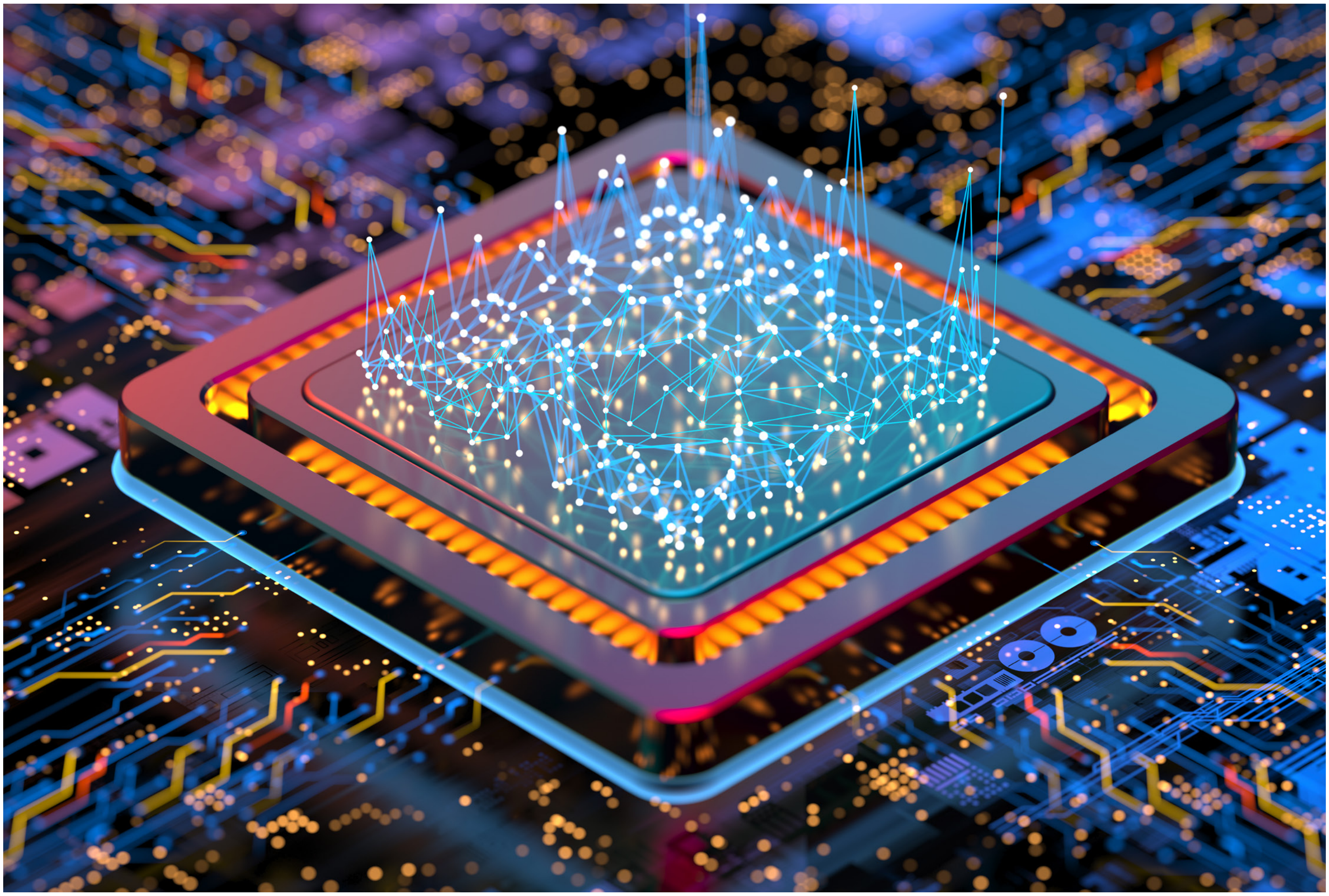
AUDIOLOGY STUDENTS' GUIDE TO SUCCESS:

Understanding the Future of Audiology

Six captivating chapters with insights that will empower students to excel in an exciting yet uncertain future



A Fuel Medical Group Au.D. Education Series Publication
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Related Fuel Medical Group Publications on Which this Book Is Based:

- The Intelligence Revolution in Hearing Health Care Delivery, Nielsen, D., W. (2024)
  A Fuel Medical Group White Paper, Fuel Your Future Series, 24 pages, Open access at https://fuel-medical.com/wp-content/uploads/2025/01/fm_march2024_intelligence_revolution_paper_v1.pdf
- Genomics and Precision Medicine: The Astonishing Revolution of Hearing Health Care. A Call to Action for Audiologists. Nielsen, D., W. (2024)
  A Fuel Medical Group White Paper, Fuel Your Future Series. 31 pages, Open Access at: https://fuel-medical.com/wp-content/uploads/2024/08/fm_paper_genomics_and_precision_medicine_v2-2.pdf

FUEL MEDICAL

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INTRODUCTION FOR STUDENTS

THE PURPOSE OF THIS GUIDE IS TO PREPARE YOU FOR THE FUTURE

We are witnessing the emergence of innovations and new technologies revolutionizing hearing health care. This transformation is creating uncertainty for audiology students, who will be entering a redefined profession. Our goal in creating this Guide is to help alleviate this uncertainty by introducing students to the technologies and innovations that are rapidly advancing health care, which may not be covered in their coursework. Each chapter presents a different aspect of health care's transformation and explores its impact on audiology and you, the future doctors of audiology.

Chapter 1 focuses on adopting the right mindset to effectively leverage new innovations and technologies as they emerge. This chapter aims to enhance your critical thinking skills and make you aware of the resistance that these transformations may face. It will also teach you how to harness that resistance to advance your profession. The skills and mindset developed here will benefit you throughout your entire career.

Chapter 2 explores new and powerful ways to improve health care through artificial intelligence (AI), the key platform for hearing health care transformation. It offers a condensed overview of the different types of AI and their potential to modernize health care delivery throughout your career. Understanding these advancements is crucial for enhancing hearing health care (HHC) and leveraging them to benefit your patients, profession and yourself.

Chapter 3 informs that when you graduate and enter audiology as a doctor, you will encounter a system where not all needy patients can adequately be served. This chapter discusses the game-changing potential of generative AI (GenAI) to create realistic virtual providers. GenAI will also help categorize patients into two groups: those who require direct medical treatment from a doctor and those who nonmedical audiology extenders and virtual providers can effectively serve at a lower cost and with greater accessibility. Understanding how to triage patients this way is critical for your career success.

Chapter 4 shows medicine often relied on a one-size-fits-all approach before the advent of more powerful computers and GenAI. Patients received the same average treatments regardless of their individual needs. However, when you graduate, you'll encounter precision medicine and a new landscape emphasizing a more precise, personalized and beneficial approach to hearing health care. This chapter outlines the fundamentals and advantages of precision medicine, which is rapidly becoming the new standard in medical care. Understanding and appreciating this shift is important for your future success.

Chapter 5 introduces genomics to explore audiology's advancements beyond traditional treatment devices. Genomics is a powerful tool within the precision medicine framework and is expected to play a central role in audiology, otolaryngology and broader medical care. Throughout your career, being knowledgeable and comfortable with genomics and genetics will be essential to provide your patients with the highest quality of medical care and enhance your value in the clinic.

Chapter 6 dives into the fascinating world of health care transformation, revealing how computing power and speed surges have transformed the field. Imagine a time when complex medical data could be processed in the blink of an eye, reducing costs and making health care more accessible than ever. This chapter takes you on a journey through the history of computers, showcasing the incredible advancements that have shaped our current landscape.

But it doesn't stop there! A peek into the future unveils the exciting potential of quantum computing—a technology poised to revolutionize health care and the fabric of our daily lives. As an Au.D. student, you're standing on the brink of this technological evolution. Chapter 6 highlights these advancements and equips you with the knowledge to embrace quantum computers in your future practice. Get ready to be inspired and prepared for a groundbreaking era in health care!

You are joining the health care community during an exciting and challenging period. As we look to the future, technology's rapid advancement and integration will be pivotal in creating a more efficient, responsive and resilient hearing health care system. We hope this book helps you navigate the challenges while enabling you to embrace the excitement and thrive as you courageously tackle obstacles. The boxed-in-blue RESOURCES section after each chapter will help you learn more about the chapter's content and provide a path to more detailed knowledge sources.

We conclude with some career wisdom from Adam Grant.

> Building a career isn't about avoiding risk. It's about managing risk.
> In the long run, our biggest regrets are often the risk we didn't take."
> —Adam Grant

INTRODUCTION FOR FACULTY

THIS GUIDE WILL PREPARE YOUR STUDENTS FOR THE FUTURE

This "Audiology Students' Guide to Success" is the third in the annual series created by Fuel Medical Group to support university Au.D. programs, their students and their faculty. For this series, we attempt to choose essential topics that many programs cannot fit into their courses. This year, we aim to increase students' understanding of the future of audiology and their roles and responsibilities in it. Students often have concerns about their professional future. Discussing the content of this Guide with them can help alleviate those concerns. We hope you will assist us and your students with this project by distributing this Guide to students and faculty. It can also be used as a model of self-motivated continuing education by encouraging students to master it on their own, alone or in teams.

WHY IT MATTERS

We are witnessing the emergence of new technologies that are revolutionizing health care. The upcoming surge of technological innovation is neither inherently good nor bad. How we prepare for, adapt to and choose to use these technologies will determine whether they become a force for progress or disruption. To achieve positive outcomes, we and our students must first understand the true capabilities of these tools. This Guide will help.

THINGS TO CONSIDER

- What is hard to appreciate about these technology-based changes is the rapidity of their improvement curve and the size and significance of the transformations they are stimulating.
- While innovative technology changes rapidly, professions, stifled by tradition and self-interest, change slowly. Also, humans consistently overestimate the speed at which they adopt and adjust to technology. As time passes, the gap grows between flourishing technologically driven advances, like AI and genomics, and audiology's ability to keep pace. We have the opportunity and responsibility to close that gap.
- Closing the gap is not easy. These transformations are often disruptive, even destructive, of best practices and current health care and business models. They involve radical change and introduce promising alternatives to traditional practice.
- We are training students to be medical professionals for the next 40 years or more. Our responsibility is to educate them to serve patients for their long careers. We don't know precisely how health care will change in 40 years, so establishing continuing education as a daily habit is critical to long-term success. Still, we have strong indications of coming changes in the next decade. We present this shorter-term future in this Guide.
- Taking advantage of rapid technological advances requires these two steps:
- Redefining our profession: Based on the challenges and opportunities presented by new technologies, which enhance patient care and outcomes, affordability and access, we need to specify and justify which tasks should be performed, who is responsible for them and what tasks should be avoided.
- Transforming our education process: We must shape future professionals to thrive in this redefined profession. Technological changes will combine with economic, demographic and political changes to drive this transformation of academic audiology.
- Here, we focus on how new technologies are redefining the profession. We will consider transforming the education process at another time.

This Guide concerns computer intelligence and how we can use it to benefit our patients and upgrade our profession. Human intelligence is also critical to audiology. Here are Adam Grant's thoughts about human intelligence.

> "Intelligence isn't a substitute for knowledge. Being smart doesn't mean you've taken the time to be informed.
>
> Knowledge isn't a substitute for wisdom. Being informed doesn't mean you've developed good judgement.
>
> Good judgement requires the humility to know what you don't know."
>
> —Adam Grant

Because of the rapid progress of health care-changing innovations and technologies, we must continually update our understanding of a new, broader knowledge base for audiology. Faculty, clinicians and researchers must all become students again. So, while this book is aimed at Au.D. and Ph.D. students, faculty may also find this Guide helpful in creating a foundation for learning about ongoing health care transformations. The boxed-in-blue RESOURCES section after each chapter will help you learn more about the chapter's content and lead to more detailed knowledge sources. Enjoy!

RESOURCES

1

GOING FORWARD:

Preparing for the Transformation of Hearing Health Care

EXECUTIVE SUMMARY

Over the past 60 years, the author has transformed hearing health care (HHC) organizations. Today, he sees the field of audiology on the brink of a major transformation driven by increased computer power, generative artificial intelligence (GenAI) and advancements in genomics and precision medicine. This revolution is redefining the fundamental principles and operational models of HHC, challenging long standing assumptions and practices.

One lesson the author has learned is that the coming transformation of HHC will encounter resistance despite its benefits. He briefly explains these challenges, offers solutions and prepares students for this inevitable professional transition.

This first chapter also emphasizes the importance of reframing mindsets to empower audiologists to lead this revolution. It aims to help Au.D. students navigate the upcoming changes in their profession and prepare them to thrive in a transformed health care system. In the subsequent chapters, we will dive deeper into the details of the transition.

The field of audiology is poised for a prosperous future characterized by promising developments in health care. The emergence of generative artificial intelligence (GenAI) and its powerful applications in genomics and precision medicine are transforming health care in every corner. This transformation will result in a complete revolution in the profession as it redefines its fundamental principles and establishes a cutting-edge operational model to maximize health care potential.

This transition will fundamentally transform HHC and challenge the longstanding assumptions that have directed our actions, roles and boundaries. Audiologists are being called to embrace a new mindset, develop innovative strategies and deliver services that foster sustainable, transformative changes. The significance of this transition cannot be overstated, as it enables us to address the dynamic demands of HHC and drives the progress of audiology as we embrace a computer-powered, GenAI-guided system, all while staying true to our core principles.

RESISTANCE TO CHANGE

Anytime we face change, we can frame it as either a threat or an opportunity. Our reliance on what we have always done, our struggle to keep pace with rapid technological advancements and our fear of the unknown all contribute to framing the transformation as a threat and continuing with traditional HHC approaches while inhibiting novel innovations. Understanding these challenges is the first step toward preparing for HHC's transformation. In the following chapters, we will provide a more thorough analysis of the details of this transformation.

EXPERTS SAY IT'S IMPOSSIBLE AND DANGEROUS!

For years, experts said that the human body is incapable of running a four-minute mile. It isn't just impossible, they said; it is dangerous. Then, in 1954, Roger Bannister ran the mile in 3:59.4, doing the impossible. As a youngster, I learned from this event that the impossible does not mean it can't be done. It just means we can't do it now. My experience in health care research has taught me that doing the impossible also applies to medicine.

In graduate school in the 1960s, we were taught that there was no sensory neural hearing loss treatment, and it was impossible to see how the problem could ever be solved. Then, in 1974, I attended the First International Conference on Electrical Stimulation of the Acoustic Nerve. The conference was a raucous debate, with some of the country's most respected scientists saying the cochlear implant (CI) would never work. It was impossible! They also raised concerns that the CI was dangerous because it could cause brain infections. But as with the four-minute mile, the expert naysayers were wrong. Today, more than one million CI devices are implanted worldwide. We even have brainstem implants for patients whose auditory nerves are cut to treat their neurofibromatosis type 2.

While this series introduces new ways to practice and deliver hearing health care, it's essential to acknowledge that experts may strongly criticize some as dangerous or impossible. It's worth remembering that what appears impossible at first often just requires more time and is usually less risky than initially anticipated.

THE TRADITION TRAP

One of the greatest challenges to transforming HHC is tradition and precedent. People and the professions in which they work are often trapped by implicit historical concepts that guide their decisions and actions. Because many of these concepts are not conscious, they can't be refuted with data or logic. But consciously or not, they influence actions and create precedents over time. So, precedent becomes crucial in influencing health care provision. However, precedent often contains implicit and unverified assumptions. It promotes obsolete historical perspectives that restrict or deny promising new medical procedures, thus hindering the advancement of current and future health care services. Here are five ways tradition and precedent traps the advancement of health care (Pfeffer et al., 2000).

1. When your profession, university or clinic has such a strong identity, anything new is considered "inconsistent with who we are," thus denying or delaying constructive change that may require rethinking or redefining the group's identity.
2. When pressures exist to be consistent with past decisions, avoid admitting mistakes and show perseverance. This form of resistance is often seen in health care, where errors can be disastrous, making them challenging to admit.
3. When people have strong needs for cognitive closure and avoiding ambiguity, as we often experience in health care.
4. When decisions are made based on implicit, untested and inaccurate models of behavior and performance: "It's the way we have always done it."
5. When people carry expectations from the past about what is and isn't possible and what can and can't be done in the future. This challenge is often the first challenge experienced when considering novel or innovative changes.

To flourish during this HHC transformation, we must identify and eliminate these history-based barriers to doing things differently. This requires changing systems or structures that undermine the change vision.

Overcoming ingrained behaviors can be difficult but not impossible. Freeing ourselves and our clinics, universities and professional organizations from the limiting restrictions of precedents requires that we bring to the surface the implicit assumptions on which past decisions rest. Once we decide to make changes, we must carefully consider which practices to keep, which to invent and which to borrow from other groups. In addition, when we decide to do things in a new way, we can make it difficult for people to do things in the old way. We can also build a culture that encourages constantly questioning tradition and resisting developing automatic reliance on old ways of doing things. For instance, we can encourage continuous learning to ensure precedent never becomes overly important. We can also decentralize decision-making to motivate people to learn. In a decentralized organization, people are responsible for getting themselves educated before deciding rather than relying on authoritative direction from above.

Understanding and adopting these precedent-freeing strategies will help you thrive in the fast-changing world of HHC. As you progress on your professional HHC journey, you will experience these strategies in groups that strive to be leaders and incorporate novel HHC practices.

THE TECHNOLOGY-DRIVEN ADVANCEMENTS TRAP

Striking novel technological health care advances are being announced regularly. However, while innovative technology changes rapidly, professions, which are often stifled by tradition and self-interest, change slowly (Susskind, R., Susskind, D., 2022). As time passes, the gap grows between flourishing technologically driven advances, like artificial intelligence and genomics, and audiology's ability to keep pace. We have the opportunity and responsibility to close that gap.

Closing the gap is not easy. These transformations are disruptive, even destructive, of best practices and current health care and business models. They involve radical change and introduce promising alternatives to traditional practice. This Guide will help you navigate this transformation, which will dominate much of your professional life.

THE FEAR TRAP

Transformation raises fear of an unknown future. It is the fear that accompanies uncertainty. To increase the odds that a new health care operating model will be effective today, leaders must ensure that the model addresses the problems of operating under highly uncertain conditions. Here are some transformation concerns and pitfalls that fear and uncertainty create (Roberto, 2011).

1. There is fear of personal failure, as people worry about whether they can succeed in a new environment and whether their power, status or job security will be lost due to the transformation.
2. Paralysis is also an issue during uncertainty. Employees may be concerned that the transformation cost may exceed the benefits, and the resulting turmoil can lead to paralysis.
3. AI and genomics may threaten personal values as employees become concerned about the new ethics of the transformed HHC and whether those values will resonate with them.
4. If people perceive a loss of control of their career and work, this will also inhibit the transformation.

We need to provide people with knowledge to alleviate fear of the unknown. A proven way to accomplish this is to give them a vision of the future that explains how this health care transformation will benefit them and their patients. Persistent interactive communications are required to clarify the unknown and build trust in the transformation.

INCORPORATE THE CHANGE INTO THE CULTURE

Knowledge of needed transformations does not change behavior. As future audiology leaders, students must develop strong relationships that give people hope that change is possible. We must consistently prioritize transformation as our top priority and adopt a long-term, transformation-focused mindset. We must repeatedly learn, practice and master activities and actions that allow and facilitate the changes we must make. We must also reframe the desired transformation with new ways of thinking about and understanding our situation and the importance of change. The main objective of this Guide is to help you reframe your mindset, empowering you to take charge of the future and develop the courage to lead in this revolution.

RESOURCES

Transformational Leadership: How Leaders Change Teams, Companies, and Organizations
By Roberto, M.A., (2011), The Teaching Company, The Great Courses, Chantilly, Virginia.

Discover an essential handbook for strategies, concepts and insights into the dynamics of transformational leadership in these 24 lectures, which take you on an in-depth examination of the leadership behaviors and capabilities essential to creating positive change in teams and organizations. Filled with case studies and lessons from leaders in business, politics, sports and the military, as well as specific skills and strategies you can use in your career, this lecture series is an authoritative guide to successful transformational leadership.

Professor Roberto has arranged "Transformational Leadership" into four key modules, each of which offers a focused look at a particular aspect of leadership: models of leadership (which surveys critical issues such as human behavior and long-term goals); the change process (which focuses on resistance to change as well as ways to institutionalize it); critical skills and capabilities (including motivation, persuasion, negotiation and teamwork); and creativity, innovation and learning (which is devoted to everything from after-action reviews to systems thinking to mentoring). This is a stirring call to responsible leadership and a learning experience that's as informative as it is inspiring.

The Knowing-Doing Gap: How Smart Companies Turn Knowledge into Action

Pfeffer, J., Sutton, R. I., (2000), Harvard Business School Press. $21.18, 314 pages.

"The Knowing-Doing Gap" is the first book to confront the challenge of turning knowledge about improving performance into actions that produce measurable results. Jeffrey Pfeffer and Robert Sutton, well-known authors and teachers, identify the causes of the knowing-doing gap and explain how to close it.

2

GRASPING AI:

The Master Platform of the Hearing Health Care Revolution

EXECUTIVE SUMMARY

We must grasp the essence of AI because it is the master platform for transforming health care to solve numerous problems. In doing so, AI is remaking and modernizing health care provision and reshaping audiology. As a result, we will be practicing in a very different hearing health care system than the one that exists today. This chapter will ease that transition and help you understand it.

Here, we introduce the basics of AI, including its different types and uses, such as deep-learning models, machine learning, GenAI and large language models. You will discover AI's advantages and the factors contributing to its unprecedented growth.

Ultimately, you will be granted the opportunity to witness the future by observing AI's remarkable advancements and the exponentially more powerful computers that will fuel its progress.

This second chapter is aimed at helping Au.D. students navigate the upcoming changes in their field and preparing them to thrive in a transformed health care system. It highlights AI's transformative potential in hearing health care and emphasizes the need for audiologists to adapt and integrate these technologies into their practice.

WHY IS ARTIFICIAL INTELLIGENCE IMPORTANT?

We must understand GenAI because it is the master platform for transforming health care to solve numerous problems, and in doing so, it will remake and modernize health care provision during your career. It is driving both cultural and technological change in health care. This transformation brings many exciting opportunities to improve patient care, especially access and affordability, while increasing revenue. It also offers you the opportunity to be a changemaker and assume leadership in this unstoppable transformation of HHC. The capabilities and progress of HHC will depend on how well we transform HHC into a GenAI-based system while retaining our core values.

THE AI PROBLEM:

AI technology is incredibly powerful and evolving rapidly, fundamentally altering the landscape of HHC. This Intelligence Revolution is disrupting traditional HHC delivery and business models, and the path forward is uncertain. As providers of HHC services, Au.D.s are at the forefront of this transformation. Your role in this transformation is significant, and your contributions are invaluable.

THE SOLUTION:

The resolution to taming this disruption is understanding GenAI and harnessing its potential to create new AI-enabled health care delivery and business models that solve HHC's most pressing challenges. This Guide aims to create that knowledge, encourage the use of AI to solve HHC's struggles and rethink the assumptions of health care delivery.

AI OVERVIEW

Professor John McCarthy created the term artificial intelligence (AI) in 1956 when he gathered a small group to spend a few weeks pondering on how to make machines do things like use language (Simonite, 2023). They failed, but they planted a fertile seed. AI, the ability of software to perform cognitive functions traditionally associated with human minds, became a new field of study. We have used AI for years when we talked with Siri or Alexa, searched the internet or used a chatbot. However, basic AI could not generate original content. That came recently.

Deep-learning-based models use circuits and algorithms based on brain neural networks nested in layers, with connections between and among layers weighted differently as they train and learn. The first layer receives the input, and the last layer yields the output. Just as scientists who study the brain don't understand precisely how the brain works, the experts who create neural networks don't always understand what happens in the neural networks they make. Deep-learning models excel at learning from text, images, audio and code, from which they can produce new original text, images, audio, code, simulation and videos. They can understand sequential data, such as how a word is used in a sentence and are drastically changing the way we approach content creation.

Researchers at Dishbrain are taking neural network modeling to the next level by fusing computer chips with living human and mouse brain tissue. Their goal is to enhance neural-network-based AI models with biological intelligence. According to Blain (2023), this approach shows promise.

Machine learning (ML) is a form of AI that can learn from data patterns without human direction. We train ML on an extensive database from which it detects patterns and learns how to make predictions and recommendations. It also adapts, becoming more efficient with new data and experiences. Generative AI (GenAI) is a form of machine learning based on deep learning and has more capabilities than basic AI. It can generate new content responding to a prompt by identifying patterns in massive quantities of training data and then creating original material with similar characteristics. Outputs from GenAI models can be indistinguishable from human-generated content. GenAI can be used out of the box or fine-tuned to perform specific tasks.

Large language models (LLM) are a type of GenAI, such as ChatGPT, trained exclusively on text. Because language allows us to build models of the world, even absent any other stimuli, like vision or hearing, LLMs can write fluently about the relationships between different sounds even though it has never heard either.

The Intelligence Revolution refers to the massive transformation of society caused by the exponential growth of computer power and the unrelenting desire to create machines that do everything humans do. It is a profound revolution in how we think, work and think of ourselves as humans. It is transforming our society, including the HHC professions.

In later chapters of this Guide, we will consider how AI facilitates HHC provision, including machine-learning models and their predictions, as well as the new systems for care delivery they enable.

WHAT ARE THE ADVANTAGES OF GENAI?

- GenAI drives down the time taken to perform a task. It enables multitasking and eases the workload for existing resources. These advantages improve productivity and increase cost savings.
- GenAI enables the execution of hitherto complex tasks without significant cost. It avoids hiring competent but expensive new experts.
- GenAI operates 24/7 without interruption or breaks, surpassing the dedicated performance of even our most loyal and committed clinic employees.
- GenAI facilitates decision-making by making the process faster and wiser. It has access to more knowledge and can analyze it quicker and more intelligently.
- GenAI allows for rapid query, analysis and summary of massive amounts of data. As detailed in Chapter 4 of this Guide, this enables precision medicine in HHC, an innovative approach to tailoring disease prevention and treatment that considers differences in people's genes, environments and lifestyles.

- GenAI is being deployed across industries, so its use is becoming commonplace. It is the fastest diffusing innovation ever. Patients will expect HHC to use GenAI, and its use will define the best care.

WHY IS GENAI CHANGING SO RAPIDLY? It is a powerful human bias to expect tomorrow to be like today. So, we wildly underestimate how quickly AI systems will transform health care. Let's look at what is countering our bias and driving the rapid changes in AI.

- GenAI is popular: ChatGPT drew one million users in its first five days of existence. In 40 days, it had 100 million users, the fastest adoption of any innovation ever.
- GenAI is easy to use: It operates with natural language processing, which means it understands instructions in natural language, the language you use daily. There is no need to know computer programming to communicate with or instruct GenAI.
- GenAI feeds itself: GenAI is self-improving because now that we can partner with AI, we can improve and amplify what we do to push science and technology forward. This results in a massive increase in scientific and technological advancement, creating a more powerful AI, which will produce more advances in technology and science and an even more improved AI. In this enhancement feedback loop, AI experiences explosive progress.
- GenAI is competitive: Big tech and startups know its promise. They are spending billions of dollars in an epic race for AI platform dominance. In 2023, enterprises spent $16 billion on GenAI solutions. In January 2025, Oracle Chairman Larry Ellison, OpenAI CEO Sam Altman and SoftBank CEO Masayoshi Son announced the Stargate project, a mindboggling $500 billion investment in a new AI infrastructure, including a one-million-square-foot facility in Texas. Meanwhile, China's DeepSeek AI, a super-efficient, open-source software, now rivals those of OpenAI, Google and Meta, all while using less expensive and less sophisticated technology.
- GenAI is universally necessary: Business leaders realize that GenAI is crucial to staying competitive across industries. Everyone, including HHC providers, is aware and impatient to add AI to their operations or get left behind.
- GenAI is not stopping or pausing: The AI race is in full swing, forever changing how we provide HHC. Competitors, spending billions of dollars and racing to dominate AI, will not pause for fear that they will lose the race. In this race, the "transformation train" has left the station, and we cannot stop it, so we must learn how to control and use GenAI.

FUTURE AI

HERE IS A LOOK AT THE ADVANCES AI WILL MAKE GOING FORWARD.

Artificial general intelligence (AGI), the stage at which AI can do any job that a human can do, only better, is the longer-term future of AI. It is a central theme of the Intelligence Revolution. This Guide will not specifically cover AGI, but it is a fascinating, controversial and fast-moving field of study that offers a world without work (Susskind, D., 2020). It raises the supposition that AI may not be artificial. Some suggest we should refer to it as inorganic or machine intelligence. I prefer "computer intelligence" because, as we examine in Chapter 6, computers are its base; without computers, this intelligence does not exist. We encourage readers to keep abreast of AGI, monitor its progress and imagine how it will further transform HHC. But first, this Guide provides an essential background of GenAI and its application to HHC now, at the dawn of the Intelligence Revolution. In later sections, we will attempt to answer the fundamental question: What do we do?

Artificial superintelligence (ASI) is a hypothetical future AI that is significantly more intelligent than the best human minds across various categories and fields of endeavor. ASI does not exist.

Improving AI

There are three main dimensions to quickly improve AI: size, data and applications (Bertics, A., 2023).

- Size: Traditionally, we have considered larger models to be better. However, increasing size results in enormous costs. The new focus is to maintain performance by making models smaller and faster. This transformation is done by training a smaller model using more training data. We can also shrink size by reducing the numerical precision of the parameters within a model. Small models are less expensive to run and are becoming available on laptops and cellphones.
- Data: We can also shift the focus from how much data there is to improving the quality of the model's data. Furthermore, we can create more effective models by increasing and combining data types to give them new capabilities.
- Application: AI has advanced quicker than we have taken advantage of, so one way to improve AI is to learn how to use it more effectively. There are three main ways to use AI.
    - Prompt engineering feeds the model with specific phrases or questions based on the desired goal.
    - Fine-tuning a model to improve it, such as adding an extra round of training using papers from HHC journals to make it better at answering HHC questions.
    - Embed LLM in a more extensive, more robust architecture, such as combining an LLM with extra software and a database of knowledge to make it less likely to produce falsehoods.

Computer Advances and AI

The power of AI comes from its training materials and computer power. As computer power increases, AI becomes faster and more powerful.

Personal computers (PC): In 2024, PC power is increasing due to the addition of GenAI to smartphones and personal computers, allowing them to run GenAI algorithms directly on their hardware without the internet or expensive cloud computing services. Lisa Su, who leads Advanced Micro Devices, says AI-enabled PCs will fundamentally redefine the computing experience over the coming years.

Supercomputers: In one second, Aurora, the newest exascale supercomputer, can perform two quintillion operations, the number two followed by 18 zeros. It will become functional in 2025 and have 70% more memory than the previous top supercomputer. Aurora's creators will equip it with the latest advances in AI and use it to address medical issues, among other goals. In addition, Lawrence Livermore National Laboratory and Tesla are each building even more powerful supercomputers.

Quantum computing has the advantage of being quantum-based like nature rather than digital-based like supercomputers, so it can simulate reality that digital computers struggle with. Quantum computers also promise to be more powerful than digital computers. The best supercomputer before Aurora would take an astonishing 47.2 years to match a computation by Google's newest quantum computer (Kaku, M., 2023). Quantum systems have the potential to solve problems the fastest classical supercomputers could not crack in millions of years.

The rapid growth of more powerful computers, which will be explained in more detail in Chapter 6, and the accompanying expansion of expertise will accelerate the use and capabilities of AI. Improved AI can help design even faster, more powerful computers. The Intelligence Revolution is on a fast track!

Integrating novel data and providing new services is crucial to health care AI development. As GenAI combines with HHC, we must shape it to solve critical problems in the HHC environment. You can participate by learning more about AI using the resources and references below.

RESOURCES

The Future of the Professions: How Technology Will Transform the Work of Human Experts, Updated Edition

by Richard Susskind and Daniel Susskind, (2022). Oxford University Press. $8.99 Kindle, $13.94 Paperback, 588 pages.

This book is a must-read if you want to know how AI will impact audiology. It is the first book to ask if professions still matter in the 21st century. It predicts how professions will decline and introduces the people and systems that will take over. We won't require or desire doctors, teachers and other professionals to work the same way as in the 20th century. In this transformation era, it's on us to redefine our profession—what to do, who does it and what not to do. A basic understanding of AI and its practical implementations is vital for effectively revolutionizing audiology and HHC. This book explains how technology will transform professions. It will inspire you to consider in depth how audiology will be transformed.

The Intelligence Revolution in Hearing Health Care Delivery

By Donald Nielsen, (2024). A Fuel Medical Group Publication. 24 pages, available free at https://fuelmedical.com/wp-content/uploads/2025/01/fm_march2024_intelligence_revolution_paper_v1.pdf

Much of the content in this chapter is derived from this publication. Dr. Nielsen provides a comprehensive analysis of AI, detailing its impact on the delivery of hearing health care. He goes on to describe AI's transformative impact on our health care system and briefly introduces precision medicine and genomics.

The Intelligence Revolution presents countless opportunities for HHC providers to grow and expand. The paper argues in favor of incorporating AI and precision medicine into HHC, stressing the significance of holistic care, continual learning, ethical AI implementation and cooperation among diverse health care sectors.

If you are new to AI, precision medicine or genomics, this paper serves as an excellent introduction. The summary covers the evolution of HHC from the past to the present and looks ahead to the future and the health care revolution that will benefit us going forward.

Co-Intelligence: Living and Working with AI

by Ethan Mollick, (2024). Portfolio Penguin $17.79, 256 pages.

Wharton professor Ethan Mollick is one of the most prominent and provocative explainers of AI, focusing on the practical aspects of how these new tools for thought can transform our world. In "Co-Intelligence," Mollick urges us to engage with AI as co-workers, co-teachers and coaches. He assesses its profound impact on business and education, using dozens of real-time examples of AI in action. By following his lead, you can come up with your own examples of how it can be used in HHC. "Co-Intelligence" shows what it means to think and work together with smart machines and why it's imperative that we master that skill. Mollick challenges us to utilize AI's enormous power without losing our identity, learn from it without being misled and harness its gifts to create a better human future. Let's accept his challenge.

The AI Revolution in Medicine: GPT-4 and Beyond

By Lee, P., Goldberg, C., Kohane, I., (2023). Pearson Education Inc. $15.65 Kindle, $23.81 Paperback, 304 pages.

This book is the ultimate opportunity to learn about GPT-4's use in health care from three insiders who have had exclusive early access to it. They show how it can greatly improve diagnoses, summarize patient visits, streamline processes, speed up research and do much more. Brace yourself for authentic GPT-4 dialogues, no rehearsals or filters, the good and the bad, with valuable context, honest commentary, real risk insights and up-to-the-minute takeaways.

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3
UNDERSTANDING PATIENT POPULATIONS:
Matching the Provider to the Patient's Needs

EXECUTIVE SUMMARY

Generative artificial intelligence (GenAI)-enabled hearing health care delivery will transform and enhance hearing health care (HHC) provision by utilizing AI to assign providers most efficiently and even create more providers. Importantly, it promises to significantly improve access and affordability, a key concern in the health care industry. This reassures health care professionals and fosters a sense of hope and optimism for the future of HHC.

To truly grasp GenAI's transformative power in providing HHC, we must first acknowledge the diversity of our patient base and their unique needs. This patient diversity, coupled with the assortment of needs, is not a challenge but a driving force behind the redefinition of HHC providers and the transformation of their roles.

This third chapter aims to help Au.D. students navigate the upcoming changes in their profession and prepare them to thrive in a transformed health care system. The pivotal themes here are matching the provider to the patient's needs, extending providers to increase accessibility and providing low-cost providers when appropriate to increase affordability.

In the previous chapter, "Grasping AI," we discussed the basics of AI and introduced you to GenAI. That article explained several ways AI can enhance HHC. Here, we focus on HHC delivery and present promising alternatives to using the time of expert humans, such as audiologists and otologists. We also explain how GenAI's transformation of HHC provision is a significant stride toward solving its accessibility and affordability problems while freeing Au.D.s to care for more patients with complex hearing issues that demand their attention and medical approach.

However, first, we must appreciate our patient base's diversity and varied needs and then the customized solutions we can provide.

HEARING HEALTH CARE'S PATIENT POPULATIONS

Figure 1 separates our patient base according to the severity of their hearing loss and the costs and complexity of their treatments. The figure shows that 75% of patients with measurable hearing loss have mild or moderate losses that can be addressed with basic treatments. In contrast, only 5% have profound hearing loss, necessitating complex interventions. It lists the overwhelming differences in the health care needs of these patient groups. Much hearing loss is chronic, and as time passes, the hearing loss gets more severe, so treatments and providers must evolve to accommodate those changes.

HEARING LOSS	TREATMENT & PATIENT PARAMETERS
Profound Hearing Loss	Mostly elderly patients Complex, sophisticated treatment High device customization High treatment costs
Moderate to Severe Hearing Loss	Mostly later middle-aged patients Wide range of treament sophistication Wide range of device customization Wide range of treatment costs
Mild to Moderate Hearing Loss	Mostlty middle-aged patients Simple treatment devices No customization Low treatment costs
No Audiometric Hearing Loss, but Self-Percieved Hearing Loss	The patient and treatment variables are being researched. Mild amplification and improving hearing in noise may be a promising treatment for some

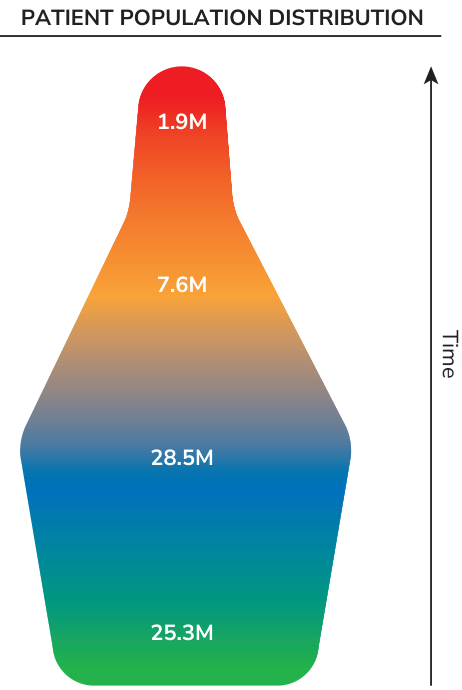

Figure 1. The distribution of patients according to their degree of hearing loss and the costs and quality of their treatments (Nielsen, 2024). Adapted from Taylor and Nielsen 2019, with data from Nash 2013, Lin 2011, Wallhagen 2008, Humes 2021 and Edwards 2020.

The key idea is that audiology is experiencing a significant transformation due to utilizing GenAI. This technology allows us to effectively cater to various patient groups by aligning their specific needs with appropriate care, reducing costs and increasing accessibility.

This transformation sharply contrasts with the status quo, where audiologists are encouraged to see all patients. Importantly, audiology clinics must serve all types of patients as their hearing changes and attract, understand and build trust with patients early in their experiences with hearing issues. That should not change. Still, not all clinic patients need to be served by an audiologist. We will elaborate on alternatives below, but first, let's consider which patients see which providers.

MATCH THE PROVIDER TO THE PATIENT'S NEEDS

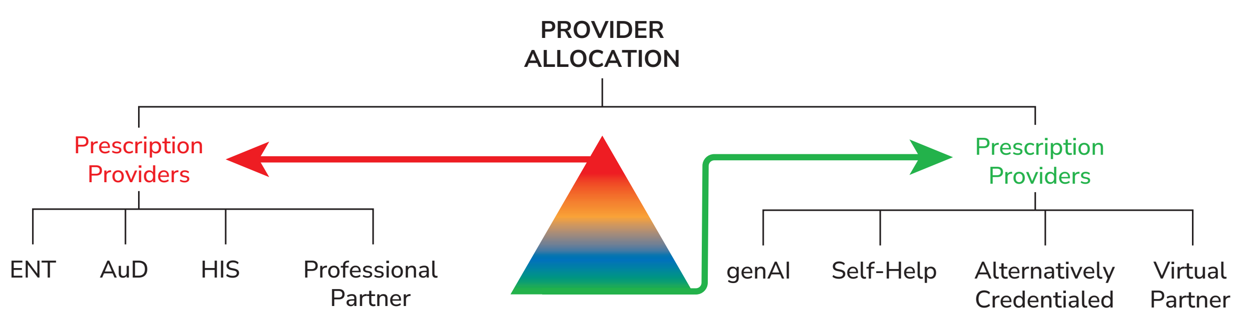

Figure 2. Patients in the upper portion of the triangle have complex prescription needs (see Figure 1) that are best met by providers using the medical model. Providers who do not use the medical model best serve patients in the lower part of the triangle.

Figure 2 illustrates that we must split the diverse patient base in Figure 1 into those requiring medical model care (pre¬scription providers) and those who will do well with nonmedical model care (nonprescription providers). This triaging matches the patient's needs to the appropriate provider and allows us to assign providers most effectively while improving access and affordability. Let's take a closer look.

GENAI'S ROLES IN FACILITATING THE PATIENT/PROVIDER MATCH

Approximately 40 million people in the U.S. have hearing issues. That demand far exceeds the availability of the 12,000 practicing audiologists. Figure 1 shows HHC patients distributed according to their hearing loss. However, people don't know where they are in this population distribution or which providers they should see. They require guidance to match their needs with the right provider. AI's enormous contribution to HHC delivery is its ability to facilitate that match and even create new providers. Our first example will examine how AI can facilitate appropriate HHC provider guidance and selection in primary care clinics.

AI'S ROLE IN MATCHING HHC PATIENTS AND PROVIDERS VIA PRIMARY CARE PROVIDERS (PCPS)

Why PCPs matter: PCPs play crucial roles in HHC. PCPs are often the patient's initial interaction point. They are responsible for identifying hearing loss in older patients' annual Medicare wellness exams. Kochkin's 1998 survey showed that people with hearing loss are five times more likely to seek a hearing solution if their PCP gives a positive recommendation for HHC. A March 2021 ASHA YouGov Poll found that 42% of adults report that a recommendation from a medical professional would play the most prominent role in their decision to purchase an over-the-counter hearing aid, with cost being a distant second at 18%. PCPs can play an instrumental role in the early identification of hearing issues, guiding appropriate and timely choices for addressing patients' recognized or unrealized hearing concerns. This role of the PCP in guiding patients and managing hearing loss can be improved by enlisting the help of GenAI.

PATIENTS' POINTS OF ENTRY FOR SENIOR HEARING HEALTH CARE

7,380
Hearing Aid Specialists

12,020
Doctors of Audiology

12,609 ENTs
1,324 Neurotologists
6,557 General ENTs
4,728 Pediatric and Non-Otologic Specialties

441,735
Primary Care Physicians
By far the most extensive possible point of entry into hearing health care

Figure 3. PCPs are the largest and most trusted entry point into senior HHC.

The problem: My experiences and observations are that most audiology clinics and audiologists have not established firm relationships with their local PCPs. They have missed an exceptional opportunity to educate PCPs and their staff about chronic hearing issues and their life-altering effects and to expand audiological services to treat more patients. As a result, screening for hearing loss and providing timely referrals are not a top priority for PCPs. Only 15%, or less, refer patients to hearing care (Popp et al., 2002), and many are confused or anxious about identifying the hearing health path their patients should follow. Additional research (Wallhagen et al., 2008) reveals that up to 85% of older patients report having no spontaneous advice from their PCP regarding hearing loss. Consequently, hearing problems may remain undetected and untreated or may not be addressed by the best health care provider.

The AI solution: We need a robust solution that can enhance PCP groups' involvement in HHC without significantly increasing patient visit duration or requiring them to make decisions outside their comfort zone or training. That sounds impossible, but with your support and involvement, AI is poised to offer that solution. Here is how.

When patients turn 65, they are eligible for Medicare physical exam coverage. Their first exam is called an initial preventive physical exam (IPPE). Then, once every 12 months, patients get a routine annual wellness visit (AWV). The IPPE and AWV provide an opportunity for an AI-based solution.

We can embed AI into the IPPE and periodic AWV patient intake forms to identify hearing loss and whether the patient needs a medical exam to address their hearing problem. For instance, we could embed the RHHI-S (Cassarly et al., 2020) and the CEDRA (Klyn et al., 2019) (Nielsen, D., 2018) and automate the scoring. The embedded AI can also be trained to consider various treatments, including a broad range of hearing devices, from simple nonmedical amplification devices to sophisticated medical devices, and match the patient to the appropriate device or treatment suggestions based on its analysis. It can consider several local providers and suggest the most suitable and accessible providers that the PCP might recommend to the patient. Sarah Sable-Antry has developed an initial version of a tool like this at www.hcrpath.com. In the near future, precision medicine will significantly improve this approach by incorporating genomic and additional personal information into the patient's database and integrating it with the intake form to make better-informed decisions than are now possible. This will enhance and perfect the analysis. See www.hcrpath.com and Nielsen (2024a) for more details. Also, see Chapters 4 and 5 for additional information about precision medicine and genomics.

To modernize the provision of HHC, a strong partnership between HHC providers and PCPs is necessary. AI can facilitate and strengthen that relationship. Audiology's involvement in developing and introducing AI to the PCPs adds expertise, credibility and sophistication and builds trust. We must work toward integrating AI-enabled HHC in the PCPs' domain. This will free audiologists from routine tasks and allow them to provide more complex treatments. Audiologists and ENTs will gain from working with PCPs and their AI systems to be the clinician(s) the AI recommends.

Let's turn to AI's role in solving other HHC problems centered on matching the patient and provider.

AI'S MODIFICATION OF HHC DELIVERY

The recent blossoming of GenAI and the concurrent proliferation of nonprescription hearing treatments have reshaped how audiologists can serve the lower portion of the patient triangle, who can benefit from nonprescription providers. Audiologists must learn to use these emerging provider types driven by GenAI. Like audiology technicians or assistants, self-help and virtual providers will extend your patient reach and the services you can provide.

A NEW GENERATION OF AI-ENABLED PROVIDERS ARE AUDIOLOGY EXTENDERS

Self-Help: Patients as Partners: A limitation to promoting patients' self-investigation into their health issues is the traditional perception of patients as passive recipients who only seek medical assistance when necessary. However, increasing offerings improved by GenAI let patients identify and triage medical issues and care for them independently, only bringing in a doctor when necessary.

Patients can test their hearing at home. See https://yeshearing.com/blog/the-top-12-ways-to-test-your-hearing-at-home/. Meanwhile, many sophisticated medical devices have been customized for self-help and are moving from the doctor's office to the home, from blood tests (https://www.questhealth.com/) to EKGs (https://www.healthline.com/health/ecg-monitor). Over-the-counter (OTC) hearing aids are self-fit devices. Even cochlear implant recipients can self-test at home to monitor implant performance with smartphones or tablets (Wasmann et al., 2023). We must encourage people to use self-tests and consider them proactive partners in diagnosing and treating their hearing issues. Because of the shortage of audiologists and the demand for audiologists to treat complex medical problems, we have no choice. To lower costs and serve more patients whenever and wherever needed, we must extend our provider base by integrating self-triaging and self-testing into our clinic protocols.

Virtual Providers: GenAI allows us to provide accessible, competent virtual providers instead of one-on-one, in-person medical care. These AI-enabled providers were initially used when patients needed constant or repetitive advice or instructions. With the increased sophistication of GenAI, they can now be used for more sophisticated medical issues. We call the AI that empowers virtual providers telepresence. Let's take a deeper dive into its operation and use.

Telepresence—These technologies allow people to feel as if they are physically present with someone whom technology represents digitally. Given the widespread use of cellphones and computers, telepresence is rapidly evolving to strengthen health care and increase affordability and accessibility.

Previous technologies, like internet chat blogs, were not lifelike or personal—questioning and answering required laboriously written interactions with long delays, frustrating misspellings and mistaken interpretations. Notably, the elderly find them challenging and unnatural.

Videos are an improvement over text-based chatbots; however, if you have assembled furniture while watching a YouTube video, you understand the limitations of the video instructional model. Self-help videos give limited instructions, lack interactions and are often problematic. GenAI allows us to do better.

AMIE is a telepresence-style chatbot created before GPT-4o to provide medical advice to patients. It was compared to human doctors to assess its ability to show empathy and engage in conversations. AIME performed better than doctors in 24 out of 26 aspects of conversation quality, offering patients an equal or higher level of empathy and support as human physicians (Haseltine, W., 2024).

Virtual providers using GenAI, like AIME, can learn, converse and problem-solve like humans. Still, with the advent of GPT-4o, they can do better because GPT-4o is natively multimodal, which means it can "see," "hear" and "speak" in an integrated way with almost no delays. It can blend all these modes together. It can see what you are doing, instantly react to it, respond to interruptions, use realistic voice tones and create images. Virtual providers can react like humans and influence patients as humans do (Mollick, E. 2024). GPT-4o is free (https://openai.com/index/hello-gpt-4o/)—experiment with it to discover its many attributes and imagine its use with 3D virtual providers. Virtual providers can exceed routine human communication by adding captioning, clear speech, synced in-focus and accurate lip movements. They have quickly evolved to be competent co-workers.

Contrary to popular belief, AI can express emotions by reacting to the feelings of others. GenAI-based systems can determine a patient's emotional state by analyzing speech patterns and other cues, such as facial expressions and physiological measures. These systems can inform a virtual provider in real time if the patient is or is not engaged and what material is resonating. The virtual presenter could slow down, show more empathy or make other changes. Patients will develop relationships with 3D virtual providers as they do now with friendly front office staff and providers.

GenAI facilitates the development of new care delivery capabilities that fundamentally change how HHC teams spend their most valuable resource: time. Now, we can provide patients with needed information 24/7 from a 3D virtual person who can answer any verbal or written question and present a pleasant, empathetic personality. Virtual providers will be a critical driver of increased accessibility and affordability of HHC.

GENAI'S INFLUENCE ON OTC DELIVERY AND ACCEPTANCE

The FDA promoted OTC hearing aids to provide high-quality hearing aids that people with mild to moderate hearing loss could buy online or at local pharmacies and big-box stores. However, acquiring hearing aids over the counter can still feel challenging. Not everyone with hearing loss is comfortable with online sales or do-it-yourself adjustments via apps. ASHA's OTC Hearing Aid Survey, 2023, found that only 24% of those patients who were at least somewhat confident an OTC device could assist them were satisfied they could choose the correct device. They want help.

AI-enabled platforms could be the key to patients adopting more OTC care options. Consider how helpful interactive dialogue with a quality virtual provider could be in informing patients about OTC devices and monitoring their reactions. Patients could discuss whether the devices are appropriate treatments for their hearing issues. If so, they can also get suggestions about which OTC device to purchase and how to unbox, fit and maintain it. This system would introduce patients to HHC in a less expensive, more accessible, more prosperous and more rewarding way than it currently does.

AI-powered virtual health care has the potential to be both convenient and cost-effective. Patients no longer need to schedule appointments, travel to a health care provider or wait for an in-person, one-on-one meeting with their provider.

CONCLUSION

PCPs, audiologists and patients will use AI to diagnose and triage hearing issues. By directing the appropriate patients to new GenAI-equipped channels to empathetically diagnose and treat their nonprescription HHC needs, GenAI will streamline patient triage so only those needing qualified, prescription-capable providers will see physicians and audiologists. This liberation of medical providers will result in more patients with prescription needs being appropriately seen and treated, significantly improving HHC and its accessibility and affordability.

RESOURCE

The AI Revolution in Medicine: GPT-4 and Beyond

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Exercise: Play at innovation and entrepreneurship. Using Chapter 3 as inspiration, please read this book while experimenting with GPT-4o (https://openai.com/index/hello-gpt-4o/) and consider ways to use it to improve HHC. Chapter 5 of the book will prove most helpful.

Keep these questions in mind: Can you improve an existing HHC decision process? Can you enable a new HHC decision process or change how a decision is made? How are other HHC decisions affected by your innovation? What are the challenges and trade-offs in taking down the existing system and building the new one? Are there any shifts in power associated with your proposed changes?
Pair with another student and challenge other student teams to see which can create the most innovative yet doable solutions to an HHC problem or problems. As you complete this exercise, note that the AI application opportunities can be hidden from view. Question everything to reveal them.

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4
UNDERSTANDING PRECISION MEDICINE:
The New Ecosystem for Health Care

EXECUTIVE SUMMARY

It is important to abandon outdated practices from the 1900s and instead adopt new diagnostic and treatment methods, such as precision medicine, which capitalize on rapidly evolving opportunities.

Precision medicine amplifies audiologists' capabilities and reach by empowering them to analyze vast datasets, unearth previously inaccessible relevant information and leverage that information for personalized patient diagnosis and treatment decisions. The transformative potential of precision medicine in how we deliver prescription HHC cannot be overstated, underscoring the urgency of its adoption. It is your future!

The pivotal theme in this fourth chapter is switching from one-size-fits-all medicine, in which we develop treatment and development strategies for the average person, to precision medicine, in which we customize them for each individual patient.

Our health care system is outdated, which makes it weak. Figure 4 shows some of its most challenging weaknesses, which we can now eliminate by rejecting traditional one-size-fits-all medicine and replacing it with precision medicine, a modern customized approach. Precision medicine provides a new, more robust health care ecosystem based on the latest technologies and innovations, highlighting the urgent need for reform in our health care system. I use precision and personalized medicine interchangeably throughout this book.

Fortuitously, computers, GenAI, genomics, precision medicine and big data analysis/systems are all experiencing simultaneous growth and advancement. With this integration of innovations and novel technologies, audiologists, as key health care professionals in hearing health care, are not just bystanders but essential players who can adopt a range of new, improved and competitive options, thereby contributing significantly to the advancement of health care.

ONE-SIZE-FITS-ALL MEDICINE DOES NOT WORK WELL!

Traditional medical approaches based on broad population averages often miss the mark because they do not account for the individual differences that are critical for effective and safe medical care.

We need a personalized approach to identify who will benefit from clinician-recommended treatments and who will not, sparing them from unnecessary expense and side effects.

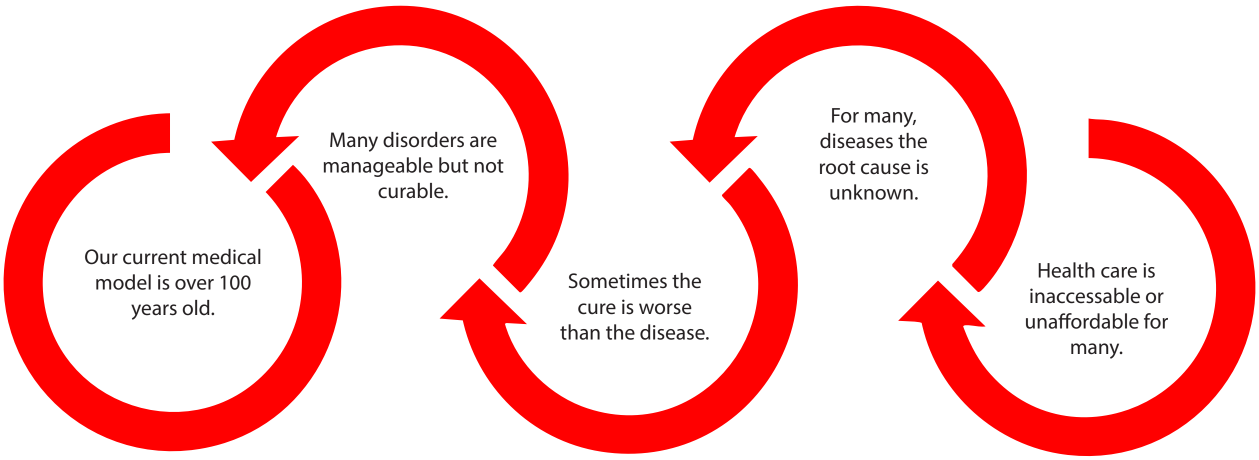


Figure 4. Reasons our current medical system fails many people.

These four emerging innovative technologies—computers, GenAI, big data analysis and genomics—are interacting and maturing simultaneously to give life and significance to precision medicine. President Obama launched the Precision Medicine Initiative in 2015 with a proposed $215 million investment to revolutionize health care and medical treatments, including establishing a voluntary research cohort of at least one million Americans from whom to collect genetic data, biological samples and health information to create a large database for research to revolutionize health care and medical treatments (Obama White House, 2015).

The initiative emphasizes public-private partnerships, engaging academic medical centers, researchers, patient groups and the private sector to develop the necessary infrastructure and approaches for precision medicine. Precision medicine is not just a passing trend but a transformative force that is here to stay. It will provide the organizing ecosystem for 21st-century health care, inspiring us all with its potential to revolutionize our field.

PRECISION MEDICINE

Precision medicine considers individual variability in genes, environment and lifestyle for each person and targets the right treatments to the appropriate patients at the right time. It encompasses emerging approaches to disease diagnosis, prevention and treatment based on individual variations in genetics, environment and experiences (Rudman et al., 2018).

Precision medicine uses large datasets, including lifestyle, medical and genomic information, to make health care more personalized and effective. This approach allows doctors and researchers to predict more accurately which treatment and prevention strategies for a particular disease will work in which groups of people. It contrasts with a one-size-fits-all approach, in which disease treatment and prevention strategies are developed for the average person, with less consideration for individual differences (Cerrato, P., & Halamka, J., (2018); Cerrato, P., & Halamka, J., (2023).

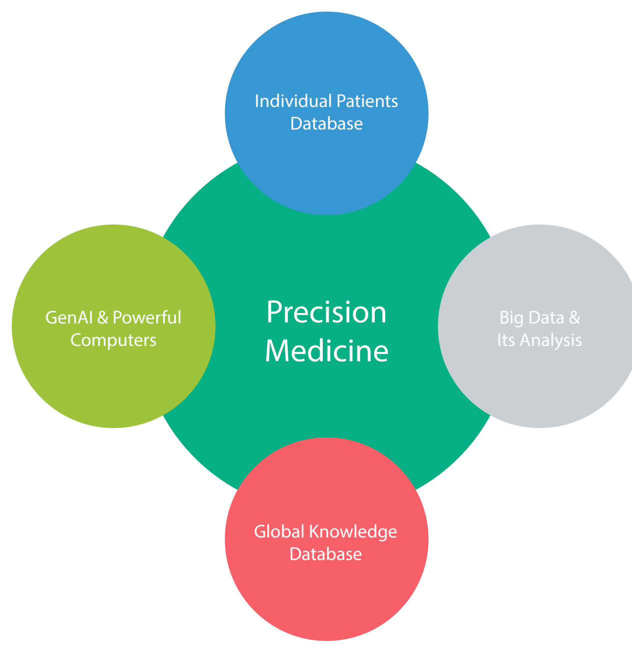


Figure 5. The building blocks of Precision Medicine.

THE BUILDING BLOCKS OF PRECISION MEDICINE

Computers serve as the foundation and driving force behind advancements in preventative medicine and the health care revolution. Health care advances as computers advance. Discover more about these developments in Chapter 6.

As discussed in Chapter 2, generative AI harnesses the growing speed and power of computers and new learning models to enhance its capabilities. In its various forms, generative AI serves as the intellectual foundation, providing the working memory and insights necessary for precision medicine.

The growth of computer technology and AI has significantly enhanced big data analysis, enabling it to process increasingly larger datasets from a wide range of sources, including electronic medical records, research data and individual information from wearables, genetics and lifestyle records. These datasets surpass our ability to analyze them. Consequently, big data analysis serves as the driving force behind precision medicine.

Recent advancements in genomics are crucial to developing precision medicine and offer remarkable patient outcomes. The above building blocks also contribute to the rapid progress in genomics, improving quality of life and revealing its life-saving potential. Our next chapter will be dedicated entirely to genomics, which is precision medicine's most powerful and useful medical tool.

Patients' and global knowledge databases fuel precision medicine. The more data it collects, the better precision medicine performs.

HOW DOES PRECISION MEDICINE WORK?

Precision medicine is a new term that encompasses emerging approaches to disease treatment and prevention based on individual variations in genetics, environment and experiences.

Precision medicine is a new concept, but it is familiar to audiologists. Personalizing hearing treatments has been a fundamental aspect of audiology since its inception. For instance, when we perform a hearing aid's first fit, we tailor it to the patient's audiogram. When we incorporate real-ear adjustments, we adapt the treatment to the individual patient's external ear canal. Precision medicine, informed by massive informational data sets, enabled by AI and driven by fast and powerful analysis, takes this customization to more extreme limits.

The goal is to provide personalized patient care. As illustrated on the following page, precision medicine gathers extensive data, including information about an individual's health, lifestyle and environment and a vast global knowledge base about disease mechanisms. It then analyzes these data, identifying patterns and using them to make predictions and recommendations. To fully participate in precision medicine, we must improve our collection and reporting of more patient information. We must also be knowledgeable enough about genetics and other professions to know when their information and expertise are critical to success.

We require precision medicine-focused tools and capabilities to level the accessibility and affordability playing field. This will also enable more intelligent and simplified patient triaging and stratification. Precision medicine pushes us to stratify patient populations even more effectively than we proposed in the previous chapter. It helps ensure that individuals receive timely screenings and longitudinal monitoring aligned with their unique risks. This leads to earlier diagnosis and treatment, which can reduce the likelihood of advanced disease (Singh, 2024).

THE PRECISION MEDICINE ECOSYSTEM

PATIENT

The ecosystem works by including all existing data, so we must educate patients to consent to release personal data and samples to the system to help research, themselves and others.

INDIVIDUALIZED DATABASE

- Internal Health System Records
- Personal Genomics
- Self-Report
- Mindset
- Lifestyle
- Home Medical Devices and Wearable Sensor Data
- Health Care Claims
- Social Media
- Environmental Data
- Psycho-Social Vulnerability
- Family Medical History

GLOBAL KNOWLEDGE DATABASE

- Diseases's Symptoms, Causes and Cures
- Numerous Patients' Data from Multiple Sources
- Clinical Trials Data
- Basic Medical Research Data
- Transformational Research Data
- Pharmaceutical Research Data
- Manufacturers' Research Data
- Nontraditional Medicine Research Data
- Patient Feedback Data

GENAI/BIG DATA ANALYSIS

The GenAI analysis detects patterns and matches commonalities in the two massive databases to prevent and diagnose diseases and recommends personalized treatments specific to the individual.

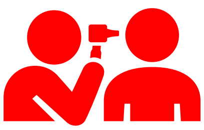
PERSONALIZED DIAGNOSTICS,
PREVENTION STRATEGIES,
TREATMENTS AND CURES

Precision medicine is revolutionizing health care by making it more predictive, preventative, personalized and participatory. Here is how:

Targeted Treatment: Precision medicine tailors medical treatment to individual characteristics, increasing the effectiveness of treatments.

Early Disease Detection and Prevention: Precision medicine enables early detection of diseases. By taking a proactive approach, we can prevent diseases from progressing, potentially saving lives and reducing health care expenses.

Customized Medication Dosages: Precision medicine allows for customizing medication dosages to optimize efficacy and minimize adverse reactions, improving medication adherence and reducing the risk of complications.



Enhanced Patient Engagement: Precision medicine empowers patients by involving them in their health care-related decision-making processes. Access to personalized genetic information and treatment options makes patients more engaged and motivated to participate actively in their care.

Improved Patient Outcomes: Precision medicine is not just a theoretical concept but a practical tool that will improve patient outcomes by customizing treatments. This will produce higher treatment success rates, reduce side effects and improve overall health outcomes. This potential should motivate us all to commit to its implementation.

Reduction in Health Care Costs: Although initial implementation costs may be higher, precision medicine can reduce long-term health care costs by avoiding ineffective treatments, minimizing hospitalizations and preventing disease progression through early intervention and prevention strategies.

Advancement in Research and Development: Precision medicine contributes to advancing medical research and development by providing insights into the underlying mechanisms of diseases and individual responses to treatments. It positions audiologists to effectively treat the heterogeneous causes and manifestations of hearing loss on a more effective individual basis.

PRECISION MEDICINE HAS TREMENDOUS BENEFITS, BUT IT ALSO FACES CHALLENGES

The fundamental challenge is assimilating, analyzing and integrating genomic data, electronic medical records (EMRs), data obtained with mobile health devices and other data about hundreds of millions of people.

We also need more providers, including audiologists and otologists, who are educated and experienced in precision medicine.

Another essential challenge is the need for more AI-ready data. Data that is not AI-ready slows the adoption of AI, machine learning and precision medicine. Preprocessing will be necessary to extract meaning and ensure data usability from numerous diverse datasets.

Health care quality varies from region to region and person to person, so we must develop a universal precision medicine infrastructure available nationally.

An additional crucial challenge is appropriate participant inclusion, particularly regarding ethnic diversity, geographies and other demographics. This includes the medically disenfranchised who lack EMRs or ready access to the internet.

Finally, users of precision medicine must address privacy and security concerns.

WE MUST BRING THE POWER OF PRECISION MEDICINE TO HEARING HEALTH CARE

Precision medicine represents a momentous shift toward more individualized care and the promise to revolutionize health care. Powerful computers armed with GenAI and the massive datasets of precision medicine reveal long-hidden relationships, enlightening us with new knowledge about the causes and effects of diseases and health care and how to perfect HHC.

Presently, small practices don't have access to the large patient datasets and computer and AI resources required by precision medicine to analyze these datasets. Large medical centers have these resources and are leading the development of precision medicine. Students interested in learning more about precision medicine should expand their knowledge and experience by acquiring externships and employment in these medical centers.

The breadth of precision medicine is creating new partnerships between scientists in a wide range of specialties, as well as people from patient advocacy communities, universities, pharmaceutical companies and others. Audiologists must become active participants and leaders in these partnerships.

The emergence of precision medicine will revolutionize the roles within the hearing health care system. For example, with its insights, we will be able to minimize the need for cochlear and brainstem implant surgeries and empower audiologists to collaborate with geneticist partners to prevent, cure or manage these patients' conditions. Educating yourself about genetics and other aligned professions is essential for thriving in the new health care ecosystem.

Precision medicine is transforming hearing health care. You will enjoy using its tremendous power to help your patients through improved diagnosis, prevention, cures and treatments. You owe it to your patients, your profession and yourself to stay abreast of developments in precision medicine and their applications to hearing health care.

Genomics is a crucial component of precision medicine, and their combined influence on HHC is snowballing. In the following chapter, we will concentrate on genomics and its powerful potential to reshape HHC and improve your capabilities as an HHC provider.

RESOURCES

Redefining the Boundaries of Medicine: The High-Tech, High-Touch Path into the Future

Cerrato, P., Halamka, J., (2023). Mayo Clinic Press. $26.49 Kindle, 199 pages. Free loan at the library.

"A timely and captivating book that challenges us to rethink and reimagine how we deliver health care in the 21st century. It is an informative and engaging read."

—Eric Horvitz, Chief Scientific Officer for Microsoft

Nothing is more crucial to your professional future than understanding how health care will evolve in the next generation. This book will assist you in achieving that objective.

Health care as it stands today needs to be reimagined. "Redefining the Boundaries of Medicine" by Paul Cerrato and Dr. John Halamka challenges the profession to renegotiate its priorities and address the fact that it's become timid and reluctant to explore new care delivery models. The guiding premise of this book is that rethinking and reimagining the way medicine is practiced in the 21st century will improve health outcomes and that technology is central to this transformation. They advocate for a high-tech, high-touch approach to medicine that puts the patient at heart and respects dignity, autonomy and preferences.

The authors are nationally recognized experts leading the development of the Mayo Clinic Platform. They concentrate on revolutionizing health care by using artificial intelligence, connected health care devices and a network of trusted partners to discover, validate and provide improved diagnostics and treatments through computer science, data analysis and virtual health services. They are the experts in precision medicine and determining the future of health care and its ongoing transformation.

What role will audiologists play in our transformed health care system? Reading this book is essential to understanding your future in health care and the more diverse and necessarily integrated system in which you will operate.

Building the Foundation for Genomics in Precision Medicine

Aronson, S., Rehm, H. Nature 526, 336–342 (2015). https://doi.org/10.1038/nature15816.

Precision medicine aims to enable clinicians to quickly, efficiently and accurately predict the patient's most appropriate course of action. This Nature article describes the basics of precision medicine in 2015 and explains how precision medicine accomplishes its aim. This is a sufficient but dated substitute if you cannot afford to buy a copy of "Redefining the Boundaries of Medicine" (Cerrato & Halamka, 2023). Aronson and Rehm nicely integrate genomics into the precision medicine system, as we have attempted in the next chapter.

This article's strength is that the authors explain the precision medicine ecosystem and present its benefits from several points of view. They note that the role of the patient in supporting precision medicine has become increasingly important because of the necessity to maximize patient data in the system. They also explain how precision medicine simplifies the multiple-component process of clinical data interpretation. Clinical and research laboratories also benefit from precision medicine.

The authors explain how the vital building of clinical genomic knowledge, centralized knowledge repositories and biobanks linked by the precision medicine ecosystem drive the collection and analysis of genomic data and lend precision and personalization to the medical decision process.

The authors acknowledge precision medicine was primitive in 2015, but they capture its required components and how they work together to improve health care. This collaboration is creating a new culture as researchers, clinicians and patients embrace open data sharing to facilitate the advancement of health care.

Genomics and Precision Medicine: The Astonishing Revolution of Hearing Health Care. A Call to Action for Audiologists.

Nielsen, D., W. (2024). Fuel Medical Group White Paper, Fuel Your Future Series. 31 pages, available free at: https://fuelmedical.com/wp-content/uploads/2024/08/fm_paper_genomics_and_precision_medicine_v2-2.pdf

Once you have grasped how health care will change, you will benefit greatly by understanding precisely how audiology will change and be practiced in this new 21st-century environment. This white paper is a necessary and engaging first step in that direction.

While "Redefining the Boundaries of Medicine" clarifies the future of health care in general, this paper explains in more detail how hearing health care (HHC) providers will function in a precision medicine-based system. This more detailed white paper lists the HHC problems precision medicine must solve. These struggles are the driving force shaping the reinvention of HHC. The paper also explains the crucial steps in analyzing big data, its critical applications and the role that traditional audiology will continue to play.

It explains how to significantly improve the precision and effectiveness of hearing health care, offering patients more tailored and more effective interventions for various forms of hearing loss.

The assumptions traditionally underpinning audiology, dictating decisions about what to do, who does it and what not to do, no longer align with our new AI-enabled, precision medicine-driven reality. This misalignment underscores the necessity of reevaluating and updating our practices. Crucial to your success, this paper explains how you do that. It is a call to action for audiologists and includes 13 practical steps to integrate the advantages of our reinvented health care system with audiology.

Finally, this paper explains how genomics is revolutionizing HHC, which is the topic of our next chapter.

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5

GENOMICS:

Hearing Health Care's Most Useful New Tool

EXECUTIVE SUMMARY

Too often, we focus only on advancements within our field, overlooking how developments in other areas may impact hearing health care (HHC). Genomics, the Swiss army knife of health care, is on the brink of a transformative era. It will enhance and revolutionize health care across multiple dimensions, from improving diagnostic accuracy to personalizing treatment strategies and preventing and curing diseases. Genomics allows us to delve into the intricate structure of genes, their interactions and their impact on patients, inspiring a new wave of possibilities in health care.

With its power to treat diseases more effectively and efficiently, genomics is not just a tool but a catalyst for change in health care. It will provide patients with better options, reshape health care dynamics and redefine health care providers' roles and priorities.

The pivotal theme in this fifth chapter is that genomics is the ultimate personalizer of medical care. It offers striking new opportunities for customized prevention and cures, as well as remarkable improvements in diagnosis and treatments. Genomics is revolutionizing health care and will radically reshape your future roles and opportunities in HHC.

Genomics involves examining an organism's entire DNA, including all its genes. The focus is on the genomes' structure, function, evolution, mapping and editing.

Genomics involves studying genetic sequences to understand genes' structure, interactions and effects on patients. This process includes analyzing the general characteristics and measurable attributes of all genes, their connections and their collective influence on a patient's growth and development.

The progress in genomics has been driven by the development of technologies that enable fast and cost-effective DNA sequencing and analysis, which is central to transforming medicine. The cost of sequencing the first human genome was $2.7 billion, and it took several international institutes, hundreds of researchers and 13 years to complete (https://www.genome.gov/about-genomics/fact-sheets/Sequencing-Human-Genome-cost). Today, it can be done for $100 (Albert, H., 2024; Pennisi, E., 2022), unlocking the full potential of the human genome. Genomics is poised to significantly improve health care across multiple dimensions, from enhancing diagnostic accuracy to personalizing treatment strategies and preventing and curing diseases. A patient's medical records will soon routinely include their sequenced genome.

The Transformational Potential of Genomics for Health Care Lies in its Ability to:

PREDICT DISEASE RISK
This predictive capability enables preventive measures to be taken before the onset of symptoms, potentially preventing the development of diseases or significantly altering their courses.

ENHANCE DIAGNOSTIC ACCURACY
Genomics enables the precise identification of genetic mutations responsible for diseases. This can significantly reduce the time and resources spent on trial-and-error approaches to understanding a patient's condition, leading to faster and more accurate diagnoses.

PERSONALIZE TREATMENT PLANS
Genomics facilitates the development of personalized treatment plans tailored to individual patients' genetic profiles.

ENABLE PHARMACOGENOMICS
Genomics enables health care providers to prescribe drugs that are more effective for the individual based on their genetic makeup, minimizing adverse drug reactions and improving therapeutic outcomes.

REDUCE HEALTH CARE COSTS
Genomics will enable more precise diagnostics, targeted treatments and effective prevention strategies, leading to the more efficient use of health care resources and reducing overall health care costs. Early intervention and personalized treatment plans can decrease the need for extensive and expensive care later.

Four innovative technologies—GenAI, big data analysis, genomics and advanced computing—are concurrently developing to advance precision medicine. We discussed GenAI, big data analysis and precision medicine in previous articles. Now, let's examine genomics' commanding influence on transforming hearing health care (HHC).

HOW GENOMICS IS REVOLUTIONIZING HEARING HEALTH CARE

GENE THERAPY

Gene therapy, a medical approach that utilizes genetic material to treat or prevent diseases by correcting the underlying genetic problems, involves modifying a person's genetic makeup, usually by introducing new genes and repairing or replacing faulty genes within the body's cells. Gene therapy can be administered in two primary ways: ex vivo (outside the body, where cells are modified and reintroduced into the patient) and in vivo (directly into the body), the preferred method. A new technique, CRISPR, allows us to edit DNA within a cell in vivo. Let's examine this versatile tool in detail (Hahn & Avrahm, 2023).

GENE EDITING

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats), the prevailing gene-editing technology, is revolutionizing genetics and health care by providing a powerful tool for precisely manipulating DNA sequences in patients. It offers new possibilities for disease treatment, diagnostics and research. This gene-editing tool is known for its precision, simplicity and efficiency. It is being applied in various medical fields, including hearing disorders (Xu et al., Z., 2020).

Understanding the Mechanism: The CRISPR-Cas9 system, the backbone of CRISPR technology, is a two-part system. The first part is the Cas9 enzyme, which acts as molecular scissors, cutting DNA at specific points. The second part is a guide RNA (gRNA), which acts as a GPS, directing Cas9 to the exact location in the genome that needs editing. CRISPR can also target multiple genetic mutations simultaneously (Tao, Y. et al., 2023). This unique system enables precise modifications to the DNA of living organisms, allowing for the correction of hearing genetic defects at their source.

CRISPR's Advantages:

1. Precision and Targeted Correction: One key advantage of CRISPR therapy is that it can directly correct the genetic mutations that cause hearing loss at the DNA level. This is a significant departure from traditional treatments, which often only manage symptoms without addressing the underlying genetic cause.
2. Permanent Solutions: Unlike hearing aids or cochlear implants, which provide symptomatic relief, CRISPR therapy has the potential to offer a long-lasting, if not permanent, solution to genetic hearing loss by correcting the mutation itself (Fliesler, N., 2019; Chien WW., 2018).
3. Broad Application Spectrum: CRISPR's adaptability allows it to target a wide range of genetic mutations associated with hearing loss, including both recessive and dominant forms of the condition. This broad applicability could make it a viable option for many patients who currently have limited treatment options (Yin et al., 2023; Tao Y. et al., 2023).
4. Safety and Specificity: By delivering the CRISPR-Cas9 protein directly into the inner ear cells, researchers have improved the treatment's specificity, reducing the risk of off-target effects that could arise from more systemic delivery methods. This enhances the safety profile of CRISPR therapy (Gao et al., 2018).
5. RNA Editing Capabilities: CRISPR therapy is not limited to DNA editing. CRISPR-Cas13 can target RNA, offering a reversible and potentially safer alternative for modulating gene expression without permanently altering the genome (Zheng Z. et al., 2022; Xiao et al., 2022; Leslie, 2024).
6. Overcoming Limitations of Existing Therapies: Current treatments like hearing aids and cochlear implants do not cure hearing loss but rather amplify sound or stimulate the auditory nerve directly to improve hearing perception. CRISPR therapy aims to correct the root genetic cause, potentially restoring natural hearing without the need for external devices.
7. Diagnostic Applications: CRISPR technology can be adapted for diagnostic purposes, allowing for the precise identification of genetic mutations that cause hearing loss and leading to earlier and more accurate diagnoses, essential for effective treatment planning and management of hearing disorders (Wu, J. et al., 2023; Yin et al., 2023).
8. Innovative Research Tool: CRISPR facilitates the exploration of the genetic landscape of hearing loss, helping to uncover new genes involved in auditory function and disorders. This can lead to the discovery of novel therapeutic targets and strategies for preventing or reversing hearing loss.

Audiology clinics have limited options to slow down or reverse genetic deafness. Luckily, CRISPR therapy is a major breakthrough in addressing genetic hearing loss, providing accuracy, the possibility of long-lasting correction, flexibility and enhanced safety. As scientific advancements carry on, CRISPR will surely continue to revolutionize the treatment and diagnosis of genetic hearing loss and overcome the drawbacks of current therapies.

Examples of Gene Therapy

Example 1: Pioneering animal genetic research. The Spns2 tm1a mouse mutant has a faulty Spns2 gene, which causes it to be unable to maintain the local ionic environment of the inner-ear sensory hair cells. This results in a decreased endocochlear potential, a neurological disorder causing irreversible hearing loss.

In this pioneering research, Martelletti et al. (2023) used genetic intervention to reactivate the faulty Spns2 gene and found they could reverse an existing neurologically based hearing loss.

By activating Spns2 gene transcription at different ages after the onset of hearing loss, they discovered a crucial factor in this therapy. The timing of the therapy was critical. The earlier the activation of the Spns2 gene, the more effective the reversal of the hearing loss was, underscoring the importance of early intervention for this therapy.

This successful study in mice opens possibilities for gene therapy for reactivating hearing in people with similar hearing loss. That brings us to Example 2, the first demonstration of gene therapy for human hearing loss.

Example 2: The first successful hearing-restoring gene therapy for humans. Autosomal recessive deafness 9, caused by mutations of the OTOF gene, is characterized by congenital or prelingual, severe-to-complete, bilateral hearing loss. Before this study, no treatment was available for this congenital deafness.

This single-arm, single-center trial enrolled six children (aged 10 months–18 years) with severe-to-complete hearing loss and confirmed mutations in both alleles of OTOF and without bilateral cochlear implants. A single injection of AAV1-hOTOF was administered into the cochlea through the round window (Jun Lv et al., 2024).

The gene expression had a time-release pattern. Five of the six children recovered some hearing over time. At 26 weeks after treatment, they showed an average 40–57 dB improvement in the auditory brainstem response (ABR) thresholds at 0·5–4·0 kHz.

The gene therapy technique in these studies overcomes a significant challenge presented by large genes, such as OTOF, which exceeds the capacity of the widely used adeno-associated virus (AAV) vectors. Researchers addressed this by dividing the OTOF gene into two, encapsulating the halves into separate viruses and injecting a mixture with both halves into the cochlea. This innovative approach allowed the cellular machinery to assemble the complete protein, restoring the cells' ability to transmit signals to the brain.

The children were cochlear implant candidates, but after acquiring enough hearing from gene therapy, they were no longer eligible for implants. They will be treated with hearing aids. Researchers are following the patients for five years to see if their hearing continues to improve.

Successful OTOF gene therapy treatments are continually emerging, underscoring the importance of pediatric gene therapy. Auditory Insights has published a summary of these studies at https://auditoryinsight.com/wp-content/uploads/securepdfs/2024/02/Gene-Therapy-Clinical-Trials-Results.pdf. For a summary of recent advances in gene therapy for hereditary hearing loss, see Jiang et al., 2023.

Example 3: Genomic testing for newborns. A study by Ziegler et al. (2024) has improved our understanding of the feasibility of implementing genome sequencing as an adjunct to traditional newborn screening (NBS) in newborns of different racial and ethnic groups.

Over 11 months, 5,555 families were approached, and 4,000 (72.0%) consented to participate in newborn genetic screening! Testing was successfully completed for 99.6% of cases. The screen-positive rate was 3.7%, including treatable conditions not currently included in NBS.

DNA sequencing offers an additional method to improve screening for conditions already included in NBS and to add those that cannot be readily screened because no biomarker is currently detectable in dried blood spots. This study encourages us that new parents will welcome newborn genomic screening.

POTENTIAL BENEFITS OF USING GENE THERAPY TO TREAT GENETIC DISORDERS IN EMBRYONIC HUMANS

INTRAUTERINE FETAL GENE THERAPY

As innovative and promising as the above therapies are, intrauterine fetal gene therapy (IUGT) offers even more promise. Peddi and colleagues (Peddi et al., 2022) have written a comprehensive review that offers an overview of the current knowledge in the field of prenatal gene therapy and potential future research avenues. It is recommended reading.

Here are some of intrauterine fetal gene therapy's distinctive benefits:

- Less Invasive Approach

IUGT provides minimally invasive approaches to preventing genetic disorders by releasing vectors into the embryonic fluids.

- Prevention and Cure of Genetic Disorders

IUGT can prevent or cure genetic diseases by correcting gene mutations in embryos, giving individuals a chance at a healthy life beginning at birth.

- Elimination of Hereditary Disorders

Germ-line gene therapy, which targets reproductive cells, can potentially permanently remove hereditary disorders from a family line.

- Reduction in Health Care Costs

By preventing genetic disorders before they manifest, IUGT could significantly reduce the long-term health care costs associated with hospital stays, treatments and lifelong care.

Peddi and colleagues also point out that small fetal size, accessible proliferating progenitor cells and tolerogenic fetal immune systems make treatment delivery more efficient, safe and long-lasting than after the baby is born.

IUGT provides minimally invasive approaches to preventing genetic disorders. IUGTs are the future of fetal and neonatal medicine to improve quality of life and potentially cure monogenetic disorders before irreversible pathology occurs.

As a result, there are increasing calls to adopt a simultaneous genetic hearing loss screen to the current neonatal health screening guidelines (Luo, H., 2022). Suppose a NICU AI-based computer vision monitor detects a cerebral dysfunction (Gleason et al., 2024) or a screening test indicates a possible problem—or the parents' age, family history or medical history puts the baby at increased risk of having a genetic problem. An invasive prenatal diagnostic test and IUGT might be considered in that case. Imagine the benefits of this approach combined with newborn hearing screening to start an otherwise deaf child's life with hearing.

ETHICAL AND CULTURAL CONSIDERATIONS

Ninety to 95% of deaf children are born to hearing parents (Mitchell et al., 2004), many of whom would like to make hearing possible for their children. For them, this is a miracle; they can choose gene therapy. However, we must be sensitive to the idea that some deaf parents prefer deaf children and, in both cases, support the parents' decision. This ethical mindfulness is crucial for ensuring that treatments are developed in a way that respects patient autonomy and diversity (DesGeorges, J., 2016).

RESULTING PATIENT DEMOGRAPHIC SHIFTS

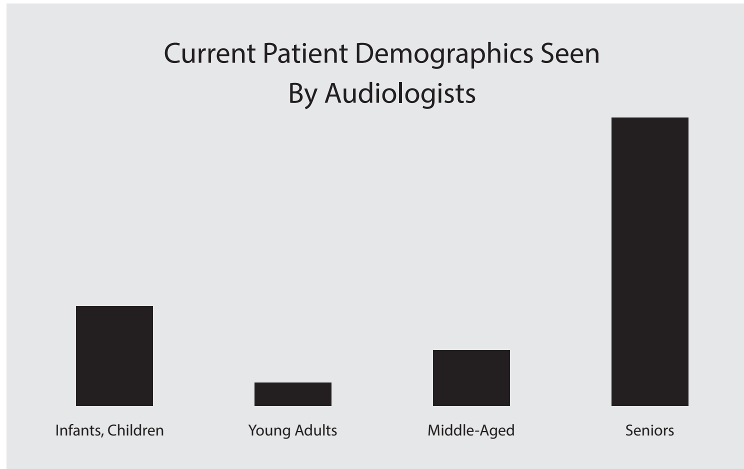
Most therapies work best when they are started as early as possible. The gene therapy examples discussed above confirm that gene therapies also conform to this "earlier is better" rule. In addition to the IUGT advantages listed above, it is the earliest possible therapy. As a result, we can expect an increase in pediatric and fetal patients receiving treatment.

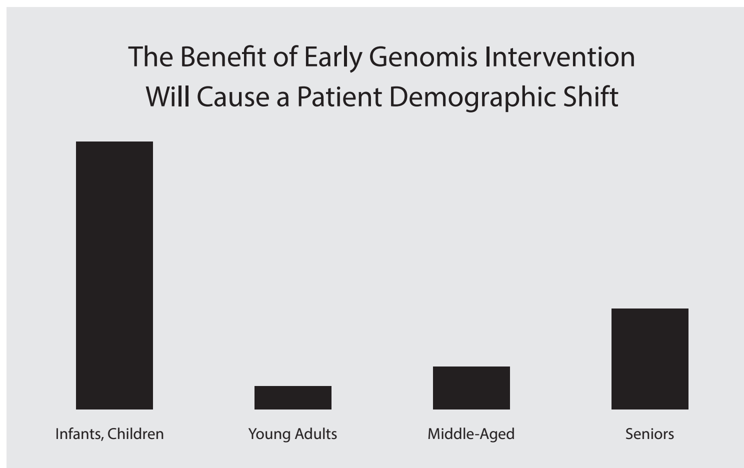
Currently, newborn hearing screening demands a small cadre of pediatric audiologists.

Most audiologists treat seniors, where the demand is greatest.

Still, because gene therapies work best in younger patients, we must plan for an increased emphasis on pediatric patients and inter-uterine fetal gene therapies.

To the extent gene therapy is successful, IUGT patients may experience a lifetime without congenital sensorineural hearing loss, reducing the demand from older patients.





TRADITIONAL AUDIOLOGY STILL HAS A ROLE

Gene therapy will not entirely replace hearing aids and cochlear implants—at least not for a generation or two. Because gene therapy works best at younger ages, the boomers will still need and expect traditional therapies while we shift toward younger genome therapy patients. The baby boomer generation's peak is reaching 65 years of age—4.1 million Americans are reaching age 65 annually. Many of those at 65 still have 10, 20 or even 30 years ahead as life expectancy increases. Additionally, the second half of this large boomer generation is still under 65.

Gene therapies are still in their infancy and need time to be perfected. Gene therapy has shown that it is not always a complete solution or cure for humans (Jun Lv et al., 2024) and animals (Martelletti et al., 2023). For instance, in the case of OTO-F-treated children, while they no longer required cochlear implants, they still needed hearing aids. This highlights the imperfections of gene therapy. Not all gene therapies will immediately work perfectly or last a lifetime. This is when the collaboration between audiologists and geneticists becomes crucial. It is our future! Together, we must devise successful new treatments for patients who have undergone gene therapy. Some of these treatments will be traditional, some will be modifications of traditional treatments and some will be innovative solutions that we can't yet envision.

Because of the rapid development and success of gene therapy, we indeed must now plan for the shift of our expertise to younger patients and a growing partnership with genomics. Those forces will dominate the future for today's and tomorrow's audiology students. To allow us to make this shift, we must use audiology extenders and AI to care for nonprescription patients and to free us to work with geneticists to treat more complicated patients requiring prescription care. Audiologists who participate in precision medicine and actively collaborate with geneticists will thrive.

Soon, audiologists will work in a health care world based on precision medicine, utilizing advanced machine intelligence on powerful computers, personalized by genomics and massive datasets. Prepare yourself!

RESOURCES

Advances in Gene Therapy Hold Promise for Treating Hereditary Hearing Loss

Jiang, L. et al., (2023) Molecular Therapy, Vol. 31 No. 4, April 2023. Open Access. 16pp.

Up to 60% of congenital (a condition present at birth) and early-onset hearing loss is caused by genetic factors. Gene therapies potentially restore hearing by targeting genes that cause hearing loss or deafness.

This article reviews the progress of gene therapy for hereditary hearing loss (HHL) in much greater detail. The authors discuss gene replacement, gene suppression and gene editing therapies. They summarize which is best for specific monogenic diseases based on their pathogenic mechanisms, focusing on their successful application in preclinical trials for HHL.

Auspiciously, they conclude that "gene therapy is a promising curative approach for HHL, as it can provide precise treatment to restore auditory function, which cannot be accomplished by traditional medicine." They summarize 163 references, proving their point while providing additional resources for you to explore. Genomics is the future of health care. Future doctors of audiology must be well informed about genomics and comfortable with it. This article will help you begin.

Intrauterine Fetal Gene Therapy: Is That the Future and Is That Future Now?

Peddi, N.C. et al. (2022) Cureus 14(2):e22521doi: 10.7759/cureus.22521, 8 Pages, Open Access.

To gain a deeper understanding of intrauterine gene therapy (IUGT), you'll want to read this comprehensive review that provides an overview of the current knowledge in the field of prenatal gene therapy and explores potential future research directions. It evaluates the risks associated with prenatal gene therapy, such as the potential for oncogenesis, the transfer of genetic mutations from mother to child and the risk of fetal disruption. These risks are weighed against the anticipated benefits, which include the prevention of severe early-onset illness symptoms, targeting previously inaccessible organs and establishing tolerance to therapeutic transgenic proteins, all of which contribute to permanent somatic gene correction. Additionally, the review discusses the scientific, ethical, legal and sociological implications of these innovative techniques for preventing genetic diseases, as well as the parameters that must be met for future clinical applications to be considered.

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6

ADVANCES IN COMPUTER POWER:

The Foundation and Driver of Hearing Health Care's Transformations

EXECUTIVE SUMMARY

The seed of the current revolution in health care is the computer!

Everything else—artificial intelligence, big data analysis, precision medicine, genomics, drug discoveries, virtual remote extensions, in-office technology, improved treatment devices and more—is a by-product (Harari, Y., H., 2024).

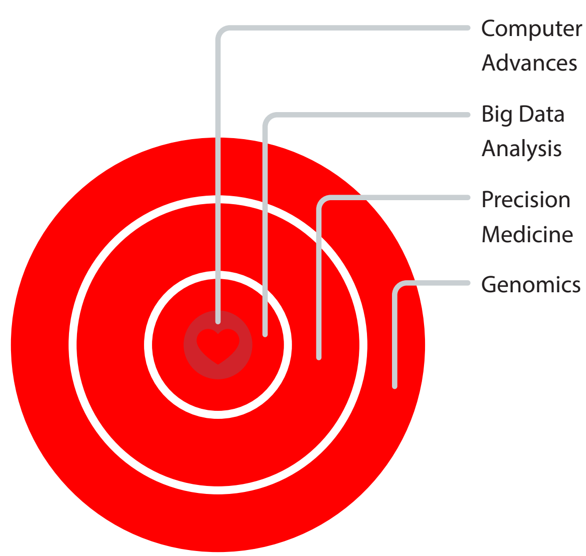
Advancements in computer hardware will significantly enhance health care outcomes. To truly understand the transformative revolution around us, it's essential to delve into the fascinating origins and swift evolution of computers, which continuously adapt and enhance their capabilities. Imagine a world where supercomputers, the current pinnacle of processing power, are outpaced by cutting-edge quantum computers. This technological leap will unleash an unprecedented surge in computing power and speed, shattering the barriers imposed by chip size, manufacturing complexities and other challenges that some think will constrain us.

Picture this: an exponential increase in our computing capabilities that could amplify human intelligence a million-fold (Kurzweil, 2024)! The implications of this leap are simply astounding. We stand on the brink of a new era where health care advancements could redefine the fabric of our well-being, ushering in breakthroughs that we once only dreamed of. The future is not just near—it's accelerating rapidly, and we must be ready to grasp the infinite possibilities that lie ahead!

This sixth and final chapter is aimed at helping Au.D. students navigate the upcoming changes in their profession and preparing them to thrive in a transformed health care system. Here, we will trace the historical path of computer progress and clarify the ongoing development of quantum computers that will drive the future of health care.

As discussed in previous chapters, artificial intelligence (AI), big data analysis, precision medicine and genomics are revolutionizing the health care landscape. The rapid growth in computing power and speed is at the heart of this transformation. This chapter explores the significant advances in computing technology and their impact on health care and audiology. It will also explore how emerging computational paradigms, especially quantum computing, are set to accelerate the transformation of medical practices and patient care.

Quantum computing, leveraging quantum mechanics, will transform life sciences by analyzing vast amounts of medical data more efficiently and accurately than classical computers.



By using rapid simulations and complex molecular modeling, quantum computing will accelerate drug discovery, genomics and precision medicine development. We will focus on quantum computing more, but first, let's explore classic computers' evolution into today's primary driving force behind health care's transformation.

Historical Perspective

Just as childhood experiences influence adult behavior and thinking, computing's history affects the present and future of computing. Understanding the history of computers is also essential for appreciating the power and potential of quantum computing. By studying this history, we can recognize the extent and pace of its progress. I will weave in a sampling of my computer experiences to give you a glimpse of the history and role of computing in hearing health care (HHC).

Early Mechanical Computer Concept In 1822, Babbage conceptualized the Difference Engine, the first automatic computing machine designed to approximate polynomials. It could perform only basic arithmetic operations, primarily addition (https://www.computerhope.com/issues/ch000984.htm) (https://www.britannica.com/biography/Charles-Babbage) (Harper, C. 2019). The machine was relatively simple and operated using a series of gears and levers (Harris et al., 2023). It could compute several sets of numbers and make hard copies of the results.

Before mechanical computers, a "computer" was a person who performed mathematical calculations. Babbage's revolutionary idea was to create a machine that could perform these calculations automatically, inspired by seeing complex mathematical tables in France (Harris et al., 2023). In 1848, Ada Lovelace, working with Babbage, wrote the world's first computer program, further advancing the conceptual foundations of computing (Williamson, T., 2023).

THE FIRST MACHINE TO RECORD AND STORE INFORMATION

In 1890, Herman Hollerith developed a method for machines to record and store information on punch cards for the U.S. census. Hollerith's machine was approximately 10 times faster than manual tabulations, saving the census office millions of dollars. Hollerith later formed the company we know today as IBM (https://www.computerhope.com/issues/ch000984.htm).

Punch Cards: As mentioned above, early computers could not store files like modern computers do. As a result, punch cards were used to create data files and programs. Punch cards are paper cards with holes punched in them to represent computer data and instructions. They served as a standard method for inputting data into early computers. A complete program could be stored by combining hundreds or even thousands of these cards. One primary concern with punch cards was the risk of dropping them. If the cards were dropped or became disorganized, restoring the program to its original order could take days or even weeks.

THE FIRST FULLY FUNCTIONAL DIGITAL COMPUTER

J. Presper Eckert and John Mauchly invented the ENIAC (Electronic Numerical Integrator and Computer) at the University of Pennsylvania. Construction began in 1943 and was not completed until 1946. It occupied about 1,800 square feet, used about 18,000 vacuum tubes and weighed almost 50 tons. (https://www.computerhope.com/issues/ch000984.htm) .

Personal Experience: Sixty years ago, as graduate students in the Auditory Research Laboratory at Wayne State University (WSU), we were permitted to use one of these types of computers for our research. It was a very large mainframe computer housed remotely in a vast facility, accessed by a limited number of hard-wired remote terminals and programmed using punch cards. Analyzing the data took days.

When Ray Kurzweil attended the Massachusetts Institute of Technology (MIT) at this same time (1965), they had a state-of-the-technology IBM 7094 mainframe computer. It cost $3.1 million in 1963, which is $30 million in 2023 dollars, and could perform a quarter of a million operations per second. Thousands of students and professors shared it. By contrast, the iPhone® 14 Pro, new, costs $999 and achieves up to 17 trillion operations per second. The iPhone 14 Pro is 68 million times faster than the IBM 7094 and less than one-30,000th the cost. A two-trillion-fold improvement (Kurzweil, 2024)!

THE FIRST COMPUTER WITH RAM

MIT introduced the Whirlwind machine on March 8, 1955. This revolutionary computer was the first digital computer with magnetic core RAM (random-access memory) and real-time graphics. These computers soon evolved into the first laboratory minicomputers and transistor computers.

Personal Experience: In the late 1960s and early '70s at the University of Florida, I immersed myself in a remarkable journey as a postdoctoral student and faculty member in Don Teas' laboratory. Our workspace was dominated by an extraordinary, custom-built computer called HAVOC, sourced from MIT and Washington University, St. Louis—a behemoth. This massive machine, a labyrinth of intricate electromechanical devices, filled an entire room and filled the air with an enchanting symphony of clicking sounds. It demanded a chilly 50 degrees Fahrenheit environment to function perfectly. Research assistants wore coats in this Florida laboratory.

The primary function of this colossal computer was "simply" to calculate average electrophysiological waveforms, specifically the N1-P2 components, which we recorded from the surface of the skull in response to auditory stimuli. Later, we advanced to a more sophisticated computer, the PDP (programmed data processor) developed by Digital Equipment Corporation, to record and analyze inner ear potentials and auditory nerve impulses in response to sound.

This era of technological innovation was electric, quite literally, as we pushed the boundaries of our understanding of electrical potentials, physiology and micromechanics of the inner ear and the resulting nerve stimulation (Konishi, Nielsen, 1978). Researchers using these computers laid the knowledge base for developing algorithms to help create cochlear implants, changing countless lives. Looking back, it was an exhilarating and fruitful time, marked by creativity and discovery. Thanks to advances in computing, we felt like we were on the brink of unlocking the secrets of hearing itself.

THE FIRST PERSONAL COMPUTER (PC)

In 1975, Ed Roberts coined the term "personal computer" when introducing the Altair 8800. However, many consider the first personal computer to be the KENBAK-1, launched in 1971 for $750. The KENBAK-1 used several switches for data input and provided output by turning various lights on and off (https://www.computerhope.com/issues/ch000984.htm).

THE FIRST LAPTOP OR PORTABLE COMPUTER

The IBM 5100 was the first portable computer, released in September 1975. It weighed 55 pounds and had a five-inch CRT (cathode ray tube) display, a tape drive, a 1.9 MHz PALM processor and 64 KB of RAM. Some years later, I purchased my first portable laptop computer, an HP, which weighed only 14 pounds!

Personal Experience: At Henry Ford Hospitals Otologic Research Lab in the 1970s, before Apple or PC computers were available, we embarked on a successful journey to repurpose a compact, desktop-sized HP computer, initially designed for the rigors of machine and assembly line control, to train and test animals' hearing. Our mission? To delve deep into the intriguing effects of noise on hearing (Nielsen et al., 1986).

Meanwhile, in the Audiology Clinic at HFH, a generous $40,000 grant from the March of Dimes empowered us to dream big. We constructed a device capable of measuring pediatric auditory brainstem responses

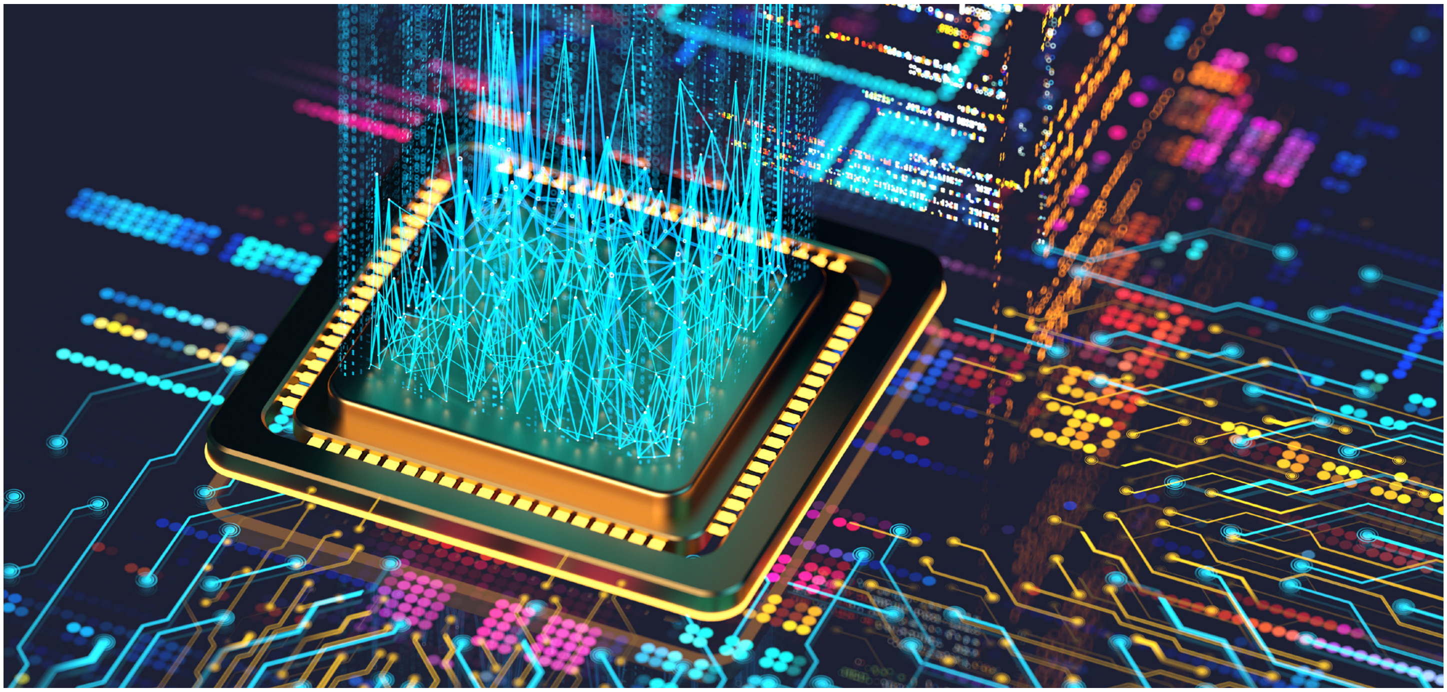
(ABRs). At a towering six feet, this technological marvel required the specialized care of an electrical engineer.

Computers were shrinking in size at this time, but they still had hefty price tags; my first word processor, complete with a printer, set us back $6,000 in the ’80s and took over our entire dining room table! Fast forward just a decade, and the world had transformed. We proudly purchased a compact word processor for our daughter for under $1,000, equipping her for the digital age and her first year in college.

Today, the landscape looks astonishingly different. Word processing has become an essential feature on any laptop, which seems almost a miracle compared to those early days. Pediatric ABRs are now performed on newborns using sleek, portable devices operated by skilled medical technicians and nurses in the lively, often noisy environments of neonatal intensive care units (NICUs). Think of what tomorrow will bring.

As classical computers continued their rapid evolution, shrinking in size while exponentially increasing power, their applications penetrated every facet of daily life. Today, an astounding 90% of Americans and 60% of people around the globe are owners of smartphones, each boasting more computing power than the elaborate research systems we once relied upon. Today’s hearing aids use computers and AI to provide sophisticated algorithms to improve patients’ hearing. The transformation of classic computers into supercomputers has sparked an incredible wave of innovation. This shift is dramatically reshaping the health care sector, enabling advancements that once seemed like science fiction and establishing new, higher benchmarks for quantum computing to achieve.

QUANTUM COMPUTING



Classic Supercomputers: At the Argonne National Laboratory, in one second, Aurora, the newest exascale supercomputer, can perform two quintillion operations, the number two followed by 18 zeros. It should be functional this year and have 70% more memory than the previous top supercomputer. Aurora’s creators will equip it with the latest advances in AI and use it to address medical issues, among other goals. In addition, Lawrence Livermore National Laboratory and Tesla are each building even more powerful supercomputers. These supercomputers set the benchmark for quantum computers to beat.

Quantum Computing: In classical computing, we try to force nature into two states, zeros or ones. Quantum computing has the advantage of being quantum-based, more continuous-based, like nature rather than zero-one digital-based like supercomputers, so it can simulate reality that digital computers struggle with. Quantum computers also promise to be more powerful than digital computers. The best supercomputer, before Aurora, would take an astonishing 47.2 years to match a computation by Google's newest quantum computer (Kaku, M., 2023). Quantum systems have the potential to solve problems the fastest classical supercomputers could not crack in millions of years. The implications for solving health care problems are genuinely revolutionary.

Quantum computing represents a paradigm shift in computational power, leveraging the principles of quantum mechanics to process information in probabilistic ways that classical computers cannot. Quantum computing is based on the principles of quantum mechanics, which describe the behavior of matter and energy at the smallest scales. To understand quantum computing, you need to grasp a few key concepts from quantum physics (Schneider et al., 2024) (Nielsen & Chuang, 2011).

Quantum bits, or qubits, are the fundamental units of quantum information. They can exist in multiple states simultaneously, which is known as superposition, unlike classical bits, which can only be in one of two states. Combining two quantum states will create an entirely new state; inversely, each quantum state can be represented as a combination of two or more states (Scott, 2024). This property allows qubits to process vast amounts of information in parallel, potentially exponentially faster than classical bits for many computations.

Quantum entanglement occurs when two or more particles become interconnected so that the quantum state of each particle cannot be described independently. That is, knowledge about one gives you immediate knowledge about the other, no matter how far apart they are. This property allows quantum computers to perform many calculations exponentially faster than classical computers.

Quantum interference is the phenomenon where the wave-like nature of quantum particles can lead to constructive or destructive interference patterns. This property is harnessed in quantum computing to amplify correct solutions and cancel out incorrect ones.

Quantum computers can perform calculations in parallel thanks to the laws of quantum mechanics and entanglement between qubits, meaning the fates of different qubits can instantly change each other. Classical computers, by contrast, can work only in sequence (Afifi-Sabet, 2024a).

Quantum computers are essential for optimizing complex tasks. Traditional computers struggle or fail when solving problems with numerous potential solutions. In contrast, quantum computers can evaluate all possible solutions simultaneously and identify the optimal one rapidly. They also enable more extensive and complex datasets for AI training, resulting in more sophisticated systems. In summary, quantum computing enhances AI's capabilities by removing the limitations of data size, complexity and problem-solving speed. They can simulate complex biological systems; speed up machine learning algorithms; expand and personalize disease diagnosis, prevention, cures and treatments; and advance drug discovery. The point where quantum computers overtake classical ones is known as "quantum supremacy," and researchers are working toward that goal.

Quantum computers are susceptible to interference from external sources (external quantum interference) that causes errors. Alexis Morvan and the Google research team have discovered a way to limit this interference. When quantum computers enter this specific "weak noise phase," they can perform computationally complex calculations that outpace the performance of the fastest supercomputers. This research, demonstrated on Google's 67-qubit Sycamore chip, suggests that quantum computers can outperform classical computers in specific calculations (Afifi-Sabet, 2024b).

Today's large quantum computers are at the developmental stage that classic mainframe computers were in the 1950s. However, many are not occupied on-site but in the cloud and are easily and rapidly accessible by remote devices wirelessly. Even so, the first quantum computer fully dedicated to health care and life sciences is an IBM quantum computer being installed on Cleveland Clinic's Cleveland campus (Scott, 2024). No punch cards are required.

Exponential progress is being made in the development of quantum computers. Quantum systems are naturally susceptible to errors due to environmental interference and the delicate nature of quantum states. However, Google's newest 105-qubit quantum processor, named Willow, has recently demonstrated the ability to significantly reduce errors by increasing the number of qubits (Acharya R. et al., 2024). This breakthrough lowers the error rate to an acceptable level and paves the way for constructing larger and more reliable quantum systems that can address complex real-world problems. In one demonstration, Willow completed a sophisticated mathematical calculation in less than five minutes—a complex calculation that one of the world's most powerful supercomputers would be unable to accomplish in 10 septillion years, a duration far exceeding the universe's age.

Additionally, advancements are being made in applications that will significantly benefit health care. Here are some examples.

Quantum Computer Applications in Health Care

Quantum computing harnesses the laws of quantum mechanics to solve complex problems that traditional computers, including today's supercomputers, cannot. Quantum technology can consider numerous variables that interact with each other in complicated ways. In health care, this offers the potential to advance precision medicine, drug discovery and diagnoses through complex analyses.

Realistically, classical computers will continue to be used for most current applications. However, cloud-connected quantum computers or hybrid ecosystems are already being implemented to explore various advanced applications. We can expect this advanced technology to impact health care as quantum computing progresses.

Quantum Computing has the Potential to Revolutionize These Aspects of Health Care:

DATA PROCESSING AND ANALYSIS

Quantum computing offers superior data processing capabilities and new approaches to AI and machine learning:

- Quantum computers allow for simultaneous information processing through quantum parallelism, drastically reducing the time required for complex health care computations and improving the ability to analyze larger medical datasets, like those in precision medicine we discussed in Chapter 3.
- They will analyze complex medical imaging data or patient information in real time, surpassing the capabilities of classical supercomputers.
- They can process and analyze health care data in fundamentally different ways from classical computers. This could reveal patterns and insights in large-scale health data invisible to classical systems like Aurora.

ADVANCED DIAGNOSTICS AND IMAGING

Quantum computing enhances diagnostic capabilities:

It improves the speed and accuracy of analyzing medical images, potentially leading to earlier disease detection.

- Quantum-enhanced algorithms will improve the sensitivity and specificity of diagnostic tools.

- There's potential for quantum MRI machines to generate extremely precise imaging, allowing visualization of single molecules.

PRECISION MEDICINE

Quantum computing is revolutionizing precision medicine:

- Quantum computing will produce faster, more complete genome sequencing and analysis, allowing for the universal inclusion of that analysis in patients' electronic medical records and tailored treatments based on individual genetic profiles.
- This technology helps reduce the trial-and-error approach often associated with treatment planning, reducing side effects, improving patient outcomes and lowering health care costs.

PREDICTIVE HEALTH CARE

Quantum computing enhances predictive capabilities in health care:

- It enables more accurate predictive models for disease progression and treatment outcomes.
- The technology facilitates genome analysis and virtual reconstruction for precise, individualized data, determining an individual patient's biological tendencies and enhancing twin simulators where risky treatments can be tried.

CLINICAL TRIALS AND RESEARCH

Quantum computing could revolutionize clinical trials:

- It may enable widespread use of "in silico" clinical trials, which are perfectly simulated trials performed without using any living cells.
- This could propel medical research forward by allowing hypotheticals and theories to be tested without real-world drawbacks.

ENHANCED DRUG DISCOVERY AND DEVELOPMENT

Quantum computing significantly accelerates the drug discovery process:

- It can simulate complex chemical reactions and molecular interactions at the atomic level, which is crucial for drug discovery.
- While supercomputers like Aurora can screen up to 22 billion drug molecules per hour, quantum computers have the potential to simulate larger and more complex molecules that are beyond the reach of classical supercomputers.
- Quantum computing enables more efficient molecular simulations, allowing researchers to model complex chemical reactions for new drug development.
- Quantum simulations transform chemical formulas into 3D structures, which is crucial for fields such as drug discovery, therapeutics and immunotherapy.
- This technology will lead to more rapid and accurate identification of new drug candidates, particularly for challenging targets, and will reduce the time and cost of developing new drugs. This could rejuvenate the pharmaceutical approach to HHC for noise exposure prevention, tinnitus and more.

IN CONCLUSION

Although Aurora and other supercomputers are currently more practical for many health care applications, quantum computers are expected to surpass them in specific complex tasks that align well with quantum algorithms. Quantum computing will revolutionize health care by enabling more precise diagnostics, personalized treatments, efficient drug discovery and advanced data analysis. While challenges still exist, the potential benefits of this technology in improving patient outcomes and advancing medical research are revolutionary.

A third way computer intelligence will improve health care is by combining it with human intelligence in a brain-computer interface (Singularity), where humans augmented with brain-implanted computer intelligence will have the capability and power to control and participate in computer intelligence (Kurzweil, 2024). The result will be a combined superintelligence exceeding classic and quantum computers, and human intelligence used separately.

The combination of quantum and classical computing will likely offer the most powerful tools for enhancing medical research and health care in the near future, which will also influence your professional trajectory. Staying informed about advancements in computing is essential for your success. Next, we present some resources to help you get started.

RESOURCES

What is Quantum Computing? Free access

By Schneider, J., Smalley, I. (2024). https://www.ibm.com/topics/quantum-computing

This is a thorough introduction to quantum computing by the industry leader. It presents the content concisely and clearly and lists resources for further study. Its contents include: What is quantum computing, how do quantum computers work, key principles of quantum computing, classical computing versus quantum computing, when is quantum computing superior, quantum computing use cases, quantum advantage versus quantum utility, making quantum computers more useful, quantum computing components, quantum software, related solutions and resources.

This is the ideal follow-up to this chapter. If you wish to learn more about quantum computing, read this first.

Quantum Computing and Machine Learning in Healthcare, 14 pages, Free access

By Quantum News (2024). November 14. https://quantumzeitgeist.com/quantum-computing-and-machine-learning-in-healthcare/

If you want to learn more about quantum computing's use in health care but not more about its underlying physics, this is an excellent introductory-level review article. It is worth reading for its broader and more detailed coverage of computing in health care than this chapter. At 14 pages, it is much shorter than the books suggested below, and it's free!

Quantum Supremacy, 352 pages, $16.19 Amazon

By Kaku, M., (2023). Double Day, New York.

This book is an excellent introduction to quantum computers and their overtaking of classic computing. It is well written by Professor Kaku, an elite science author and physicist from the City University of New York. If you are interested in quantum computing and wish to establish a strong foundation to gather more knowledge and experience, this is the book to study.

"Quantum Supremacy" expertly unpacks the complex world of quantum computing, making it accessible to tech enthusiasts and general readers alike. It takes us on a journey from the theoretical foundations of quantum mechanics to the cutting-edge developments poised to redefine industries, economies, health care and even our understanding of reality itself. The book underscores the relevance of quantum computing in today's world by drawing clear connections between quantum advances and the pressing challenges we face.

Quantum Computation and Quantum Information: 10th Anniversary Edition

Nielsen, M., Chuang, I. (2010). Cambridge University Press. 700 pages, $84 Amazon. E-Textbook $63. A paperback edition, which is not updated, is available for $35.

One of the most cited books in physics of all time, "Quantum Computation and Quantum Information" remains the best textbook in this exciting field of science. This is a must-read if you are serious about understanding quantum computing in depth. This 10th-anniversary edition includes an introduction from the authors, putting the work in context. This comprehensive textbook describes such remarkable effects as fast quantum algorithms, quantum teleportation, quantum cryptography and quantum error correction. Quantum mechanics and computer science are introduced before describing what a quantum computer is, how it can be used to solve problems faster than classical computers and its real-world implementation. It concludes with an in-depth treatment of quantum information. This well-known textbook is ideal for courses on the subject and contains a wealth of figures and exercises. It will interest beginning graduate students and researchers in physics, computer science, mathematics and electrical engineering who are serious about quantum computing.

The Singularity is Nearer: When We Merge with AI

By Ray Kurzweil, (2024). VIKING, New York. 704 pages, $14.99 Kindle, $22.49 Paperback.

Ray Kurzweil received the National Medal of Technology and was inducted into the National Inventors Hall of Fame. He is a principal researcher and AI visionary at Google.

Kurzweil's concept of singularity represents a transformative event in human history, driven by rapid technological advancement and resulting in human and machine intelligence integration. This merging of human and computer intelligence will expand human intelligence a millionfold and lead to a future fundamentally different from anything we can currently imagine. The theme of this book is to explain and defend the idea of singularity.

The author discusses the journey to technological singularity, highlighting how computer intelligence enables us to transform linear advancements, including in medical technology, into exponential growth. Based on his 60 years of experience in computing, he quantifies and describes the astonishing progress of technology in captivating detail.

The author dedicates a chapter to exploring how combining AI, digital simulations and biotechnology can advance medicine and benefit health care through exponential growth. These simulations will allow for rapid testing of candidate vaccines in just minutes and can validate them within an hour. AI technology will enable the simulation of systems ranging from proteins to entire organs. By utilizing computer-driven AI, we will be able to cure diseases that are currently too complex for today's medical practices. Leveraging AI and the extensive data from precision medicine, we will create digital twins of patients, of systems ranging from proteins to entire organs. By utilizing computer-driven AI, we will be able to cure diseases that are currently too complex for today's medical practices. Leveraging AI and the extensive data from precision medicine, we will create digital twins of patients, enabling us to test cures, treatments and surgical procedures without risk. Furthermore, nanobots will be able to repair us one atom at a time.

This captivating and thought-provoking book extends beyond this Guide's scope while consistently engaging your attention. You will find this book rewarding if you are interested in the future from scientific and philosophical perspectives.

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As the leading business advisory company serving over 1,000 audiology and ear, nose and throat clinics nationwide, Fuel Medical Group provides an award-winning array of custom insights, tools and actionable solutions that enhance practice performance and impact patient outcomes.

For more details or to contact Fuel, please visit www.FuelMedical.com.

About the Author

Dr. Nielsen brings over 60 years of experience in hearing health care and research to his role as the Audiology University Advisor at Fuel Medical Group.

Don began his interest in hearing while building high-fidelity sound systems in high school. This led to his professional journey as a fundamental scientist, studying the complex mechanics of the inner ear. He collaborated with William A. Yost to publish the highly acclaimed introductory textbook, "Fundamentals of Hearing: An Introduction." Don served on the leadership teams in the ENT department at Henry Ford Hospital and the House Ear Institute. As the head of research, he successfully led transformative initiatives for both institutions.

Dr. Nielsen has held several prestigious positions in audiology, including Director of the Central Institute for the Deaf, Chair of the Speech and Hearing Department at Washington University in St. Louis, Director of the Audiology Clinic and Translational Research at Northwestern University's Communication Sciences Department.

He has earned membership in several prestigious organizations, including Psi Chi, the National Honorary Society in Psychology; Sigma Xi, the Scientific Research Society of North America; and the New York Academy of Sciences. Dr. Nielsen has had significant roles as a leader and board member of the Society of Research Administrators and the Association of Independent Research Institutes. Additionally, he is a charter member, former secretary-treasurer and past president of the Association for Research in Otolaryngology. Here, we know him as a futurist dedicated to preparing audiology for a future driven by computer intelligence.

"Shame on all of us... if we cannot, at this moment in time, come together and create the pathways and the architecture to be able to do what we already know we can do: provide better outcomes for patients at a scale that was unimaginable a few years ago."

—Gianrico Farrugia, M.D., President and
Chief Executive Officer of the Mayo Clinic

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