of your company. Companies that provide additional security will be a strong decisive factor for patients when choosing a product.

CENTRAL THEMES

Synthetic Humans

Our bodies are increasingly merging with supporting technology, creating new opportunities and ethical questions. We are making progress in deciphering how exactly our brain works: Last year, scientists re-created sounds and images a person perceived, and for the first time AI could convert a person's thoughts into words through noninvasive methods. And we are also capable of transmitting that deciphered information within or outside the body, increasingly wirelessly: A paralyzed man can walk again by wirelessly transmitting his thoughts to move to his legs, a stroke victim can speak through a digital avatar connected to her brain, and a robot can be controlled through a noninvasive wearable, a headband. The FDA approved Elon Musk's DeepMind's request for human trials of brain implants for paralysis patients. The ethical implications of literally reading other people's minds are yet to be examined, and guardrails are needed to effectively protect the most private and personal layers of our human existence.

The Empowered Consumer

Health care is seeing the kind of democratization that other fields, namely the creative industries, experienced a couple of decades ago. A wider variety of sensors can measure an increasing number of metrics that we now know signal specific biological developments. These can range from overuse of certain muscles to early Alzheimer's detection. The data coming from our myriad devices is increasingly collected by health platforms and synthesized and analyzed to give us overarching stats of our well-being, and monitor developments on an ongoing basis. Direct-to-consumer health care and wellness services, such as microbiome or stress-level analysis, complement the self-care capabilities. Consumers will not only be able to proactively maintain their health but also have higher expectations of the services they receive from health care providers.

Reversing major diseases

Noncommunicable diseases are on the rise, and the WHO projects that by 2050, 86% of deaths might be attributed to them. Last year's scientific discoveries give a glimmer of hope: A pancreatic cancer vaccine shows promise and entered phase 2 of clinical trials. Moderna announced plans to offer vaccines against a variety of cancers and heart disease by 2030 or sooner. CRISPR-based therapies against Alzheimer's disease were introduced. An inverse vaccine—meaning it removes the immune system's memory of a particular molecule—shows promise to cure autoimmune diseases like multiple sclerosis, And in a small study, semaglutide eliminated the need to inject insulin in people with Type 1 diabetes. With initiatives, such as a task force led by Nobel Prize winner Jennifer Doudna, focusing on decreasing the price of gene therapies, such new treatments could become available for the wider public earlier than expected. This could eventually upend legacy stakeholders whose income is based directly or indirectly on traditional treatment of these diseases.

CENTRAL THEMES

Focus on Interrelationships

The gut-brain axes, or the gut microbiome, had its moment in the sun in 2023. However, bodies have a number of microbiomes, including in our mouth, skin, and vagina. Researchers have become increasingly aware of the roles these ecosystems play for our health, diagnostics (Parkinson's patients have similar gut microbiomes but so do people who live in the same household), and treatment (fecal microbiota transplants can help treat inflammation in the digestive tract). The same goes for the concept of holobionts, which is exploring health in the context of a host organism and its associated communities. While the insight that the environment you live in impacts your health is far from new, it's a novel approach to study these ecosystems from a microbiological perspective and allow it to flow into medical analysis. However, we are just starting to decipher the workings of the microbiome and how it affects the rest of our body.

AI for Mental Health

As the mental health of large swaths of the population continues to deteriorate after accelerating during the pandemic, and insurance companies refuse to pay appropriate rates for mental health services (if they cover them at all), digital health services are trying to alleviate the situation. However, the failure of two significant players in 2023—Mindstrong and Pear Therapeutics, both offering digital products to diagnose and monitor mental health—showed that effectiveness and valid business models of these new therapeutic approaches still need to be explored. Large language models seem destined to fill in the gap left by a lack of human therapists, and several AI chatbots focused on mental health were released last year, including Pi, by Mustafa Suleyman's Inflection AI. But their use is highly controversial. The technology has not matured enough to grasp the nuances of human behavior, and its habit of hallucinating is especially harmful when communicating with vulnerable adults.

Climate Change Effects on Health

Extreme weather events dominated the news last year. And while it surprises no one that excessive heat, ash-laden air from wildfires, or flooding negatively impact our physical and mental health, the effects are only growing more significant. In China, people had to isolate in air shelters; in Arizona, they waited until night time to go outside; in New York, they had to stay indoors for extended periods to avoid asthma attacks. In Europe, Asian tiger, bush, and yellow fever mosquitos are becoming increasingly common as temperatures warm and humidity rises—in a pattern repeating in other areas of the world where insects (and other pathogens) are migrating to new areas and bringing their diseases with them. As climate conditions worsen, we need to prepare for adjustments in our lifestyle to protect our health, as well as prepare for the new risks that exposure to new pathogens will bring.

ONES TO WATCH

Yu Takagi and **Shinji Nishimoto,** researchers at Osaka University, for their use of diffusion models to re-create versions of what a person has seen by analyzing fMRA scans.

Jinbo Huang, molecular biologist at ETH Zürich, for developing a device that can activate genes through electrical currents, such as to trigger insulin production.

Mishal Mendiratta-Lala, professor of radiology at Michigan Medicine, for heading the human trial for using sound to destroy liver cancer tumors.

Debora Marks, professor at Harvard Medical School, for developing an artificial intelligence tool that can predict virus mutations.

Kevin Barnham, professor at the Florey Institute and Austin Health, for developing a way to detect Parkinson's disease years before physical symptoms show.

Marc Goldberg and **Christine Carville,** co-founders of Resilience Lab, for developing a sustainable model for expanding access to therapy through their online platform.

Dr. Nusrat J M Sanghamitra, founder and CEO of CyGenica, for using nanotechnology for targeted delivery of cancer drugs that minimize side effects.

Jeffrey Hubbell, professor at the University of Chicago, for developing a vaccine that could reverse autoimmune diseases like multiple sclerosis.

Gert Cauwenberghs, professor at University of California, San Diego, for developing 3D-printed sensors that can be fused with earbuds to detect neurodegenerative diseases.

Elizabeth Gazda, CEO of Embr Labs, for developing a wristband that cools the body to counteract menopausal hot flashes.

David Baker, director at the Institute for Protein Design at the University of Washington, for developing an AI that can design custom, functional proteins that could be produced in live cells.

Tae-Jin Kim, associate professor at Pusan National University, for developing a biosensor that can detect DNA damage in real time.

Lorenz Hofbauer, Maria Teresa Pisabarro, and Dr. Vera Hintze, professors at TU Dresden, for developing molecules that promote bone regeneration.

Zhuomin Zhang, Ph.D. candidate at City University of Hong Kong, for his development of a piezoelectric biomolecular film that could be used for implantable microdevices.

Mike Curtis, president and CEO of eGenesis, for advancing research into xenotransplantation.

Dr. Nicole Robb, co-founder of Pictura Bio, for building a diagnostics platform that can detect pathogens within a minute based on a digital image.

Noam Band, CEO of HealthWatch, for developing the only remote monitoring garment that received clearance from the US Food and Drug Administration.

Zhou Nie, professor at Hunan University, for developing a DNA-based robot that can walk on the surface of cells and influence their behavior.

Matt Anderson-Baron, CEO and co-founder of Future Fields, for creating the first synthetic biology system that uses fruit flies to produce proteins for affordable CRISPR therapies.

Philip Roche, CEO of Jenthera Therapeutics, for developing the CRISPR-based gene therapy that uses the fruit fly proteins mentioned above.

Jennifer Doudna, founder and chair of the Innovative Genomics Institute Governance Board, for her vision of making genetic therapies affordable and accessible to all.

Woon-Hong Yeo, researcher at Georgia Institute of Technology, for creating a device that can wirelessly monitor the vascular system in real time without needing batteries or circuits.

John A. Rogers, researcher at Northwestern University, for developing an electromechanical system that dissolves after a specific period of time, reducing electronic waste.

Robert Knight, neuroscientist at the University of California, Berkeley, for training a computer to analyze brain activity and re-create the song a person was listening to.

IMPORTANT TERMS

Biomalware
Malicious technology or software designed to attack, alter, or exploit biological systems, such as human DNA. It represents a potential cybersecurity threat in the field of biotechnology, where genetic data and biological processes could be manipulated for harmful purposes.

Electronic health record (EHR)
A digital system that stores a patient's comprehensive medical history, treatment plans, test results, and other health information. EHRs allow for efficient sharing and management of patient data among different health care providers, enhancing the continuity and quality of care.

Holobiont
An ecological unit comprising a host organism and the various microorganisms living in or on it, such as bacteria, viruses, and fungi. This concept emphasizes the interdependent relationship between a host and its microbiome, recognizing them as a single, integrated biological entity.

Microbiome
The collection of microorganisms, like bacteria, viruses, and fungi, living in and on the human body, crucial for functions like digestion and immune response, and unique to each individual.

Personalized medicine
A medical model that customizes patient care based on an individual's unique lifestyle and environmental factors. It involves tailoring treatments and preventive strategies to achieve optimal health outcomes for each person.

Precision medicine
A branch of medicine that uses genetic information to guide the diagnosis, treatment, and prevention of diseases, focusing specifically on the individual genetic profile of each patient.

Nanobots
Tiny robotic devices, often at the scale of nanometers, designed to perform specific tasks at a microscopic level, such as in medical applications for drug delivery or cellular repair. They operate in the realm of nanotechnology, utilizing advances in miniaturization and precision engineering.

Nootropics
Also known as "smart drugs" or cognitive enhancers, these substances are claimed to improve cognitive function, particularly executive functions, memory, creativity, or motivation, in healthy individuals. They range from naturally occurring substances like caffeine to prescription medications, and are used with the aim of boosting mental performance.

Xenobots
Programmable biological robots, created from living cells, typically stem cells from frogs. These tiny organisms, designed using computer algorithms, can perform simple tasks, offering potential applications in fields like medicine, environmental remediation, and biological research.

Xenotransplants
The process of transplanting organs, tissues, or cells from one species to another, typically from animals to humans. This medical procedure is explored as a potential solution to the shortage of human organs for transplantation, with pigs being the most common donor species due to their physiological similarities to humans.

Exoskeleton
A wearable external framework that provides support and enhances physical capabilities, often used for rehabilitation or to assist individuals with mobility impairments. It can also be employed in industrial or military settings to augment human strength and endurance for demanding tasks.

Piezoelectric
Piezoelectricity refers to the electric charge that accumulates in certain solid materials, like crystals, ceramics, and biological matter such as bone, in response to applied mechanical stress. This property allows for the conversion of mechanical energy into electrical energy and vice versa, making piezoelectric materials useful in sensors, actuators, and energy harvesting applications.

THE BUSINESS OF HEALTH CARE

6TH YEAR ON THE LIST

BIG TECH DISRUPTS HEALTH CARE

WHAT IT IS

Everyone wants their hand in the health care system. The sector faces increasing costs, staffing shortages, and an aging population, making it vulnerable to disruption. Big Tech companies are leveraging their user bases, advanced technology, and data access to offer superior health care services, filling some gaps in the system.

HOW IT WORKS

Despite facing extensive scrutiny regarding its role in the mental health crisis and access to personal health data, Meta recently secured patents confirming extensive research in wearable health care solutions that measure biomarkers and brain activity. Apple Watch introduced a new feature that can measure sun exposure using sensor and GPS technology. And Samsung unveiled its new Open Innovation Initiative in collaboration with leading universities and academic hospitals to expand its digital health ecosystem. Seeking to diversify its health services, Samsung is also implementing the B.well Connected Health platform, which enables users to create a longitudinal health record, receive proactive health insights, and access care from a growing network of providers through a secure app. Salesforce has updated its Health Cloud software solution, including enhancements such as in-home treatment scheduling, a data cloud that connects various patient data sources in real time, and a patient contact center. These additions leverage Salesforce's real-time data, Einstein AI, and Flow automation technologies to improve patient experiences and reduce operational costs.

WHY IT MATTERS

Big Tech's involvement in health care is driving the consumerization of the industry, and every company has its niche. Given its reputation as a lifestyle brand, Apple is focused on lifestyle and personal wellness. Amazon is prioritizing primary care. Microsoft is seeking to provide the technological infrastructure for health care, including cloud, analytics, and AI support. Among these companies, Google has the most diversified portfolio of products and services: Its priorities have included research, consumer wellness, improving health care access, and providing tools and platforms for health care professionals to effectively access and manage health data. With the introduction of new health care technology on consumer devices, patients have higher expectations and expect a more personalized consumer-centric experience as they become more inclined to prioritize long-term wellness and preventive care. This shift underscores the importance of collecting personal data to provide directly communicated, personalized solutions to patients.

4TH YEAR ON THE LIST

DTC HEALTH CARE MODELS

WHAT IT IS

Startups and health care providers are bypassing traditional intermediaries by adapting direct-to-consumer (DTC) health care models, which aim to offer consumers cost savings, convenience, and accessibility to products and services.

HOW IT WORKS

Increasingly, large retailers are offering health care products and services directly to their consumers. In early 2023, Amazon acquired primary care provider One Medical for $3.9 billion. Now, the company can offer access to health professionals, 24/7 virtual care, and same-day appointments for less than $200 a year. One Medical's platform also includes Mindset, its suite of mental health services, like virtual therapy and coaching, as well as a variety of programs to help patients reduce stress and anxiety, sleep better, and improve their mood. Walgreens is introducing a DTC telehealth service for consumers in select states to speak with a health care professional virtually from the comfort of their home. If a patient requires medication, Walgreens Virtual Health can send that prescription to a Walgreens pharmacy or have it delivered to their home on the same day. Costco has partnered with direct-to-consumer marketplace platform Sesame to offer members online health checkups for as low as $29. Sesame doesn't accept health insurance, and this new program caters to uninsured Americans or those with high-deductible plans. LifeMD and Ascend Therapeutics launched an integrated direct-to-consumer telehealth model for hormone therapy. As nontraditional retail companies broaden their footprint to include health care services through DTC models, traditional players are undeniably pressured to expand their digital offerings.

WHY IT MATTERS

The retailization of health care is prompting a reinvention of the traditional primary health model. More than ever before, consumers are focused on their overall health and wellness, necessitating products and services that take a holistic approach. Subscription-based models are emerging to create more comprehensive platforms, integrating single-use platforms with existing solutions to offer a more inclusive experience for consumers and providers. By leveraging digital technologies, the primary objective of DTC models is to offer convenience, accessibility, and affordability for a more diverse consumer population. Akin to the traditional retail shopping experience, DTC models seek to empower and engage consumers by giving them more control of their health care decisions. The significance lies in the democratization of health care, where consumers can actively participate in managing their own health. The US, where digital health revenue is the highest, is anticipated to have 370 million digital health users in 2024, up from 290 million users in 2022.

To keep up with on-demand health care services, stakeholders need to seek new, unexpected partnerships, not only within the tech industry but across different sectors and startups, to create adaptive business solutions.

4TH YEAR ON THE LIST

HEALTH AT THE WORKPLACE

WHAT IT IS

The Covid pandemic changed the way we work. The remote work environment afforded employees greater work/life balance, resulting in a reluctance to return to the office. In seeking solutions, companies are prioritizing employee health and well-being.

HOW IT WORKS

Companies of all sizes, from startups to Fortune 500 corporations, are experimenting with new partnerships to offer employees new health benefits. More than 800 companies are working with Spring Health, which provides "precision mental health care" that matches employees to the most effective care for them. The solution includes mindfulness and meditation, care navigation, coaching, therapy, and medication management. Microsoft initiated a partnership with Joye, a Singapore-based tech company, to bring mental fitness capabilities to global users of Microsoft Teams. The add-on analyzes work patterns to deliver suggestions and coaching for improved mental health. Transcarent, a company that offers direct access to quality low-cost medical services, announced new partnerships with 10 major health systems. Other companies are incentivizing healthy behaviors and data collection; United Healthcare offers a benefit of up to $1,000 annually for select employers and fully insured clients in exchange for individual health data, such as steps, sleep, and daily activity. And WebMd's acquisition of Limeade aims to offer a comprehensive well-being solution for organizations. The integration of Limeade's employee feedback solutions with WebMD's services enables more personalized experiences for holistic well-being. A growing number of employers are seeking solutions to prevent burnout, costly medical procedures, and health-related absences.

WHY IT MATTERS

Preventing health issues is more cost-effective than treating them. While upfront costs may be associated with wellness programs, the long-term savings can be substantial. Health programs can help reduce sick days and absenteeism due to illness. Healthy employees tend to be more productive, exhibiting a higher level of creativity, problem-solving ability, and innovative thinking. They have higher energy levels, reduced stress, better concentration, and are generally more engaged in their work. When employees see that their well-being is a priority, it can boost morale and lead to higher job satisfaction.

The shift to remote or hybrid work has only exacerbated the mental health crisis, prompting discussions about the blurred boundaries between professional and personal life. While remote work offers flexibility, the growing need for clear boundaries has led to global action for the "right to disconnect." The US is slow to adopt, while other countries, like Kenya, are passing legislation to prevent employers from contacting employees after work hours. Such rules can seem impractical due to global operations that span time zones, but proponents say they restrict flexibility in an increasingly asynchronous work environment. Nonetheless, such actions are arguably necessary to ensure employee well-being.

2ND YEAR ON THE LIST

CONSIDERING HEALTH EQUITY

WHAT IT IS

Barriers like global access, cost, provider availability, and care quality limit health care for some. Disparities disproportionately affecting certain populations can be overcome through investment and reform of the infrastructure of universal health systems to bridge gaps in care.

HOW IT WORKS

Several academia and health care institutions worldwide have created task forces and research centers to address health disparities. They're joined by efforts to promote information equality, like YouTube Health's THE-IQ, a video series that examines equity in mental health, maternal health, and health care access.

To address health equity, it is crucial to rectify biases in data collection, research, and analysis. The National Institutes of Health launched the All of Us research program to collect data from 1 million US citizens and create diverse medical data sets. The World Health Organization launched the Health Inequality Data Repository, the largest collection of disaggregated data about health and determinants of health. The data can be used to assess the state of inequality across featured health topics or settings, conduct ongoing monitoring and evaluation, and inform the development of policies and programs.

Rural health is big retail's latest target, and Uber and Walmart are making the biggest splash. Uber Health users covered by eligible Medicare Advantage plans will be able to use their benefit cards to pay for nonemergency medical rides and supply delivery through a new partnership with Optum. Walmart introduced a new institute to expand the reach of clinical trials to women and underserved communities. Walmart also plans to continue expanding its community health center footprint by adding 28 new centers in 2024.

WHY IT MATTERS

Technology offers great potential for addressing health disparities through telemedicine and remote care options, automation of services, and AI-driven analytics—even though these efforts won't reach those without digital access. Data governance is essential for ensuring that technological advancements positively contribute to health equity. Still, there are downsides, like AI's proven ability to reinforce bias: A 2019 study found that a health care risk-prediction algorithm used by major insurers extensively underrated the health risks of Black patients. As technology aims to standardize, even improve, quality of care, under- and misrepresentation of minority populations in data analysis for clinical research and trial methodologies must be addressed.

A rise in health equity officer roles shows a commitment in many companies to identify racism within organizations, work on community partnerships, and review clinical algorithms for bias. While these sorts of roles used to be most prominent among hospital systems and state offices, several companies—CVS, Humana, and the NFL Players Association, to name a few—recently hired their first health equity executives or officers as the industry grapples with global health disparities. In the wake of the growing number of chief medical officers at Big Tech companies as well as in the retail industry, health equity positions are expected to follow suit.

1ST YEAR ON THE LIST

CONSIDERING ENVIRONMENTAL IMPACTS OF HEALTH CARE

WHAT IT IS

Efforts to reduce ecological footprints of health care labs and facilities are gaining momentum, with areas like water consumption, waste reduction, and pharmaceutical development the most readily available for improvement. Key to this effort are advancements in remote care.

HOW IT WORKS

Most hospitals are focused on adopting circular economies to enhance sustainability by implementing practices that prioritize resource efficiency, waste reduction, and the reuse or recycling of materials. Cardinal Health's Sustainable Technologies, a leading provider of single-use device (SUD) collections, reprocessing, and recycling services in the US, has expanded its facilities, allowing for testing new ways to reprocess medical products. In 2022, the company collected 18.3 million SUDs, diverting more than 5.6 million pounds of waste from landfills. This reprocessing contributes to a circular economy—extending the life of devices to reduce both product cost and waste. A collaboration between the Health Innovation Centre of Southern Denmark, Danish Technological Institute, GMAF Circular Medico, and BD is assessing the viability of recycling used blood collection tubes, currently disposed of via incineration, to reduce greenhouse gas emissions. The pilot program at Odense University Hospital aims to demonstrate the reusability of plastics in health care facilities. As pressure on hospitals systems to reduce their carbon footprint mounts, suppliers will need to provide carbon data. Organizations like Vizient are incorporating carbon emissions information into their contract templates, so providers can make informed purchasing decisions.

WHY IT MATTERS

Hospitals account for 8.5% of the US carbon footprint. Health care laboratories and facilities are inherently energy-intensive and water-consuming, and generate substantial hazardous waste, making them a significant contributor to global water shortages, greenhouse gas emissions, and pollution. In response, health care organizations globally continue to actively adopt sustainable measures, including energy-efficient building designs, renewable energy sources, waste reduction through recycling programs, and effective hazardous waste management. However, with the continued growth of telehealth and remote care options, the industry is poised to greatly decrease its environmental impact. Beyond cost savings and convenience for consumers, the benefits of telehealth include curbing the carbon emissions associated with commuting, minimizing the need for physical infrastructure expansion, and streamlining distribution processes for an optimized supply chain. As the adoption of telehealth expands, sustainable procurement and manufacturing practices are gaining traction, with a focus on sourcing materials with minimal ecological footprints and optimizing drug production processes. Still, the industry is ripe for change, yielding significant opportunities for innovation from outside the industry.

HEALTH CARE ADMINISTRATION

6TH YEAR ON THE LIST

HEALTH DATA INFRASTRUCTURE

WHAT IT IS

More than ever before, we have greater access to an abundance of data points that help us evaluate individual health and well-being. And yet, getting a complete picture of our overall health continues to be a challenge. The widespread adoption of AI is playing a pivotal role in connecting the dots between EHR systems and patient-generated health data to provide a more comprehensive, real-time, and personalized view.

HOW IT WORKS

As of 2021, fewer than 10% of health care organizations had been utilizing AI for more than five years. As AI advancements expand to the health data infrastructure, tools and platforms to improve process workflow are being introduced into the health care industry. Software as a Medical Device can be used to diagnose, monitor, and treat and/or prevent medical conditions. Google Cloud introduced an AI-powered search capability through the Vertex AI Search platform for health care workers to retrieve information from clinical notes, scanned documents, and EHRs, seamlessly and efficiently. Microsoft Fabric aims to simplify the analytics process through an end-to-end, unified analytics platform that integrates various data and analytics tools into a single product.

Patient-generated health data refers to information like vital signs, symptoms, and lifestyle details generated by patients themselves. Health technology platform Folia Health is expanding its patient-reported data collection to include multiple sclerosis, Huntington's disease, and myasthenia gravis. Patients and caregivers can use it to capture their daily observations of treatment response and disease progression. And Oracle is expanding its partnership with Zoom to enhance telehealth services; the collaboration will connect Zoom's telehealth capabilities with Oracle Cerner Millennium, so providers can seamlessly join patient appointments with relevant EHRs.

WHY IT MATTERS

The convergence of electronic health systems and patient-generated health data herald a new era of personalized care, leveraging technology to provide a comprehensive view of an individual's health. The clinical data of EHR systems now seamlessly integrate with patient-generated health data collected from wearables and apps. This mingling gives providers access to a continuous health narrative. As patients produce and record real-time data, integration with their EHRs enables more accurate insights that even consistent medical appointments cannot provide. Introducing a greater volume and diversity of health data facilitates more informed and shared decision-making. Essentially patients become active participants in their care as a collaborative relationship in their health needs forms.

But this integration poses challenges for the health care data infrastructure. Seamless integration requires interoperability between EHR systems and the disparate sources of patient-generated health data, leading to investments in robots, health information exchange (HIE) platforms, APIs, and standardization efforts. Integration efforts must be scalable and able to safeguard the growing volume and variety, and sensitivity of health data. Harnessing the full potential of integrated health data ushers in a new era of preventive and personalized health care.

2ND YEAR ON THE LIST

DEFINING PATIENT ACCESS TO MEDICAL DATA

WHAT IT IS

Amid the increased volume of patient-generated data due to recent innovations, policymakers are grappling with the need for revised regulations and policies that will address the evolving landscape of health data ownership and privacy.

HOW IT WORKS

In April, Washington state's governor signed the My Health My Data Act, a first-of-its-kind consumer health data law that requires explicit consent to collect and share consumer health data. Aimed at addressing gaps not covered by the Health Insurance Portability and Accountability Act (HIPAA), the law prevents traditional advertising practices while even prohibiting some, like geofencing around health care facilities. Following suit, several other states, including California, Colorado, Connecticut, Utah, and Virginia, have taken action to strengthen protections of personal health data. Similar laws aim to safeguard consumers from the unwarranted sale of personal health information. In 2023, safeguarding action was taken against several companies, including Costco, BetterHelp, and Premom, which were accused of selling private patient information. In Europe, legislators still debate how the European Health Data Space (EHDS) regulates the secondary use of health data, such as sharing for research purposes or policymaking. The EHDS aims to provide a single market for electronic health record systems, medical devices, and AI systems while enabling EU citizens to share and have access to their health data across borders.

WHY IT MATTERS

The debate about patient ownership of health records continues to grow, with some arguing that not all health data is generated by the patient and should therefore not belong to the patient. While the EU's General Data Protection Regulation and HIPAA do not explicitly define ownership rights, they acknowledge patients as data subjects, giving them increased ownership, including the right to access their medical data and restrict its use by other parties.

As technology has shifted the way that health data is produced and collected, a greater volume of data exists. Patient-generated health data allows for more accurate real-time data to be collected outside of clinical environments. Access to this information can be game-changing, and lead to further innovations in the industry. Researchers and pharmaceutical and biotech companies also face a paradigm shift: With consumers in control of their personal data, these institutions may need to leverage incentives to access the data necessary for their work. Trust and consumer sentiment will likely play a role in whether access is granted. The changes may usher in new intermediaries to facilitate data access, to service this need on behalf of institutions.

1ST YEAR ON THE LIST

INCREASING INTEROPERABILITY OF DATA INFRASTRUCTURE

WHAT IT IS

The fragmented state of the health care industry's infrastructure is a result of the incompatibility between health care devices, applications, and information systems, which hinders the seamless exchange of patient data and information. Increasing interoperability is a necessary and welcome change.

HOW IT WORKS

The Office of the National Coordinator for Health Information Technology (ONC) reported increased hospital engagement in key interoperability domains, with 6 in 10 hospitals actively participating in information sharing and integrating summary of care records into EHRs. This is promising, as the ONC advances data sharing and interoperability through the 21st Century Cures Act. The office's proposed provisions, known as HTI-1, focus on implementing the EHR reporting program and revise the ONC Health IT Certification Program. Most notably the changes expand exceptions to information-blocking regulations in support of information sharing.

Among companies, Philips achieved enhanced interoperability between its Capsule Medical Device Information Platform and the Patient Information Center iX, giving hospitals the ability to synthesize data from a variety of non-Philips devices—like third-party vital sign monitors, ventilators, and infusion pumps—and view the information on a single, standardized interface. CareSource IT addresses health care data interoperability challenges through API utilization. Michigan Health Information Network Shared Services and Amazon Web Services are launching Interop.WORLD, a virtual innovation center focused on health care interoperability. The center plans to host challenges using an open-source health data sandbox to encourage developers and organizations to design cloud-based health care IT solutions that support interoperability.

WHY IT MATTERS

Limited data exchange has been a growing issue since medical providers first implemented EHRs, and many benefits can be realized by facilitating the rapid exchange of health information. This approach can optimize human capital, patient-centric care, and public health emergency preparedness. Providers will experience reduced turnaround times, enabling them to render higher-quality care services to their patients. Patients will be more engaged in self-managing their well-being. The public will also benefit from early detection and prevention of disease outbreaks.

Despite this, achieving interoperability is a complex challenge. Overcoming these challenges will require a willingness of stakeholders to collaborate on information exchange. Blockchain-based HIEs, like MedRec, OmniPHR, and MeDShare have gained traction, as have Fast Healthcare Interoperability Resources, like Google Cloud, Epic, Cerner, and Allscripts. These are promising tools to facilitate seamless data exchange and collaboration among health care providers. However, ensuring the security and privacy of patient data remains a paramount concern. Governments are likely to regulate interoperability standards and practices, with US compliance requirements like HIPAA and the Cures Act shaping the landscape. Financial constraints and varying levels of readiness, especially for smaller providers, pose challenges in adopting the necessary infrastructure and technologies, potentially leading to industry consolidation.

5TH YEAR ON THE LIST

AUTOMATION OF PROCESSES

WHAT IT IS

Automation is transforming health care, making the industry more efficient and reliable. Big Tech is championing workforce automation while introducing process efficiency solutions for appointment scheduling, billing, supply chain management, health management, admissions and discharges, follow-up care, prescription management, quality assurance, and compliance.

HOW IT WORKS

Last year saw a rise in AI-generated note-taking tools as several companies, including Microsoft and Amazon, launched their versions. Microsoft-owned Nuance Communications released its Dragon Ambient eXperience Copilot, which is integrated with large language model GPT-4 and automatically drafts clinical summaries of conversations with patients conducted in an exam room or via telehealth. Amazon Web Services introduced HealthScribe, a new HIPAA-eligible service that leverages speech recognition and generative AI to automatically create preliminary clinical documentation from patient-clinician conversations. Microsoft's cloud division Azure is releasing a new functionality for clinical report simplification. With the use of generative AI, the tool simplifies clinical jargon so patients can better understand medical information. OpenLoop's API-driven platform can be aligned to meet workflow needs and securely houses patient personally identifiable information with its built-in HIPAA compliance software.

XTend Robotics has developed patented robot technology to deploy modular service robots that can adapt to any industry. Multitasking intelligent robots can be used in hospitals and ambulatory care facilities to interact with patients, automating the check-in and vitals collection process. Increasing efficiency over 70%, the robots take dictation and automatically update patients' files on the facility's EHR system.

WHY IT MATTERS

Automation, driven by technologies such as AI and robotic process automation (RPA), leads to greater efficiency, accuracy, and improved patient outcomes. Administrative tasks, appointment scheduling, billing, and data entry, which traditionally demanded significant human resources, can now be streamlined. Though there is an upfront cost for adoption, the automation of processes will save time and preserve limited staff. Automation enables health care providers to focus more on direct patient care. Moreover, in clinical settings, AI-driven tools aid in diagnostics, treatment planning, and personalized care, leveraging vast data sets to identify patterns and make data-driven predictions. Automation promises a minimal standard of care, reinforcing adherence to regulation and quality assurance.

1ST YEAR ON THE LIST

INCREASED CYBERSECURITY THREATS

WHAT IT IS

Cybersecurity concerns are on the rise, and the threat to health care organizations, information systems, and patient safety are substantial. According to IBM's Cost of Data Breach 2023 Report, the global average cost of a data breach in 2023 was $4.45 million, a 15% increase over three years.

HOW IT WORKS

In a Ponemon Institute survey of 653 health care IT and security practitioners, 88% of respondents reported experiencing an average of 40 cyberattacks within the past 12 months. A significant number of large companies have experienced some sort of a breach. PharMerica, operated by parent company Bright Spring Health, disclosed a breach to the Office of Civil Rights in May that impacted more than 5.8 million people. Managed Care of North America suffered a major data breach that lasted nearly two weeks, impacting 8.8 million people. Henry Schein, distributor of medical and dental supplies, announced a cybersecurity attack that caused the company to take systems offline. 23andMe issued a notice of data concerns due to suspicious activity at its operations in October. Perry Johnson & Associates, a US medical transcription service, fell victim to a cyberattack that exposed highly sensitive information of 9 million patients, the second-largest after HCA Healthcare's 11 million-record earlier in the year. And a new ransomware threat, NoEscape, has targeted the health care industry. Despite being new to the landscape, the ransomware group has very rapidly made a name for itself. In response to the increase in threats, UC San Diego School of Medicine was awarded $9.5 million to research cybersecurity in health care and launched its Center for Healthcare Cybersecurity, which will focus on identifying early indicators of cyberthreats using simulated ransomware.

WHY IT MATTERS

PwC's Global Digital Trust Insights survey reveals a concerning trend: Businesses experiencing data breaches resulting in damages exceeding $1 million jumped from 27% to 36% in the past three years. While traditional threats like ransomware, DDoS, and social engineering persist, emerging cyberattack categories include biomalware, medical deepfakes, and machine learning simulations mimicking users' digital activities. Of particular concern is biomalware targeting and manipulating biological systems, such as DNA. This biomalware can take various forms, such as viruses or Trojan horses operating at the genetic or cellular level, and can be used to disrupt research, harm individuals, or access genetic information.

AI-powered security solutions have introduced groundbreaking features, such as continuous threat monitoring, anomaly detection, predictive analysis, and vulnerability assessment. AI's ability to process vast amounts of security data can predict vulnerabilities and automate patch management. AI is especially adept at identifying zero-day exploits, when an attacker identifies a software vulnerability even before the vendor has become aware of it. A first-of-its-kind unified security platform, Microsoft Security Copilot integrates tools for automatic detection and response. Recently IBM introduced Threat Detection and Response Services, an AI-enabled service delivering 24/7 monitoring, investigation, and automated remediation of security alerts across hybrid cloud environments.

SCENARIOS

SCENARIO YEAR 2040

Biological Data Vaults

To increase data security and enable environmentally sustainable storage of our data, a new solution emerged in the early 2030s: encoding sensitive information directly into human DNA. This technique, which leverages the vast data storage capacity and unique personal signature of DNA, converts critical data such as medical and financial records into nucleotide sequences. The approach transforms individuals into secure carriers of their own encrypted information.

But recently, this innovative system became the focal point of a sophisticated cyberattack, orchestrated by a rogue state-sponsored hacking group to undermine trust in this new technology and to extract high-value information for espionage and financial gain. The attack employed a digital virus specifically tailored to breach the interface between biological and digital security systems. It was introduced into the population through common medical channels, such as standard blood tests or vaccines, using genetically modified vectors to deliver the payload.

Once inside the host, the virus lay dormant until remotely triggered. Upon activation, it employed complex algorithms to decode the encrypted data stored within the DNA and converted it back into a digital format. The virus harnessed the body's bioelectrical system, which is primarily generated through the activity of neurons and the body's way to communicate internally, to transmit this data to the attackers, leaving no physical evidence of the breach. The modified electrical signals the neurons produce because of the virus are received by sensors specifically designed to detect and interpret these bioelectrical patterns.

Once the data was extracted, the hackers engaged in a dual-pronged approach: They sold sensitive personal and financial information on the dark web, targeting high-net-worth individuals and key corporate figures for identity theft and financial fraud. They also exploited corporate and governmental data, which was stored in the DNA of leadership individuals, for espionage, seeking competitive intelligence and state secrets to threaten overall geopolitical security.

REMOTE CARE

9TH YEAR ON THE LIST

IN-HOME CONSUMER HEALTH TECHNOLOGY

WHAT IT IS

Digital biomarkers are behavioral and physiological data, such as heart rate, blood pressure, body temperature, sleep patterns, and physical activity, collected through digital devices. Smart home technology is evolving to facilitate the monitoring of digital biomarkers, creating an integrated ecosystem for health information that complements wearables.

HOW IT WORKS

It's easier than ever for consumers to measure and monitor their digital biomarkers. Freestyle Libre's continuous glucose monitoring wearable sensors received FDA clearance for connectivity with automated insulin delivery systems. Abbott is introducing Lingo, a wearable that will measure glucose levels for people without diabetes and deliver personalized plans for healthier habits. Somavedic Technologies launched the Attune Health app, which takes AI-enabled biomarker analysis of blood pressure, heart rate, oxygen saturation, stress levels, and hemoglobin based on a facial scan on a smartphone camera. It measures changes in red, green, and blue light reflected from the skin. The Gao Lab at the California Institute of Technology introduced a finger patch for microfluidic sweat sampling of estradiol. Only requiring a miniscule amount of sweat, the device consistently learns and recalibrates based on salt levels, skin temperatures, and sweat pH. The team is working to miniaturize the sensor for placement in a ring, as the device can already wirelessly communicate with an app.

Today's digital biomarkers are not limited to wearables; they're also making their way into the infrastructure of the home. With the U-Scan from Withings, a sensor is placed under the rim of a toilet bowl to measure biomarkers and metabolites in a person's urine. A recently approved patent application shows that Apple, which purchased Finnish technology company Beddit, is developing an in-bed sensor system to collect physiological data during sleep.

WHY IT MATTERS

Biosensors, compact devices designed to detect biological elements and convert them into measurable signals, are increasingly finding their way into homes. Imagine furniture textiles that measure vital signs to predict minor sickness and maintain body temperature, toothbrushes that detect dehydration and make dietary recommendations, optical sensors in televisions that can detect stress and cognitive decline, windows that can measure vitamin D deficiency and control smart light bulbs in response, smart plumbing that can filter bacteria from the water supply, and air purifiers that measure clean oxygen supply and recommend houseplants to improve air quality. Whether these sensors are integrated with wearable devices or standalone units, the technology offers a comprehensive view of our well-being by tracking vital signs and other health parameters in real-time. Revolutionizing personal health care management, biosensors empower users to make informed decisions for fostering preventive health care.

While the integration of biosensors into everyday life offers unprecedented benefits, it raises concerns about data security and privacy. Given the ability to generate vast amounts of data, there are necessary ethical considerations surrounding data usage. Our homes will play a crucial role in health management, and if the health data infrastructure can overcome challenges stemming from data standardization and interoperability, expect to see further development supporting holistic sensor ecosystems. In 2022, the global market for biosensors was valued at $26.8 billion, and it is projected to grow significantly in the coming years.

4TH YEAR ON THE LIST

SCALING OF TELEMEDICINE

WHAT IT IS

Telemedicine leverages technology for remote health care delivery. While the Covid pandemic initially prompted the emergence of remote care options,the trend is clearly here to stay and will even expand beyond primary health. The market is forecasted to be valued at $460 billion by 2030.

HOW IT WORKS

The global telehealth market is on track to achieve remarkable growth due to increasing technology adoption. AI and machine learning play a crucial role, by providing personalized, predictive, and preventative guidance, which has helped telehealth evolve beyond primary health virtual consultations to encompass virtual pharmaceutical, translation, and surgical services. The Midday app facilitates direct communication to promote healthy aging. Aimed at supporting menopausal women, the end-to-end platform evaluates menopause progression to deliver personalized insights, and evidence-based strategies and education. Amazon's RxPass, a $5-per-month subscription, offers affordable and convenient pharmacy services without insurance. Subscribers can have generic medications for more than 80 common health conditions sent to their home. Voyce introduces professional language interpreters, enabling real-time medical interpretation in more than 240 languages, including American Sign Language. The technology seamlessly integrates with EHRs, automatically documenting sessions for future reference. In Singapore, a groundbreaking robotic telesurgery trial utilized Japan's first surgical robot. It remotely performed a gastrectomy from a Singapore-based surgeon cockpit, with movements transmitted and replicated by a robotic unit in Japan. This collaboration represents a pivotal stride in making remote surgeries accessible to patients, demonstrating the transformative potential of telehealth.

WHY IT MATTERS

Consumers are increasingly comfortable with telemedicine options. In a recent study, 55% of patients expressed more satisfaction with virtual visits than in-person visits. Rural communities and underserved populations stand to gain the most as health care providers expand their reach and fill gaps in care delivery caused by provider shortages and limited facilities. And there's potential for cost reduction on both ends of the spectrum: Subscription services, available with or without insurance, are more affordable, while providers benefit from the savings associated with not maintaining physical offices. Investments in telehealth have also expanded to specialty care, and the future of telemedicine could include extended reality (XR) technology offering more lifelike virtual interactions, especially for remote surgery.

But access remains a big hurdle due to challenges related to digital technology access and connectivity. Zero-latency connectivity is essential for virtual visits, as it ensures real-time guidance and critical decision-making without delay. Starlink provides almost global satellite coverage, and Amazon launched Project Kuiper, a satellite system aimed at providing high-speed internet access globally. With the promise of reliable access to broadband, the system's success will be a game changer for achieving interoperability. The attainment of global connectivity is poised to reduce the prevalence of medical tourism, by making telemedicine a more reliable and accessible alternative.

4TH YEAR ON THE LIST

REMOTE PATIENT MONITORING

WHAT IT IS

As the population ages, remote patient monitoring (RPM) is increasingly relevant for achieving a higher quality of life. RPM ensures continuous communication between patients and their health care provider team by utilizing digital technologies and devices to collect and transmit patient health data outside of traditional health care settings.

HOW IT WORKS

Increasingly, health data can be transmitted to providers from anywhere, and companies are offering new services to take advantage of the trend. A new hospital-at-home program from Best Buy collaborating with Atrium Health sends members of the retail giant's Geek Squad to patients' homes; they set up technology that remotely monitors heart rate, blood oxygen level, or other vitals, and train patients and caretakers to use the devices. The tech then securely shares the data with doctors and nurses through the telemedicine hub from Current Health, a UK-based tech company. There's also Cardinal Health's Velocare, a supply chain network for the fulfillment of care devices and products. In coordination with care teams, Cardinal Health facilitates seamless delivery of medical essentials to home care patients, eliminating challenges in transitioning hospital care to a patient's home.

On the equipment side, Noccarc's smart ventilator enables real-time remote monitoring of patient conditions. Physicians can seamlessly access vital patient information through a proprietary app-based platform, even when patients are not physically present in the ICU. BioPix-T launched Pebble, a portable diagnostic device to facilitate connections between health care providers and patients: It enhances access to the tools needed to detect and monitor infectious diseases and health issues despite geographic location. Sleepiz, a Zurich-based medtech company, received FDA clearance for its Sleepiz One+, a contactless bedside device that measures respiratory and heart rates.

Researchers at NYU Langone Hospital have also launched the Diabetes in Pregnancy Remote Patient Monitoring Program. The pilot program has supported 1,000 patients at risk for gestational diabetes with digital glucose monitors that automatically transmit daily glucose levels to EHRs for review by the maternal-fetal medicine team.

WHY IT MATTERS

RPM harnesses digital technologies in the continuous collection and transmission of patient health data, allowing patients to receive necessary care anywhere. The ability to facilitate prompt interventions makes it particularly valuable for managing chronic conditions, monitoring postoperative recovery, and delivering ongoing home-based care. Particularly pertinent as the population ages, RPM ensures a higher quality of life for geriatric adults by enabling hospital-level care in the comfort of their homes, with medical-grade equipment and remote monitoring tools. Hospital-at-home services offer significant cost savings for health care systems by curbing hospital admissions and emergency room visits through early intervention and improved disease management. Patients also benefit from increased engagement in their health monitoring through better outcomes. As such there has been a growing adoption of hospital-at-home devices and telemedicine technology in senior care and assisted living facilities, where the integration of these innovations enhances on-site care for residents. Though broader adoption in patients' homes has been slow, this hesitance is likely due to space constraints or limited support (i.e., family members, nurse aides) preventing consumers from feeling comfortable or safe receiving care outside clinical facilities.

SCENARIOS

SCENARIO YEAR 2035

The Optimization Score

The health care industry's lethargy in responding to change led the Big Tech companies to fill the void with cheaper, higher quality, and more price-transparent products and services. Already trusted partners in a personal and professional context through their hardware and software products, integrating health care offerings was actually welcomed as it facilitated a holistic and seamless approach to optimizing quality of life.

The digital ecosystems continually capture and synthesize health data from a myriad of sources: wearable devices, smart home systems, and even public infrastructure. AI health platforms meticulously analyze this data, and synthetic "health coaches" offer tailored suggestions to optimize physical and mental well-being. This constant monitoring and guidance ensure that individuals are not just living but thriving, under the vigilant eye of technology.

To incentivize healthier living and alleviate the strain on health systems, a health scoring system was introduced, reminiscent of the credit scores of the early 21st century. The Health Score, a dynamic and comprehensive metric, reflects an individual's health habits, lifestyle choices, and overall well-being. Initially devised as a tool for personal motivation and friendly competition, it quickly evolved into a societal benchmark, a digital ledger of one's health consciousness. The Health Score is not just a number; it's a reflection of one's commitment to a healthy lifestyle, tracked and fostered by ever-present AI.

This scoring system has profound implications on everyday life. High scorers enjoy perks ranging from priority in job applications and access to exclusive amenities, to favorable terms on loans and insurance policies. Displayed on digital profiles and wearable device screens, the score has become a status symbol, a digital badge of honor showcasing a person's dedication to health. In contrast, those with average or low scores, or those who opt out of this system, find themselves at a significant disadvantage. They face hurdles in securing employment, higher premiums, and restricted access to certain societal privileges. The Health Score, while not mandatory, has become a de facto requirement for a comfortable and prosperous life.

EMERGING DIAGNOSTICS

2ND YEAR ON THE LIST

SMART MATERIALS

WHAT IT IS

Incorporating sensors into textiles offers noninvasive data collection for advanced health monitoring and analysis. The smart textiles market is expected to grow to $6.6 billion by 2026. But scalability presents formidable challenges, as these textiles must be able to endure prolonged use while continuing to deliver accurate measurements.

HOW IT WORKS

Right now, the field is focused on overcoming manufacturing challenges that hinder scaling of smart textiles. In collaboration with researchers at the University of Cambridge, scientists from Aalto University have incorporated liquid crystalline elastomer yarns into woven textiles to create a reactive fabric that responds to heat. At Purdue University, researchers are looking at smart fabric breathability, as it is associated with comfort: They've developed a patent-pending method of coating everyday fabrics with polymer electronic sensors, PEDOT, using a technique called oxidative chemical vapor deposition. MIT researchers have used a unique plastic yarn to create a knit textile, 3DKnITs, that when interspersed with sensors using a novel digital knitting technique, can continuously detect multipoint pressure across its surface in real-time. A new cotton-based conductive thread, PECOTEX, developed by scientists at the Imperial College of London, embeds a low-cost sensor (just 15 cents per meter of thread) to monitor breathing, heart activity, and even gases like ammonia. Israel-based company HealthWatch has emerged as a pioneer in the development of smart-digital garments, particularly with its development of the Master Caution. The only 12-lead ECG smart clothing that has been cleared by the FDA, Master Caution is a sensor-rich textile garment that provides continuous cardiac monitoring.

WHY IT MATTERS

Embedding sensors into textiles is a minimally invasive avenue to collect data about daily activity and environmental exposure. Compared to wearables, smart materials are more versatile, adaptable, and less disruptive to consumers' lives. Their integration lets consumers receive real-time feedback, promoting healthier habits. And their ability to generate substantial data offers valuable insights for continuous health monitoring, early detection of medical conditions, and remote patient care. Scientists are considering ways to monitor and respond to biological hazards and environmental conditions, including air quality, pollution levels, and radiation exposure. Advancements in materials and production methods suggest that smart textiles could greatly reshape the industry.

Researchers are exploring innovative materials, such as spider silk and elastomers, and cost-effective production methods, including traditional industrial knitting machines. But challenges with scaling production have prevented smart textiles from flooding the market just yet. Concerns have also arisen regarding the potential effects of increased electromagnetic field exposure. At this juncture, the military is expected to account for a sizable amount of the market for smart textiles, as applications include enhanced insulation, motion tracking and GPS, and advanced health monitoring. For the broader population, smart textiles hold immense promise in the shift toward personalized care and holistic health.

1ST YEAR ON THE LIST

BIOSENSOR AND CHIP-BASED DIAGNOSTICS

WHAT IT IS

Biosensors recognize biological material as it binds to a specified target and convert the biological response into a detectable signal. Advanced data analysis and machine learning techniques are being integrated with biosensors to enhance diagnostics by recognizing patterns and trends in large data sets.

HOW IT WORKS

Researchers are developing new tools using biosensors to uncover new biological insights. Wireless earbuds, developed by MindMics and Scripps Research Institute, use embedded sensors to record heartbeat vibrations once a second to indicate heart disorder and abnormalities. Researchers at Ohio State University designed a wearable sensor, resembling a blood pressure cuff, to detect muscular atrophy. The device embeds transmitting and receiving coils in a flexible fabric to measure deterioration as it stretches to a person's movement.

An international team led by the Gwangju Institute of Science and Technology has proposed a synergistic biosensing tool called DeepGT. It leverages AI in Gires-Tournois biosensing platforms to quantify nanoscale bioparticles, including viruses, without needing complex sample preparation methods. The system can also indicate the severity of the infection including if it's asymptomatic.

A Malmö University researcher developed a wireless battery-free biosensor powered by induction from a cellphone. A nanoscale sensor system, put together by a team at the University of Toronto and Northwestern University, identifies biomarkers by exploiting DNA aptamers to detect clinical levels of a marker protein for cardiovascular disease without using external reagents. And Hememics Biotechnologies and General Graphene have partnered to produce 32-plex graphene biosensor chips, tested to be 100 times more sensitive than lateral flow devices; the chips can detect pathogens from one sample of blood or saliva.

WHY IT MATTERS

Biosensors offer a paradigm shift in patient diagnosis through the early detection of medical conditions. Recent advancements are focused on highly sensitive and versatile sensors capable of performing multiple tests simultaneously despite the presence of different biological particles at varying concentrations. Biosensors have application in industries where precise and rapid detection of harmful substances is crucial. Beyond a clinical setting, biosensors can be used to detect contaminants and pathogens—for example, spoilage indicators in food products, or pollutants and toxins that affect air and water quality.

With the acceleration of point-of-care diagnostics, researchers are working on the development of microfluidic chips with embedded biosensors for greater precision. The integration of these concepts in a highly sensitive portable device paves the way for remote diagnostics. As biosensors are increasingly incorporated into wearable and in-home devices for continuous monitoring, the need for frequent in-office or hospital visits decreases.

2ND YEAR ON THE LIST

MOLECULAR DIAGNOSTICS

WHAT IT IS

Molecular diagnostics leverage the sensitivity and accuracy of CRISPR technology to analyze genetic material for early detection of disease, aiding timely intervention. The application of CRISPR in developing advanced molecular diagnostic tools enables interventions based on individual genetic profiles and opens up more effective and precise health care strategies.

HOW IT WORKS

At the University of Oxford, researchers have innovated a method for protein analysis to efficiently build protein inventories of single cells and tissues. This new categorization method makes it easier for doctors to identify the protein variants associated with disease on an individual basis. Genomic sequencing company Illuma developed PrimateAI-3D, which is trained to make predictions based on genome analysis and scans 70 million genetic variants in a person's genome to detect harmful variants. Illumina plans to release the tool broadly, after completing testing on the UK BioBank. While identification and analysis are key to preventative diagnostics, just as important is recognizing abnormal activity. Researchers at Weill Cornell Medicine have developed a novel method for organ mapping that could inform the design of future treatment and interventions. Spatial PrOtein and Transcriptome Sequencing can record gene activity patterns, identify key proteins, and map precise locations of cells in tissue samples.

An increasing number of health care institutions, like UCSF Benioff Children's Hospital, are implementing in-house rapid whole genome testing to assess and diagnose risk for infants with suspected genetic diseases. Ultra-high-throughput gene sequencers aim to make whole genome sequencing more affordable, as two companies, Ultima and Complete Genomics, introduce platforms that lower costs to less than $100 per genome.

WHY IT MATTERS

In infectious disease control, molecular diagnostics are pivotal for rapidly and accurately detecting viruses and bacteria. This capability is critical for implementing timely public health measures, and techniques like polymerase chain reaction, DNA sequencing, and microarrays enable the early detection often before symptoms manifest. This allows for a shift in focus toward developing informed treatment plans rather than simply identifying the problem. Harnessing CRISPR, researchers have developed highly specific tests for detecting genetic mutations, pathogens, and various molecular markers. The integration of CRISPR into biosensors has further advanced on-site testing capabilities, fostering the creation of rapid and accurate point-of-care diagnostic tools. Notably, scientists used CRISPR in the development of rapid tests for detecting Covid.

Anticipating a fundamental shift in health care practices, molecular diagnostics, augmented by AI and nanotechnology, is set to become routine in patient care. Efforts are underway to enhance user-friendliness and cost-effectiveness for accessibility across different health care settings, and even at-home use. Integration with wearables and telemedicine platforms is on the horizon. The prospect of full-genome screening tests for newborns and infants is gaining momentum, with studies showing whole-genome sequencing to be much more effective than targeted gene sequencing in identifying abnormalities responsible for genetic disorders.

4TH YEAR ON THE LIST

INCREASED CAPABILITIES OF POINT-OF-CARE DIAGNOSTICS

WHAT IT IS

Conveniently performed near a patient, point-of-care (POC) diagnostics offer speed, convenience, and accessibility. Now, smartphone-enabled POC devices enable real-time data transmission and expand the reach of telemedicine. Modern POC devices can perform multiple tests simultaneously, allowing for the detection of various diseases or conditions from a single sample.

HOW IT WORKS

Polish telemedicine startup Healthnomic offers an at-home polygraph examination to remotely diagnose and treat obstructive sleep apnea, by gathering data in a patient's natural sleeping environment. GrapheneDx is harnessing graphene in developing urine-sample tests to detect sexually transmitted diseases within minutes. A new facial recognition software for germs, developed by Oxford scientists and licensed by Pictura Bio, is a universal diagnostic imaging platform that identifies the presence of pathogens in a nasal or throat swab sample in seconds. Quest Diagnostics has introduced the AD-Detect test for Alzheimer's disease, a blood-based biomarker test available for purchase by consumers. AD-Detect overcomes current diagnostic methods—limited by the need for specialized clinics and trained staff—through an in-home blood test that determines risk for developing Alzheimer's disease by measuring abnormalities of beta-amyloid protein. At-home diagnostics startup Viome Life Sciences has launched Oral Health Pro with CancerDetect, to detect biomarkers associated with oral and throat cancers. With a specificity of 95% and sensitivity of 90%, the test uses RNA sequencing technology and AI to measure gene expression of the oral microbiome and cells of each patient's saliva. Though these and similar tests are still ordered and evaluated by physicians, they're a first step—albeit an imperfect one—in equipping consumers with convenient methods of early detection.

WHY IT MATTERS

POC diagnostics offer immediate on-site medical testing with results made available in real time. Common examples are rapid tests to identify infectious diseases (used to combat the Covid pandemic), pregnancy tests, and glucose monitoring. Unlike traditional laboratory testing that involves sending samples to centralized facilities, POC diagnostics bring testing to the patient, minimizing delays in triage and treatment. They reduce the workload on central laboratories, by addressing backlogs and delays in test results. In resource-limited settings, where access to sophisticated laboratory infrastructures is limited, POC diagnostics present a new level of care. In developing worlds, POC diagnostics could make a difference in the rapid spread of disease.

Integral to telemedicine and remote monitoring, POC allows health care providers to assess patients' conditions and make decisions without the need for in-person visits. Recent developments in POC testing include: wireless integration for real-time results and insights to be delivered via an app, portable diagnostic devices that can perform multiple tests simultaneously from a single sample, and customization of biomarker panels for testing of specific diseases or conditions. In addition, POC devices for gene sequencing and molecular diagnostics are on the horizon. For the adoption of a patient-centric model, POC diagnostics ensures that medical decisions are as timely as they are accurate.

1ST YEAR ON THE LIST

XR IN DIAGNOSTICS

WHAT IT IS

XR is transforming medical diagnostics by introducing ways to interact with medical data, patient information, and anatomical structures. The technology enables the visualization of disease progression, immersive training simulations, and remote collaboration. While XR holds great promise, issues of data privacy, accuracy, and regulatory compliance should be considered.

HOW IT WORKS

AI and machine learning algorithms are automating the analysis of medical images and aiding in the early detection and diagnosis of disease. Imidex received FDA clearance for VisiRad XR, a machine learning platform that detects subtle, often overlooked, lung nodules on chest X-rays. Nutex Health has integrated DRAid Chest XR into the radiology workflow of its hospitals. A research team led by Michigan Medicine developed DeepGlioma, a AI-based diagnostic system that uses rapid imaging to screen for genetic mutations in brain tumors in under 90 seconds during surgery. Stable Diffusion is an AI-algorithm able to read fMRI brain scans to re-create realistic images based on what a person has seen. The algorithm was recently retrained, enhancing its accuracy. The technology, currently tested on a limited data set, holds promise for further cognitive neuroscience research.

Avatar Medical's VR surgical planning solution, which generates patient avatars from CT scan and MRI images, has received FDA clearance. GigXR released Dicom XR Library, a platform that generates realistic 3D medical imagery from MRI and CT scans for training and learning purposes. MedView XR received FDA clearance for its XR90 AR platform, which renders 3D images with the use of CT scans during minimally invasive procedures. MedView aims to improve surgical visualization and promote collaboration; it's secured $15 million in funding from notable industry players, including the Mayo Clinic and GE Healthcare.

WHY IT MATTERS

XR technologies offer new ways for health care professionals to visualize and interact with medical data, patient information, and anatomical structures. Using head-mounted wearable technology, XR technologies can integrate real-time patient data and diagnostic history into a clinician's field of view during medical examinations for more accurate diagnostics. Beyond the exam room, XR facilitates remote collaboration and fosters communication between patients and medical professionals. Experts from different locations can virtually collaborate on diagnosing complex cases, share insights, and arrive at accurate diagnoses more quickly. Through immersive explanations and visualizations of medical conditions, XR enhances patients' understanding of symptoms and overcomes language barriers. Interactive 3D models can potentially support medical professionals in explaining their diagnosis and treatment plans to patients. Overall, patients will better understand their conditions and treatment options and make more informed decisions.

In imaging interpretation, virtual reality and augmented reality enhancements enable radiologists and imaging specialists to immerse themselves in detailed 3D reconstructions of patient scans. Medical students and practitioners can also train on XR platforms to refine their diagnostic skills in a risk-free environment and practice patient interactions through simulated office visits. Medical students can also study disease pathology through the visualization of disease progression. While the promise of XR in medical diagnostics is evident, it's imperative to address concerns of data privacy, accuracy, and regulatory compliance. As XR technologies advance, they will likely play an increasingly prominent role in the medical diagnostics process.

2ND YEAR ON THE LIST

MEDICAL DEEPFAKES

WHAT IT IS

Medical deepfakes involve the use of AI to manipulate medical data or images and present a double-edged sword: They're promising for the advancement of medical education and research, but involve substantial risk when used maliciously. Amid AI's rapid sophistication, health care organizations have been slow to regulate.

HOW IT WORKS

Given the difficulty in deciphering real and synthetic data, deepfakes compromise data integrity. A study in Finland demonstrated that on average, more deepfakes were mistaken for real X-ray images than the opposite. A surge in deepfakes has prompted insurance companies, including Aetna and Cigna, to deploy machine learning algorithms to evaluate insurance claims, and nearly 60% of insurers are using this fraud detection strategy to ensure fair and accurate coverage. Though the action is justifiable, it has led to unintended consequences, like the mislabeling and subsequent denial of legitimate claims.

Clinical-stage drug discovery company Insilico Medicine is utilizing deepfakes to design molecules with disease-treating ability. Its AI platform, Pharma.AI, can discover novel therapeutic targets, formulate new pharmaceutical drugs, and predict the results of clinical trials. Alongside researchers and Nobel laureates, the company applied AlphaFold, Google DeepMind's protein structure database, to Pharma.AI, identifying a novel treatment pathway for hepatocellular carcinoma in only 20 days. Korea University researchers proposed the use of StyleGAN2 to create synthetic mammographic images and an anomaly detection method to detect breast cancer on mammograms. Their generative AI model showed comparable fidelity to real images, while results indicated that the anomaly detection was highly sensitive. The study presents a promising approach for improved breast cancer detection.

WHY IT MATTERS

In a world where deepfakes proliferate, the very essence of the patient-doctor relationship is at risk. Their presence erodes the trust and reliability in the health care system. Researchers conducting studies or clinical trials may use deepfakes to manipulate research findings to skew results in support of a particular agenda or to secure funding. Fraudsters may use medical deepfakes to forge insurance claims or to exaggerate injuries and illness in a personal injury lawsuit. Cybercriminals may use medical deepfakes to gain unauthorized access to patient records and sensitive medical information. Sinister groups may defraud the public during a health crisis or outbreak to generate fear and panic.

While there is a dark side to medical deepfakes, their accuracy can also aid in the development of diagnostic tools and drug treatments, accelerating the pace of scientific discoveries and innovations. When used to generate synthetic data, they ensure patient privacy and compliance with regulations. In training and education, medical students and practitioners can interpret and diagnose a wide range of medical conditions via simulated cases.

The health care industry has only begun to invest in technologies and protocols to detect and prevent deepfake manipulation. A watermark created by DeepMind in partnership with Google Cloud SynthID, the first of its kind, embeds an immutable mark directly into images created by Imagen.

EMERGING TREATMENTS

2ND YEAR ON THE LIST

NANOBOTS

WHAT IT IS

Nanobots offer precise, minimally invasive treatment for targeting disease and improving drug delivery. Concerns include material toxicity and genetic modification, and yet the technology could enable precise and efficient procedures with reduced side effects and adverse reactions.

HOW IT WORKS

Researchers at the Indian Institute of Science and Theranautilus have developed helical nanobots able to penetrate dentinal tubules where antibiotic-resistant bacteria accumulate. Controlled by a magnetic field, the nanobots' heat generating capability was effective in killing bacteria. Similarly, researchers from the University of Pennsylvania have developed magnetically controlled nanorobots with catalytic properties to generate antimicrobial oxygen-containing molecules that eliminate fungi within 10 minutes.

At the Shenzhen Institute of Advanced Technology, self-propelling nanobots offer precise gastrointestinal inflammatory therapy; these TBY-robots penetrate the mucus barrier and autonomously navigate to the inflamed site. MIT scientists developed magnetically controlled soft-bodied polymer robots measuring millimeters long that can navigate confined spaces like blood vessels, enabling the delivery of drugs. A dual-action approach involving the delivery of lactate oxidase enzymes via tiny nanocapsules to promote immune cell activity was developed by researchers at UCLA. Engineers at University of Colorado Boulder developed a self-propelled robot that measures only 20 micrometers wide and can travel at a speed of 3 millimeters per second, demonstrating potential for drug delivery. The researchers hope to make these robots fully biodegradable so that they would dissolve in the human body.

WHY IT MATTERS

The industry is witnessing an unprecedented surge in the integration of robots. At the forefront are nanobots, miniscule robots that operate at nanoscale to perform highly targeted activities in the body. They can deliver medication to a tumor without affecting healthy tissues or perform intricate surgeries in delicate, hard-to-reach areas. Nanobots minimize side effects, reduce immune response, and accelerate recovery time, thereby reducing risks. Extending beyond surgery, they are applicable in telerobotics given the ability to be remotely controlled across distances, enabling prolonged observation of chronic conditions and real-time delivery of drugs.

Equipped with sensors and diagnostic tools, nanobots detect biomarkers and abnormalities. Molecular nanobots can be designed to respond to biological signals, adapting shape and function to conditions within the body. And researchers are exploring self-propelling features for autonomous operation. This would increase the efficacy of cancer treatment through drug delivery and targeted tumor therapy, while the nanobots' ability to navigate the blood-brain barrier also opens avenues for treating neurological disorders. But concerns exist around the possibility of unintended consequences resulting from genetic modification. While synthetic nanobots offer precise engineering, they could be toxic with long-term exposure. Ultimately, the choice whether to use the technology hinges on the medical task, safety considerations, and personalization.

4TH YEAR ON THE LIST

AR/VR THERAPEUTICS

WHAT IT IS

A versatile technology, extended reality is being increasingly used in therapeutics for a wide range of physical and mental health issues including rehabilitation, pain management, exposure therapy, and reducing stress and anxiety. Augmented reality/virtual reality introduces gamification to therapeutic techniques, increasing patient engagement and motivation through immersive experiences.

HOW IT WORKS

A pilot study by Stanford Medicine researchers suggests that VR therapy could help people with a hoarding disorder declutter in real life. The therapy allows patients to rehearse relinquishing possessions in a simulation of their own home, helping them practice skills learned in cognitive behavioral therapy. Immersive VR appears to alleviate pain and distress in cancer patients, according to a pooled data analysis published in BMJ Supportive & Palliative Care. The study suggests that VR may help patients better cope with required medical treatments and the emotional impact of their conditions. Samsung's advanced AI app operating within diminished reality, Unfear, is interoperable with Samsung Galaxy earbuds to filter known trigger sounds to calm and assist patients with autism spectrum disorder, auditory PTSD, and hearing disorders. An Australian startup, RecoveryVR, gamifies VR technology for neuro-rehabilitation. AI Rehab is a UK-based startup that designs telehealth solutions for patients recovering from hip and knee surgeries. Its products combine AR and wearable remote sensors to make it easier for patients to perform pre- and post-operative exercises. Built-in alerts for remote notification and patient-reported outcome measures ensures standardized feedback and measurable data.

WHY IT MATTERS

Governments and industry professionals are under increasing pressure to explore innovative and accessible solutions to address the growing mental health crisis, and XR technology is an incredibly viable way to do this. Through the use of virtual rooms for therapeutic care, XRHealth revealed that VR therapy reduces stress and anxiety in patients by 34%. The study underscores the efficacy and accessibility of VR therapy to provide engaging and effective mental health treatment options. XR technology also allows for remote treatment and monitoring, mitigating risks of unwanted side effects common to pharmaceuticals.

With AR, rehabilitation techniques can be gamified, resulting in increased patient engagement and greater adherence to treatment plans. The technology is utilized in exposure therapy for the treatment of anxiety disorders and phobias, by creating controlled immersive environments for gradual confrontation of fears and anxieties. AR and VR are particularly useful in preparation for medical procedures, distracting patients exhibiting signs of distress before or during. But widespread adoption still faces challenges, including high hardware costs, limited bandwidth in remote areas, and regulatory complexities. XR therapy solutions must meet rigorous regulatory standards to ensure patient safety and data privacy, and navigating these regulations can be complex and time-consuming. Also, XR therapy's coverage by insurance is not guaranteed, making it just as inaccessible as current mental health treatments.

2ND YEAR ON THE LIST

IN-WOMB TREATMENTS

WHAT IT IS

In-womb treatments address fetal conditions pre-birth through surgery or medication. Early intervention, like repairing defects and treating anomalies, aim to improve outcomes for the deliverance of a healthy baby. Ongoing research and clinical trials seek to expand the scope of conditions that can be treated in utero.

HOW IT WORKS

Technology is making it increasingly feasible to treat fetuses while they're still in the womb, improving future health outcomes. In Boston, a team of doctors successfully performed a novel fetal surgery to treat a rare prenatal brain condition known as vein of Galen malformation, where blood vessels in the fetus' brain are improperly connected. A groundbreaking clinical trial at UC Davis Health delivered the world's first stem cell treatment for spina bifida in-utero. Scientists at UC San Francisco are pioneering in-utero stem cell transplants for the treatment of genetic disorders. A $2 million University of California, Davis project aims to cure Duchenne muscular dystrophy by editing genes using lipid nanoparticle injections in utero. The use of a fetoscopic approach for in-utero repair of gastroschisis is being tested in clinical trials at Texas Children's Hospital. And a student-led team at Johns Hopkins created a novel port system able to pierce through tissue, aiming to reduce the risk of membrane rupture during in utero surgery.

Advanced pharmaceutical and diagnostic technology is progressing toward use on pregnant patients and their fetuses. Trikafta, a drug treatment for cystic fibrosis administered to a pregnant mother, showed promise in reducing symptoms at birth. Treatments for the mother began at 24 weeks pregnant, and the baby was born without the bowel complications that had previously affected her two sons. The FDA has approved a blood test by Thermo Fisher Scientific that can identify pregnant women at imminent risk of severe preeclampsia, a leading cause of maternal mortality. The test measures the ratio of two proteins produced by the placenta, with up to 96% accuracy in predicting whether a woman will develop preeclampsia in the next two weeks. However the impact on outcomes remains uncertain as an effective treatment for this condition has yet to be developed.

WHY IT MATTERS

In-womb treatments are designed to address specific medical conditions or abnormalities in an unborn child. Fetal surgery may be performed to correct congenital anomalies, including procedures to repair neural tube defects, congenital diaphragmatic hernias, or twin-to-twin transfusion syndrome in identical twins, among others. Beyond surgery, in-womb treatments can involve the administration of medications directly into the amniotic fluid or through the umbilical cord to address certain fetal conditions, such as heart arrhythmias or anemia. But these treatments can be costly, raising questions about accessibility, health insurance coverage, and the financial burden on families. It also requires that expectant parents have access to comprehensive, unbiased information about the potential risks, benefits, and alternatives to in-womb treatments.

At the same time, advances in genetic testing promise earlier and more accurate prenatal diagnosis. Gene therapy research is exploring the possibility of in utero gene therapy to correct genetic disorders and inherited conditions before birth, while noninvasive prenatal testing based on cell-free fetal DNA is increasingly used to screen for chromosomal abnormalities. Future advancements include developing treatments for conditions like congenital heart defects, neurological disorders, and genetic diseases. This ongoing research into less invasive and safer procedures aims to reduce risks for both fetus and mother.

4TH YEAR ON THE LIST

COGNITIVE AND NEURAL OPTIMIZATION

WHAT IT IS

There is a growing focus on optimizing brain performance by enhancing cognitive function and mental well-being. Nootropic foods and extended reality–based training exercises aim to stimulate brain function to boost neuroplasticity. While available research supporting proof of concept is limited, increasing demand has fueled scientific interest.

HOW IT WORKS

Researchers are beginning to report success in using XR technology to improve brain function and well-being. A study investigating virtual cognitive behavioral therapy for depression indicated that, on average, this approach through absorption training reduces stress in adults. The NeuroGrow Brain Fitness Program, a 12-week brain training program, has shown statistically significant improvements in cognitive tests and notable decreases in sleep decline and emotional symptoms in patients with ADHD and memory loss. A study published in Scientific Reports identified a positive correlation between a stronger sense of presence in VR environments and enhanced cognitive abilities, demonstrating the application of VR technology in brain training. Virtuleap, a VR brain training platform, entered clinical trials for its immersive experience featuring a telehealth tool for continuous patient monitoring. And the University of Texas at Austin has modified a Meta VR headset, by installing a noninvasive EEG device to measure brain activity during VR simulations.

There's also an increased interest in the growing nootropics market, valued at $2.5 billion in 2022. Nootropics are cognitive enhancers that aim to improve memory, focus, and creativity. According to a survey conducted by Mintel, 42% of US consumers have expressed interest in food and drinks to improve their focus and 72% of respondents showed interest in nootropics, by stating they either currently drink, have tried, or are willing to try beverages with cognitive-enhancing benefits.

WHY IT MATTERS

Brain health goes beyond a balanced diet, regular exercise, and adequate sleep: Cognitive functions such as memory, attention, problem-solving, and creativity require training and intervention for increased neuroplasticity. Psychological well-being, stress reduction, and emotional resilience play integral roles in overall cognitive health as well. Recent advancements have prioritized neurofeedback, emphasizing the practice of self-regulation. Some AR apps offer mindfulness and relaxation exercises that guide users through breathing exercises, meditation, and stress-reduction techniques, while others facilitate cognitive learning and skills-based training. Alternatively, nootropics have expanded beyond supplements and "smart drugs" as they are adapted into consumable food and beverages. While this market is expected to grow at a compound annual growth rate of 15.47% over the next 10 years, it is important to note there is limited scientific evidence to support their cognitive-enhancing properties. Though the science has not narrowed down a best approach, there is growing demand for treatment that optimizes brain performance, or at least extends the longevity of it.

1ST YEAR ON THE LIST

MICROBIOMES AND HOLOBIONTS

WHAT IT IS

Our bodies are hosts to trillions of microbiota—communities of microorganisms that inhabit specific parts of our bodies, and as a whole, a microbiome. The holobiont concept defines the interconnectedness of a host organism and its associated microbiota, highlighting that as one ecological unit they function together so changes to one affect the other.

HOW IT WORKS

MIT engineers have developed a technology to probe the connections between the brain and the gut using fibers embedded with sensors and light sources. It allows for precise measurement of neuronal signals within milliseconds, providing insight into the gut-brain communication network. A group of researchers also successfully tested a smart pill, the size of a blueberry, in pigs for the diagnosis and treatment of bowel disease. The pill detects and reports key biological molecules associated with inflammation, converting the data to a wireless signal transmitted in real time to a user's smartphone. Developed by Seres Therapeutics, SER-109, the first oral drug designed to treat the microbiome has received FDA approval. Clinical trials showed promising results, with 88% of participants avoiding another C. difficile infection eight weeks after a single dosage. And Ayble Health launched an app that harnesses behavioral therapy techniques to treat chronic gastrointestinal conditions. The 15-week program retrains the connections between the mind and gut to ease GI symptoms.

WHY IT MATTERS

The human body is not just an individual organism but a complex ecosystem, where trillions of microorganisms coexist and interact with the host's cells. The composition of the microbiome is unique to each individual and influenced by factors like diet, exercise, mental health, antibiotics, and environmental conditions. These concepts have stimulated research into how our environment, as it is related to these microorganisms, affects our bodies. As we gain a deeper understanding of the intricate connections of the holobiont, microbiome data will become a vital component of holistic wellness and medical assessments, enabling the development of personalized health care plans tailored to individual microbial compositions.

Recently research has focused on exploring the impact of gut microbiota on the interactions of gut-brain axis, as it is directly involved in the body's stress response. The aim is to develop treatments that target gut microbiota to influence brain function. Ideally the outcome will yield targeted interventions for metabolic disorders, autoimmune disease, and chronic stress and anxiety disorder, by harnessing synthetic biology to engineer microbes as "living drugs." Several start-ups have leveraged AI to analyze and translate microbiome data for personalized health recommendations and insights; others are developing microbiome-based therapies targeting immuno-oncology, gastrointestinal diseases, and neurological conditions.

7TH YEAR ON THE LIST

BRAIN-COMPUTER INTERFACES AND NEUROPROSTHETICS

WHAT IT IS

Brain computer interfaces (BCIs) establish a direct communication pathway between the human brain and computers, enabling body control without the use of the peripheral nervous system or muscles. For example, neuroprosthetics restore motor function by simply harnessing one's thoughts. Future advances seek to nurture human-machine symbiosis and redefine cognitive boundaries.

HOW IT WORKS

Varying in function and ability, BCIs are being used to restore speech and mobility. Electrodes implanted in the brain or worn outside the body can translate neural signals into commands for the prosthesis, allowing for natural and intuitive limb movement. One example is the groundbreaking bionic arm controlled by thought given to an amputee who lost both arms. Doctors at the Rehabilitation Institute of Chicago connected existing nerve endings from the shoulder to chest muscles via a nerve-muscle graft, enabling electrodes to receive through generated impulses. At UCSF, a neurosurgeon used a brain implant to capture the neural signals controlling facial expressions and speech. When combined with AI, this created a digital avatar that mimicked facial expression, allowing a participant who suffered from a stroke 18 years ago to communicate in almost real time.

Future advancements, like the BCI implant developed by Neuralink, aim to enhance cognitive ability by creating a direct connection with AI to reshape the human experience. Founded by Elon Musk, Neuralink is seeking volunteers for a six-year clinical trial. Its N1 chip is able to interfere with more than 1,000 brain cells and communicate via an end-user app that translates these brain signals into computer actions. In the meantime, noninvasive BCIs are being adopted into consumer technology. NextMind's EEG electrode, acquired by Snap for its AR glasses, was designed to decode neural activity to control smart devices.

WHY IT MATTERS

The once speculative domain of science fiction writers is now a tangible reality as computers increasingly contribute to the enhancement of both mental and physical capabilities. The emergence of BCI technology is actively shaping the potential of the human race. By redefining human computer interaction, BCIs open up new avenues for restoring sensory function and mobility to the physically impaired. Recent advancements have concentrated on neuroprosthetics; BCIs allow patients with damaged neural pathways to control prosthetics or assistive devices using their thoughts, restoring independence. However, sustained effectiveness and safety of implanted devices will require addressing the long-term impact, including tissue damage and sign degradation, on the nervous system. Many such devices are still in their trial phases, which has led to complex questions about long-term maintenance, upkeep, and support.

Increased investment and research highlights the applicability of BCIs beyond the physically and cognitively impaired. BCIs could amplify human capabilities and redefine the boundaries of human potential. Think Iron Man's ability to seamlessly interact with his environment and enhance his ability by manipulating AI and XR technologies. Advancements are seeking to improve the human experience by redefining mind control. However, the thought of achieving human-machine symbiosis is triggering fundamental fear about what is human and our ability to maintain privacy.

1ST YEAR ON THE LIST

PRECISION MEDICINE

WHAT IT IS

Precision medicine replaces the traditional one-size-fits-all approach by tailoring treatment and prevention to an individual's environment, lifestyle, and genetic makeup. Through precise and targeted genome editing, doctors can develop treatments that are either highly specific to each patient or to a disease, increasing efficacy and minimizing side effects.

HOW IT WORKS

The first CRISPR-based treatment for sickle cell disease and beta-thalassemia has received approval in the UK, and the US FDA may approve it soon. The Casgevy therapy, also known as "exa-cel," was developed by Vertex Pharmaceuticals and Crispr Therapeutics. For patients with sickle cell disease and beta thalassemia, both inherited blood disorders, the therapy prevents pain episodes and eliminates the need for regular blood transfusions respectively. The treatment involves editing a gene using CRISPR and infusing the modified cells back into patients. However, the cost, likely to be $2 million per patient, and the treatment's complexity pose challenges for accessibility. A task force led by Nobel Prize winner Jennifer Doudna proposes a mixed organizational model to lower the cost of innovative cell and gene therapies, with a goal of making them more accessible.

Researchers have shared preliminary results from a study that used CRISPR base editing on the PCSK9 gene in liver cells necessary for the production of low-density lipoprotein cholesterol. This study is evidence that editing a single DNA letter in the liver can have a clinical effect. Given these and similar advancements, scientists are also exploring CRISPR-based therapeutic approaches for complex diseases, like Alzheimer's, that are not considered genetic. Scientists at Duke University are testing an approach that aims to reduce the activity of the APOE4 gene, which is associated with an increased risk of Alzheimer's.

WHY IT MATTERS

The goal is more targeted health care by enabling doctors to predict how a patient will react to a drug and prescribe an individualized treatment. Precision medicine accounts for individual variations in a patient's genes, while considering the person's environment and lifestyle. It also lends to the exploration of disease biology, crucial for gaining insights into the causes of diseases and identifying potential targets for therapeutic interventions. In this context, precision medicine holds promise for expanding the scope of diagnostics and introducing innovative gene therapy treatments.

Gene editing is part of a broader revolution targeting the root causes of diseases, enabled by advancements in AI for increased efficiency, specificity, and data analysis. Researchers can modify genes associated with diseases to better understand their function. They can then develop drugs that specifically target these genetic mutations, potentially extending the lives of individuals affected by rare disease. But widespread adoption of precision medicine faces challenges related to the accessibility and affordability of whole genome testing, despite growing support from public health care systems. Efforts are underway to reduce costs through collaborations, new manufacturing models, and the development of "over-the-counter" or "off-the-shelf" therapies. However, the rapid progress and refinement of CRISPR gene-editing technology may expand its application to a wider variety of diseases and lower the associated costs.

1ST YEAR ON THE LIST

DESIGNING AND EXTENDING LIFE

WHAT IT IS

Breakthroughs in synthetic biology have ignited interest in designing and prolonging human life. Ethical considerations involving the altering of parenthood, mortality, and the intentional manipulation of human design are greatly influencing advancements.

HOW IT WORKS

While the idea of genetically modified babies remains widely debated, scientists continue to explore revolutionary methods of reproduction. EctoLife, the first artificial womb facility, is seeking to optimize genetic material, while addressing infertility and population decline. Biotech startup Conception is introducing a different approach; it's working to commercialize in vitro gametogenesis (IVG), the creation of human eggs from stem cells. The experimental technique could benefit women who have lost eggs due to cancer treatment, those unable to produce healthy eggs, and women with aging eggs.

Entrepreneurs, including Jeff Bezos (Altos Labs), Brian Armstrong (New Limit), Peter Thiel, Larry Page, and Sam Altman, have invested millions in the exploration of extending human lifespans, and possibly achieving immortality. One approach, "rejuvenate" blood, was inspired by studies at Duke University that extended the lives of old mice via blood transfusions from young mice. Though the study does not provide an antiaging treatment for humans, it hints that the blood of young mice contains compounds that promote longevity. Biotech company Rejuvenate Bio claims to have successfully used a reprogramming technique to extend the lifespan of mice. Adding three reprogramming genes to 77-year-old equivalent mice increased their lifespan by 7%. The technique involves resetting cells to a younger state, which has been the focus of significant research and investment as a potential anti-aging intervention.

WHY IT MATTERS

A race to immortality? From genetic interventions to rejuvenation therapies, the wealthy elite is rewriting the narrative of aging, turning it into a conquest rather than an inevitability. These tech moguls envision a future where age is just a number, and death becomes an obsolete concept. The convergence of Silicon Valley and life sciences has given rise to ambitious ventures seeking to unlock the secrets of longevity. As they pour resources into extending human lifespan, ethical concerns emerge, adding complexity to our understanding of death and the right to die, while intensifying the demand for health care and exacerbating social inequalities.

By harnessing CRISPR technologies to selectively modify the DNA of embryos, babies can be customized for desirable traits. The practice has been particularly controversial, raising ethical concerns like the potential for unintended consequences, long-term health effects, the loss of cell identity, and the exasperation of genetic disparities. Advocates champion the opportunity to eradicate hereditary diseases and unlock unprecedented human potential, while critics emphasize the ethical complexities and potential societal consequences associated with manipulating the fundamental building blocks of life. In this ethically charged arena, scientists instead look to overcome infertility challenges by providing a source of gametes independent of natural reproductive processes, offering new possibilities for fertility treatments.

1ST YEAR ON THE LIST

PHAGES

WHAT IT IS

Natural predators of bacteria, phages regulate bacterial populations in the human body. With engineering, they also have enhanced ability to detect and attack bacteria. Though extensive research of phages is fairly recent, they show immense promise for addressing bacterial maturation and present a promising strategy to address antibiotic resistance, a significant global health concern.

HOW IT WORKS

Phages are viruses that specifically target and infect bacteria, offering a highly -targeted and precise therapeutic approach. An MIT student discovered that a protein on the phage's surface, capsid protein, sometimes activates a defense system known as CapRel during infection. This restricts the phage's ability to bypass the bacteria's defense mechanism, offering insights that further the understanding of how phages work. While they offer a highly personalized approach to combating drug-resistant bacteria, additional research is needed to understand how phages react to different individuals and bacteria. The Geneva University Hospitals and the University of Geneva successfully treated a patient suffering from an antibiotic-resistant chronic bacterial lung infection with phage therapy. The treatment was a last resort when the patient was unresponsive to continuous intravenous antibiotic therapy.

Researchers at ETH Zurich have developed a rapid test that detects a urinary tract infection using bacteriophages. The scientists identified the phages effective against the bacteria most common to UTIs and modified them to emit a light signal when the bacteria is detected within the sample in less than four hours. This method holds promise for immediate antibiotic prescriptions tailored to a patient based on the strength of light signals. With $2.3 million in seed funding, Parallel Health has introduced a custom phage therapy skin solution. The serum features phages customized to users for treating chronic skin conditions—but requires facial swab every six months to account for changing skin microbiomes.

WHY IT MATTERS

Drug-resistant infections are one of the most serious threats to global health, but bacteriophages offer a promising avenue in combating antibiotic-resistant bacteria. Researchers and health care professionals are exploring phage therapy as an alternative or complementary treatment. Phage therapy allows providers to practice precision medicine through customized treatments based on a patient's specific bacterial infection. Unlike broad-spectrum antibiotics, phages can be tailored to target specific strains of bacteria while minimizing impact to the body's beneficial microbiota. Though phage therapy is not a new concept, its resurgence in mainstream health care reflects the urgent need for innovative solutions to combat antibiotic resistance. Ongoing research aims to refine protocols and expand its application within the entire health care industry.

3RD YEAR ON THE LIST

EXPANDING MEDICAL MIS- AND DISINFORMATION

WHAT IT IS

Misinformation and disinformation entail the spread of false information and the deliberate intent to deceive, respectively. Both fuel confusion and lead to poor health choices and trust erosion, which is especially dangerous during pandemics by hindering vaccine efforts. Social media and AI-driven communication accelerate the potential for an infodemic, excess of information, amplifying the dissemination of inaccurate information.

HOW IT WORKS

Researchers at Flinders University attempted to generate disinformation about vaping and vaccines using generative AI. Within an hour, they were able to produce over 100 misleading and deceptive blogs, images, and videos promoting health disinformation, highlighting the urgent need for government and industry guardrails to protect public health from the malicious use of generative AI tools. Social media sites have implemented policies to combat mis- and disinformation on their platforms through warning labels on false content, reducing the reach of such content, or removing it entirely. Despite enacting these policies, social media platforms have notably downsized content monitoring staff, risking their effectiveness. On TikTok Shop, merchants are defrauding consumers, publishing videos featuring deepfake doctors to deceive buyers into believing that health products are being promoted by medical professionals. These videos have garnered more than 10 million views, illustrating the deceptive power of disinformation and the extreme difficulty in deciphering between real and synthetic content. Amid security and privacy concerns, TikTok issued new community guidelines for the regulation of manipulated content. In the UK, YouTube has begun to validate health care professionals creating content on its platform. Applicants must meet strict criteria and confirm that they have an active medical license; when they're approved, their profile features a badge that verifies to users that the content comes from a reliable source.

WHY IT MATTERS

AI-generated content may seem like viral fun, but its role in perpetuating the infodemic has been rather damaging. In the era of the internet and social media, misinformation and disinformation tend to spread more rapidly, facilitated by the ease of access to a wide audience. Left unchecked, false narratives about diseases, treatments, and preventive measures can lead to fear and confusion. At the individual level, misinformation can lead to misguided decisions about treatment, vaccination hesitancy, and reliance on unproven remedies, exacerbating health issues. At the societal level, public health efforts are compromised as misinformation fuels resistance to evidence-based practices, resulting in delayed or inadequate care. Misinformation-driven health trends can also divert attention and resources away from genuine public health concerns, hindering effective allocation of resources. As demand increases for certain medications or interventions, shortages may arise and lead to escalating costs. Collaboration between health care professionals, policymakers, and technology platforms is crucial to curb the spread of false information online. Tackling misinformation requires a multifaceted approach that includes strategic communication strategies, media literacy initiatives, and responsible content moderation on digital platforms. For instance, social media platforms can make their algorithms more transparent, so users understand how content is promoted, to decide what information to take seriously.

SCENARIOS

SCENARIO YEAR 2045

A New Kind of High

Nanobots, initially designed for revolutionary medical applications such as targeting disease at the cellular level and repairing tissue damage, have found a new, unconventional use. Beyond their medical prowess, these tiny robots have entered a more controversial territory: cognitive and emotional manipulation.

This new application involves nanobots interfacing with a user's neurological system to manipulate emotional states and cognitive abilities. Once introduced into the body, these nanobots navigate to specific brain regions responsible for emotional regulation and cognitive processing. They can release neurotransmitters or alter neural pathways to induce a range of desired states, from heightened happiness and confidence to suppressed anxiety or sadness. The allure is potent: the ability to control one's emotional and mental state with precision, bypassing traditional therapeutic methods.

While initially seen as an effective measure to improve population mental health, users became increasingly dependent on nanobots for emotional and cognitive regulation, losing touch with their natural capacity to experience and process emotions authentically. This overreliance also raised significant concerns about the long-term impact on brain function and mental health. The distinction between artificial and genuine emotional experiences becomes increasingly blurred, leading to societal debates and ethical concerns about the nature of human experience in the age of advanced technology.

These developments inevitably lead to complex ethical and legal challenges. Regulatory bodies were hard-pressed to address issues surrounding consent, mental health implications, and the definition of personal identity in an era where emotional and cognitive states can be externally controlled. The widespread use of nanobots for nonmedical purposes challenged the understanding of human agency and authenticity, igniting a global discourse on the boundaries of technological intervention in human life and the fundamental aspects of what it means to be human.

IMPLANTS, PROSTHETICS, & WEARABLES

2ND YEAR ON THE LIST

EMERGING IMPLANTS

WHAT IT IS

Scientists seek a more custom approach to implants. The focus is on bioabsorbable and biocompatible material, including nonhuman sources, to eliminate issues of body rejection. New in-body 3D printing techniques promise new levels of personalization. Manufacturing limitations, durability, and extended lifespan need to be overcome for successful development.

HOW IT WORKS

Implants are no longer just synthetic; increasingly, they're designed from biological material to meld seamlessly with the human body. At Northwestern University, researchers developed a biocompatible water-soluble implant designed to relieve pain without drugs and naturally absorb into the body after use. The device delivers targeted cooling—numbing nerves to block pain signals to the brain—and users can remotely activate the device and adjust its intensity. As 3D printing has evolved, it has revolutionized biofabrication and tissue regeneration. Researchers in Sweden developed a 3D-printed eye implant for cell-based therapy to treat diabetes. The device, only 240 micrometers long, was placed between the iris and the cornea: This location in the anterior of the eye is considered to be immune-privileged, allowing for the implantation of pancreatic cells without triggering an inflammatory response. In the pursuit of biocompatible material, xenotransplantation—implanting animal cells into a human—introduces a new dimension. Doctors at the University of Maryland completed the second successful xenotransplantation of a modified pig heart in a patient with end-stage heart disease, who lived for six weeks after surgery. Engineers from Duke and Harvard have created a unique biocompatible ink that can transform into various 3D structures inside the body by absorbing ultrasound waves. This innovation allows the ink to reach tissues, bones, and organs that were traditionally only accessible through surgical procedures.

WHY IT MATTERS

Biotech's influence on the health care industry has given rise to the volume and diversity of data outputs in the human body. Compared to wearable technology, implantable devices offer more precise data due to their reach within the body. However, as scientists are forced to consider the body's innate immune response, it has become critical to evaluate the materials used and how they are disposed of afterward. This is especially important as built-in sensors are increasingly incorporated for real-time monitoring and data transmission. One viable solution is potentially xenotransplantation. Through this technology, we may be able to overcome compatibility issues, as ongoing experimentation hopes to neutralize immune response to nonhuman organs. If successful, xenotransplantation could greatly expand the pool of available organs. However opinions on acceptance vary, as it raises concerns about animal welfare and disease transmission. The use of neurostimulation for enhanced function and monitoring is also generating extreme interest. The industry is seeking ways to harness or control brain function for improved health, like the treatment of pain without the use of opioids. Its continued focus on durability and extended lifespan could address the ongoing issue of "abandon-ware," implants that go unserviced after the fall of a neurotech company.

2ND YEAR ON THE LIST

EMERGING PROSTHETICS

WHAT IT IS

Innovations in prosthetic design aim to improve sensing capabilities with synthetic skins and novel surgical procedures. More broadly applicable, electronic tattoos are nearly invisible sensors attached to a user's skin, enabling wireless transmission of health information. Such advancements hope to preserve our natural appearance, avoiding an android-like resemblance.

HOW IT WORKS

Stanford University scientists developed an electronic skin (e-skin) that converts signals from pressure and heat sensors into brain signals. The e-skin mimics biological skin by detecting pressure or warmth, sending sequences of electrical signals to the brain. In trials the e-skin prompted a rat to kick its leg in response to pressure or heat, showcasing potential applications in improving prosthetics. BeBop Sensors has also unveiled RoboSkin, a flexible and thin tactile-sensing covering for humanoid robots and prosthetics to enhance their sense of touch.

The OPRA Implant System is the only FDA-approved bone-anchored prostheses in the US. NYU Langone Health conducted the first surgery using osseointegration, which involves permanently implanting a titanium device into the bone for direct attachment to an artificial limb. A practical substitute for conventional socket prostheses, benefits include enhanced mobility, increased comfort, and minimized pressure. The implant system results in improved surface perception, reduced residual limb pain, heightened stability, and greater utilization of prosthetic limbs.

At UT Austin, scientists developed a lightweight, wireless electronic tattoo for continuous heart monitoring outside clinical settings. Attached to the chest, the e-tattoo involves two sensors measuring electrical signals from the heart and acoustic signals for a comprehensive report of cardiac health by measuring cardiac time intervals.

WHY IT MATTERS

Advancements aim to make prosthetics feel and look more natural, helping people feel more comfortable in their "own" skin. Synthetic or electronic skin not only looks like real skin, but advanced sensing capabilities enable feeling through electronic stimulation. Biotech companies are harnessing neurostimulation for increased movement and sensory feedback. The departure from hyper-realistic bionic limbs aims to empower users by fostering a sense of identity and breaking down societal stigmas surrounding disability. Scientists are also exploring the design and surgical attachment of prosthetics, with a focus on enabling function that mimics the human body. Newly designed prosthetics and surgical techniques, like osseointegration, aim to achieve better integration with the human body. But accessibility remains a hurdle as prosthetics are often costly and options are limited, especially for people of color. Efforts to combine affordability, functionality, and individualized design are underway, recognizing the diverse needs and preferences of users.

With the rise in use and function of wearable technology, scientists are harnessing the understanding of skin function to develop advanced sensing technologies that can be discreetly and comfortably worn on the skin. Such sensors promise more accurate data and measurements of biomarkers; e-tattoos can potentially replace the need for multiple devices for continuous monitoring, while ensuring comfort and durability.

12TH YEAR ON THE LIST

EMERGING WEARABLES

WHAT IT IS

The next frontier of wearable technology not only transcends the boundaries of convenience but ushers in a new era, where our daily experiences are interconnected with the advanced capabilities of these devices. Ultimately, this will shape the way we navigate and understand the world around us.

HOW IT WORKS

The AR smart glasses market is becoming more competitive. An Apple patent filing signals the development of smart glasses for daily use, featuring a digital crown for controls, heads-up display for notifications and music control, and AR capabilities. Meta, which already introduced smart glasses through a partnership with Ray-Ban, plans to release its first pair of smart glasses with AR display in 2027, accompanied by a neural interface smartwatch for control. While health monitoring capabilities in these AR glasses remain uncertain, ongoing research, such as Cornell University's sonar glasses, hints at potential features. These glasses, outfitted with micro sonar that can track the wearer's upper body movements in 3D through a combination of inaudible soundwaves and AI, could offer advanced tracking of physical and behavioral data.

Parallel advancements in concealed wearable technology concentrate on miniaturized devices. Humane, founded by ex-Apple employees, revealed the Ai Pin, aiming to simplify interactions by eliminating traditional interfaces. Although its initial release features limited health functions, such as scanning for nutritional information, the Ai Pin shows promise for future applications in detection and continuous health monitoring. MIT researchers have developed a wearable ultrasound scanner designed to attach to a bra, aiding in the early detection of breast cancer. And Stanford has a smart bandage that leverages wireless circuitry and electrical stimulation to monitor and accelerate wound healing, minimizing infection risks.

WHY IT MATTERS

The proliferation of wearables, driven by their ability to provide unparalleled access to personalized health insights, has led to a growing demand for inconspicuous devices that can either substitute for or be concealed within our clothing. Progress on smart glasses and AR-enabled devices suggests a future where technology seamlessly enriches our lives without imposing on our personal style or daily routines. These wearables offer a subtler and more user-friendly experience that encourages users to wear them consistently, facilitating the collection of long-term health data. While the primary focus of these devices is on enhancing user interactions, the uncertainty surrounding health applications is getting research attention. These devices indicate a move toward a hands-free, augmented reality interaction with the world, opening up new possibilities in preventive health care by providing individuals with unprecedented access to personalized health insights and continuous monitoring. The technology aims to positively impact consumer behavior by inspiring better habits and heightened awareness as they embrace these devices. Still, concerns about data privacy persist, and so do worries around data security and the potential misuse of personal information.

12TH YEAR ON THE LIST

MATURE WEARABLES

WHAT IT IS

As wearables become more sophisticated, they offer unparalleled access to personalized health insights and environmental interactions, becoming indispensable tools for maintaining well-being. However, ongoing progress is rendering wearables unnecessary, as innovations aim to seamlessly measure individual health data without the need for external devices.

HOW IT WORKS

Apple's and Samsung's patent filings suggest a shift in health marker measurement through smart rings. While ongoing research targets improved capabilities, a noteworthy development is the OmniRing, a smart sensing ring by a Penn State team, leveraging XR. The device uses inertial measurement unit sensors to capture finger motion and photoplethysmography sensors to measure biomarkers. It was introduced with an open-source design to spur diverse applications. Simultaneously, companies like Baracoda aim to enhance wrist wearables. Its smartband, BHeart, with its "endless" battery, utilizes BMotion energy harvesting from motion, body heat, and sunlight, redefining self-recharging. Beyond traditional health metrics, Neurable's brain-sensing headphones and BitBrain's Ikon neuro-headband measure brain activity. Neurable tracks brain signals to respond to cognitive states, while Ikon, with smart textiles and EEG electrodes, measures brain activity during daily tasks.

As our wearables gain capabilities, there are instances where "invisible monitoring" is preferable. Toronto-based Xandar Kardian is deploying its radar technology in 50 US health care facilities, providing contactless vital sign detection. The XK300 sensor gauges macro (body motion), micro (respiratory rate), and nano (heart rate) vibrations, offering early indicators of potential medical events. Singapore's Alexandra Hospital uses a Smart Ward ecosystem, streamlining nursing with virtual management. Internet of Medical Things components include smart beds, patches for vital sign monitoring, AI food scanners, and smart glasses for tele-rounding and teleconferencing.

WHY IT MATTERS

Wearables have significantly evolved beyond basic activity trackers and health metrics, incorporating advanced features for comprehensive health monitoring. The trajectory suggests innovations to measure an extensive array of health markers, as these devices now integrate sensors to measure vital signs, detect anomalies, track brain activity, and provide real-time health insights that factor in lifestyles and environments. Simultaneously, wearables are evolving beyond passive data collection to actively inspiring healthy habits and decisions. This active engagement with users can have profound implications for enabling personalized and proactive health care, motivating individuals to prioritize their well-being. However, as wearables mature and enhance functionality, there is a potential paradox emerging. The same advancements that make wearables indispensable could also render them superfluous. Wearables may become so seamlessly integrated into our lives, offering continuous health insights and habit reinforcement, that the need for a distinct wearable device diminishes. Striking a balance between enhancing functionality and maintaining the relevance of wearables will be critical. As wearables continue to mature, the challenge lies in ensuring that they not only collect a wider variety of health data but also meaningfully contribute to individuals' well-being while avoiding redundancy.

RESEARCH

2ND YEAR ON THE LIST

SYNTHETIC HEALTH DATA

WHAT IT IS

Synthetic health data is artificially generated health data that mimics real data properties without privacy risks. Coupled with machine learning, the application of synthetic health data accelerates research and clinical trials for the development of novel medications, treatments and therapies.

HOW IT WORKS

Already, companies are harnessing AI and machine learning to advance research. LabGenius' system automates the design, creation, and testing of antibodies, revolutionizing the antibody discovery process. Its machine learning algorithm designs antibodies to target specific diseases, and automated robotic systems build and grow them in the lab. The data is fed back into the algorithm, creating a closed-loop system. DeepMind has released a catalog of genetic mutations that can affect the function of human proteins. Developed using AlphaMissense, an AI that classifies missense variants, the model categorized 89% of all 71 million possible missense variants as either likely pathogenic or likely benign. This can accelerate research providing insights into the consequences of genetic mutations.

Generative AI also plays a pivotal role in creating synthetic data sets that closely resemble real-world data without compromising privacy. Snowflake's marketplace now offers access to synthetic data sets, including synthetic human face and financial data. This enables businesses to train AI algorithms and conduct tests and simulations while maintaining data confidentiality. Gretel has entered an exclusive agreement with AWS, providing access to synthetic data generation models and privacy tools. The program aims to enable teams to safely test, train, and fine-tune proprietary large language models using high-quality synthetic data designed to be private.

WHY IT MATTERS

Synthetic health data replicates the characteristics, patterns, and statistical properties of real health care data without the risk of compromising patient privacy. When "real data" is insufficient, synthetic data is invaluable for ensuring that research data is comprehensive. AI holds the potential to drastically reduce the time required for research and clinical trials, providing industries dependent on these processes with remarkable flexibility for product innovation. Using synthetic data, medical researchers are harnessing AI and machine learning for critical tasks. Faster drug development is facilitated by synthesizing data on drug performance, screening drug compounds, predicting potential side effects, and optimizing dosages. This can lead to overhead cost reductions, making treatments more affordable and accessible. Early and precise diagnosis is facilitated by simulating disease progression, anticipating risk factors, and predicting treatment resistance. In disease eradication efforts, synthetic health data supports containment and eradication strategies by modeling disease spread to identify preventative measures while protecting patient privacy. Through the analysis of large datasets, synthetic health data becomes a valuable tool for advancing therapy research, optimizing treatments, and accelerating the development of novel therapies for disease.

1ST YEAR ON THE LIST

NEW TRIAL METHODS

WHAT IT IS

Traditional trials suffer from lengthy timelines—averaging 10 years—and significant costs related to the recruitment and retention of participants. Now, remote, virtual reality, and in-silico trials are viable options. The goal of faster development of novel drugs and therapies could be achieved through improved efficiency, accuracy, and speed of clinical trials.

HOW IT WORKS

Last May, the FDA released landmark guidance to encourage the use of remote clinical trials, which leverage digital tools to collect participant data remotely. The Decentralized Clinical Trials draft guidance advises on how to incorporate remote clinical trials safely and strategically for greater diversity in clinical trial populations, and shows a clear shift toward the use of technology for conducting clinical trials. And companies have seen success transitioning from hybrid intervention to remote clinical trials. In making the switch, GROWell's strategy yielded a study completion rate of 82%, as well as improved screen failure rates and increased task adherence. In-silico trials, on the other hand, aim to remove human involvement in clinical trials altogether through digital simulations, or digital twins. Novadiscovery, specializing in AI-driven in-silico clinical trial simulation, has successfully predicted the findings of the MARIPOSA Phase III clinical study through its jinkō platform. The predictive findings closely align with actual trial results, highlighting the potential of in-silico approaches for optimizing the development of innovative treatments. Accenture Ventures has invested in Virtonomy, a company specializing in data-driven simulations using digital twin technology for accelerated development of life-saving medical devices. Virtonomy's solution enables manufacturers to create model patient virtual environments for device testing, reducing costs and regulatory complexity.

WHY IT MATTERS

Recent innovations in clinical trials aim to reduce time-to-market, while improving or maintaining quality and minimizing drawbacks. Covid led to the emergence of app-based, remote trials, which showed promise in expediting them without compromising quality. Other clear benefits include increased accessibility: Remote trials enable broader participation across a wider demographic diversity. The digital aspect of remote clinical trials also allowed for streamlined data collection. The next generation of such advancements will be VR trials, which will offer researchers increased control over the trial environment.

But in-silico clinical trials—leveraging AI and VR—go even further, eliminating human involvement in clinical trials altogether. They use synthetic data and simulations to produce comparable results to the human trials, and could potentially cut trial durations in half. Regulators like the FDA are exploring ways to incorporate in-silico trial data into the drug approval process. Additionally regulatory frameworks are being developed to ensure the reliability and validity of in-silico trial results.

Remote, VR, and in-silico clinical trials are disrupting the traditional practices of the health care industry, which have been rigid and slow to change. Their streamlined processes will make trials more efficient and cost-effective, and drastically reduce the time it takes to bring new medical innovations to market. Accelerated trials and shorter cash flow timelines will transform the investment landscape, potentially allowing new entrants to compete without the conventional need for substantial capital. The decreased risk associated with trials may encourage companies to embark on ambitious and high-risk projects, leading to a new wave of innovations.

1ST YEAR ON THE LIST

LAB-ON-A-CHIP

WHAT IT IS

Lab-on-a-chip (LoC) devices are revolutionizing POC diagnostics by integrating sample preparation, testing, and analysis on a single microchip. LoCs are transforming how laboratory analyses are performed, offering portability and convenience, efficiency, and versatility.

HOW IT WORKS

Increasingly, one microchip can do it all. SiPhox Health's kit can test for 17 biomarkers, including inflammation, cardiovascular health, metabolic fitness, and hormone balance. Sold on a subscription basis, kits are $95 with a monthly membership that includes access to continuous glucose monitors and personalized biohacking tools. The company is also developing an at-home device.

At the University of Bath, researchers have developed a prototype virus diagnosis device. Called LoCKAmp, it uses LoC technology and can provide lab-quality results within three minutes. It employs reverse transcription loop-mediated isothermal amplification to multiply specific RNA sequences for virus detection. Originally developed to detect Covid, LoCKAmp can be easily adapted to detect other pathogens. And a new signal processing method for biosensors from University of California, Santa Cruz and Brigham Young University researchers allows for simultaneous detection of particles in both high and low concentrations. The technique could lead to the design of LoCbiosensors that can detect multiple analytes across vast concentration ranges simultaneously. The researchers used an optofluidic biosensor chip with fluorescence detection and a new signal processing method to accurately identify the concentration of different colored nanobeads in a mixture. The technology is being commercialized by Fluxus, a California-based medical device company.

WHY IT MATTERS

Also known as a microfluidic chip or micro total analysis system, LoC is an automated miniaturized laboratory system that enables multiple medical tests to be performed at once. Traditional laboratory analyses often involve large quantities of reagents and samples, contributing to high costs. By requiring smaller sample sizes for accurate analysis, LoCs significantly reduce sample size volumes, risks of contamination, and associated costs. Given their compact and portable nature, LoCs allow for rapid and real-time analysis due to short fusion distances within the microchannels. This enables point-of-care testing, making this technology invaluable in patient diagnostics and biopharmaceutical development. It's especially useful for developing countries, where high incidences of disease persist due to limited resources and proper facilities. Increased focus on patient-centric care means that we can expect to see an increase in consumer LoCs to supplement remote care. In research, LoC devices facilitate high-throughput screening and experimentation. Researchers can conduct multiple analyses simultaneously, significantly accelerating the pace of discovery in fields like genomics, proteomics, and drug development. This will contribute to advancements in understanding disease mechanisms and the development of targeted therapies.

1ST YEAR ON THE LIST

BODY-ON-A-CHIP

WHAT IT IS

Body-on-a-chip (BoC) technologies typically consist of microfluidic channels and chambers that contain manufactured biomaterials, allowing researchers to simulate the behavior of various tissues and organs. By mimicking the function and mechanics of an organ, they provide a potential alternative to animals for drug development and toxin testing.

HOW IT WORKS

The use of "on-a-chip" models aim to mimic the physiological conditions of organs to provide a controlled environment for studying various phenomena. Researchers at the University of Birmingham have developed a "vein-on-a-chip" model designed to emulate human veins, offering a unique platform for studying blood clot formation. This innovative device incorporates operational valves that simulate real vein mechanisms, coupled with a single layer of endothelial cells covering the vessel's interior. Similarly, a global team of bioengineers and immune-oncologists collaborated to create an immune-infiltrated kidney tissue model, specifically focusing on investigating the on-target, off-tumor effects of T-cell bispecific antibodies (TCBs). This model—known as an immune-infiltrated human kidney organoid-on-chip—enables the assessment of TCB impacts on kidney cells. Additionally, researchers at Boston University devised an organ-on-a-chip model replicating lymphatic vessels capable of targeting the ROCK2 protein to reverse lymphedema in mice. And biotech company Emulate introduced a novel feature to its liver-on-a-chip model—an adeno-associated virus (AAV) transduction application. This groundbreaking technology enables gene therapy researchers to efficiently and safely test the delivery of AAV vectors in a validated, human-relevant liver model, providing results within weeks rather than months. In a previous study, Emulate's liver chip accurately identified 87% of tested drugs known to induce liver injury in patients.

WHY IT MATTERS

BoC systems, often referred to as microphysiological systems, replicate the complex interactions of organs and tissues within a human body on a miniature scale. By simulating the interactions between different organs, BoC devices demonstrate how drugs will behave in the human body. BoCs offer faster, cost-effective, customizable, more ethical and safer alternatives to human or animal trials for biological research and development, and could transform the drug development process that heavily relies on animal subjects. The application of BoCs will improve the efficiency of drug screening, reduce the number of failed clinical trials, and decrease time-to-market. While BoCs hold immense promise for advancing drug development, challenges for adoption include standardizing protocols and regulatory frameworks that adapt to accept these models.

1ST YEAR ON THE LIST

3D BIOPRINTING

WHAT IT IS

A rapidly evolving technology, 3D bioprinting involves the creation of functional structures that imitate the complexity of biological tissues and organs by layering living cells and bioinks. While 3D bioprinting holds tremendous promise, it has technical challenges to overcome, such as ensuring viability and functionality.

HOW IT WORKS

A team at Monash University has successfully printed neural living networks composed of rat brain cells that mature and communicate like a real brain, while University of Oxford researchers fabricated a two-layered brain tissue from 3D printing human neural stem cells. Through the use of a novel droplet printing technique, the tissue maintained its cellular architecture for weeks in the culture. This marks a significant advancement in the fabrication of materials with the structure and function of natural brain tissue.

At the University of Sydney, researchers developed a blueprint for advanced human lung models with the use of 3D structures grown from human primary cells: They built two different lung models, healthy and diseased, to study the therapeutic effectiveness of drugs. Scientists at the Terasaki Institute for Biomedical Innovation have made advancements in 3D bioprinting of native-like skeletal muscle tissues. They used a specialized bioink with microparticles engineered for sustained insulin-like growth factor-1 delivery, promoting mature skeletal muscle tissue formation and structural alignment for more effective regeneration. And a multidisciplinary team at Stanford University received a $26.3 million federal contract to bioprint a fully functioning human heart and implant it into an immunodeficient pig within five years. This approach uses patient-specific stem cells that will not require immunosuppression when transplanted into the same patient.

WHY IT MATTERS

3D bioprinting is revolutionizing traditional approaches to tissue engineering and regenerative medicine. By precisely depositing cells in a spatially controlled manner, bioprinters can fabricate functional tissues and organs unique to individual patients.

This has huge implications for organ transplants. According to the US Health Resources and Services Administration, 106,800 people are on the national organ transplant waiting list, while Centers for Disease Control and Prevention data shows only 6,000 organs on average are provided by living donors each year.

The customization of 3D bioprinting is relevant to reconstructive surgery and preoperative planning: Medical providers can create patient-specific implants to match exact dimensions and specifications. Additionally, the ability to incorporate multiple cell types and biomaterials in the printing process allows for the creation of tissues with enhanced functionality. In research, 3D-bioprinted tissues offer more accurate representations of human physiology than traditional 2D cell cultures. With these models, researchers can assess drug response and toxicity with greater precision, while reducing, or even eliminating, the use of animals for testing. The biggest challenge of 3D bioprinting is sustaining larger, more complex tissues. For implanted tissues or a larger size to survive, the tissues must be vascularized to ensure proper nutrient supply and waste removal. Researchers are exploring bioink formulations, printing techniques, and post-printing strategies to overcome these challenges for clinical validity.

1ST YEAR ON THE LIST

QUANTUM'S EFFECT ON RESEARCH

WHAT IT IS

The processing power of quantum computers rivals traditional computers. Quantum computers process complex data and construct computationally intensive models at unimaginable scale and speed. With its ability to analyze vast amounts of data and explore numerous possibilities simultaneously, quantum computing is ushering a new era of computational capability.

HOW IT WORKS

Intel announced the release of Tunnel Falls, a 12-qubit silicon chip, only available to the quantum research community. This and other actions—like a recent collaboration with the Laboratory for Physical Sciences—demonstrate Intel's commitment to advancing quantum computing research and accelerates its potential application in health care. IBM unveiled the first health care–focused quantum computer in the US, installed at Cleveland Clinic. The IBM Quantum System One, part of a 10-year Discovery Accelerator partnership, utilizes quantum computing, AI, and high-performance computing to accelerate biomedical discoveries. Gero, a biotech startup focused on aging and longevity, used a hybrid quantum-classical machine learning model to interface between classical quantum computational devices. Its aim was to demonstrate the application of quantum computing to generate novel chemical structures in drug discovery. Insilico Medicine combined the functions of quantum computing and generative AI to explore the quantum advantage in small molecule drug discovery. The researchers substituted each part of MolGAN, an implicit generative adversarial network for small molecular graphs, with a variational quantum circuit. Insilico plans to integrate the hybrid quantum GAN model into Chemistry 42, its proprietary small molecule generation engine, to accelerate and improve its AI-driven drug discovery and development process.

WHY IT MATTERS

Long considered in the realm of science fiction, quantum computing is more realistic than ever. In a world characterized by rapid technological advancements, the incorporation of quantum computing offers significant implications for drug discovery, genetic analysis, and optimization solutions. Harnessing quantum computing could lead to rapid identification of novel drugs and therapies, recognition of genetic markers associated with disease, and customized treatment plans based on genetic makeup. From optimizing treatment plans to managing health care supply chains, quantum algorithms can quickly pinpoint optimal solutions. This efficiency can enhance the overall effectiveness of health care systems, ensuring better allocation of resources and improved patient care. For instance, its rate of computing holds potential in enabling widespread genome sequencing for tailored treatments based on a patient's genetic profile. While quantum computing in health care holds great promise, it is still in the early stages of development, as several technical challenges need to be addressed. These challenges include improving the stability and error correction of quantum computers, as well as developing algorithms tailored to health care applications.

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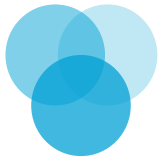

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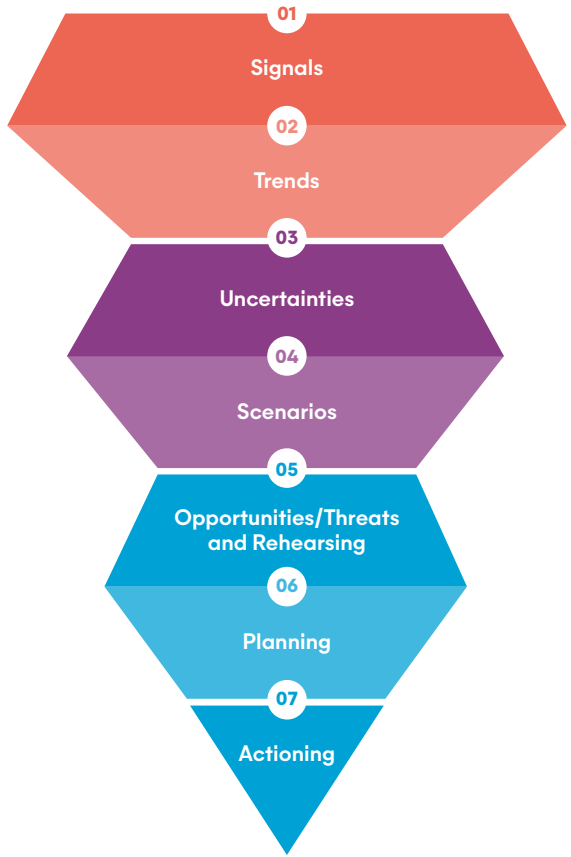

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