HEALTHCARE GAPS THAT ONLY TECHNOLOGY CAN FILL

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ABSTRACT
Healthcare currently contains major gaps in the areas of chronic and acute disease, the role of genetics and the environment, lack of access based on location and income, the process of aging and the role of fitness and wellness, among others. Some of these gaps may be filled by technologies, and some of these gaps may *only* be filled by technologies.

Digital Health is comprised of applications of wearable and implantable technology, web and email, mobile technology, software and social networking, and data management and analytics. Some of the prominent emerging areas of technology that will be relied upon include:

- Artificial Intelligence
- Big Data
- Wearables
- Fitness and consumer-related products
- Medical technology and devices

The growing worldwide aging population is stretching healthcare capabilities and resources, leading to another set of gaps. Many of the initial Digital Health offerings were developed by technology and healthcare companies and offered to patients and consumers with limited adoption. Consumers' preference and desire for wearable technology has led to more patient-owned technology solutions that are more readily adopted.

The concept of "Connected Care" presents a comprehensive environment in which technology can transform healthcare. However, several frameworks will be required for the technology infrastructure and applications to fall into place. As they come together, fundamental types of innovation can occur in healthcare, creating unprecedented and sizable opportunities for Technology, Biotechnology, and Medical Technology (Tech+Biotech+Medtech).

Gaps in the Current State of Healthcare
While significant advances have been made in healthcare worldwide during the last century and the first two decades of the 21st century, it seems as though some gaps have been accentuated. While much attention has resulted in substantial advances against acute disease, with the result of 80% of an individual's healthcare costs being expended during the last 10% of life, advances in chronic disease, which often underly great personal and economic impact, have been more difficult to achieve. Progress against diabetes, neurodegenerative disease, and even chronic heart disease has been incremental, even with great sums spent on research and therapeutics. And while our understanding of genetic and environmental impacts on *chronic* disease has advanced, our understanding of those factors—especially multidimensional influences--on *acute* disease still remains largely unknown or undiscovered.

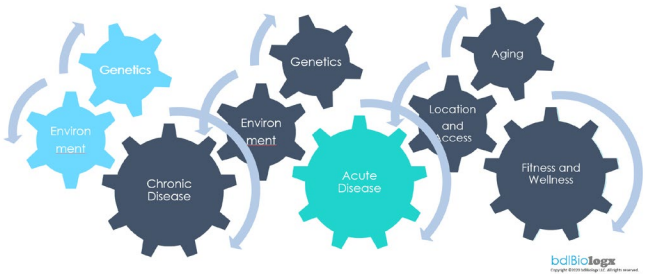

Figure 1.

In addition to the medical aspects of healthcare, several other factors remain troublesome gaps. The aging process is not well understood nor is it well-managed. A person's location, in rural or underserved neighborhoods, and in places where access is financially challenging or otherwise constrained by public policy, remain enormous gaps, especially in the United States The role of fitness and the concept of wellness, as opposed to sickness, and their impacts on health are underappreciated and not well understood. Yet these very gaps represent some of the greatest attainable prospects for technology to fill. These areas are precisely where the powerful tools of technology are being directed to improve human health.

Digital Health technology is emerging to fill these gaps in a number of noteworthy and high-profile ways. Chronic disease treatment and management is benefiting from Digital Health advances, such as diabetes, hypertension, and respiratory disease, using tools such as Livongo. In the area of acute disease, the practice of medicine incorporating genetics, pharmacogenomics, epigenetics, and genetic-based personalized medicine have experienced recent innovations. Digital Health provides a greater understanding and delivers actionable techniques to deal with the environment in the areas of air and water quality, climate change, and comprehensive immersive medicine, using smart sensors, virtual reality, and artificial intelligence.

The greatest immediate contribution of Digital Health technologies can be seen in the areas of location and access, fitness and wellness, and aging. Telemedicine/telehealth and virtual care have become prevalent, reducing the challenges of delivering quality healthcare to rural and under-resourced

locations. Remote imaging, radiology, and pathology allow work to be conducted in lower cost locations, often off-shore, with highly trained and skilled practitioners. Applications for patient monitoring and intervention have become prevalent, although adoption rates have been disappointing.

Areas of fitness and wellness benefit from strong consumer demand and have resulted in the largest financial returns for Digital Health. Some of the greatest impacts have been from:

- Multi-modal sensor-laden wearable devices, such as Apple/Samsung Watches
- Single-purpose fitness trackers such as basic Fitbit
- Activity-specific fitness tracking apps such as Strava and Komoot

The Challenge of Delivering Health Care to an Aging Population Worldwide

The global population is aging faster than population growth. The population over 60 years old has grown from 0.5 billion in 1990, to 1 billion in 2017, and will be 2.1 billion in 2050 and 3.1 billion in 2100.[i] This represents at least a 6-fold increase in 120 years. This rapidly aging population is primarily due to improved health and economic conditions world-wide. It is especially prevalent in developed economies, but not limited to them. Health care needs are stressing medicine, technology, and the economy. This phenomenon is not limited to developing countries. In fact, leading healthcare authority William A. Haseltine of the Harvard School of Public Health states, "Demographic change is a defining issue of our time. As the worldwide population ages, the healthcare systems of every country, including the United States, will face significant challenges to meet the needs of an aging population." [ii]

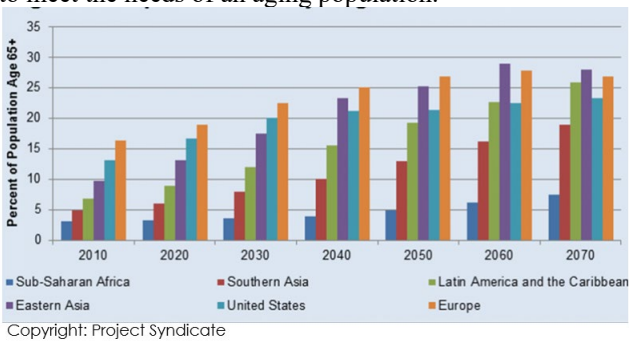

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Figure 2.[iii]

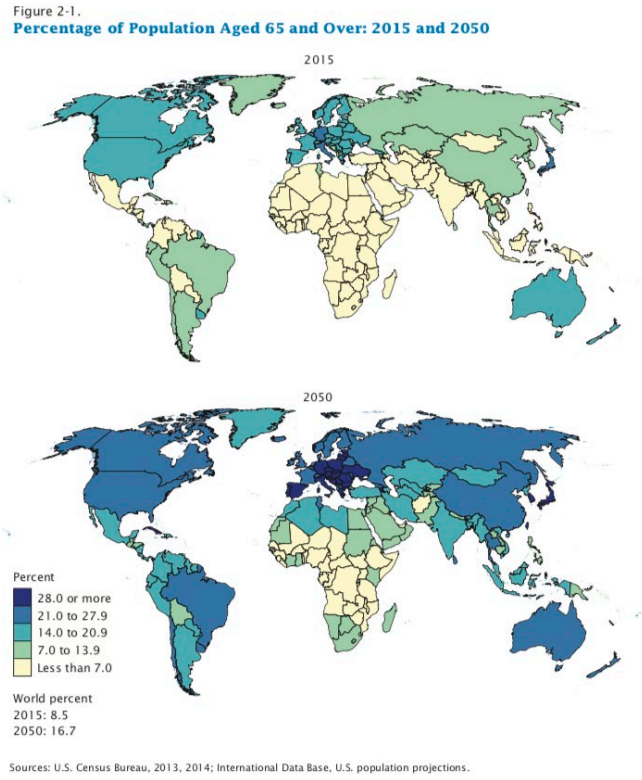

Figure 3.[iv]

At the same time, the population is becoming better connected, and "baby boomers" now comprise the fastest growing and largest portion of the aging population. These folks are much more comfortable and much more dependent on technologies for all aspects of their lives. Some of their preferred technologies include:

- Smartphone vs. regular phone
- Laptop vs. desktop
- Wearables
- Home assistants

In order to bridge the healthcare gaps of the aging population, technology is enabling aging in place, cognitive health assessment and improvement, and understanding the science of aging. The aging population has accelerated the use of technology to address health concerns.

Emerging Role of Patients and Consumers: Push vs. Pull in the New World of Wearable Technology

The adoption of Digital Health technologies has been uneven, progressing with "fits and starts." For at least a decade, technology and healthcare companies have pushed solutions that they think are appropriate and helpful for patients. These have primarily fallen into the categories of healthcare delivery tools and compliance and monitoring devices. The design of these solutions have been awkward for consumers and the cost to the consumer has been high, so various schemes have emerged for reimbursement.

In contrast, some areas of Digital Health have become very popular. Consumers are demanding (and paying for) wellness and fitness technology and applications as well as ways to track their own medical records and data. It is apparent that when consumers "pull" these solutions, greater adoption occurs than when they are "pushed" by technology companies and healthcare enterprises.

The market for wearable devices has dramatically grown to $23 billion in 2018 and is predicted to reach $53 billion in 2023 before the growth rate flattens.[v] These are very sizable and have "blown past" analyst estimates. A number of factors are driving the growth of wearables as well as their prominent role in filling gaps in healthcare. Wearables are often the consumers' first step in tracking and owning their personal health information. Health care is moving towards a delivery model that is patient-centered and value-based. Mobile technologies can facilitate the shift in the relationship between clinicians, payers, life sciences companies and patients that will be required to implement this new model. Improvement opportunities exist along the value chain, from engaging patients to maximizing provider productivity to controlling costs.[vi]

One of the most dramatic and recent applications of wearable technology is illustrated by the Apple Heart Study. It started with a large scale clinical trial: 400,000 patients at Stanford and Duke, using Apple Watch 4. The study performed tracking heart rhythms in real time, to enhance diagnosis and identification of atrial fibrillation. FDA recommends the Apple Watch only for healthy patients interested in monitoring heart activity, but does not recommend use of these devices to track activity in those diagnosed with arrhythmias, such as atrial fibrillation patients.[vii] This is one of the largest clinical trials ever performed.

Wearables are not just worn on the wrist; they are being employed across multiple locations of the body, including:

- Head
- Eyes
- Arms
- Legs and feet
- Ears
- Body (torso)
- Wrist
- And others

Figure 4.[viii]

Opportunities for Tech+Biotech+Medtech to transform healthcare

"Connected Care" is a term for a comprehensive set of technologies employed to enhance a healthcare system. It can help sustain the health of an aging and mobile population. A young business technology consultant,
Rendy Satria Dalimunthe, from Indonesia summed it up:

> "Connected care enables information sharing between all parts of the health system. On the very lowest level, this involves a smart watch or mobile application that tracks a person's key health indicators such as heartbeat, nutrition, calories burned, or even sleep routine. On a higher level, this data is collected, analyzed and interpreted by sophisticated algorithms, so that whenever abnormal health results — even the slightest ones — are detected, the app can quickly alert the person while at the same time sending a notification to a doctor or hospital for further follow-up." [ix]

In order to achieve Connected Health, technology capabilities must come to together in appropriate manner that provides the capabilities for such a fundamental transformation of healthcare. This condition will not just "appear" but requires a number of structural changes to be present in order for this degree of change to occur that encompass not only physical changes but also attitudinal shifts. In a recent report by the Deloitte Center for Health Solutions, an effective Connected Health ecosystem is built with four frameworks:

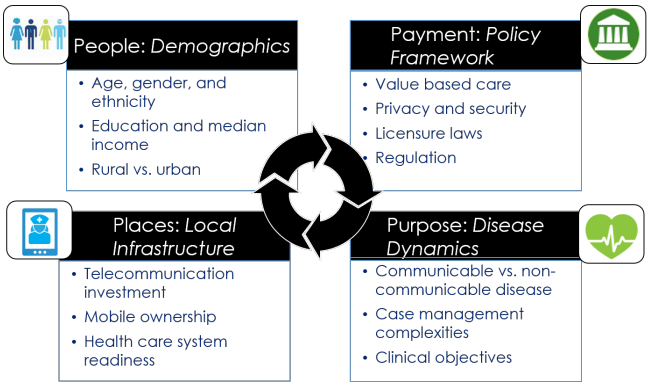

Figure 5.[x]

As in other applications of technology, it is essential to have a foundation, or infrastructure, on which the key technologies can be applied. The technology infrastructure for Digital Health includes many components that are advancing in fits and starts. Some of the key elements of that infrastructure include:

- Cloud Computing
- Health & Fitness Apps (260,000)
- Real World Data Acquisition
- Big Data Analytics
- Artificial Intelligence and Deep Learning
- Bitcoin and Blockchain
- Advanced Sensors
- Implantable Membranes
- 3D Printing
- Digital Therapeutics
- Multi-organ "Human on a Chip"
- Cultural & Leadership Transformation

With that emerging basis, the most compelling applications are in the following areas:

- Consumer and Patient Applications: Wearable Technology
- Computational Biology
- Gene Sequencing
- Companion Diagnostics
- Telemedicine
- Artificial Intelligence in Radiology
- Electronic Health Records
- Robotic Surgery
- Continuous Monitoring

These technologies and applications are having profound effects on healthcare, and they are driving change in fundamentally different ways. In classical observation of the role of technology, Clay Christensen and other researchers have observed the following modes of innovation and technology:

Sustaining Technology. Technology that involves improving a product that has an established role in the market.

Enabling Technology. Equipment and/or methodology that, alone or in combination with associated technologies, provides the means to generate giant leaps in performance and capabilities of the user.

Disruptive Technology. In business theory, a disruptive innovation is an innovation that creates a new market and value network and eventually disrupts an existing market and value network, displacing established market-leading firms, products, and alliances. Disruptive innovations originate in low-end or new-market (or hybrid) footholds and they don't catch on with mainstream customers until quality catches up to their standards.[xi]

In summary, the opportunities for technology to impact human health are immense. As the technology infrastructure comes into place, with an emphasis on the twelve key elements, Digital Health technology and applications can and will change the practice of healthcare. The ways in which technology will fill these gaps in healthcare will, in many cases, be disruptive and transformational. The combination of wearable and implantable devices, software and social networking, and healthcare represent an opportunity for the industries of Technology, Biotechnology, and Medical Technology (Tech+Biotech+Medtech) to transform human health.

[i] United Nations Department of Economic and Social Affairs. 2017.

[ii] William A. Haseltine, Professor at Harvard Medical School and Harvard School of Public Health, Forbes 2019.

[iii] Project Syndicate. https://www.project-syndicate.org/onpoint/the-myth-of-the-aging-society-by-andrew-scott-2018-05?barrier=accesspaylog 2018.

[iv] U.S. Census Bureau 2014: International Data Base. U.S. population projections..

[v] GlobalData 8/2018.

[vi] GlobalData 8/2018.

[vii] Stanford Medicine: https://med.stanford.edu/news/all-news/2018/11/stanford-apple-describe-heart-study-with-over-400000-participants.html

[viii] Inspired by IDTechEx 2018 http://ow.ly/QCYd306WF7u

[ix] Rendy Satria Dalimunthe, Connected care and aging population. The Jakarta Post, October 18, 2016.

[x] Deloitte Center for Health Solutions report, Accelerating the adoption of connected health 2016.

[xi] Clayton M. Christensen, Michael E. Raynor, and Rory McDonald. What Is Disruptive Innovation? Harvard Business Review 2015. and http://www.businessdictionary.com/definition/enabling-technology.html