2025 TECH TRENDS REPORT • 18TH EDITION

HEALTH CARE & MEDICINE

FTSG

Future Today Strategy Group's 2025 Tech Trend Report

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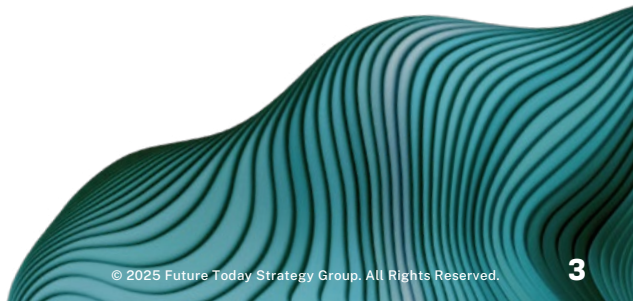


Amy Webb
Chief Executive Officer

Big Tech is redefining health care.

This year marks a pivotal shift in health care's competitive landscape, with technological advancement catalyzing new business models and redefining traditional market boundaries. As industry giants like Google and Microsoft deepen their health care presence, they're not just bringing technology; they're fundamentally reshaping how care is delivered, accessed, and monetized. Big Tech's deepened role has accelerated the adoption of AI-driven diagnostics, cloud health platforms, and wearable technology. AI has evolved beyond administrative efficiency to enable new care delivery models, with generative AI transforming everything from clinical documentation to real-time decision support. Simultaneously, improvements in electronic health record interoperability have made data sharing seamless while reducing errors. Telemedicine, combined with remote patient monitoring, has become essential in chronic disease management and is expanding care access globally.

We're also witnessing breakthrough developments in emerging diagnostics and treatment capabilities that are creating new centers of value. CRISPR-based diagnostics and liquid biopsies could revolutionize early detection programs, particularly in oncology. Meanwhile, continued research into in-womb therapies and nanotechnology will enable innovative treatments of genetic disorders. The development of advanced implants and prosthetics, such as bioresorbable devices and brain-computer interfaces, will one day help patients regain mobility and recover quicker.The FDA has already started to approve clinical trials.

As health care enters this new era, success will depend on the ability to adapt to a rapidly evolving competitive landscape where traditional boundaries between payers, providers, and technology companies become fuzzy. With AI accelerating both research and care delivery, and precision medicine moving into the mainstream, 2025 should see the emergence of new business models that challenge conventional approaches to health care. The organizations that thrive will be those that can navigate this transformation while building sustainable competitive advantages in an increasingly dynamic market.

Digital health is putting patients in the driver's seat.

1

Telehealth adoption drives revenue stream diversification

As telehealth use continues even post-pandemic, health systems have opportunities to expand market share and reduce care delivery costs. Remote monitoring programs could improve patient care over time, reducing readmissions and facilitating chronic disease management.

2

Consumer health care disruption threatens traditional relationship models

The rise of direct-to-consumer prescription services and virtual-first providers is reshaping patient expectations and challenging traditional referral patterns, requiring health systems to reevaluate their digital front door strategy.

3

New devices present data integration challenges and opportunities

The proliferation of patient-generated health data from wearables creates both clinical and liability considerations. Health systems must develop infrastructure to meaningfully integrate this data while managing risk and ensuring clinical workflow efficiency.

4

AI implementation offers administrative cost reduction at scale

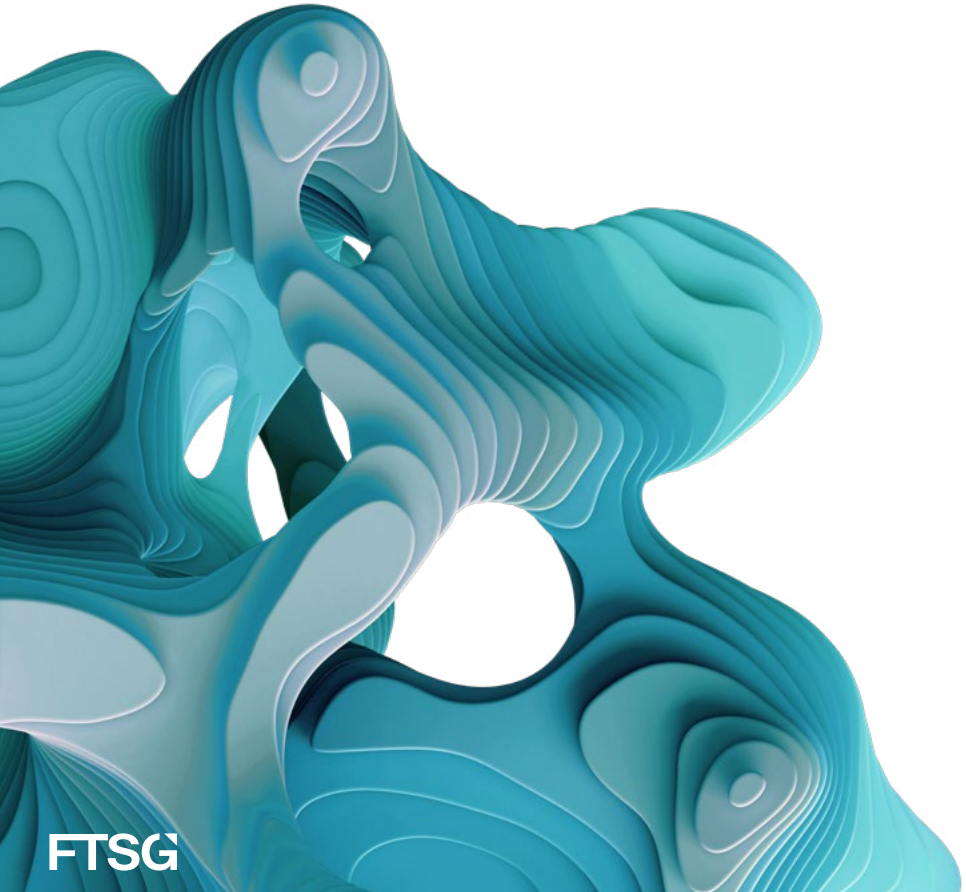
Early adopters of health care AI can enjoy reductions in administrative overhead through automated documentation, coding, and revenue cycle management. This technology represents a significant opportunity to improve margins without compromising care quality.

5

Health data interoperability: strategic investment or disadvantage?

Enhanced data-sharing capabilities are becoming a key differentiator in value-based care success and strategic partnerships. Without this, health systems risk exclusion from profitable narrow networks and could struggle to demonstrate quality metrics to payers.

As technology reshapes health care's foundations, industry leaders must evolve or risk irrelevance.



The convergence of technology and health care in 2025 extends far beyond digital transformation, signaling a fundamental shift toward intelligent health systems. While established organizations have historically competed on reputation, scale, and location, new entrants are leveraging edge computing, advanced APIs, and seamless integration layers to rewrite the rules of care delivery.

This shifting competitive landscape is particularly evident in primary care and chronic disease management, where traditional providers face mounting pressure from Big Tech. Cloud-native architectures and intelligent automation are reshaping care delivery, from Apple's transformation of AirPods into FDA-cleared hearing aids, to Amazon's API-first Clinic platform and One Medical acquisition. In pharmaceutical distribution, Mark Cuban's Cost Plus Drugs has leveraged blockchain and smart contracts, forcing established players to modernize their technology stacks and patient engagement platforms.

The proliferation of Internet of Things medical devices and edge-enabled care platforms is democratizing access to medical expertise. Rural health care facilities are evolving into hybrid care hubs, using 5G networks and edge computing to combine local emergency services with low-latency remote specialty consultation. Best Buy Health is deploying smart home technology and ambient sensors for aging-in-place solutions, while Walmart's retail clinics integrate IoT diagnostics and cloud-based electronic health records (EHRs). Meanwhile, real-time analytics and predictive modeling are revolutionizing value-based care delivery, supported by advances in distributed sensors and edge-processed biometric data.

The technology stack for treatment modalities is equally advancing, with augmented reality/virtual reality therapeutics leveraging spatial computing and haptic feedback. Meta's investment in VR-based mental health treatments utilizes advanced biometric tracking and neural networks, while AppliedVR's FDA-cleared pain management platform demonstrates the maturation of immersive therapeutics. These developments parallel breakthroughs in quantum computing for molecular modeling and 3D bioprinting with smart materials, accelerating both drug discovery and personalized medicine. However, this rapid evolution introduces new challenges in edge security, distributed systems resilience, and regulatory compliance—technical hurdles that demand sophisticated architectural solutions from industry stakeholders.

From brain implants to nanobots, 2024 pushed medical boundaries into new territory.

JANUARY 2024

Neuralink's Human Trials Begin

The neurotech company successfully implants its first brain-machine interface in a human.

MAY 2024

Cyberattack Impacts Health Services

A cyberattack at Ascension, a nonprofit health system with 140 hospitals, disrupts emergency care.

JULY 2024

FDA Approves Alzheimer's Drug

The US regulatory agency OKs Donanemab for use at the early stage of the disease.

AUGUST 2024

AdventHealth Commits to Renewable

The company signs a virtual power purchase agreement, aiming to achieve 100% renewable energy by 2026.

SEPTEMBER 2024

Nanobots for Brain Aneurysms

Researchers successfully use nanobots to treat brain aneurysms in animal models.

« PAST

From AI to biotech, 2025 will set new rules for health care innovation.

FUTURE »

EARLY 2025

Medicare Expansion for Weight Loss

The Biden administration proposed expanding coverage to anti-obesity medications; approval will be up to the Trump administration.

MID 2025

FDA Guidance on AI/ML in Medical Devices

The agency will issue new guidelines on how AI is used and marketed when developing medical devices.

MID 2025

Launch of Oracle Health EHR

Oracle is launching a new AI-powered EHR that will automate administrative processes.

FALL 2025

Apple Watch Series 11

The newest Apple Watch will likely have even more optimized health insights.

MID TO LATE 2025

Passage of the BIOSECURE Act

The US House-approved bill limiting foreign adversary funding for biotechnology will likely go to the Senate floor in 2025.

Traditional health care business models are facing disruption on all sides.

The Real Returns of Health Care Analytics

While AI and analytics promise transformative insights, health care organizations face significant challenges and costs converting data into actionable value. Rather than delivering clear competitive advantages, data capabilities are increasingly table stakes—the real differentiation comes from an organization's ability to execute on insights while balancing the investment against practical considerations like workflow integration and staff adoption.

Virtual Care's Market Disruption Challenge

Virtual care platforms enable geographic expansion yet erode market barriers. Local health systems now compete with national telehealth providers and retail health players—all targeting their primary care base. Success in remote care demands fundamental changes to operational models, provider compensation, and patient engagement—adjustments that require time and attention.

Preventive Care Tech Reshapes Revenue Models

The rise of diagnostic technologies like biosensors presents a complex strategic challenge: the need to diversify revenue streams to rely less on expensive acute care episodes and specialty interventions. Offsetting the revenue impact requires consideration of new business models, whether through high-volume wellness services, or value-based care arrangements with payers.

Balancing Tech Innovation With Strategy

While cutting-edge technologies like AI attract attention, companies need to focus on making strategic investments that enhance existing service lines and support scalable care delivery models. Organizations must balance innovation against implementation costs, staff readiness, and clear paths to ROI, particularly as patients increasingly prioritize access and affordability.

Hidden Costs of Big Tech Health Care Alliances

Potential partnerships with tech giants offer a lot of promise, but they also come with caveats. These collaborations often require data sharing and investment that creates long-term dependencies. Big Tech could eventually evolve to a competitor. Organizations must compare short-term benefits to the risk of becoming commoditized in tech-controlled health care ecosystems.

Wearables Create New Provider Responsibilities

Health care providers face growing pressure to integrate real-time patient data from wearable devices. This data influx creates new obligations for provider response and intervention, requiring investment in data management infrastructure and the creation of clear protocols. As data availability grows, providers must manage patient expectations and legal responsibilities.

These individuals are at the forefront of transformation in pharmaceuticals, medical devices, and health care technology.

- **Emil Fristed,** **CEO at Novoic,** for her leadership in developing AI-powered speech analysis tools that detect early signs of neurological diseases like Parkinson's and Alzheimer's.
- **David Liu, professor at Broad Institute,** for his innovations in base editing—a more precise form of CRISPR—that has successfully corrected genetic mutations related to diseases like progeria.
- **Dimple Parmar, CEO at ZenOnco.io,** for creating a platform that integrates conventional and complementary cancer care services, opening up personalized treatment solutions across India.
- **Dr. Miriam Merad, director of Mount Sinai's Precision Immunology Institute,** for her contributions to leveraging immunotherapies to treat solid tumors.
- **Kristian Ranta, CEO at Meru Health,** for integrating professional therapy and mindfulness practices into an app to address global mental health challenges.
- **Sarah Tishkoff, professor at University of Pennsylvania,** for her research in population genomics, particularly related to the genetic basis of diseases prevalent in African populations.
- **Dr. Toshio Suda, director at International Research Center for Medical Sciences,** for his discoveries on the role of metabolism in stem cell maintenance and aging.
- **Dr. Fiona Watt, director of the European Molecular Biology Laboratory,** for her advancements in stem cell research, particularly her work on tissue regeneration.
- **Eirini Rapti, CEO at Inne,** for developing hormone-tracking biosensors that enable women to manage their reproductive health more effectively.
- **Dr. Sarah-Jane Dawson, a group leader at Peter MacCallum Cancer Centre,** for her research in liquid biopsies and circulating tumor DNA.
- **Michael Hayden, CEO at Prilenia Therapeutics,** for his work in developing treatments for neurodegenerative diseases, particularly Huntington's disease.
- **Dr. Shobi Ahmed, CEO of Sama Therapeutics,** for creating an AI-based platform that provides tailored brain health evaluations to speed up the development of safer and more effective treatments for complex patients.

New technologies enable better care and stronger margins...

OPPORTUNITIES

New Care Models

Early intervention technologies and enhanced monitoring capabilities are enabling health systems to develop new value-based care models and risk-sharing arrangements that could significantly improve margins on population health management.

Broader Geographic Footprint

The rise of virtual care and remote monitoring creates opportunities for geographic expansion and new revenue streams without the traditional capital investments in physical infrastructure.

Expense Reduction

Artificial intelligence and automation technologies offer the potential to dramatically reduce administrative overhead while improving revenue cycle efficiency through enhanced clinical documentation and coding.

Improved Data Inputs

Health care organizations can monetize their growing data assets through research partnerships, value-based care contracting, and the development of new analytics-driven services.

...but threaten traditional revenue streams and provider relationships.

THREATS

Biosecurity Breach Risk

Advances in molecular diagnostics and biosensors may increase the likelihood of biosecurity breaches, such as the misuse of these tools for bioterrorism or the accidental release of biological data, posing significant global risks.

New Competitors

Big Tech companies could evolve from enablers to competitors, potentially disintermediating health care providers from their patients. This could relegate traditional organizations, especially in primary and preventive care, to commoditized service providers.

Disrupted Revenue

The shift toward preventive care and virtual services is disrupting traditional revenue models and is particularly threatening to high-margin acute care services and facility-based revenue streams.

Increased IT CapEx

The growing cost of maintaining competitive technology infrastructure, including cybersecurity, data management, and analytics capabilities, threatens to outpace revenue growth and strain capital budgets.

Health care ROI demands targeted transformation, not total overhaul.

Develop a technology evaluation framework that separates commodity IT investments from strategic differentiators. This will put a focus of premium investment on patient engagement platforms and clinical workflow automation that can drive market share in an increasingly competitive landscape.

Map current revenue streams against emerging technologies to identify existential threats, particularly from diagnostic and preventive innovations that could reduce dependence on traditional acute care services. Develop mitigation strategies for each vulnerable service line.

Rather than building comprehensive data infrastructure, identify three specific service lines where improved data integration could protect market share from digital-first competitors, and focus investments there while monitoring clear ROI metrics for each initiative.

Create an innovation partnership model that maintains control of patient relationships and data while leveraging external technology capabilities, explicitly defining which capabilities should be built versus bought, with clear governance structures for data sharing and usage rights.

Establish rapid prototyping capabilities to test new care delivery models with existing technology. Focus on areas where virtual and physical care integration could create barriers to entry for digital-only competitors, while maintaining flexibility to scale successful pilots quickly.

Instead of following industry trends, design a five-year technology roadmap that prioritizes investments based on their ability to either defend core services from disruption or capture new revenue streams, with clear metrics for measuring success at each stage of implementation.


Technology Deployment


Capital Expenditure


Talent Development


Regulatory Influence

Important terms to know before reading.

BIOFACTURING
The process of producing biological products and materials, such as tissues, enzymes, or drugs, using living organisms or cells. In 2025, biofacturing is being scaled up for sustainable production of everything from lab-grown meats to biomaterials for construction, offering a low-carbon alternative to traditional manufacturing.

BIOMALWARE
Malicious technology or software engineered to attack, alter, or exploit biological systems, including human DNA and other living organisms. As biotechnologies like CRISPR and gene-editing tools become more accessible, biomalware presents a new cybersecurity threat, potentially targeting genetic data and health care infrastructure, or even modifying biological processes for nefarious purposes.

CYBER-PHYSICAL HEALTH SYSTEMS
The convergence of physical health care infrastructure with cyber technologies, such as IoT devices, AI diagnostics, and real-time monitoring systems. Cyber-physical health systems are enabling seamless data exchange between patients and health care providers, offering predictive health insights and remote care management that improve preventive medicine.

ELECTRONIC HEALTH RECORD (EHR)
A comprehensive digital system that stores a patient's entire medical history, including treatment plans, test results, and other health data. EHRs are increasingly interoperable, powered by AI to predict health risks, automate administrative tasks, and optimize personalized care across health care systems, enhancing both efficiency and patient outcomes.

EXOSKELETON
A wearable, external framework designed to enhance human physical capabilities. Exoskeletons have evolved beyond rehabilitation tools, becoming integral to industries like logistics, construction, and the military, where they improve worker endurance, reduce injuries, and augment physical performance through real-time AI feedback and adaptive control systems.

GENETIC PRIVACY
The right of individuals to control access to and use of their genetic information. This concept has become central to debates around data ownership, as genetic data is increasingly used for everything from health optimization to law enforcement, necessitating new frameworks for privacy protection in the face of rapid biotechnological advances.

HOLOBIONT
An integrated ecological unit composed of a host organism and its associated microbiome, including bacteria, viruses, fungi, and other microorganisms. Increasingly, the study of holobionts plays a critical role in personalized medicine, recognizing the microbiome's influence on health, disease, and even behavior, transforming our understanding of human biology as interconnected systems.

MICROBIOME
The unique community of microorganisms (bacteria, viruses, fungi) that inhabit the human body and play critical roles in processes like digestion and immune response. Advances in microbiome research are leading to the development of microbiome-targeted therapies and precision probiotics that tailor treatment to individual microbial profiles, revolutionizing fields like gut health and chronic disease management.

NANOBOTS
These microscopic robots, often at the scale of nanometers, are designed to perform specific tasks at a cellular or molecular level. Nanobots are increasingly used in medical applications such as targeted drug delivery, cancer treatment, and cellular repair, operating

autonomously within the human body, often in combination with AI-driven diagnostics for highly precise interventions.

NOOTROPICS

Often referred to as “smart drugs” or cognitive enhancers, these substances are intended to improve cognitive function in healthy individuals. They are increasingly bioengineered and personalized, with enhanced formulations that leverage genomics and AI for targeted cognitive enhancements, sparking both ethical debates and potential regulatory challenges.

PERSONALIZED MEDICINE

This type of health care model tailors medical treatments and preventive measures to an individual’s specific characteristics, including genetics, lifestyle, and environment. With the increased involvement by big data, AI, and bioinformatics, precision medicine enables more precise interventions for everything from cancer treatments to chronic disease prevention. This often incorporates real-time health data from wearable tech.

PIEZOELECTRICITY

Piezoelectricity refers to the ability of certain materials (such as crystals and biological tissues) to generate an electrical charge in response to mechanical stress. Piezoelectric materials are being used in innovative applications, such as wearable energy-harvesting devices, ultra-sensitive sensors, and even in biomedical implants that convert movement into electrical signals to power medical devices.

PRECISION MEDICINE

A medical approach that uses detailed genetic, molecular, and environmental information to tailor treatment plans to individual patients. Precision medicine is integrated into routine health care, with AI-enhanced genetic testing providing real-time data to guide personalized therapies for conditions ranging from cancer to rare genetic disorders.

QUANTUM HEALTH CARE ALGORITHMS

These algorithms utilize the principles of quantum computing to process complex biological data at unprecedented speeds. They are being explored in genomics, drug discovery, and complex systems modeling, with the potential to revolutionize personalized medicine by accelerating the development of individualized treatment plans based on vast genetic datasets.

SYNTHETIC BIOLOGY PLATFORMS

These technological ecosystems enable the engineering of new biological entities or the redesign of existing organisms. The platforms, often powered by AI and automation, are accelerating innovation in fields like biofuels, agriculture, and pharmaceuticals, raising ethical considerations around the manipulation of life-forms.

XENOBOTS

Programmable living robots built from biological cells, often using stem cells from animals like frogs. These biological robots are evolving in their ability to perform complex tasks such as targeted drug delivery, environmental remediation, or tissue repair, offering new possibilities in regenerative medicine and sustainable technologies.

XENOTRANSPLANTS

The transplantation of organs, tissues, or cells between different species, primarily from animals (like pigs) to humans. Advancements in gene editing and immunosuppressive therapies are pushing xenotransplantation closer to widespread clinical application, aiming to alleviate the global organ shortage while addressing cross-species compatibility and ethical concerns.

HEALTH CARE & MEDICINE TRENDS

THE BUSINESS OF HEALTH CARE

7TH YEAR ON THE LIST

BIG TECH DISRUPTS HEALTH CARE

WHAT IT IS

Big Tech's push into health care is reshaping the industry through AI, cloud infrastructure, and consumer-driven innovations but faces substantial barriers from regulatory challenges and incumbent partnerships. Success will rely on collaboration rather than full disruption.

HOW IT WORKS

Big Tech is entering health care through artificial intelligence, cloud computing, wearables, and direct-to-consumer services, aiming to streamline medical practices, enhance patient care, and integrate digital health. Google, Microsoft, Amazon, Nvidia, and Apple are leading the charge. Google's AI advancements are focused on improving clinical workflows and diagnostics through tools like Vertex AI, which assists in medical records management. Its life sciences branches, Verily and Calico, explore longevity and genomics, furthering research in health data analytics and personalized care. Microsoft's strategy revolves around cloud-based enterprise solutions, enhanced by the acquisition of Nuance, whose AI-driven speech-to-text capabilities reduce physician burnout. Amazon focuses on telehealth and pharmacy services, using acquisitions like One Medical and innovations such as HealthScribe to integrate AI in patient care documentation. Nvidia's GPU technology powers AI-driven health care devices, such as AI-enhanced robotic surgery systems. Apple brings health data straight to consumers with its wearables, integrating health-monitoring technologies like heart rate and oxygen tracking. These technologies aim to make health care more efficient and accessible while addressing physician shortages, cybersecurity, and consumer trust.

WHY IT MATTERS

Big Tech's involvement in health care has the potential to transform the industry, but displacing health care incumbents, deeply rooted in regulation and infrastructure, is a major challenge. Instead of direct disruption, the near future will likely see more collaboration between technology companies and health care providers. Google and Microsoft are partnering with hospitals to integrate AI and cloud services, enhancing clinical and administrative processes rather than replacing them. However, data privacy remains a critical concern. Scandals involving sensitive health data misuse by companies like Meta and Google could hinder consumer trust, particularly as regulations like HIPAA evolve to address new challenges in digital health. Generative AI is also emerging as a transformative tool, with companies like Microsoft and Amazon using it to assist in diagnostics, give treatment recommendations, and reduce administrative burdens. Ultimately, the success of tech companies in health care will depend on navigating regulatory landscapes, addressing privacy concerns, and fostering trust among patients and health care providers. The health care market represents an enormous growth opportunity, but Big Tech must balance innovation with ethical considerations and collaboration with established players to unlock its full potential.

5TH YEAR ON THE LIST

DTC HEALTH CARE MODELS

WHAT IT IS

Direct-to-consumer (DTC) health care models are reshaping patient expectations and experiences by offering more accessible, personalized, and tech-driven care solutions, challenging traditional health care providers.

HOW IT WORKS

The DTC health care model is transforming patient experiences by using technology to bypass traditional barriers. As dissatisfaction with conventional health care grows due to high costs, complex processes, and impersonal care, DTC models offer direct access to virtual consultations, at-home diagnostics, and personalized care.

Digital health platforms are attracting major pharmaceutical attention, as evidenced by Eli Lilly's new partnership with Ro, which strengthens DTC access to medications through integrated prescription services. LillyDirect streamlines medication delivery and chronic disease management through digital pharmacies. K Health's AI platform provides symptom analysis and virtual consultations, partnering with institutions like Cedars-Sinai to enhance care. Telehealth platforms like Teladoc Health have expanded to mental health and offer text-based and video therapy via services like BetterHelp.

Strategic partnerships are further enhancing DTC health care. In 2024, Sanofi partnered with DarioHealth to integrate digital therapeutics into chronic disease management, while GE HealthCare's collaboration with Mass General Brigham focuses on AI-driven solutions to optimize clinical operations and improve access to diagnostics. These alliances show how merging advanced tech with traditional care drives more efficient, patient-centered health care.

WHY IT MATTERS

DTC health care models are a game-changer, democratizing access to health care services by putting the consumer at the center. This shift toward consumer-driven care challenges the traditional health care paradigm, where patients had little control over their care experiences. But patient expectations have changed: 70% of consumers are willing to switch providers in search of better options. Health care is no longer confined to traditional settings but is accessible at the click of a button, whether through a smartphone app or an at-home diagnostic kit.

This trend is driven by several factors, including rising health care costs, technological advancements, and an increasing consumer desire for convenience and control. As the US at-home diagnostics market is projected to reach $5.23 billion by 2033, the financial potential of DTC models is clear. However, this growth also brings challenges, including ensuring continuity of care, addressing data privacy concerns, and managing the risks associated with self-diagnosis and treatment without professional oversight.

Health care providers must adapt by integrating digital tools, enhancing patient engagement, and forming strategic partnerships to remain competitive. Failing to do so may result in losing patients to more innovative and consumer-centric competitors. The DTC model represents not just an evolution but a potential revolution in health care, one that could redefine patient care in the decades to come.

5TH YEAR ON THE LIST

HEALTH AT THE WORKPLACE

WHAT IT IS

Employers are enhancing workplace mental health programs. This reflects a growing demand for comprehensive health benefits that address both mental well-being and rising health care costs, alongside evolving treatments like ketamine-assisted therapy.

HOW IT WORKS

Companies are reevaluating traditional health programs like stress management workshops and fitness classes, with research showing little measurable impact on well-being. But as 91% of employers increase their investment in mental health benefits, AI chatbots are becoming critical tools. Ollie Health offers 24/7 AI-powered mental health support with constant access to live therapists, making it a robust solution for employee well-being in large, dispersed workforces. Wysa and Woebot Health both leverage cognitive behavioral therapy to help employees manage stress and depression through personalized interventions. These tools are particularly effective in remote and hybrid work environments, where employees increasingly prefer engaging with AI for mental health support rather than their manager. There's a cost incentive, too. These lower-cost options are attractive, especially as employees are increasingly filing lawsuits over mismanagement of health care expenses, as seen in cases against Wells Fargo and Johnson & Johnson, where workers accused their employers of overpaying for prescription drugs, leading to inflated premiums and out-of-pocket costs. These lawsuits have forced companies to face federal mandates requiring them to prove responsible use of employee contributions.

Employers are also adding alternative therapies to their health plans. Despite the FDA's recent rejection of MDMA for PTSD, ketamine is gaining traction for treatment-resistant depression, and these therapies are increasingly an option for some employees.

WHY IT MATTERS

Employers are shifting their approach to workplace mental health as stress, anxiety, and depression increasingly impact productivity. Traditional wellness programs are being replaced by solutions addressing deeper issues like heavy workloads, inflexible schedules, and low compensation. By focusing on these core organizational changes, companies can better support employee well-being, leading to lasting improvements for both workers and business outcomes.

At the same time, digital tools like telemedicine, mental health apps, and AI-powered chatbots are becoming essential in workplace wellness strategies, making it easier to scale services in remote and hybrid work settings. These AI-driven tools reflect a broader trend toward tech-based, accessible mental health care that meets diverse employee needs.

While psychedelic-assisted therapy remains a niche offering, treatments like ketamine are gaining traction for severe mental health conditions like treatment-resistant depression. Despite societal and legal barriers, these therapies could become a more significant part of workplace health benefits. By integrating digital tools, flexible health options, and systemic organizational improvements, employers can better support their workforce's mental health while managing health care costs and legal risks.

3RD YEAR ON THE LIST

CONSIDERING HEALTH EQUITY

WHAT IT IS

Efforts to improve health equity focus on closing gaps in care for vulnerable populations, such as people with disabilities, children, and communities of color, by enhancing access to data, policy reforms, and care resources.

HOW IT WORKS

Often, integrating data is one way to reduce inequities. In Worcester, Massachusetts, the Worcester Integrated Health Data Exchange combines data from the University of Massachusetts Chan Medical School, city officials, and local health organizations. Initially targeting opioid use disorders, the platform now focuses on communities of color disproportionately affected by opioid use and employs the Observational Medical Outcomes Partnership model to monitor prescriptions and risk factors, aiming to prevent patients from obtaining opioids from multiple sources. Success could lead to applications for other conditions like diabetes and hypertension.

Data collection is also vital in addressing the greater barriers to health care that 1.3 billion people with disabilities encounter around the world. However, nearly a third of countries lack datasets on disability challenges. Tools like New Zealand's National Child Health Information Platform (NCHIP), which tracks a child's health milestones, illustrate how data sharing can enhance health equity: Immunization rates and general practitioner enrollment increased for children on the platform.

Social determinants like education, income, and access to services account for 80%-90% of health outcomes. In Bogotá, initiatives like Care Blocks support caregivers by bringing services directly to them. And the AI4HealthyCities initiative by the Novartis Foundation combines data across sectors to identify health risks, influencing urban policies.

WHY IT MATTERS

Achieving health equity requires comprehensive data and collaboration across sectors. Initiatives like the data exchange in Worcester show data sharing's potential to tackle disparities in opioid use and other health conditions. Similarly, digital platforms like NCHIP and AI-driven tools offer scalable solutions to track health outcomes and address gaps in vulnerable populations, from children to people with disabilities.

As health care inequities continue to grow, improving data collection standards and leveraging technology will be critical to ensuring that every individual, regardless of race, gender, or disability, has access to high-quality care. Policymakers, health care providers, and communities must work together to integrate these tools and approaches, fostering an environment where health equity can be achieved on a larger scale.

2ND YEAR ON THE LIST

HEALTH CARE'S ENVIRONMENTAL IMPACTS

WHAT IT IS

Health care is increasingly adopting sustainable practices such as renewable energy, waste reduction, and green certifications. Despite high operational demands, collaborative initiatives and policy advocacy are helping hospitals reduce their ecological footprint.

HOW IT WORKS

The health care sector contributes more than 4% of global carbon dioxide emissions, more than aviation or shipping, with hospitals emitting 2.5 times more greenhouse gases than commercial buildings. To address this, hospitals are adopting renewable energy, improving the energy efficiency of medical equipment, and promoting sustainable behavior. For example, Mass General Brigham targets the environmental impact of metered-dose inhalers, which contain hydrofluorocarbon gases with high global warming potential, by promoting alternatives like dry powder and soft mist inhalers.

Collaborative efforts, like those led by the Institute for Healthcare Improvement, support hospitals in implementing sustainability projects, such as decommissioning nitrous oxide systems and eliminating the anesthetic desflurane in operating rooms. These initiatives not only reduce emissions but also save money, encouraging the creation of dedicated sustainability roles.

Hospitals are also investing in renewable energy projects like the Mutkalampi wind farm in Finland, which supplies clean energy directly to health care facilities, reducing reliance on fossil fuels and lowering carbon emissions. Beyond energy sourcing, hospitals are integrating digital health technologies and AI to optimize operations. AI-driven systems improve energy management by predicting peak usage times and adjusting heating, cooling, and lighting to reduce waste.

WHY IT MATTERS

The health care sector's environmental impact extends beyond its direct emissions, affecting both public health and global sustainability efforts. Reducing the carbon footprint of hospitals is critical, as they are major contributors to greenhouse gas emissions and environmental degradation. Sustainable health care practices not only help mitigate climate change but also align with the growing demand from clinicians and patients for environmentally responsible care.

But driving meaningful change toward sustainable health care requires leadership commitment and cross-sector collaboration. By setting clear standards and rules, governments can create a level playing field that incentivizes decarbonization efforts. This is both an environmental imperative and a public health priority, as sustainable health care systems can contribute to overall planetary health and resilience.

Hospitals adopting sustainable practices, such as green operating rooms, reusable medical devices, and eco-friendly inhalers, are leading the way in reducing their industry's environmental impact. By integrating sustainability into their operations, health care providers can improve efficiency, reduce costs, and enhance patient outcomes, setting a precedent for other high-impact industries to follow.

HEALTH CARE ADMINISTRATION

7TH YEAR ON THE LIST

HEALTH DATA INFRASTRUCTURE

WHAT IT IS

The future of health care hinges on robust health data infrastructure, focusing on enhancing electronic health record (EHR) systems with usability, security, and interoperability. Integration of AI, cloud solutions, and data governance is crucial for this transformation.

HOW IT WORKS

Health data infrastructure encompasses systems used to collect, manage, and use health information, with EHRs at its core. Historically, EHRs faced challenges such as poor usability, lack of interoperability, and data security concerns, hindering efficient data exchange and increasing administrative burdens.

Innovations are now addressing these issues. At Emory Healthcare, Epic Hyperspace works on Apple operating systems to streamline workflows and reduce documentation time, allowing clinicians to focus more on patient care. Wellsheet uses interoperability solutions powered by Fast Healthcare Interoperability Resources APIs, which enable seamless data sharing across different EHR platforms, ensuring comprehensive patient histories.

Cloud-based EHR systems, such as Cerner Millennium, offer real-time data access, simplified updates, and enhanced security features like encryption and multifactor authentication. Providence's Praia Health platform has leveraged cloud infrastructure to scale its new patient-facing features from 2-3 per year to more than 40. AI integration, such as Wellsheet's AI-enabled clinical workflows, supports predictive analytics and automates tasks like pre-filling forms, reducing clinician burnout.

But with increasing cyberthreats, enhanced security protocols—including encryption and multifactor authentication—are critical for protecting valuable health care data.

WHY IT MATTERS

By making EHR systems more user-friendly and interoperable, health care providers can reduce administrative burdens and focus more on patient care. Interoperability enhances the continuity of care, ensuring that all health care professionals involved in a patient's treatment have access to comprehensive and accurate information. This not only improves patient outcomes but also reduces the risk of medical errors.

AI and machine learning hold transformative potential for health care. Predictive analytics can identify at-risk patients, prevent adverse events, and personalize treatments. As AI becomes more integrated into health care systems, the potential for improved clinical decision-making and operational efficiency grows.

Among these EHR innovations, cloud-based solutions provide scalability and flexibility, allowing health systems to adapt quickly to changing needs, such as in the case of a pandemic or other public health emergency. We recently saw the importance of having flexible and secure digital systems capable of managing surges in patient data and facilitating remote care during the early years of the COVID-19 pandemic.

However, the widespread adoption of these technologies is not without challenges. Interoperability remains a significant hurdle, with different EHR systems often using incompatible formats.

3RD YEAR ON THE LIST

DEFINING PATIENT ACCESS TO MEDICAL DATA

WHAT IT IS

As data protection laws evolve in Europe, the UK, and the US, patient access to medical data is increasingly shaped by both opportunities and challenges, with new regulations demanding a balance between transparency, privacy, and cross-border data sharing.

HOW IT WORKS

Significant shifts in data protection laws across countries are redefining how patients access and control their personal medical data. In the European Union, the European Health Data Space (EHDS) is set to evolve patient data access. By 2030, all EU citizens will have access to their electronic health data through MyHealth@EU, a cross-border digital infrastructure that connects national health systems and will facilitate data sharing across EU countries. This decentralization ensures patient privacy while promoting secondary data use for research.

In the UK, the Data Protection and Digital Information (No. 2) Bill reflected post-Brexit divergence from the EU's GDPR. It introduced adjustments to patient data-sharing rules, impacting cross-border access for providers, but ultimately fell through because of the Parliament's May 2024 prorogation before its general election. Meanwhile, Switzerland's updated Federal Act on Data Protection (FADP) aligns more closely with GDPR, ensuring stricter sanctions for data misuse.

The US faces a fragmented landscape. While no federal-level law exists, states such as California and Washington have implemented rights-based data protection frameworks, leaving patients to navigate a patchwork of regulations. New laws, such as Nevada's consumer health privacy regulations, emphasize consumer access and deletion rights, complicating nationwide data management for organizations collecting patient data.

WHY IT MATTERS

The global shift toward more stringent, rights-based data protection laws, places patient data access at the forefront of health care transparency. The EHDS offers a template for enhanced patient control, enabling cross-border data sharing while ensuring privacy. This will improve care continuity for patients moving between countries and foster research by making anonymized health data more accessible under secure conditions.

However, the complexity of regulations in the US and UK presents challenges. The lack of a unified federal framework in the US means health care providers must adapt to varying state regulations, which can complicate patient access to data, especially when dealing with cross-border or multistate medical histories. In the UK, post-Brexit data regulation changes may limit the ease of international research collaboration, requiring new data-sharing agreements.

The rise of health data breaches, with a 239% increase in hacking-related incidents from 2018 to 2023, adds another layer of urgency to this trend. Health care institutions must not only focus on regulatory compliance but also implement robust cybersecurity measures to protect patient data from breaches and unauthorized access. The shift toward digital health infrastructure, as seen with the growing role of private companies like Klinik Healthcare Solutions and Palantir Technologies in the UK's National Health Service, raises concerns about transparency and the commercialization of patient data.

2ND YEAR ON THE LIST

INTEROPERABILITY OF DATA INFRASTRUCTURE

WHAT IT IS

The rapid growth of health data in fragmented silos is driving the urgent need for global interoperability standards. To enable seamless data exchange, international bodies are coordinating to focus on harmonizing data formats and terminologies.

HOW IT WORKS

The vast expansion of health data presents both an opportunity and a challenge for the health care ecosystem. This data is often stored in decentralized and disparate systems, lacking unified standards that would enable smooth data sharing. The current landscape consists of unstructured health data, housed in different formats across various databases, which creates significant obstacles for researchers, health care providers, and policymakers.

To address this, the system needs syntactic and semantic interoperability standards. Syntactic standards define the structure and format of data exchange (e.g., XML or JSON), while semantic standards set agreed-upon terms and definitions to ensure that data concepts are consistently understood. The use of standards like Fast Healthcare Interoperability Resources (FHIR) aims to solve the challenge by making it easier for systems to exchange data through a common framework.

Initiatives such as Germany's National Research Data Infrastructure for Personal Health Data (NFDI4Health) have been developing tailored metadata schemas that map to global standards like FHIR, ensuring both syntactic and semantic interoperability. By categorizing standards and mapping them to data exchange protocols, these efforts enable efficient data sharing across national and international systems. Global bodies, like the Joint Initiative Council for Global Health Informatics Standardization and the Global Alliance for Genomics and Health, are working to expand these frameworks.

WHY IT MATTERS

Interoperability in data infrastructure is critical for improving patient care, streamlining research, and enabling large-scale public health initiatives. Harmonized data formats allow health care systems to collaborate, reducing diagnosis delays, and enhancing clinical decision-making. Without global interoperability, health data remains trapped in silos, limiting its potential for driving medical breakthroughs. For example, retrospective data from clinical trials or patient histories often cannot be fully utilized due to incompatibilities in data formats and terminologies. Bridging these gaps can lead to faster development of treatments and more accurate predictive models in areas like genomics and personalized medicine.

Efforts like the HTI-1 rule, which enhances data sharing by enforcing interoperability and transparency in health IT systems, and the CDC's Data Modernization Initiative, aimed at improving public health data infrastructure, show that interoperability is a public health necessity. The COVID-19 pandemic exposed the risks of siloed data, and as AI becomes more integral, unified data sharing frameworks are increasingly essential.

By building a unified data infrastructure, health care institutions can improve everything from early disease detection to large-scale epidemiological studies. Investment in international standards, including the alignment of metadata schemas and AI-driven data curation, will ensure that health data can be used more effectively everywhere.

6TH YEAR ON THE LIST

AUTOMATION OF PROCESSES

WHAT IT IS

Automation, particularly through robotic process automation (RPA), is streamlining administrative and clinical workflows in health care. The results are reduced costs, increased efficiency, and staff members who can focus on higher-value tasks like patient care.

HOW IT WORKS

The health care industry, known for its complex and burdensome administrative systems, has long struggled with inefficiencies, particularly in revenue cycle management (RCM) and billing. Hospitals and physician practices spend billions annually on billing costs, with administrative inefficiencies often leading to significant revenue loss. For example, hospitals can lose up to $62,000 per bed annually due to billing issues.

RPA is addressing this by automating repetitive tasks such as insurance verification, claims processing, and prior authorization. Health care companies can integrate the technology across various systems—from scheduling to checking the status of claims—and the automation can handle up to 70% of manual tasks, cutting operational costs by 20%-35% and reducing the potential for human error. Perhaps more importantly, it frees up health care staff to focus on critical patient care rather than time-consuming administrative tasks.

Beyond billing, automation technologies like AI are enhancing clinical documentation and patient engagement. For instance, AI-powered platforms like Greenway Clinical Assist are helping health care providers save clinicians time by automating routine documentation tasks. The use of AI extends into more complex areas, like analyzing vast medical datasets in real time to enable faster clinical decision-making, a field that Nvidia is pushing forward with its advanced AI microservices and its powerful Blackwell B200 GPU.

WHY IT MATTERS

Inefficient RCM systems and manual billing processes are responsible for billions of dollars in lost revenue each year, creating a substantial drain on health care systems. Automating these processes can help alleviate this financial strain, as well as reduce the administrative burden for employees and increase operational efficiency.

RPA and AI are also crucial in addressing the industry's labor shortages, particularly in the wake of the pandemic, which has led to widespread burnout among health care professionals. Automation lets these providers do more with fewer resources, reallocating human labor to focus on complex, patient-centered tasks that require human judgment and empathy. It's also a stepping stone to more advanced AI applications, which can further reduce administrative burden, optimize clinical decision-making, and improve patient outcomes.

In addition, automation can help health care organizations maintain regulatory compliance and manage ethical concerns related to data privacy and security. As automation becomes more widespread, it will be crucial to maintain human oversight, develop governance frameworks, and ensure that these technologies are used responsibly, particularly in highly regulated health care environments.

2ND YEAR ON THE LIST

INCREASED CYBERSECURITY THREATS

WHAT IT IS

Emerging biotechnologies and critical infrastructure systems are increasingly vulnerable to cyberattacks. As cybercriminals evolve their tactics, the need for robust, interdisciplinary cybersecurity measures is more critical than ever.

HOW IT WORKS

Cybersecurity threats continue to evolve, with emerging dangers in bio-cyber hacking and attacks on critical infrastructure. One growing risk: the manipulation of synthetic DNA to insert malicious payloads. For instance, synthetic DNA can be used to infiltrate DNA sequencing pipelines, activating Trojan malware once processed. Researchers are combating this by applying deep learning techniques, like 1D convolutional neural networks, to detect such attacks with high accuracy. However, the increasing complexity of bioinformatics systems makes them a prime target for hackers.

Beyond biohacking, ransomware groups such as Ransomhub are increasingly targeting critical infrastructure like Industrial Control Systems and Supervisory Control and Data Acquisition (SCADA) systems. Recent attacks, including one on a Spanish bioenergy plant where hackers manipulated the building systems, highlight the risks. These groups use languages like Golang and C++ and buy stolen credentials on dark web forums, amplifying their reach.

Geopolitical factors have intensified these attacks. Nation-state actors, including Chinese government-backed groups, are increasingly targeting US critical infrastructure. In 2024, the FBI disrupted Chinese hackers attempting to upend the US energy grid, water treatment plants, and communication networks, marking a significant escalation in cyberwarfare tactics.

WHY IT MATTERS

As genetic sequencing and biotechnological systems become integral to health care, bio-cybersecurity threats are on the rise. Cybercriminals can exploit vulnerabilities in these systems, leading to data theft or manipulation of biological materials, raising concerns about biowarfare.

Health care data breaches have surged by 239% over the past five years, primarily from hacking and unauthorized access. Ransomware groups target health care systems, causing significant financial and operational damage. These attacks can delay patient care and disrupt medical procedures, putting lives at risk.

Health care providers also face threats to their infrastructure, particularly SCADA systems, which control essential hospital operations like energy management and life-support systems. A cyberattack on SCADA could cripple hospital functions and endanger patient safety. With health care providers relying on interconnected networks and often outdated cybersecurity measures, they are at heightened risk of both data breaches and operational sabotage.

To address these threats, health care organizations must implement robust cybersecurity strategies. This includes investing in advanced detection systems, training staff, and fostering international collaboration. Balancing technological innovation with security is essential to protect sensitive data and critical infrastructure in a rapidly evolving health care landscape.

REMOTE CARE

10TH YEAR ON THE LIST

IN-HOME CONSUMER HEALTH TECHNOLOGY

WHAT IT IS

Innovations in home health technology are empowering individuals to take control of their health with noninvasive, easy-to-use devices, particularly for those managing chronic conditions. These tools enhance self-care, real-time monitoring, and remote patient management.

HOW IT WORKS

Recent advancements in home consumer health technology are transforming how individuals manage chronic conditions at home. Devices like Accurate Meditech's cuffless Accurate 24 BPM monitor allow seamless tracking of blood pressure, oxygen levels, and core body temperature without traditional cuffs. Alerje's Omniject integrates an epinephrine auto-injector with a smartphone case: It automatically alerts health care professionals when activated, enhancing emergency preparedness.

The xKidney portable hemodialysis unit gives dialysis patients a more convenient alternative to conventional dialysis machines by using an advanced piston-balancing pump that eliminates daily cleaning. Similarly, the GyroGlove, designed for individuals with essential tremors, uses gyroscopic technology to stabilize hand movements, offering a noninvasive, drug-free solution that enhances mobility.

Healthcare Vision's noninvasive glucose monitors provide diabetes patients with real-time blood sugar readings without the need for finger sticks. Innovations like Infuzamed's wearable infusion pump allow remote monitoring of vital signs to enable proactive care, while Vivoo's at-home UTI diagnostic kit uses smartphone apps and deep learning for quick analysis, empowering users to share results with health care providers for timely intervention. These technologies reflect the broader trend toward decentralized, personalized health care, reducing reliance on traditional clinical settings.

WHY IT MATTERS

The shift toward home-based health care technology offers significant benefits for patients managing chronic conditions like hypertension, diabetes, and kidney disease. These innovations allow for more frequent monitoring, giving both patients and health care providers better data to track health trends and intervene when necessary.

Wearable health technology offers critical support for those needing continuous care, while minimizing physical discomfort. These devices also reduce the need for frequent clinical visits, which can be costly and time-consuming. By providing patients with real-time, actionable health data, the technology enables them to take more responsibility for their health and make informed decisions with their health care providers.

And as remote patient monitoring becomes more advanced, the potential for timely medical interventions grows. These solutions improve patient outcomes by reducing delays in care, while also easing the strain on health care systems by allowing more patients to be monitored from home. The integration of AI further highlights the role of technology in transforming health care delivery, providing rapid diagnostics and enhancing communication between patients and physicians.

5TH YEAR ON THE LIST

SCALING OF TELEMEDICINE

WHAT IT IS

Telemedicine is rapidly expanding, transforming health care delivery by increasing access to care, integrating innovative technologies, and reducing barriers for underserved populations.

HOW IT WORKS

The telemedicine market is projected to grow more than eightfold by 2031—from $87.2 billion in 2023 to $728.5 billion—driven by demand for tele-consultations and remote monitoring. Telehealth's ability to manage chronic conditions and provide virtual consultations is essential for hospitals and clinics, with some facilities already experiencing success with applications of the technology, like Phoenix Children's Hospital's integration of Amazon Alexa devices allowing family members and support staff to join remotely. Johns Hopkins uses eConsults, a tool for primary care providers to consult with specialists electronically, improving access to expert advice without in-person referrals. This streamlines diagnoses and treatment, enhancing care coordination and reducing unnecessary specialist visits.

Telemedicine is also expanding in specialized care. WellSync's partnership with The Vitamin Shoppe launched a testosterone replacement therapy program, expanding men's health services and building on its successful weight loss initiatives. Mental health care has seen significant telehealth adoption, with reduced no-show rates and better access for underserved populations. Institutions like MD Anderson Cancer Center have fully integrated telehealth into everyday clinical operations, highlighting the growing importance of virtual care in comprehensive health care delivery.

WHY IT MATTERS

Telemedicine's rapid expansion is reshaping how health care is delivered, by offering scalable, cost-effective solutions for chronic disease management, preventive care, and even acute care. The growing acceptance of remote monitoring and virtual consultations lets health care systems reach more patients, especially those in underserved or rural areas who often face barriers to accessing traditional care. This shift to digital health care is essential for enhancing access, reducing wait times, and personalizing care—whether through eConsults that facilitate quicker specialist input, remote monitoring of chronic conditions, or specialized telehealth clinics offering focused care like mental health or chronic disease management.

As telemedicine technologies become more sophisticated, the need for strategic integration into health care systems grows. Solutions like Alexa-enabled hybrid visits and remote consultations highlight telemedicine's potential to reduce costs, streamline workflows, and improve care coordination. However, significant challenges remain, including ensuring digital health equity, providing sufficient workforce training, and addressing technical limitations such as broadband access in rural regions. The future success of telemedicine will depend on how well these technologies are seamlessly incorporated into clinical practice, while overcoming these barriers to make health care more accessible, efficient, and patient-centered for everyone.

5TH YEAR ON THE LIST

REMOTE PATIENT MONITORING (RPM)

WHAT IT IS

Remote patient monitoring is revolutionizing health care by enabling patients to receive hospital–level care at home. This technology has the potential to improve patient outcomes, reduce costs, and expand access, especially for those with chronic conditions.

HOW IT WORKS

Increasingly, health care systems are adopting RPM to offer high-quality care outside traditional medical settings. One example is Mass General Brigham's work to transition 10% of its medical patients to home care—a move supported by CMS's Acute Hospital Care at Home initiative, which allows hospitals to deliver inpatient-level care in the patient's home. Studies reveal that the hospital-at-home (H@H) model reduces readmissions, shortens hospital stays, lowers costs, and prevents infections.

The rise of RPM technology has also led to programs like Island Health's Virtual Palliative Supportive Care (VPSC), where patients receive end-of-life care remotely through virtual visits and RPM devices. VPSC's free services include tablets for virtual check-ins, offering patients and families continuous support without frequent hospital visits.

RPM is also gaining traction in intensive care units, with the tele-ICU market valued at $3.5 billion in 2023 and expected to reach $11.8 billion by 2032. Critical care specialists use RPM tools like physiological monitors to remotely monitor and manage ICU patients, improving outcomes and optimizing resources.

In these efforts, key players like Cleveland Clinic are leading the way by integrating RPM tools with AI-based algorithms to enhance patient monitoring. This combination of RPM and AI is proving especially effective in managing chronic diseases like heart failure.

WHY IT MATTERS

RPM is not just improving patient care—it's transforming how health care systems operate, making them more agile and capable of handling higher patient volumes without expanding physical infrastructure. As health care faces increasing pressures from aging populations and rising chronic diseases, RPM offers a scalable solution that delivers high-quality care at a lower cost. By enabling patients to remain at home, RPM significantly reduces hospital overcrowding, a critical advantage during crises like the COVID-19 pandemic. By keeping patients out of the hospital, it also lowers the risk of hospital-acquired infections, which is particularly important for vulnerable populations such as the elderly and immunocompromised.

The expansion of RPM also addresses health care access disparities, particularly in rural or underserved areas where specialist care is limited. Through tele-ICUs and home care programs, RPM extends expert medical support to regions that would otherwise face shortages in critical care. This allows for continuous, real-time monitoring, ensuring that patients receive timely interventions and reducing the likelihood of costly readmissions. As AI continues to enhance the predictive capabilities of RPM systems, health care providers can deliver more proactive care, improving patient outcomes while further optimizing resource use. The continued growth and success of RPM hinges on overcoming challenges such as digital equity and creating sustainable reimbursement models, but its potential to reshape health care delivery is undeniable.

EMERGING DIAGNOSTICS

3RD YEAR ON THE LIST

SMART MATERIALS

WHAT IT IS

The smart textile market is projected to grow at a compound annual growth rate of 25.3%, driven by technologies for health monitoring, aging populations, and rising chronic disease. Europe and Asia are seeing rapid expansion due to R&D and rising health care costs.

HOW IT WORKS

Medical smart textiles combine fabrics with advanced sensors to monitor health in real time. These textiles enhance health care by embedding sensors into clothing, wound dressings, or bedding to track vital signs like heart rate, temperature, and glucose levels.

Active smart textiles integrate sensors to track vital health data such as heart rate and respiratory patterns. Hexoskin's shirts transmit data to smartphones for real-time analysis, helping manage chronic conditions like cardiovascular diseases, while AliveCor's devices monitor heart activity to detect arrhythmias. These innovations enable continuous health monitoring, allowing for early detection of issues and timely interventions, making them increasingly valuable in both home and hospital settings.

Passive smart textiles are also gaining popularity for their antimicrobial and moisture-wicking properties, which improve patient comfort and hygiene. Outlast's temperature-regulating materials, for example, help patients maintain optimal body temperature while reducing infection risks, particularly in long-term care settings. Pecotex, a conductive cotton thread, keeps sensors seamlessly integrated in clothing so they monitor vital signs like heart and respiratory rates. Researchers are exploring materials like MXene and graphene to create textiles that harvest energy from body heat or solar power and companies like Adidas and Jabil are integrating these textiles into sportswear and medical garments.

WHY IT MATTERS

The demand for medical smart textiles is rising sharply due to the increasing prevalence of chronic diseases, an aging population, and the growing focus on home health care. These textiles provide a convenient and noninvasive way to monitor long-term health conditions, significantly reducing hospital visits and enabling personalized care. And that's not all: With health care costs surging globally, these technologies are cost-effective, improve patient outcomes, enhance patient comfort, and reduce the strain on health care systems. They can also help in early diagnosis, crucial for conditions like cardiovascular diseases or sleep apnea, where timely intervention can save lives.

The expansion of the smart textile market is not limited to the West; government initiatives in Europe and Asia-Pacific are pushing research and development, making this technology more accessible worldwide. With leading companies like Adidas, Hexoskin, and DowDupont innovating in this space, the future of medical smart textiles looks promising, particularly as they become more integrated with AI and other digital health platforms.

2ND YEAR ON THE LIST

BIOSENSOR AND CHIP-BASED DIAGNOSTICS

WHAT IT IS

Biosensors provide real-time, continuous monitoring of physiological conditions. Whether embedded in the body or worn externally, these sensors track biomarkers like glucose, proteins, and DNA, enabling early detection of diseases like diabetes, heart disease, and cancer.

HOW IT WORKS

Abbott's Lingo system and Dexcom's G7 offer continuous glucose monitoring, providing real-time insights that help manage diet and lifestyle, even for nondiabetics. By tracking these markers, biosensors enable personalized interventions, making health care more precise and proactive.

Biosensors detect biological signals—like chemical changes or electrical impulses—and transmit data to external processors. These processors analyze the information and send it to devices like smartphones or medical dashboards, where health care providers can instantly interpret the results. For example, cardiovascular biosensors that monitor heart function can detect early signs of disease, allowing for rapid intervention. Technologies like nano-electronics and microfluidics further enable minimally invasive molecular diagnostics, enhancing accuracy and patient comfort. Carterra's high-throughput biosensors, for instance, analyze thousands of molecular interactions in a fraction of the time, speeding up diagnostics and drug discovery.

Advanced biosensors are also being developed for specific applications. BioIntelliSense's multi-parameter biosensors track respiratory and cardiac health continuously, while liquid biopsy biosensors detect cancer biomarkers in blood and saliva, offering a noninvasive alternative to traditional biopsies. Even consumer wearables like the WHOOP 4.0 strap and Apple Watch integrate biosensors to track metrics such as heart rate and oxygen levels, providing continuous data for preventive care and lifestyle adjustments.

WHY IT MATTERS

Unlike traditional methods that require biopsies or surgical interventions, biosensors enable the early detection of diseases, often before symptoms appear, significantly improving treatment outcomes. This shift reduces the need for invasive procedures and allows for proactive, precise care. The ability of biosensors to provide localized, real-time monitoring is especially impactful in reducing misdiagnosis. For example, a biosensor placed near a tumor can track growth and treatment responses, allowing health care providers to adjust strategies dynamically. Devices like BioIntelliSense's multiparameter biosensors continuously monitor vital signs for conditions like respiratory or cardiac disease, while liquid biopsy sensors detect cancer biomarkers in blood and saliva, offering noninvasive alternatives to traditional diagnostics.

Biosensors are also driving the expansion of remote health care. Patients in rural or underserved areas can receive the same level of care as those in urban centers, reducing hospital visits and enabling long-term disease management. Continuous, remote monitoring ensures that any complications are detected early, prompting timely medical intervention. This capability supports a more sustainable health care system by reducing the need for repeated tests and hospital stays.

While challenges like data privacy and sensor reliability remain, the benefits of biosensors—more accurate, timely, and patient-specific health care—are set to redefine medical diagnostics and care delivery.

3RD YEAR ON THE LIST

MOLECULAR DIAGNOSTICS

WHAT IT IS

Molecular diagnostics refers to the process of analyzing biological markers in the genome and proteome to diagnose and monitor disease. It enables early detection of various conditions through blood-based biomarkers, offering noninvasive, accurate, and early diagnosis.

HOW IT WORKS

One recent breakthrough in this field, led by researchers at the German Center for Neurodegenerative Diseases, involves the identification of four key blood proteins—GFAP, NEFL, GDF15, and LTBP2—that can predict the onset of conditions like Alzheimer's and vascular dementia up to 15 years before clinical diagnosis. These protein biomarkers, when combined with other risk factors like age, sex, and genetic susceptibility, offer up to 90% accuracy in predicting dementia.

Galleri, a liquid biopsy test by GRAIL, can detect more than 50 types of cancer in their early stages by identifying circulating tumor DNA and patterns in blood samples, letting patients begin treatment much sooner. Sherlock Biosciences has introduced the Inspectr platform, a CRISPR-based diagnostic tool that enables the rapid identification of viral infections such as COVID-19. The platform can detect viral RNA in under 30 minutes using a portable device, offering fast and accurate diagnostics during outbreaks. This innovation is critical for controlling the spread of infectious diseases. Oxford Nanopore Technologies' MinION is a portable, real-time DNA and RNA sequencer that uses nanopore technology to analyze long strands of genetic material, providing highly detailed, immediate results. Unlike traditional sequencing methods, the MinION is compact and can be used outside of laboratories, making it a flexible tool for field research, clinical diagnostics, and rapid pathogen detection.

WHY IT MATTERS

Molecular diagnostics holds transformative potential across a wide range of diseases, especially through early detection. In cancer, early-stage diagnosis using liquid biopsies or protein biomarkers significantly improves survival rates by catching the disease before it spreads. Similarly, in infectious diseases, rapid molecular tests like CRISPR-based diagnostics can identify pathogens quickly, reducing transmission and saving lives. In resource-limited areas, portable diagnostics enable real-time, point-of-care testing for diseases such as HIV and tuberculosis, making health care more accessible.

Personalized medicine is also benefiting from molecular diagnostics, allowing treatments to be tailored to a patient's genetic or molecular profile. This is particularly important for chronic conditions like diabetes and neurodegenerative diseases, where diagnostics can help refine treatments. In Alzheimer's, for example, identifying distinct biomarkers can lead to targeted therapies, improving patient outcomes.

The global molecular diagnostics market, projected to reach $26.27 billion by 2032, is fueled by rising demand for early detection and personalized care. This growth lowers long-term health care costs by preventing late-stage disease management. Molecular diagnostics is accelerating drug discovery and clinical trials, identifying target populations and tracking responses more efficiently, especially in oncology and immunotherapy.

5TH YEAR ON THE LIST

POINT-OF-CARE DIAGNOSTICS CAPABILITIES

WHAT IT IS

Point-of-care (POC) diagnostics are rapidly evolving, with advances like home-based cardiovascular risk tests showing comparable accuracy to clinical tests, empowering individuals to manage their health and driving broader adoption of decentralized health care solutions.

HOW IT WORKS

Swedish researchers have developed a home questionnaire that identifies individuals at high risk for heart attacks, and it's just as accurate as blood tests and blood pressure measurements. This POC test consists of 14 simple questions and detects 65% of individuals most at risk for cardiovascular disease. This noninvasive, accessible method exemplifies how POC diagnostics can empower patients to take charge of their health without the need for complex medical procedures. POC tools are increasingly used for conditions like infectious diseases and sexually transmitted infections. Binx Health's Binx io platform provides rapid diagnosis for chlamydia and gonorrhea in about 30 minutes, allowing treatment to be delivered effectively in clinical settings like urgent care and emergency rooms. These innovations reduce time-to-result, promote early intervention, and help prevent further transmission of diseases. En Carta Diagnostics is working on a rapid Lyme disease test that can provide results within minutes, addressing a growing need for early detection in vector-borne diseases. These tests can be deployed in both clinical and home settings.

VedaBio's CRISPR Cascade detects nucleic acids in under a minute with sensitivity on par with PCR tests, making it a game changer for real-time, on-site diagnostics in industrial and clinical applications. By eliminating the need for complex laboratory equipment and lengthy amplification processes, this technology enables faster, more accessible testing in diverse settings.

WHY IT MATTERS

The rise of POC diagnostics represents a big shift in health care delivery, offering numerous advantages in terms of accessibility, convenience, and cost-effectiveness. By decentralizing diagnostic services, POC tools empower patients to manage their health proactively and enable faster medical interventions, and can significantly reduce the time between diagnosis and treatment, improving patient outcomes and reducing the spread of infections. These advancements are also shaping the future of health care in underserved and remote regions. With POC diagnostics, medical professionals can easily bring testing to rural areas or low-resource settings where access to laboratory facilities is limited. POC testing is also expected to accelerate in emerging economies where governments are decentralizing health care systems.

There will be a growing need to integrate POC diagnostic data with existing health care systems, particularly through electronic health records and telemedicine platforms. This integration will allow health care providers to track patient data more efficiently, monitor trends in public health, and respond to outbreaks faster.

As more diagnostic capabilities move to the home, there could be shifts in health care spending, with a reduction in hospital-based diagnostics and an increased focus on preventive care. Policymakers will also need to address regulations and reimbursement to ensure equitable access to these innovations, particularly for underserved populations.

5TH YEAR ON THE LIST

XR IN DIAGNOSTICS

WHAT IT IS

Extended reality (XR) combined with artificial intelligence is enabling more accurate, faster, and accessible medical assessments, from pulmonary disease detection to cancer diagnostics, improving patient care and monitoring in various health care settings.

HOW IT WORKS

AI can analyze lung ultrasound images to detect COVID-19 with precision similar to facial recognition. AI models like TRUDLMIA have demonstrated improved diagnostic accuracy for COVID-19, pneumonia, and melanoma by using supervised learning to analyze medical images, offering health care providers faster and more accurate diagnoses.

GE Healthcare is developing wearable technology that monitors lung conditions, such as detecting fluid buildup, and provides real-time alerts for medication adjustments. These wearable ultrasound AI-powered patches let patients manage conditions like heart failure or chronic respiratory diseases from home, reducing the need for frequent clinical visits and offering continuous health monitoring. Lucerno Dynamics' electron waveshaping technology has greatly improved X-ray intensity and precision, delivering beams 1,000 times more intense than conventional X-rays. This enhances image clarity, aiding in early detection of diseases like cancer and potentially lowering radiation exposure for patients, improving both safety and diagnostic accuracy.

Additionally, X-ray fluorescence imaging, which traces immune cell movement and drug delivery in tumors, is becoming more accessible. Together, Siemens Healthineers and Universität Hamburg are developing lab-based systems to make this technology more widely available. This could offer new insights into immune responses and the effectiveness of therapies, especially in cancer and infectious diseases.

WHY IT MATTERS

The integration of XR technologies in diagnostics presents a transformative shift in health care, offering a wide array of implications beyond traditional diagnostic methods. By combining virtual and augmented reality with advanced imaging and AI, XR diagnostics can improve accuracy, reduce diagnostic time, and enhance the visualization of complex medical data. This allows health care professionals to interact with patient data in immersive, 3D environments, leading to more informed and precise decision-making.

XR diagnostics can significantly reduce health care costs by minimizing the need for in-person consultations and unnecessary imaging tests. Patients can be monitored remotely using XR systems, decreasing hospital visits and optimizing the use of resources. This is particularly important for managing chronic diseases, where continuous monitoring is crucial, but frequent clinic visits are impractical.

In medical education, XR can enhance the training of health care professionals by allowing them to interact with lifelike simulations of diagnostic processes. This immersive learning experience can improve understanding of complex conditions and prepare clinicians for real-world scenarios with greater confidence and expertise.

3RD YEAR ON THE LIST

MEDICAL DEEPFAKES

WHAT IT IS

Medical deepfakes involve the creation of highly realistic, yet entirely fabricated images, videos, or audio clips, generated by AI. These deepfakes can be used to mislead patients, manipulate health care professionals, and enable malicious activities.

HOW IT WORKS

As AI capabilities advance, deepfakes are becoming more convincing and harder to detect, creating significant challenges for the health care industry. One significant risk is false endorsements of medical products or treatments. During the COVID-19 pandemic, several misinformation campaigns leveraged deepfakes and AI-generated content to spread false information about vaccines, treatments, and public health measures. While these campaigns did not always involve well-known doctors or officials, they successfully manipulated public opinion, leading to confusion and distrust in legitimate health information. In extreme cases, these campaigns contributed to vaccine hesitancy, endangering public health on a global scale.

Another rising concern is the use of deepfake technology to manipulate medical records or imaging data. Researchers have demonstrated how AI could be used to manipulate medical images, such as MRI and CT scans, to create fake but realistic tumors. These manipulated images were used to deceive radiologists into diagnosing cancer where none existed.

AI-generated voice clones are also a growing threat in health care, where scammers can mimic the voices of doctors or health care providers to defraud patients. While in the past these deepfakes have impersonated family members, they could convincingly impersonate trusted professionals, tricking patients into providing sensitive information or making payments to fraudulent accounts.

WHY IT MATTERS

The health care industry relies heavily on trust between patients, health care providers, and institutions. Deepfakes undermine this trust by blurring the line between real and fake medical information, leaving patients vulnerable to misinformation. When false videos of doctors endorsing unproven treatments circulate, patients may follow dangerous advice, abandon legitimate therapies, or fall victim to fraudulent schemes.

The implications extend beyond misinformation. Deepfakes could severely disrupt health care operations, particularly if they are used to alter patient records or medical imaging data. These disruptions can delay critical treatments, cause medical errors, and expose health care providers to legal and financial liabilities. Furthermore, cybersecurity risks are magnified by deepfake technology, as cybercriminals use these tools to perpetrate more sophisticated attacks, such as ransomware or phishing schemes targeting sensitive patient data.

The ongoing issue of medical fraud is another area where deepfakes pose a serious risk. As voice and video deepfakes become more sophisticated, fraudsters can exploit these technologies to impersonate doctors, insurance representatives, or even patients, leading to significant financial losses for health care institutions and patients alike.

SCENARIO YEAR 2050

A DAY IN THE LIFE

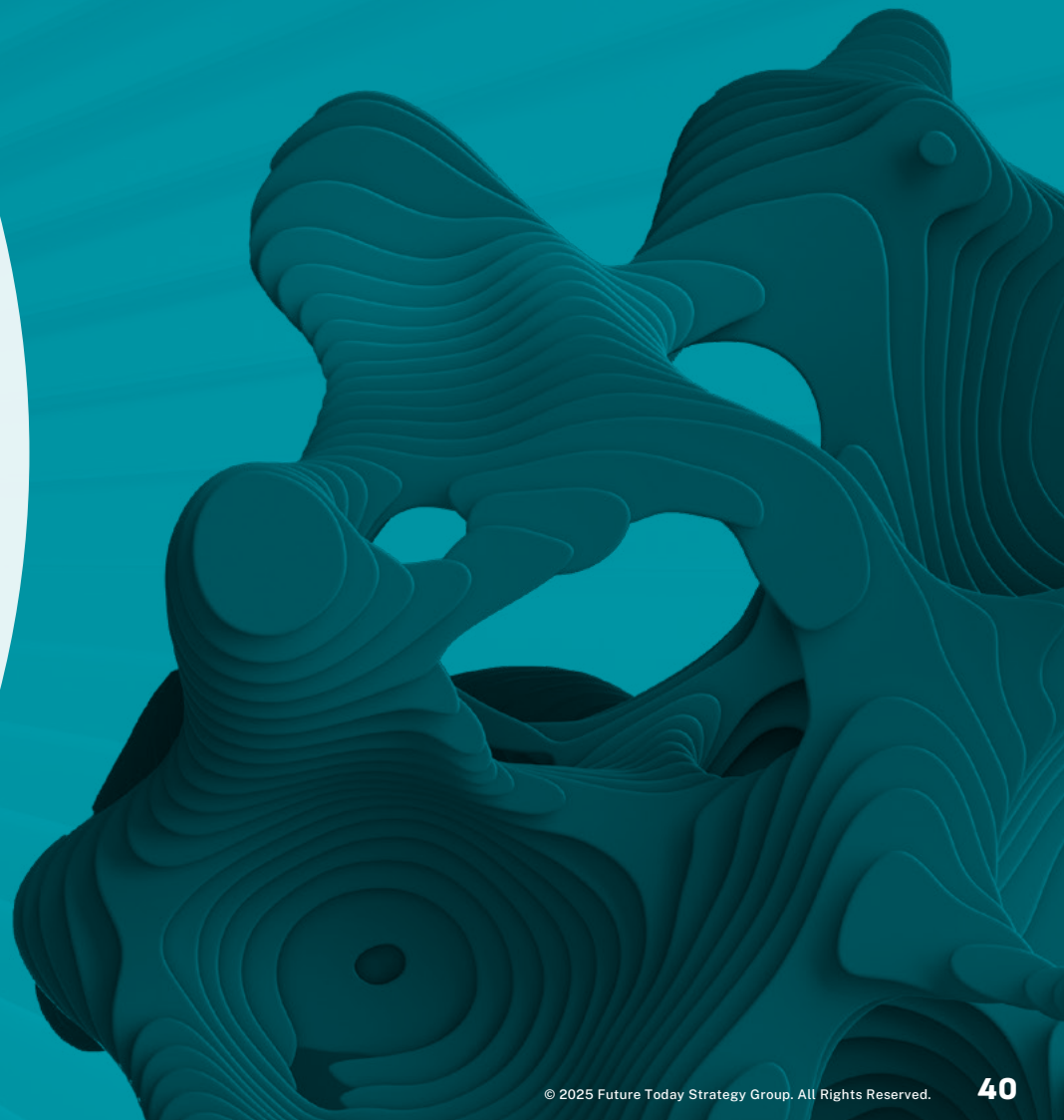
The year is 2050 and health data, diagnostics and personalized care are baked into our days, no matter where you are.

The convergence of personalized medicine, quantum computing, alternative materials and advanced biotech means cutting-edge technology is constantly improving the health of even those living in rural areas, far away from a brick-and-mortar medical center. It starts from the moment you wake up: through the night, a nanotech-powered biosensor embedded in your clothing and bedsheets has been continuously monitoring vitals like blood pressure, glucose and even stress markers. These biosensors, made from nanoscale materials and seamlessly integrated into everyday fabrics, are capable of detecting and measuring biological data at the molecular level.

When the day starts, the sensors compile your data and transmit it to the AI-driven health assistant through your home's neural hub, an advanced interface that connects all your wearable devices, AI systems, and home sensors. Before breakfast is done, the AI health assistant has already suggested some dietary tweaks based on real-time metabolic analysis. It syncs with the personalized nanobot that's been implanted into your thigh, and tells it to adjust the microdoses of vitamins and medications it's releasing directly into your bloodstream. If there's something amiss, no need to worry: the AI will go ahead and schedule a virtual checkup with a global care network specialist without even being prompted.

In the afternoon, it's time for a routine scan at the local CommPrev, a fully autonomous diagnostic station equipped with AI-guided medical scanners and gene-editing capabilities for early disease prevention. The pod performs a full-body scan using terahertz imaging, a revolutionary technique that deploys non-ionizing radiation to penetrate tissues and provide detailed internal images without harmful X-rays. Terahertz waves offer highly precise imaging, revealing abnormalities in skin, tissues, and even cell-level changes. Additionally, the pod conducts a blood analysis through a noninvasive spectrometry interface. It cross-references your results with a blockchain-secured global health database, recommending personalized health trends and optimizing preventive care protocols. If something more is needed, a built-in 3D bioprinter stands ready to create personalized medication or tissue grafts.

This decentralized health care ecosystem, powered by quantum-secure cloud systems, is now the norm. This precision-level health care, far surpassing what was previously available in even the best hospitals, is now seamlessly integrated with our daily routines.



EMERGING TREATMENTS

3RD YEAR ON THE LIST

NANOBOTS

WHAT IT IS

Nanobots, microscopic machines typically measured in nanometers, are designed to perform highly specific tasks at the cellular or molecular level. Recently, their design has gotten more sophisticated, inspired by biological mechanisms, such as those found in bacteria.

HOW IT WORKS

Researchers at ETH Zurich developed a nanobot featuring a clutch mechanism similar to the bacterium *Bacillus subtilis*, enabling precise movement control. This innovation is crucial for delicate tasks inside the human body, such as targeted cell manipulation and tissue repair. Similarly, scientists at the Harbin Institute of Technology created tPA-anchored nanobots to treat blood clots, guided by magnetic fields to deliver a clot-dissolving enzyme more efficiently, reducing the necessary dosage by 42 times and improving treatment outcomes.

At University of California, San Diego, enzyme-powered nanobots have been designed to deliver cancer drugs directly to bladder tumors, minimizing exposure to healthy tissues. Early trials have shown tumor shrinkage, and this technology may be adapted to treat other solid tumors, offering a less toxic alternative to chemotherapy. Additionally, DNA Nanobots, a company using gene-editing technology licensed from University of California, Berkeley, has developed nanobots that deliver genetic material with precision using CRISPR-Cas systems. These bots reduce the risk of immune responses and off-target effects, opening new possibilities for treating genetic disorders and cancers.

In another promising development, researchers at the University of Barcelona created radioactive nanobots to treat bladder cancer. These bots propel themselves toward tumors and release radioactive iodine, reducing tumors by up to 90% in a single dose.

WHY IT MATTERS

The development of nanobots has opened new frontiers in medicine. Their ability to operate at the cellular and molecular levels allows for unprecedented precision in treatments, reducing the need for invasive procedures and improving the efficacy of therapies. For example, cancer therapies often cause significant side effects due to the systemic delivery of drugs. Nanobots offer a solution by targeting only the affected cells, sparing healthy tissues and reducing overall toxicity.

Additionally, the use of nanobots in cardiovascular health, such as the tPA-anchored nanobots for thrombolysis, represents a breakthrough in minimally invasive therapies. The precise targeting of blood clots with significantly reduced drug doses minimizes the risk of hemorrhage, a common side effect of conventional clot-busting drugs. The retrieval capability of these nanobots further reduces the risk of complications.

Nanobots are also showing promise in treating conditions like inflammatory bowel disease by delivering therapeutic agents directly to inflamed tissues, reducing symptoms and promoting healing without the use of systemic medications. This localized approach could transform how chronic diseases are managed, reducing long-term reliance on medications with broad systemic effects.

For a detailed analysis, see the Biotechnology section of our trend report.

5TH YEAR ON THE LIST

AR/VR THERAPEUTICS

WHAT IT IS

Augmented and virtual reality therapeutic technologies immerse patients in realistic, computer-generated environments where they can practice coping mechanisms and learn new behaviors in a safe, controlled space.

HOW IT WORKS

A key feature of VR therapy is its interactive component, used in conjunction with a therapist who guides patients through the scenarios. The content and design of these experiences are crucial; poor execution could lead to ineffectiveness, making rigorous clinical testing a necessity. Solutions like GameChange, a VR therapy designed for people with psychosis, have already gained traction in health care systems such as the UK's National Health Service. This system provides cognitive therapy through simulated situations that help patients reengage with real-world activities they may avoid.

Similarly, AR-based tools like Reality DTx allow patients to undergo exposure therapy for PTSD. These systems make use of devices like the Microsoft HoloLens to offer progressive therapeutic exercises that can be tailored to the individual's condition and treatment goals. In the case of physical rehabilitation, AR systems can assist in gait and balance training for disorders like Parkinson's disease, improving physical mobility.

AR/VR therapeutic systems are not standalone treatments but are designed to be integrated into a broader therapeutic plan, with the technology serving as a medium through which patients can practice and refine the skills they need for real-world application. This emerging field is bolstered by increased funding and technological development, with AR-enhanced PTSD therapy projects like Wayne State University's, backed by the US Department of Defense.

WHY IT MATTERS

A critical advantage of AR/VR therapeutics is the ability to tailor experiences to the individual's progress and needs, which is particularly beneficial for chronic or complex conditions that require long-term management. The technology's scalability also makes it a viable solution for the mental health professional shortage. VR-based systems that offer standalone treatments or digital therapeutic avatars can expand access to care, especially in underserved populations. AR systems can also mimic real-world therapy at less cost than traditional treatments.

The integration of AR/VR technology into therapy can be more fulfilling for patients, too. By offering a more interactive and immersive experience, these therapies can keep patients more motivated and invested in their treatment plans, and this increased engagement can lead to better adherence to therapy sessions. It lets providers measure emotional and cognitive responses in real time, offering therapists richer data to adjust treatment plans more effectively.

AR/VR therapeutics also have the potential to transform training for health care providers. Universities and medical schools could integrate AR/VR into their curricula, ensuring the next generation of health care professionals is equipped to leverage these emerging technologies from the outset.

3RD YEAR ON THE LIST

IN-WOMB TREATMENTS

WHAT IT IS

In-womb treatments represent a transformative approach to addressing genetic and neurological disorders before birth, aiming to prevent the onset of debilitating conditions.

HOW IT WORKS

Around the world, researchers are working on in-womb therapies to treat a variety of conditions. At the University of California, Davis, the CuRe Trial uses placental stem cells to treat spina bifida, a severe spinal defect. Early successes in treatment highlight the potential to intervene before birth, reducing the need for invasive surgery postnatally.

University of California, San Francisco (UCSF) is pioneering in-utero enzyme replacement therapy to address Pompe disease. By administering enzymes in utero, this method allows for early intervention without triggering the immune response. The university is also testing a new way to treat Angelman syndrome, a genetic disorder, before a baby is even born. Special molecules called antisense oligonucleotides are placed in the amniotic fluid surrounding the fetus. These molecules help "turn on" a gene that doesn't work properly in children with the disease. By starting the treatment before birth, they could prevent brain damage that usually happens later.

Researchers at the University of London have developed a technique using fetal cells from amniotic fluid to create organoids that mimic fetal tissue. This approach helps doctors assess the severity of lung malformations and optimize treatment before birth. Finally, Dr. Tippi MacKenzie, also at UCSF, is advancing the use of CRISPR for fetal genome surgery. Her work, though still in the research phase, highlights the potential to treat genetic conditions like spinal muscular atrophy before irreversible damage occurs.

WHY IT MATTERS

The rapid development of in-womb treatments has the potential to improve prenatal care, offering hope to families facing devastating diagnoses during pregnancy. For conditions that currently have no cure or require lifelong management, in-womb therapies could provide an opportunity for a healthier future, reducing the physical and financial burden on families and health care systems.

One major advantage is the ability to prevent irreversible damage before birth. Conditions like Angelman syndrome or spinal muscular atrophy can cause severe neurological and physical impairments. By intervening early, these therapies can potentially halt the progression of the disease, giving children a chance at normal development. This shift from managing symptoms to addressing root causes could dramatically improve quality of life for patients and families.

Another critical implication is the potential for these therapies to reduce health care costs over a patient's lifetime. Current treatments for genetic disorders, such as enzyme replacement therapies or surgeries, are often costly and must be repeated throughout the patient's life. By addressing the issue before birth, in-womb therapies could eliminate the need for ongoing treatments, saving health care systems billions of dollars while also resulting in healthier patients.

5TH YEAR ON THE LIST

COGNITIVE AND NEURAL OPTIMIZATION

WHAT IT IS

Cognitive and neural optimization leverages substances and technologies designed to enhance brain function, improving areas such as memory, focus, and mental clarity. Nootropics, also known as "smart drugs" or "brain boosters," are central to this trend.

HOW IT WORKS

These substances—natural or synthetic—claim to boost cognitive abilities by improving nerve signal transmission, maintaining neuron health, or increasing energy production in the brain. Adaptogens like ashwagandha are gaining traction for their ability to improve cognitive flexibility, executive function, and visual memory, particularly in people with mild cognitive impairment. Similarly, creatine, widely known as a supplement for physical performance, has shown cognitive benefits in older adults. Emerging studies on paraxanthine, a metabolite of caffeine, suggest that it may offer cognitive benefits with fewer side effects, including improved memory and longer-lasting wakefulness.

Cognitive optimization is increasingly supported by neural technologies. Companies like Cymbiotika are innovating with nootropic creamers that blend cognitive-enhancing compounds like L-theanine, Alpha GPC, and L-tyrosine, designed to enhance focus and brain health. Adaptogenic blends, like those offered by London Nootropics, incorporate natural ingredients like Lion's Mane, Cordyceps, and Rhodiola rosea to combat stress and improve mental clarity through everyday products like coffee.

Paradigm Sports' partnership with Ten Percent Club brings certified nootropics to pro athletes, offering products that enhance focus, reaction time, and mental clarity. These rigorously tested supplements are designed to support athletes' cognitive performance alongside physical training, promoting peak performance in high-pressure scenarios.

WHY IT MATTERS

The rising interest in cognitive and neural optimization is fueled by a broader societal push toward enhancing human performance and managing mental health. The global nootropics market, expected to grow to $4.4 billion by 2032, reflects this surge in demand for natural, safe cognitive enhancers. As people around the world face increasing stress, burnout, and cognitive decline due to aging, there is a growing need for accessible solutions that improve mental performance and resilience.

Despite the rising popularity of nootropics for cognitive enhancement, there is a substantial lack of rigorous scientific research to confirm their efficacy, particularly for long-term use. While substances like caffeine and creatine are well-studied and show some short-term cognitive benefits, many other nootropics lack robust clinical trials. Studies on compounds such as Ginkgo biloba and Bacopa monnieri, for example, offer mixed results, with some showing limited improvements in specific cognitive functions, but overall, evidence remains inconsistent.

While some nootropics have been proven safe, their actual effectiveness in improving long-term cognitive performance remains uncertain. Many claims are based on anecdotal evidence or short-term studies, making it difficult to draw conclusive results on their impact over time. Longitudinal research is needed to better understand their effects, and whether they can truly prevent cognitive decline or significantly enhance brain function.

8TH YEAR ON THE LIST

BRAIN–COMPUTER INTERFACES AND NEUROPROSTHETICS

WHAT IT IS

Brain–computer interfaces (BCIs) and neuroprosthetics are enabling seamless communication between the brain and external devices. This is paving the way for innovations in mobility, communication, and neurological health.

HOW IT WORKS

BCIs and neuroprosthetics are developing new ways for our brains to control the world outside the body. At MIT and the University of Pittsburgh, scientists have developed neuroprosthetics that use neural signals to enable intuitive movement. By directly linking the prosthetic to the nervous system, users experience improved coordination and mobility, including the ability to walk faster and climb stairs more naturally compared to traditional prosthetics.

In 2024, Elon Musk's Neuralink implanted its BCI in a second patient after its initial human trial. This implant, part of the ongoing clinical trials, enables individuals with spinal cord injuries to control devices using their thoughts. The Swiss Federal Institute of Technology in Lausanne has developed a miniaturized brain-machine interface that translates neural signals into text, helping individuals with severe motor impairments communicate through thought-controlled text systems. BCIs are also being explored for cognitive enhancement. A Harvard University study revealed that manipulating neural circuits involved in curiosity could lead to more personalized BCIs that respond to a user's mental state. Chinese researchers have developed gene-powered BCIs that enhance the health of neurons around implanted electrodes, improving the longevity and performance of these systems. This genetically engineered approach shows promise for long-term applications, from restoring movement in paralyzed patients to enabling more complex neuroprosthetic control.

WHY IT MATTERS

BCIs and neuroprosthetics provide new solutions for people with disabilities, neurodegenerative conditions, or severe injuries. For individuals with paralysis, BCIs offer a pathway to regaining autonomy, enabling movement and communication that would otherwise be impossible. This technology could dramatically improve quality of life for people with conditions like ALS or spinal cord injuries, as it allows them to control external devices using only their brain activity.

The implications extend beyond health care. BCIs also present opportunities in gaming, virtual reality, and smart home control. As the technology evolves, it may enable users to interact with digital environments and devices in more immersive ways, enhancing experiences in entertainment and daily life. And as seen in Neuralink's early trials, the future of BCIs could include broader applications, such as enhancing cognitive functions like language learning, memory, and focus.

But as BCIs advance, there are ethical considerations that must be addressed. Issues such as privacy, data security, and cognitive autonomy are critical when developing systems that decode neural signals. Ensuring that BCI technology is accessible and safe for all users is essential as it becomes integrated into more aspects of daily life, from health care to consumer technology.

For a detailed analysis, see the Biotechnology section of our trend report.

2ND YEAR ON THE LIST

PRECISION MEDICINE

WHAT IT IS

Precision medicine is transforming health care by tailoring treatments to individual genetic, molecular, and environmental profiles. This approach allows for more effective therapies and better patient outcomes.

HOW IT WORKS

Precision medicine leverages advancements in genetic profiling, molecular biology, and AI technologies to develop personalized treatments based on an individual's unique genetic makeup. AlphaFold 3, developed by Google DeepMind and Isomorphic Labs, revolutionizes drug development by predicting 3D molecular structures, accelerating the discovery of tailored therapies. Similarly, personalized cancer vaccines using mRNA technology—such as those developed for melanoma—train a patient's immune system to target specific tumor cells, representing a significant leap in individualized cancer treatment. Additionally, the recent development of in vivo CAR-T therapies by Interius BioTherapeutics creates targeted immune responses in the patient's body, bypassing complex manufacturing processes and making cancer treatments more accessible and precise.

The approach extends beyond cancer. Researchers at various organizations, including CRISPR Therapeutics and Editas Medicine, are using CRISPR-Cas9 technologies to target genetic diseases like sickle cell anemia and hereditary blindness. By editing the specific DNA sequences responsible for these conditions, they are tailoring therapies that promise long-term solutions. In the field of metabolic diseases, studies have shown that individuals have varying insulin responses to proteins, fats, and carbohydrates, leading to personalized dietary interventions for managing conditions like diabetes. These efforts exemplify how precision medicine is expanding the potential for highly personalized health care across various medical domains.

WHY IT MATTERS

Precision medicine marks a fundamental shift from one-size-fits-all treatments to approaches tailored specifically to each individual's biology—a move that is particularly transformative for diseases like cancer, genetic disorders, and chronic conditions that previously relied on broad-spectrum treatments. By understanding the genetic and molecular underpinnings of diseases, clinicians can provide more effective, targeted interventions with fewer side effects.

This approach can significantly reduce health care costs by eliminating ineffective treatments and improving long-term patient outcomes. As therapies become more targeted, patient recovery times decrease, reducing hospital stays and the need for further interventions. For conditions like cancer or diabetes, where disease management is often ongoing and complex, precision treatments offer the possibility of more sustainable, long-term care strategies.

Beyond individualized treatment, precision medicine also opens new avenues for drug development. AI systems like AlphaFold 3 enable faster, more accurate drug discoveries, cutting years off traditional development timelines. This is particularly important for rare and neglected diseases, where traditional research methods are slow and expensive. Precision medicine also allows for the application of emerging technologies like CRISPR to correct genetic disorders at the source, offering potential cures rather than symptom management.

4TH YEAR ON THE LIST

EXPANDING MEDICAL MIS- AND DISINFORMATION

WHAT IT IS

The rapid spread of health misinformation on social media, exacerbated by AI advancements and influencer content, is eroding trust in legitimate health information. Platforms like YouTube are introducing measures to verify credible sources, but challenges persist.

HOW IT WORKS

The spread of health misinformation on social media remains a significant issue. A recent study on TikTok's content about sinusitis revealed that a large percentage of these videos, created by nonmedical influencers, contained false information, leading to misinformed health decisions. YouTube has expanded its YouTube Health initiative, which was launched to verify health professionals and prioritize their content. YouTube has also partnered with trusted organizations like the World Health Organization and the National Academy of Medicine to ensure that verified creators provide accurate information. These verified channels are becoming vital sources of reliable medical advice, especially in regions where access to health care is limited.

Another growing area of misinformation relates to cancer treatments. Some misleading claims suggest that herbal remedies or unverified dietary supplements can cure cancer. These falsehoods have led some patients to delay or avoid conventional treatments, with serious health consequences. Social media platforms and fringe websites are major vectors for these harmful narratives.

Misrepresentation of gene-editing technologies like CRISPR has fueled disinformation around precision medicine. Some claims exaggerate the dangers or ethical concerns, while others spread false hopes about curing complex diseases immediately. Such distortions not only confuse patients but also complicate the public's understanding of emerging medical technologies.

WHY IT MATTERS

Misinformation and disinformation, especially when spread by influencers or deepfake technology, contribute to a growing mistrust of health care institutions and professionals. This erosion of trust undermines public health initiatives and can lead to a decline in individuals seeking preventive care, following medical advice, or adhering to treatment regimens. As trust weakens, misinformation can foster skepticism toward vaccines, medications, and even the competence of medical practitioners, making it harder to manage public health crises and leading to poorer health outcomes on a larger scale. Misinformation also deepens health care disparities, especially in marginalized communities with medical mistrust.

Misinformation can lead to the adoption of ineffective or harmful treatments, or the avoidance of effective ones, which can result in preventable hospitalizations, complications, and deaths. This not only harms individuals but also places a significant burden on health care systems, increasing the costs associated with treating conditions that arise from following false medical advice.

While platforms like YouTube have taken steps to verify credible health professionals and flag false content, the speed at which misinformation spreads remains a major obstacle. Addressing this challenge requires coordinated efforts between governments, tech companies, and health care organizations to strengthen digital media regulation and improve public health education.

SCENARIO YEAR 2040

THE BIOTECH REBELLION

The allure of genetic enhancement and personalized biotech has established a dark undercurrent in global health care. Driven by the promise of engineered perfection—enhanced intelligence, strength, and immunity—individuals are seeking unregulated genetic modifications as mainstream biotech companies struggle to keep up with demand. Rogue biohacking communities, once niche groups experimenting in garages, have expanded into an underground industry, offering back-alley CRISPR modifications and black-market implants. The appeal is undeniable: Why wait for government-approved procedures when you can fast-track your evolution? Yet, the consequences of these DIY procedures are unpredictable and catastrophic.

In unmonitored labs and secret clinics, genetic experiments go awry. Early adopters of unregulated biotech soon face devastating repercussions—mutations spread across cellular structures, causing organ failure, accelerated aging, and aggressive cancers. Augmentations intended to enhance intelligence lead to severe neurological conditions. The impact ripples through society as hospitals, overwhelmed by biohacking injuries, are unequipped to treat novel, genetically modified diseases. Communities fracture as those with failed augmentations demand restitution and treatment while governments, caught off guard, are slow to respond. The health care system—already burdened by aging populations and chronic disease—collapses under the weight of the biotech rebellion.

As chaos mounts, regulatory bodies scramble to contain the crisis. Attempts to shut down rogue labs and enforce stricter biotech laws lead to protests, and biohackers claim their right to self-determination. Some regions, unable to enforce regulations, become biotech wastelands where genetic experimentation continues unchecked. Trust in mainstream health care plummets, and legitimate biotech research grinds to a halt as public fear of genetic modification escalates. What was once seen as the next frontier of human progress is now a battlefield—one where the consequences of unchecked ambition threaten the very fabric of society.

IMPLANTS, PROSTHETICS, AND WEARABLES

3RD YEAR ON THE LIST

EMERGING IMPLANTS

WHAT IT IS

Innovations in implant technology, powered by advanced materials and energy harvesting, are enabling smaller, more efficient, and biocompatible medical devices. These emerging implants are transforming health care by offering adaptive and minimally invasive solutions.

HOW IT WORKS

Researchers at Penn State University have developed a wireless charging device that harnesses both magnetic fields and ultrasound, generating 300% more power than current technologies. This allows the miniaturization of implants, such as bioelectronic devices, eliminating the need for bulky batteries and external components. By combining safe, low-frequency energy sources, this technology could improve the power supply for tiny medical devices, offering more comfort and convenience to patients.

The university has also developed new electrospinning techniques that are enabling the creation of nano/microrobots and implantable biosensors, addressing long-standing material compatibility issues. These biosensors can monitor conditions at the cellular level, offering precise, personalized treatments. 4D Medicine's resorbable material, 4Degra, is being used to develop bioresorbable orthopedic implants. The material, compatible with 3D printing, naturally degrades without harmful by-products, making it ideal for temporary implants.

Bioresorbable opto-electronic systems are emerging in neurology, allowing for both neural stimulation and real-time activity recording. These biodegradable implants reduce the risk of long-term complications and could transform the treatment of neurological disorders. North Carolina–based Restor3d is advancing 3D-printed orthopedic implants that are custom-designed for each patient, reducing recovery times and the need for follow-up surgeries.

WHY IT MATTERS

The rise of advanced implant technologies is transforming health care by shifting from reactive to proactive care. These devices allow for continuous monitoring and early intervention, reducing the need for invasive procedures and improving overall health outcomes. By enabling personalized, real-time treatments, implants have the potential to lower health care costs and improve management of chronic conditions like heart disease and diabetes. As these technologies become more accessible, they could also help close gaps in underserved regions, bringing high-quality health care to patients in remote areas.

As these implants become more integrated into everyday medical practice, they will likely reshape the health care infrastructure itself. From a regulatory perspective, there will be a need for updated guidelines and standards for safety, data security, and patient privacy, especially as more data is continuously collected and transmitted through these devices. From a workforce perspective, health care providers will need specialized training to manage and implement these advanced systems. This could lead to the development of new medical specialties and job opportunities focused on the maintenance, interpretation, and application of implant technology, further modernizing the health care ecosystem.

3RD YEAR ON THE LIST

ADVANCED PROSTHETICS

WHAT IT IS

Advances in prosthetics are transforming the capabilities of artificial limbs by incorporating artificial intelligence, biomimetic designs, and enhanced sensory feedback systems. These make prosthetics more functional, adaptable, and personalized.

HOW IT WORKS

MIT's Agonist-Antagonist Myoneural Interface (AMI) uses the patient's own nervous system to control bionic limbs. This allows for natural movements by reconnecting residual muscles in the amputated limb, providing proprioceptive feedback and enabling users to walk, climb, and navigate obstacles with ease. Patients with AMI implants reported feeling their prosthetic as a natural part of their body, showing improved mobility compared to traditional prosthetics.

STMicroelectronics and DuPont Liveo Healthcare collaborated to create an intelligent electronic skin patch for monitoring cardiac events. This skin patch is designed to provide continuous heart monitoring, combining smart sensing technology with AI to deliver real-time data to health care providers. Heriot-Watt University's accelerator program supported Infinity DPM in developing prosthetics with softer, human-like materials, enhancing comfort and reducing irritation caused by traditional designs.

Emerging materials and technologies are also making prosthetics more durable and user-friendly. 3D printing is revolutionizing prosthetics with customized, patient-specific designs, such as the Hero Gauntlet, a prosthetic that enhances grip strength and functionality using advanced materials like Nylon 12. At Esper Bionics, researchers are leveraging AI to create bionic hands that adapt to user behaviors, allowing for more natural, independent finger movements, which is helping Ukrainian veterans regain functionality after limb loss.

WHY IT MATTERS

The development of advanced prosthetic technologies marks a significant leap in health care, offering life-changing benefits for individuals who rely on artificial limbs. As prosthetics become more integrated with the body's own nervous system, they not only restore physical abilities but also enhance the user's sense of embodiment, leading to greater confidence and independence. This shift from mechanical to biomimetic prosthetics represents a move toward solutions that feel more natural and are better aligned with the user's lifestyle and needs.

The integration of AI in prosthetics is creating devices that can learn from the user's movements and adjust over time, offering a more personalized experience. The use of intelligent materials and 3D-printing techniques allows for faster, more cost-effective production of prosthetics that are tailored to fit each individual's anatomy. This accessibility and customization are vital for improving the functionality and comfort of prosthetics, enabling users to engage in a wider range of activities and reducing the long-term physical strain associated with traditional designs.

As prosthetics become more advanced and better integrated with the user's body, they not only restore physical abilities but also help reduce feelings of alienation or loss that often accompany limb amputations. The ability to regain a sense of normalcy through natural movements and enhanced sensory feedback can improve self-esteem and emotional health.

13TH YEAR ON THE LIST

EMERGING WEARABLES

WHAT IT IS

Emerging wearable technologies are revolutionizing health monitoring, with devices like continuous glucose monitors, smartwatches, and sensor–embedded smart fabrics offering real–time insights into personal health metrics.

HOW IT WORKS

The BeamO by Withings is a 4-in-1 health monitoring tool, combining an electrocardiogram (ECG), oximeter, digital stethoscope, and thermometer in a handheld unit. Designed for both personal use and remote medical consultations, it can detect serious conditions like atrial fibrillation, lung wheezing, and desaturation, which makes it one of the most comprehensive consumer health devices on the market. Its ability to capture heart and lung sounds for medical diagnosis sets it apart from standard wearables, which typically focus on more general metrics like heart rate or steps.

The GyroGlove assists individuals with Parkinson's disease by stabilizing tremors. This wearable glove empowers users to regain control over everyday tasks like eating and writing, offering a significant improvement in quality of life.

Microfluidic patches are another development in this space, analyzing biomarkers like glucose and cortisol directly from sweat or skin without invasive tests. Startups like LifeLeaf are pioneering noninvasive glucose monitoring, offering patients real-time insights crucial for managing chronic conditions such as diabetes. Additionally, AI-enhanced wearable ECG devices, such as those developed by STMicroelectronics, are transforming cardiac care, enabling remote monitoring of heart activity to detect early signs of stroke and other cardiac issues. These wearables are increasingly integrating with electronic health records, allowing health care providers to access continuous health data for more informed decision-making.

WHY IT MATTERS

The growing adoption of wearables is reshaping health care by promoting proactive health management and reducing the need for frequent clinic visits. With real-time monitoring, patients can receive timely interventions, which is especially valuable for managing chronic conditions like diabetes and cardiovascular diseases. The continuous collection of health data also enables more personalized treatment plans, improving patient outcomes and lowering health care costs. As these devices become more accessible, they hold the potential to address disparities in care, particularly in underserved and rural areas, where regular access to health care providers can be challenging.

The integration of AI into wearable technologies enhances their ability to process large amounts of biometric data quickly and accurately, allowing for both predictive and preventive care. By providing users and health care providers with near real-time insights into health status, AI-driven wearables can detect early signs of illness, reduce the burden on hospitals, and support long-term wellness management. As these technologies evolve, they will likely continue to play a critical role in transforming health care by fostering a more data-driven, patient-centered approach.

13TH YEAR ON THE LIST

MATURE WEARABLES

WHAT IT IS

Wearable technology has evolved from fitness tracking to become a crucial tool for personal health monitoring. With innovations in sleep, heart, and hearing health, wearables offer real-time health insights and make proactive care more accessible.

HOW IT WORKS

Apple is enhancing its Apple Watch and AirPods Pro with features designed to monitor critical health conditions like sleep apnea and hearing loss. Using the new "Breathing Disturbances" metric, the Apple Watch can detect sleep apnea signs, a condition affecting more than one billion people globally. By tracking breathing irregularities, users can share this data with their health care providers, improving diagnosis and treatment accuracy. Similarly, the AirPods Pro now feature tools aimed at hearing health, including a hearing test and basic hearing aid functions. This marks a significant shift, especially following the FDA's ruling that allows over-the-counter hearing aids in the US, democratizing access to hearing care.

Samsung is advancing its Galaxy wearables lineup, notably the Galaxy Ring and Watch7, which provide continuous health monitoring and sleep apnea detection. These devices integrate Samsung's advanced sensor technologies with AI to offer personalized health insights. The Galaxy Watch Ultra, Samsung's most durable option, caters to athletes by offering triathlon tracking and enhanced heart health metrics. With Wear OS 5, these devices deliver faster performance and power efficiency.

These wearables leverage AI to process vast amounts of biometric data, and they are seamlessly integrated into broader ecosystems. As a result, users can collect, track, and share health data across multiple devices, allowing for a comprehensive understanding of their well-being.

WHY IT MATTERS

The integration of advanced health monitoring features in wearables signals a profound shift in personal health care. This level of accessibility to health insights is critical as it addresses public health issues affecting millions globally, such as hearing impairment, which has been linked to cognitive decline and emotional well-being.

These advancements contribute to a growing trend where tech companies are positioning themselves within the health care space. By offering medical-grade monitoring and analysis, wearables are becoming more central in preventive health care strategies. This shift is particularly relevant as health care systems become strained and consumers demand more autonomy over their health.

Users can now monitor their biological age and metabolic health, offering proactive management of lifestyle diseases such as diabetes. This aligns with broader trends in digital health, where continuous monitoring and personalized data are empowering users to take control of their health before more severe interventions are necessary.

As more companies enter the wearables market, the focus on health monitoring is expected to deepen, potentially leading to early detection of more complex conditions such as cardiovascular diseases or even mental health disorders. These wearables are not a substitute for professional health care but serve as essential tools in preventive care and early intervention.

SCENARIO YEAR 2032

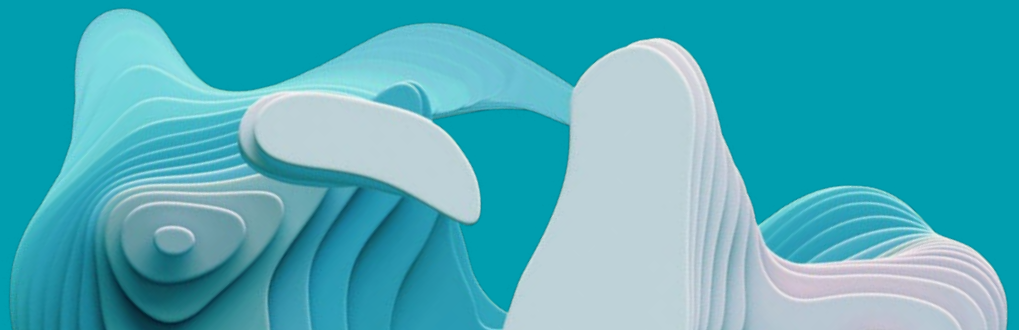
THE HEALTH CAPSULE

The overwhelming influx of data from wearables and AI-powered health platforms has reached a critical point, leaving both patients and health care providers buried in endless streams of information. With continuous tracking of everything from heart rates to stress levels, patients are anxious, unsure how to interpret fluctuating metrics. Doctors, too, struggle to prioritize relevant data, leading to burnout and delayed care. The sheer volume of health information—meant to improve outcomes—has instead created confusion, inefficiency, and mistrust in health technologies.

Enter the Health Capsule. This small, e-ink device distills the flood of data into a personalized, minimalist format that both patients and providers can easily understand. Rather than tracking every minor fluctuation, the Health Capsule gives patients simple daily summaries—like “low energy” or “good sleep”—while its AI filters out irrelevant data from wearables, identifying only the most important patterns. It provides a clear, concise health snapshot each day, displayed on its calming e-ink screen, offering natural language insights such as “Hydration needed” or “Steady improvement in energy.”

For health care providers, the Health Capsule solves a major issue: how to manage the growing deluge of patient data without sacrificing care quality. Doctors can sync the Capsule during appointments, retrieving concise insights without being overwhelmed by raw metrics. By simplifying health data into actionable summaries, the Health Capsule restores balance, making health care manageable again for both patients and providers.

RESEARCH



3RD YEAR ON THE LIST

SYNTHETIC HEALTH DATA

WHAT IT IS

Synthetic health data offers a privacy-preserving alternative to real-world patient data, enabling AI model training, clinical research, and health care innovations without compromising confidentiality. However, its accuracy and application require careful validation.

HOW IT WORKS

Synthetic health data refers to artificially generated datasets designed to replicate the statistical properties of real-world patient data without including identifiable information. These datasets are created using algorithms, such as generative adversarial networks (GANs) or diffusion models, which learn the relationships between variables in the original data. They then produce new, statistically similar records that can be used in place of actual patient data.

Several organizations are leading in this space, such as MDClone, which provides health care institutions with a platform to generate synthetic data for research and clinical trials. Nvidia's Nemotron-4 models offer developers synthetic data to train large language models (LLMs), which can be leveraged in health contexts. Academic institutions like King's College London have created synthetic 3D images of human organs, such as the brain, to study neurological diseases without relying on real patient scans.

One of the primary advantages of synthetic data is its ability to bypass privacy concerns under regulations like HIPAA or GDPR, which has enabled entities like the FDA and Veterans Affairs to use synthetic datasets for research to avoid exposing sensitive patient information. In these cases, synthetic data mimics real-world data so closely that it can be used for hypothesis testing, algorithm training, or generating "precision cohorts" for clinical research.

WHY IT MATTERS

Synthetic data holds immense potential for transforming health care. Traditional reliance on real-world patient data poses numerous challenges, from privacy risks to logistical hurdles in data access. With synthetic data, health care organizations can overcome these barriers, unlocking new avenues for AI model training, policy simulation, and clinical research.

In the age of AI, access to vast datasets is crucial for developing accurate diagnostic tools, predictive models, and personalized treatment plans. Synthetic data plays a key role in addressing data scarcity, particularly in underrepresented medical conditions or minority populations, where real-world data is limited. For example, diffusion models have been used to generate synthetic chest X-rays, significantly improving AI-based diagnostic accuracy for underrepresented groups. This not only helps to generalize health care models but also ensures that new innovations are more inclusive.

Despite these advantages, synthetic data must be rigorously validated to ensure it is representative and free from systemic biases. Flaws in the synthetic data generation process can lead to incorrect insights or model collapse, especially if the data is used to train AI systems for high-stakes decision-making. And transparency is paramount: Pulling back the curtain on how synthetic datasets are generated and maintained is vital to building trust among health care providers, researchers, and patients.

2ND YEAR ON THE LIST

NEW TRIAL METHODS

WHAT IT IS

In silico, virtual reality (VR), and remote clinical trials are transforming medical research, reducing costs, enhancing trial design, and making trials more accessible, while providing reliable regulatory evidence for drug and medical device development.

HOW IT WORKS

In silico trials use computational models and simulations to mimic human responses to drugs and medical devices without needing human or animal participants. One example is the FDA's VICTRE project, which compared breast imaging techniques using 3,000 synthetic breast phantoms. The results demonstrated that in silico models could produce reliable regulatory evidence.

VR allows researchers to simulate real-world environments in which patients can interact with medical devices or treatments. They are being used to test rehabilitation devices and mental health therapies, providing immersive environments that replicate real-life conditions. Dassault Systèmes' "Emma Twin," a digital twin avatar, has been used to simulate patient outcomes in VR environments, enabling researchers to study the efficacy of treatments for various conditions in a highly controlled, yet realistic, setting.

Remote trials, which rely on decentralized clinical trial platforms, enhance patient accessibility and engagement. They allow patients to participate from their homes, significantly reducing the need for in-person visits and increasing the diversity of trial participants. AI-driven tools like TrialGPT and Criteria2Query help match patients to trials, improving recruitment efforts and patient retention. These platforms often incorporate wearable devices and mobile health apps to collect real-time data, streamlining patient monitoring and enhancing data accuracy.

WHY IT MATTERS

In silico trials are especially beneficial for rare diseases, where gathering enough participants for traditional trials can be a challenge. They also reduce the risk of late-stage failures by allowing researchers to refine trial designs and dosing regimens early in the development process. By providing a controlled yet flexible environment, VR trials offer deeper insights into how patients interact with new treatments. Remote trials have democratized clinical research.

In addition to the cost and time savings, these new methods are also environmentally friendly, as they reduce the need for travel, on-site staff, and physical infrastructure. For pharmaceutical companies, the reduced trial costs mean lower financial risks and faster time-to-market for new treatments. According to GlobalData, the market for in silico clinical trials is projected to reach $5.1 billion by 2030.

However, challenges remain in gaining full regulatory acceptance for these new trial methods. While in the US the FDA has approved several in silico trials, including for a pacemaker designed to be safe in MRI scans, European regulators are still developing frameworks to incorporate these models into their approval processes.

4TH YEAR ON THE LIST

LAB-ON-A-CHIP (LOC)

WHAT IT IS

Lab-on-a-chip devices are revolutionizing diagnostics by integrating complex laboratory functions onto a single, miniaturized platform, enabling faster, cost-effective, and portable testing across health care, biotechnology, and environmental fields.

HOW IT WORKS

LoC devices are compact, integrated systems that replicate the functionality of entire laboratories on microchips. These devices use microfluidic technology to manipulate tiny volumes of liquids through networks of channels etched onto a chip. This allows for multiple simultaneous tests, such as chemical analysis, molecular diagnostics, and biological assays, on a single platform.

One device already doing this is LoCKAmp, developed by researchers at the University of Bath; it's capable of providing lab-quality viral detection within minutes using a highly sensitive and specific molecular technique used to detect RNA sequences. By integrating AI to figure out how to most effectively monitor and control the microfluidic processes, researchers are able to develop intelligent microfluidics that self-regulate based on real-time data, making LoC systems more autonomous and adaptable. At the University of Pittsburgh, researchers developed a self-powered, millifluidic LoC device that uses blood flow to generate electricity via a triboelectric nanogenerator. This system is being explored as a way to diagnose metabolic disorders like diabetes by measuring blood conductivity, offering portable and real-time health monitoring.

Researchers at the University of Bath have developed 3D-printed chips that function without needing an external power source. These devices, which can be produced in less than an hour, hold great promise for rapid diagnostics at a low cost.

WHY IT MATTERS

Lab-on-a-chip technologies are reshaping diagnostics and research by offering rapid, cost-effective, and portable alternatives to traditional laboratory setups. In health care, LoC systems provide immediate, on-the-spot testing, which is particularly beneficial in rural or resource-limited areas.

Sustainability is another critical factor driving the development of LoC systems. Traditional lab tests often require large amounts of single-use plastics and other non-recyclable materials, contributing to environmental waste. By miniaturizing processes and reducing the materials needed for each test, lab-on-a-chip technologies offer a more sustainable alternative. Efforts to incorporate biodegradable materials and reduce the carbon footprint of manufacturing processes align with the growing need for eco-friendly medical technologies.

These lab-on-a-chip systems are also democratizing science and health care by making advanced diagnostic tools available to a broader range of users. A notable example is the educational initiative in Bolivia, where students were introduced to programming and computational biology through internet-enabled lab-on-a-chip technologies. This initiative not only improved their technical skills but also increased their interest in pursuing careers in STEM fields, showing the potential of LoC systems to inspire the next generation of scientists and engineers.

2ND YEAR ON THE LIST

3D BIOPRINTING

WHAT IT IS

3D bioprinting is an advanced tissue engineering technique that constructs tissue by layering bioactive substances, such as living cells and biomaterials, into complex 3D structures. This addresses the demand for customized implants and reduces reliance on organ donors.

HOW IT WORKS

Mayo Clinic researchers are using bioprinting to create tissue models, such as skin replicas for studying inflammatory diseases like eczema. With bioinks—combinations of hydrogels, biomaterials, and cells—they can accurately print tissues that resemble human skin. The ultimate aim is to print fully functional organs like kidneys to address organ shortages.

Innovations in bioprinting materials are helping advance this technology. A research team at Hefei Institutes of Physical Science, part of the Chinese Academy of Sciences, mixed a special glass with biocompatible polymers to make a new material that works well for bone healing. This material helps the body form bone more easily and can be adjusted depending on the type of bone repair needed.

In space, 3D bioprinting is being tested in microgravity, allowing the development of tissues like cardiac muscle and meniscus without the need for scaffolds. On the International Space Station, the BioFabrication Facility is printing human tissues in three dimensions, advancing regenerative medicine in ways not possible on Earth. Vital3D is focusing on printing complex structures using laser light to harden bioinks. Its precision tools aim to enhance scalability for future organ bioprinting.

WHY IT MATTERS

3D bioprinting holds transformative potential across multiple areas of health care, particularly in addressing organ shortages and personalizing medical treatments. One of the most pressing applications is in organ transplantation. Millions of patients worldwide suffer from organ failure, and donor organs are limited. By enabling the printing of functional organs, 3D bioprinting could alleviate this shortage, reducing the need for donor organs and minimizing the risk of rejection by using patient-derived cells.

This technology also promises advancements in personalized medicine. By bioprinting tissues using a patient's cells, physicians can tailor treatments specifically to the individual. For example, bioprinted tissue models can simulate how a patient's body will react to drugs, allowing more precise testing of new therapies. This personalization could reduce drug side effects and increase treatment efficacy.

In regenerative medicine, bioprinting allows the development of tailored implants for bone and soft tissue repair, offering an alternative to traditional methods that often require invasive procedures. It has the potential to accelerate wound healing, particularly for patients with chronic conditions like diabetes.

2ND YEAR ON THE LIST

QUANTUM IMPROVES RESEARCH

WHAT IT IS

Quantum computing has the potential to transform scientific research across industries by enabling faster data processing, simulations, and problem–solving, especially in health care and drug discovery.

HOW IT WORKS

Quantum computing harnesses qubits, which differ from classical bits by being able to exist in multiple states simultaneously. This property, known as superposition, allows quantum computers to process complex data much faster than traditional computers. The Quantum Technologies Group at Carnegie Mellon University is investigating how quantum computing can enhance health care diagnostics, such as using quantum-inspired support vector machines for predicting diseases like pneumonia more efficiently than classical AI methods.

The University of Colorado's Anschutz Medical Campus and Atom Computing are also exploring quantum computing's potential through their collaboration with the Elevate Quantum consortium. Their focus includes improving access to health care in rural areas, detecting rare diseases, and advancing drug discovery. Another application is quantum's ability to create more accurate molecular simulations, which holds promise for personalized medicine and drug development.

Cleveland Clinic is collaborating with IBM and the Novo Nordisk Foundation to integrate quantum computing and AI into personalized medicine and drug discovery. By combining quantum computing with machine learning, these partnerships aim to customize health care solutions at an individual level, optimizing treatment plans based on genetic profiles.

WHY IT MATTERS

Quantum computing holds transformative potential for industries, particularly health care and drug discovery. Traditional computational tools struggle with the complexity of molecular interactions and large datasets, leading to limitations in research speed and accuracy. Quantum computing breaks through these barriers, enabling faster drug discovery and more precise diagnostics. For instance, quantum simulations could tailor treatments to a patient's unique genetic makeup, a major goal in personalized medicine.

Additionally, quantum computing could drastically reduce drug development times and costs by enabling simulations that replace costly laboratory experiments. This democratizes research, making high-powered computational tools available to smaller biotech firms, fostering competition, and potentially lowering drug costs. Quantum computing can also protect sensitive patient data through quantum-enhanced cryptography, a growing concern as health care becomes more digitized.

Despite these advancements, quantum computing remains in its early stages, with much of its potential yet to be realized. Key challenges, including the development of fault-tolerant quantum systems and scalability, must be overcome. However, collaborations between universities, health care institutions, and tech companies are laying the groundwork for quantum's integration into research and clinical settings, ushering in a new era of innovation.

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As founder and CEO of the Future Today Strategy Group (FTSG), Amy pioneered a unique quantitative modeling approach and data-driven foresight methodology that identifies signals of change and emerging patterns very early. Using that information, Amy and her colleagues identify white spaces, opportunities, and threats early enough for action. They develop predictive scenarios, along with executable strategy, for businesses worldwide. In addition, Amy is regularly asked to advise policymakers in the White House, Congress, U.S. regulatory agencies, the European Union and United Nations. In 2023, Amy was recognized as the #4 most influential management thinker in the world by Thinkers50, a biannual ranking of global business thinkers. With research specializations in both AI and biotechnology, Amy is the author of four books which have been translated into 23 languages. She developed and teaches the Strategic Foresight Course at NYU Stern School of Business.

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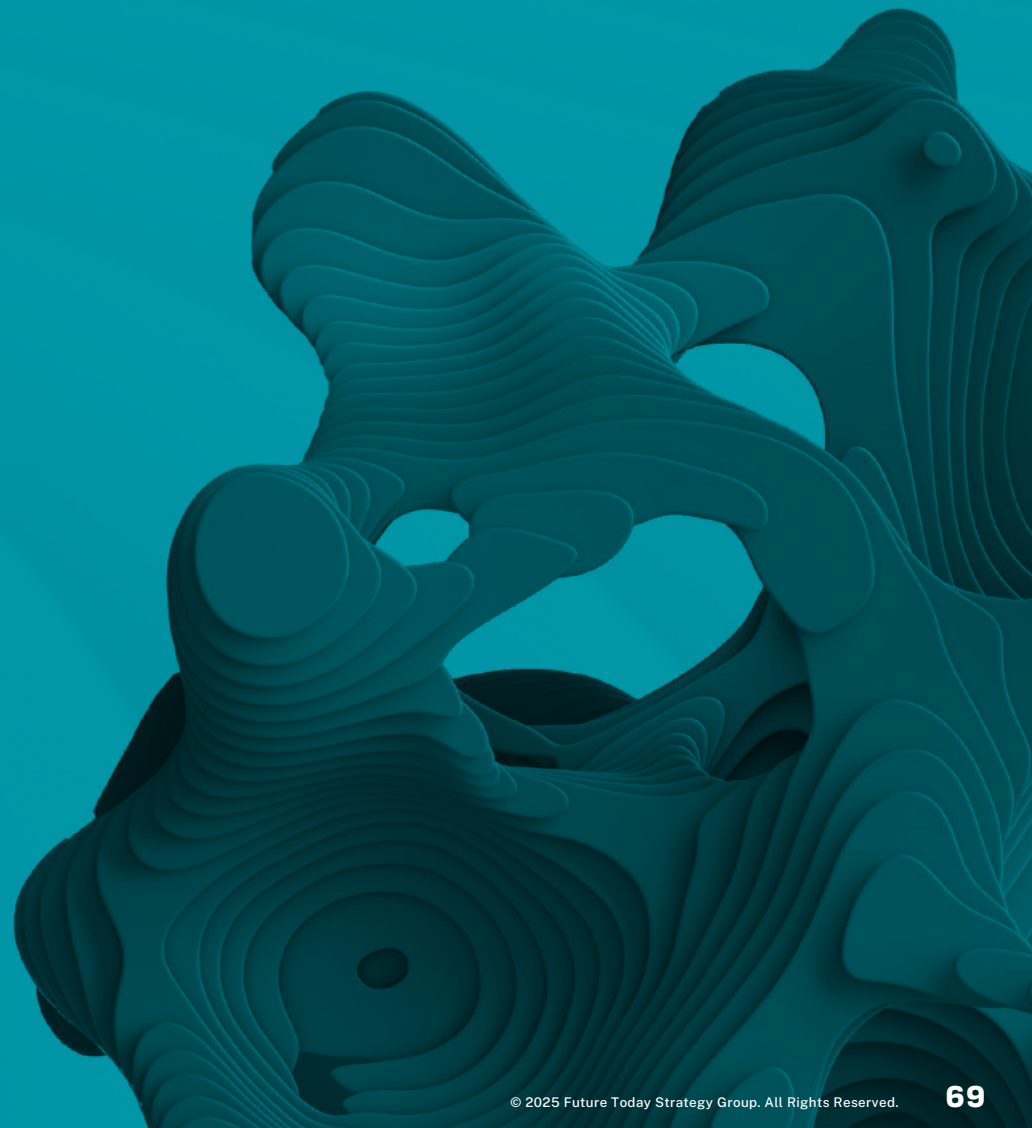

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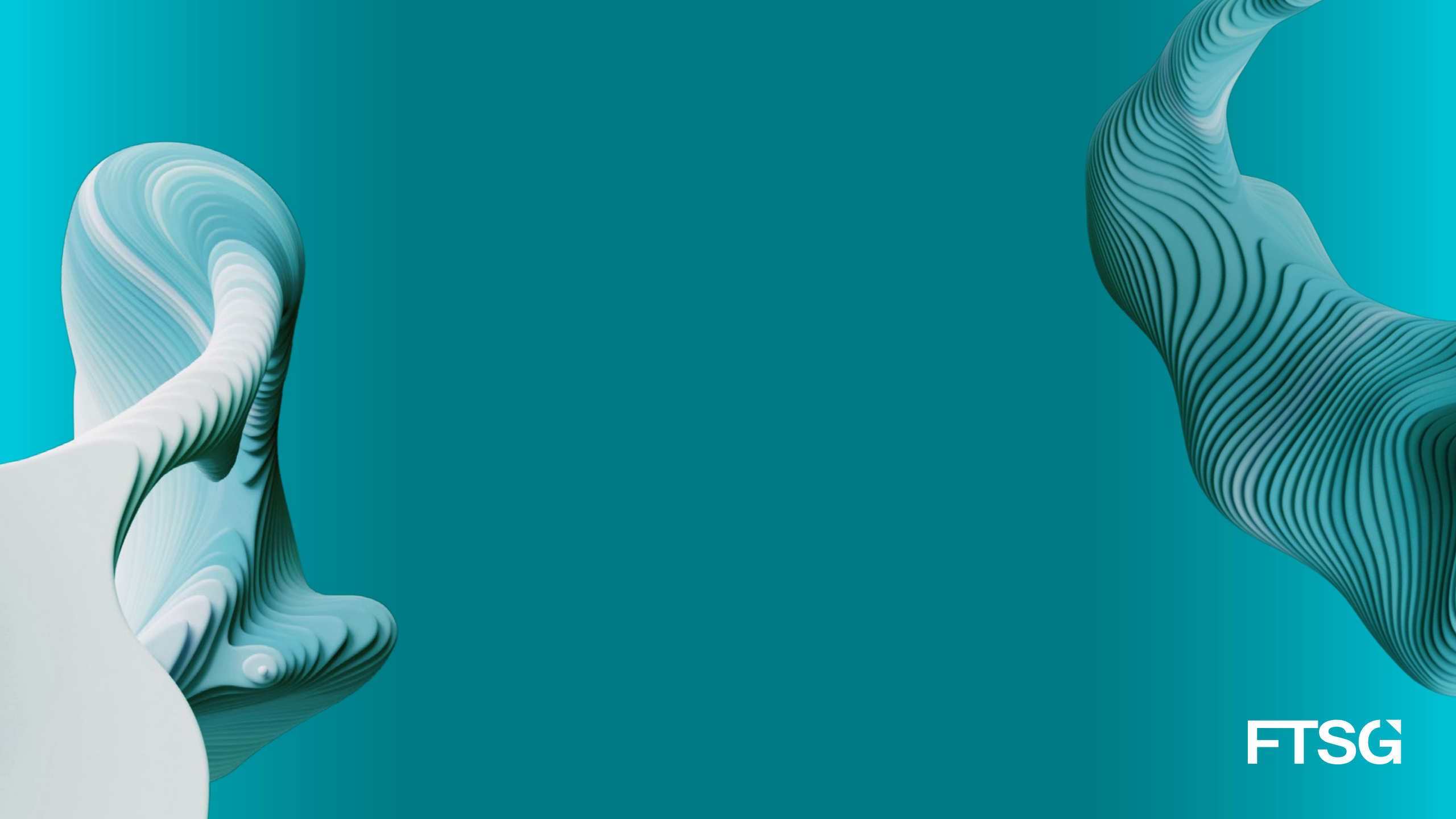
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