

INTEGRATING BIOMEDICINE AND
TECHNOLOGY TO ENABLE PERSONALIZED
HEALTHCARE: CATALYZED BY THE
BEYOND THE HUMAN GENOME (BHG)
PROJECT

Leroy Hood, MD, PhD

Chief Executive Officer, Phenome Health, Seattle

Professor, Institute for Systems Biology, Seattle

“The Future of Biomedicine: Translating Biomedical Research into Personalized Healthcare.” - Subcommittee hearing3

Vision3

P4 Healthcare 3

Mission5

Define Genome and Phenome 5

A 2nd HUMAN genome project—Beyond the Human Genome Project 5

Value Proposition6

Proof of principle PROJECTS7

The Science of Wellness, Prevention, & Healthy Aging 7

Brain Health 8

Implementation of the Beyond the Human Genome Project8

Differentiators from other large-scale precision medicine programs10

Coda11

Appendix11

Glossary12

Speaker Short Bio13

“THE FUTURE OF BIOMEDICINE: TRANSLATING BIOMEDICAL RESEARCH INTO PERSONALIZED HEALTHCARE.” - SUBCOMMITTEE HEARING

I am Dr. Leroy Hood, a member of the US National Academies of Science, Medicine and Engineering, and the CEO of Phenome Health – an organization with the mission to invent the science of wellness and prevention. In this document, I am testifying that we and other biomedical researchers have carried out extensive data-driven population health translational research studies over the past ten years that have provided powerful new approaches to the science of wellness and prevention for individual humans. The science of wellness and prevention *will usher in the data-driven ability to assess and optimize each individual's health trajectory, leading to a P4 medicine that is predictive, preventive, personalized, and participatory*. In my testimony I will discuss this vision, our mission, its scientific validation, how we are going to create the necessary infrastructure for extending this vision to all individuals and what is unique about our approach. Our team, the non-profit Phenome Health, is pioneering P4 healthcare by promoting and designing a precision population health program (lots of measurements on lots of individuals and returning clinical opportunities to the individual) termed Beyond the Human Genome (BHG). This approach will form the basis for the most profound paradigm change medicine ever—leading to the optimization of wellness and prevention for each individual throughout their lives.

VISION

Health is perhaps the most fundamental component of a fulfilled life, for it assures that we can enjoy learning, working productively, interacting with each other, and passionately pursuing our other interests. Today, biomedical research and healthcare are at a tipping point—technological advances, coupled with the social and financial pressures of healthcare, are transforming the health needs of Americans. Wellness, prevention, early disease detection, and healthy aging are becoming health priorities for many Americans and healthcare experts. It is necessary to accelerate this much-needed paradigm shift in biomedicine from disease-focused to wellness-focused research and practice by integrating novel forms of biomedical research and technology. The proposal I will discuss—Beyond the Human Genome—is formulated to lead that paradigm shift.

All healthcare stakeholders aspire to improve health outcomes at the level of the individual and offer personalized care experiences. Yet translating cutting-edge biomedical research into actionable knowledge in the clinic often takes decades. To accelerate this discovery and implementation, we must build a huge compendium of data-driven knowledge and the innovation engine that will emerge from these insights. This data ecosystem will provide insights and tools to researchers, patients, and physicians alike. This program, as described below, is committed to diversity, equity and inclusion. This data-driven, AI-informed, and disease-agnostic engine will serve diverse populations and generate health information to allow all individuals to participate in their effective healthcare—regardless of economic stature and racial origins.

P4 HEALTHCARE

In 2000, I started the Institute for Systems Biology (ISB) to pioneer a new approach to biological sciences rooted in systems thinking that is holistic, global, comprehensive, and integrative. Applying systems thinking to healthcare led to the concept that healthcare should be *Predictive, Preventive, Personalized, and*

Participatory—which I termed *P4 Medicine, as described above*. The first three Ps focus on the science of wellness and prevention and embrace a precision medicine approach to deal with disease. This science has powerful leads from the precision population health studies we have already done. The fourth P, Participatory, is the most difficult. The challenge is to persuade patients, physicians, and the entire spectrum of healthcare stakeholders to embrace wellness, early detection, and active participation in both research and care. Our proposal includes a plan to achieve this by placing actionable knowledge and tools in the hands of all stakeholders through proper education programs.

The current health trajectory for each individual can move from wellness to early disease (pre-diagnosis) to mature disease (post-diagnosis) to treatment approaches often with limited efficacy that generally address just the disease symptoms and not their root causes. We envision a different paradigm focusing on maintaining wellness and identifying the earliest detectable wellness-to-disease transitions (early diagnosis) using cutting-edge, high-throughput, data-driven technologies (measurement and computational). The ultimate deliverable is developing early intervention strategies that allow care teams to deal with diseases before they become irreversible and too complex to treat. Figure 1 captures this vision of optimizing wellness and detecting and reversing disease transitions. This P4 medicine will allow each individual to lead their entire life in wellness and move into their 90s or 100s mentally alert and physically capable. Once incorporated into standard clinical practice, this vision can democratize these resources and allow all Americans to maximize their healthy lifespans (termed healthspans—we seek to make individual lifespans and healthspans identical and long). The need to support a healthy aging population will lead to striking social changes in how we think about learning, employment, retirement, maintaining an appropriate sense of community, and the potential use of multiple extra decades of satisfying and productive life as is described beautifully in the book “The 100-Year Life” by Lynda Gratton and Andrew Scott. Accordingly, this proposal will catalyze parallel social changes in response to a healthspan extending into the 90s or 100s through these transformative healthcare changes.

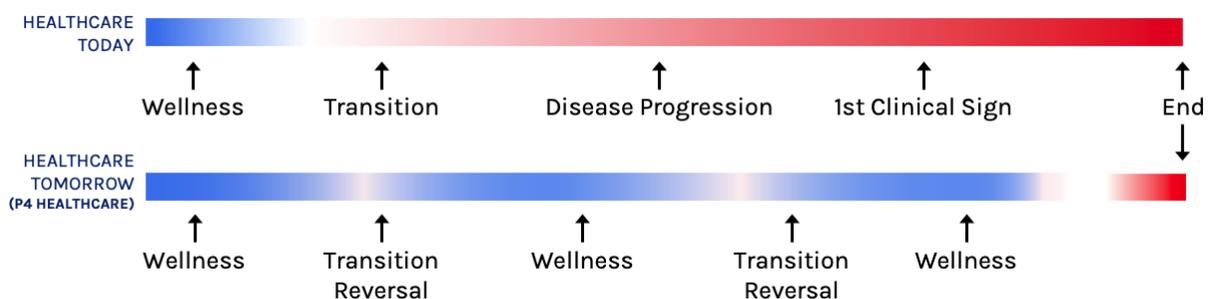


Fig. 1. Early detection of wellness-to-disease transitions enables the potential for their reversal before the emergence of clinical disease. In this manner one can optimize wellness and through the early detection and reversal of transitions avoid disease.

MISSION

We can accomplish this vision by engaging one million diverse individuals over a decade to participate in a P4 research and care program: a *precision population health* program. We will optimize wellness and healthy aging using genome and deep, longitudinal *phenome* analyses while discovering appropriate signals for early disease detection and therapies for their early reversal. To the best of our knowledge, there is no large-scale, federal-funded precision population program that adopts the data-driven approach of deep, longitudinal phenomes of Beyond the Human Genome.

DEFINE GENOME AND PHENOME

The *genome* is the sequence that constitutes an individual's genetic code—four DNA bases organized into 23 pairs of chromosomes, collectively with 3 billion bases. It is static and unchanging and provides valuable information for our lifetime risk for diseases. Yet, your genome is not your destiny, and it alone cannot inform what will happen to our health next year or in five years.

The *phenome* is dynamic and continually changes—it represents the state of an individual at any point in time as an integration of his or her unique genome, lifestyle, and environment. It is the most valuable complementary dimension of health beyond the genome, as a measure of current health status and predictor of future disease trajectories. The phenome can be measured at a given point in time by quantifying thousands of blood components, the composition and activity of microbes in the gut microbiome, digital health measurements (physical activity, quality of sleep, heart rate, etc.), cognitive assessments, dietary intake, environmental exposures, and more. Thus, *longitudinal phenome measurements are what lie beyond the human genome with far greater potential for advancing medical knowledge.*

A 2ND HUMAN GENOME PROJECT—BEYOND THE HUMAN GENOME PROJECT

The first human genome project (HGP) took 13 years to produce one genome at an estimated cost of USD 1 billion. The HGP provided a reference genome sequence for the human species and enabled human wellness and disease studies. Ten years after its completion, this federal research investment was assessed by Battelle Corp and found to have contributed to medical science, improved public health, created American jobs, and generated nearly 1 trillion USD in economic impact. The HGP had a return of USD 80 billion from an initial investment of USD 3 billion¹.

We believe that similar federal research investment is essential to generate through Beyond the Human Genome a far more significant growth impact in medical research, practice, and return on investment. We believe that the government should support the funding for Beyond the Human Genome (BHG) Project that aims to collect, organize, and share genomes and longitudinal phenomes from one million Americans over ten years in a secure and privacy-preserving cloud environment (Figure 2).

¹ <https://www.genome.gov/27544383/calculating-the-economic-impact-of-the-human-genome-project>

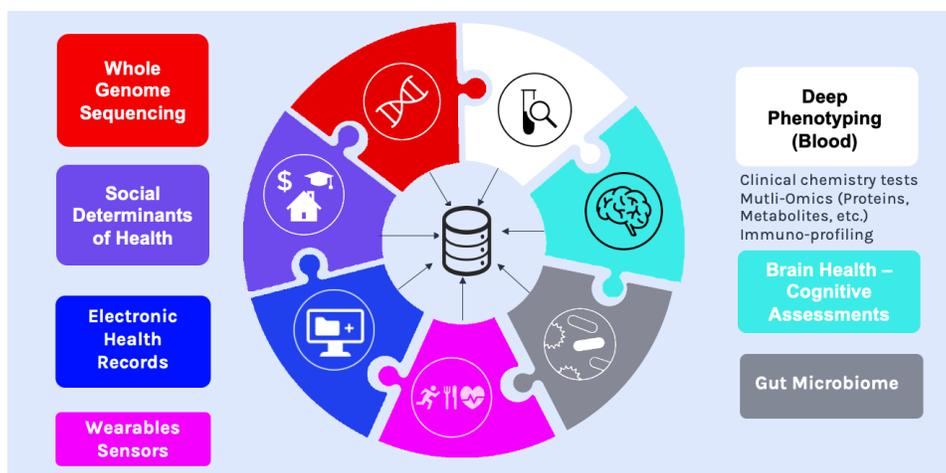


Fig. 2. Genome and deep, longitudinal phenome data comprehensively capture multiple dimensions of human health and wellness throughout ones' life.

VALUE PROPOSITION

Supporting this project, the US will continue to cement its world leadership role in biomedical research, precision population health, medicine, and technology with enormous scientific, healthcare, and economic opportunities. More specifically, the BHG Project will:

1. Catalyze the development of phenomic technologies. The HGP supported and grew an ecosystem of biotech companies that decreased the cost of DNA sequencing a million-fold. Similarly, we believe that the BHG Project will develop automated, scalable, inexpensive, and high-quality technologies for phenomic measurements, and in some cases, discover new approaches to measure human physiology.
2. Accelerate biomedical research with a scalable, open platform for deep longitudinal biomedical datasets. There are federal and commercial cloud-based platforms for biomedical research; however, none support large-scale longitudinal phenomic data processes, such as storage, analysis, or integration with clinical data. Therefore, we believe the BHG project will catalyze the development of community-approved policy and technical standards to enable responsible genomic and phenomic data sharing within a participant-driven privacy framework. Setting the standards of new data types gives one enormous advantages in world leadership in this area.
3. Create a discovery and innovation engine for P4 Medicine. The BHG Project will enable the paradigm shift toward new care models (value-based, prediction, prevention, healthy aging, and early detection) and stimulate research and development activities that will provide solutions for early disease transitions. These new models will be rooted in the principles of P4 Medicine to focus on the reversal of wellness-to-disease transitions for most chronic diseases and promote healthy aging.
4. Address inequality in research and care. The BHG Project will engage racially diverse and economically disadvantaged groups according to their general distribution in the US population to ensure the generated datasets and insights are representative of all Americans. We will deploy research-driven insights and actionable possibilities for care and R&D nationally and globally via healthcare initiatives throughout the country. Creating data that covers diversity, equity and

inclusion is a critical aspect of this program – this will also address racial biases in life science and healthcare algorithms, including AI.

5. Support a precision population health ecosystem. The infrastructure and data resulting from the BHG Project will bring together an ecosystem of academic and industry partners to design and develop P4 research and care products. Such an ecosystem will be well-positioned to address the many needs of precision population health.

We have presented the vision of the Beyond the Human Genome Project to scientific, medical, and computational leaders at DOE, VA, and NIH (All of Us and NHGRI). All have indicated an interest in exploring collaborations when the project starts.

PROOF OF PRINCIPLE PROJECTS

THE SCIENCE OF WELLNESS, PREVENTION, & HEALTHY AGING

Over the past decade, my colleagues and I have built the technology and know-how to collect genome and longitudinal phenome data from thousands of individuals. Through this early experiment, following 5,000 people up to 5+ years in a personalized wellness program, we were able to demonstrate the power of a data-driven approach for improving health:

1. **Identify wellness-to-disease transitions and putative biomarkers for early detection.** In these *5000 individuals*, we detected *167 transitions* to major chronic diseases—including cancer (20%). Analyzing the blood measurements before and after clinical diagnoses, we identified blood proteins that marked each individual transition up to 5 years before the clinical diagnoses. These data suggest that we can detect disease transition in the blood, years before it manifests clinically and in the future we will be able to intervene and reverse it at this early point, avoiding complex disease progression.
2. **Deliver actionable knowledge for personalized wellness.** We identified thousands of statistical correlations among different data types, and more than 200 of these led to insights from the clinical literature that were termed “actionable possibilities” for wellness. Each individual had a distinct list of actionable possibilities specified by the interactions of their genome, lifestyle and environment that were relevant to them. Individuals who acted upon their relevant actionable possibilities improved their wellness or helped avoid/delay disease onset. With the BHG project, we estimate that there will be 10,000 or more new actionable possibilities both for wellness and disease and that it will be necessary to deliver these by AI to physicians and their patients.
3. **Develop new tools for (i) healthy aging and (ii) disease genetic risk.** (i) Since the 5000 individuals ranged in age from 21 to 93, we could show that there is a linear loss in the ability to control the expression levels of blood proteins and metabolites. We developed an algorithm from these data that determines the “biological age” of an individual, reflecting the integrations of one’s genome, lifestyle, and environment. We were able to demonstrate that our personalized wellness program helped individuals lose up to 1.5 years of biological age for each year they were engaged in the program. The algorithm provides insights into how each individual can best improve his or her healthy aging still further. Since aging is the biggest risk for chronic diseases, slowing aging will greatly extend each individual’s wellness trajectory. Healthy aging is one key to wellness. (ii) From the complete genome

sequence of an individual and 54 different disease-related polygenic scores, we calculated the genetic risk each individual has for each of these 54 diseases. We studied the genetic risk for LDL cholesterol (a proxy for heart disease) and demonstrated that individuals' at high risk for this feature with high LDL cholesterol could only decrease the LDL levels with chemicals such as statins, whereas those with low risk but high LDL cholesterol could effectively bring it down with diet and exercise. Thus we must treat high and low risk individuals differently. We believe this will be true of most of the 54 diseases we have examined—and many others we will unveil over the life of the BHG project. Moreover, we can follow high risk individuals closely and attempt to treat their transition to disease at an early stage when it is easier to reverse the course of disease.

4. **Explore new biomedical frontiers.** We were able to show that the gut microbiome plays a major role in healthy aging, and hence may be modified to facilitate healthy aging in most individuals. Our studies and others further showed that the gut microbiome plays a major role in metabolizing prescription drugs, leading to heterogeneity in drug response and undesirable side-effects. The manipulation of the gut microbiome may lead to an optimal therapeutic effect while minimizing adverse side effects.

These results have led us to define the science of wellness (scientific wellness and healthy aging) and the science of prevention (genetic risks and early reversal of wellness-to-disease transitions). These results are documented in peer-review papers published in major scientific journals (Appendix).

BRAIN HEALTH

It is not just the body but also the brain which must be healthy. Prof. Mike Merzenich, an outstanding neurophysiologist, has pioneered the idea of brain health and plasticity throughout life, and the assessment and management of brain health through digital measurements of 40 different types that assess 25 different cognitive features (e.g., reaction time, peripheral field vision and memory). He demonstrated that on average a person's cognitive abilities increase to a maximum at 35 years of age and thereafter, for most of us, decline throughout the rest of our lives. In a clinical trial with ten 80-year old individuals, Prof. Merzenich was able to demonstrate that with brain training, they could be brought back to the cognitive capacities they should have had in their mid-30s. Thus, the brain is plastic through life and many of us have the potential to largely retain our optimal cognitive functions with digitally-driven brain practice. Dr. Merzenich started the company Posit to deliver brain health to individuals. He has carried out more than 250 successful clinical trials with more than 10,000 individuals to demonstrate the effectiveness of his cognitive training approach to brain health in dealing with health optimization for cognitively normal individuals and in dealing with certain brain diseases. Posit is a partner of the BHG Project in facilitating brain health and the delivery of brain cognition actionable possibilities to patients.

IMPLEMENTATION OF THE BEYOND THE HUMAN GENOME PROJECT

Toward launching and delivering BHG, we seek appropriate government funding and partners with unique know-how and accomplishments. Phenome Health has an advisory council from outstanding experts in business, life sciences, healthcare and computer science (Figure 3), who share the same vision with us and act as invaluable strategic counselors.



Fig. 3. Phenome Health's Advisory Council

Currently, in collaboration with six organizations, Phenome Health is discussing building our infrastructure to execute the vision discussed above.

- **Guardian Research Network (GRN)**² is a non-profit organization currently associated with 100 hospitals and 30 million patients in 13 different states in the South and Southeast. We will use their clinical research and data services to mine electronic health records (EHRs) of all patients and recruit participants at-scale for prospective clinical research in a data driven manner. GRN offers the opportunity to recruit participants that reflect the racial diversity of our country (i.e., Black and Hispanic communities) and live in urban and rural communities visiting the same physicians and hospitals throughout their lifetimes. GRN also includes economically disadvantaged individuals. We continue to look for other partners around the United States who can partner with us in a similar manner. For instance, we are currently negotiating for partnerships with healthcare systems in the West and Midwest to insure access to a geographical and social diversity of patients.
- The **Institute for Systems Biology (ISB)**³ is a non-profit biomedical research organization pioneering in multi-omics and systems thinking. ISB's Faculty and their groups will bring technological, computational, biological and medical expertise to this program. ISB has led numerous large-scale scientific efforts and multi-institutional collaborations across academia, commercial industry, and government. In particular, ISB is leading or has led the data integration efforts for large-scale NIH projects such as the Longevity Consortium, the Accelerating Medicine's Program for Alzheimer's Disease (AMP-AD), NCI's TCGA (The Cancer Genomics Atlas) and the National Center for Advancing Translational Sciences (NCATS)'s Translator, generating a wealth of computational tools that can be brought to bear for this initiative.

² <https://www.guardianresearch.org/>

³ <https://isbscience.org/>

- **Bioanalytica** is a company spun out of ISB that will generate pipelines for generation and harmonization of the genomic and phenomic data that we will produce from each patient.
- **Posit Science**⁴, a company funded by Dr. Merzenich, offers brain health services. Posit's BrainHQ brain-training program represents the culmination of 30 years of research in neurological science and related medicine. We work together to design a unique digital experience that will engage and assess the brain health of our participants.

We have chosen to work initially with two key technology providers, Deloitte for labor and services, and Google for our technology platform. We believe these providers have critical, differentiated capabilities as described below.

- **Deloitte**, a company with a strong reputation in innovation consulting and consortia management. Today, they help us to engage and recruit partners across the spectrum of healthcare stakeholders with a similar vision for the future of health. They will offer project management services, securing the timely and efficient execution of this project. They will also offer change management and consulting services to the BHG partners and vendors.
- **Google**, a cloud and AI tech leader, will offer services and talent for developing innovative solutions around data security, governance, privacy, computation, search, and storage. Cloud Life Sciences (formerly Google Genomics) enables the life sciences community to process biomedical data at scale. At the same time, Google Cloud offers a variety of partnerships with Cloud Life Sciences and Healthcare expertise, enabling our mission to build an open, interoperable platform adopted by a larger community of researchers. Finally, Google and its affiliates (DeepMind) pioneers in hyperscale AI, publish regularly in academic journals, and release projects as open source, facilitating technology and product development.

DIFFERENTIATORS FROM OTHER LARGE-SCALE PRECISION MEDICINE PROGRAMS

Similar to other national and international initiatives (such as the NIH's All of Us and UK Biobank), BHG generates the data ecosystem to revolutionize our understanding of medicine and precision population health. All programs aim to stratify the most expensive chronic diseases into refined subtypes, each of which will require distinct therapeutic approaches, while all hold the potential to transform drug discovery and development. However, BHG has several unique features in its mission to:

- Create a huge, harmonized data ecosystem for the longitudinal phenomic information from one million diverse patients, allowing the analysis and integration of genome, phenome, EHRs, determinants of health and outcomes data
- Carry out longitudinal phenome analyses for body, brain and microbiome health to discover and evaluate new actionable recommendations for wellness, prevention, and healthy aging - care for body and brain
- Engage participants and their providers by returning 1000s of new actionable possibilities through AI

⁴ <https://www.brainhq.com/>

- Develop AI tools that will accelerate new medical knowledge uptake
- Develop clinical research approaches and data resources that are disease-agnostic
- Develop the infrastructure that will enable this program eventually to be extended to diverse American healthcare systems and their patients. The infrastructural requirements are the open data ecosystem, a biobank of samples from all patients over time, the computational platforms necessary for generating, storing, harmonizing, standardizing, analyzing and integrating data, the identification and delivery actionable possibilities to physicians and patients, the computational platforms for the education of patients and physicians, the computational tools for giving academic and industrial partners access to the data ecosystem and the accelerator/incubator that will transfer this new knowledge to society
- Initiate international collaborations with colleagues in the UK, EU and Asia for future partnership on the longitudinal phenomic analysis for health and to be able to compare diverse racial populations
- Include multidisciplinary teams across scientific, federal and industry domains, and partnerships to discover new medical knowledge from many different viewpoints
- Create an accelerator/incubator for spinning out companies and intellectual property to society in an equitable way
- Provide the US with a world leadership in the science, technology and delivery of a healthcare driven by the science of wellness and prevention

We feel that Beyond the Human Genome is aligned with the Advanced Research Projects Agency for Health (ARPA-H) proposed by President Biden and captured in legislation introduced by Chairwoman Eshoo. ARPA-H would be managed independently, as has the Department of Defense's DARPA program. Inspired by a similar philosophy—build high-risk, high-reward capabilities (or platforms) to drive biomedical breakthroughs, we strongly support this transformational initiative and hope it will be one path forward for federal funding.

CODA

The Beyond the Human Genome project will catalyze a fundamental change in healthcare with a focus on extending the science of wellness and prevention and bringing the resulting new actionable possibilities to patients and their physicians. It will ensure diversity, equity and inclusion through its analysis of diverse patient populations. Its data ecosystem will generate new knowledge that Phenome Health and its partners will be able to bring to society—creating new companies, jobs, and intellectual property for licensing. It will ensure healthy aging for Americans of all races and backgrounds, from both physical and mental perspectives. Health is the foundation of happiness and enjoying learning, jobs and interactions with others. It will also catalyze some fundamental changes in the human cultural and sociological attitudes.

APPENDIX

Peer-reviewed published papers on the science of wellness and prevention and on powerful new approaches to disease (COVID 19 and deep immune phenotyping)

1. **A wellness study of 108 individuals using personal, dense, dynamic data clouds.** Price ND et al. *Nat Biotechnol.* 2017 Aug;35(8)^[1]_{SEP}

2. **Multi-Omic Biological Age Estimation and Its Correlation With Wellness and Disease Phenotypes: A Longitudinal Study of 3,558 Individuals.** Earls JC et al. *J Gerontol A Biol Sci Med Sci.* 2019 Nov 13;74^[SEP]
3. **Genetic Predisposition Impacts Clinical Changes in a Lifestyle Coaching Program** Zubair et al. *Scientific Reports* 2019; vol. 9, number: 6805^[SEP]
4. **Blood Is a Window into Health and Disease.** Yurkovich JT and Hood L. *Clin Chem.* 2019 Oct;65(10)^[SEP]
5. **Blood metabolome predicts gut microbiome α -diversity in humans.** Wilmanski et al. *Nat Biotechnol.* 2019 Oct;37(10)^[SEP]
6. **Multi-Omics Resolves a Sharp Disease-State Shift between Mild and Moderate COVID-19.** Su Y et al. *Cell.* 2020 Dec 10;183(6)^[SEP]
7. **Deep phenotyping during pregnancy for predictive and preventive medicine.** Paquette AG et al. *Sci Transl Med.* 2020 Jan 22^[SEP]
8. **A systems approach to clinical oncology uses deep phenotyping to deliver personalized care.** Yurkovich JT et al. *Nat Rev Clin Oncol.* 2020 Mar;17(3) ^[SEP]
9. **Multiomomic blood correlates of genetic risk identify presymptomatic disease alterations.** Wainberg M et al. *Proc Natl Acad Sci U S A.* 2020 Sep 1 ^[SEP]
10. **Longitudinal analysis reveals transition barriers between dominant ecological states in the gut microbiome.** Levy R et al. *Proc Natl Acad Sci U S A.* 2020 Jun 16;117(24) ^[SEP]
11. **Untargeted longitudinal analysis of a wellness cohort identifies markers of metastatic cancer years prior to diagnosis.** Magis AT et al. *Sci Rep.* 2020 Oct 1;10(1) ^[SEP]
12. **Gut microbiome pattern reflects healthy ageing and predicts survival in humans.** Wilmanski T et al. *Nat Metab.* 2021 Feb;3(2)^[SEP]
13. **Integrated analysis of plasma and single immune cells uncovers metabolic changes in individuals with COVID-19.** Lee JW et al. *Nat Biotechnol.* 2021 Sep 6^[SEP]
14. **Personal Dense Dynamic Data Clouds Connect Systems Bio-Medicine to Scientific Wellness** Omen, GS et al. *Systems Medicine* 2021 Chapter 17

GLOSSARY

P4 Medicine	The term P4 medicine (predictive, preventative, personalized, participatory) was coined by Dr. Leroy Hood of the Institute for Systems Biology to demonstrate his framework to detect and prevent disease through extensive biomarker testing, close monitoring, deep statistical analysis, and patient health coaching.
Precision Population Health	A new medical frontier that advances Population Health through Precision Medicine by 1. integrating social, environmental, and behavioral determinants of health with other “-omics” measures for both new scientific discovery and better targeted interventions, 2. increasing representation of diverse populations in both participation in research studies as well as in the receipt of precision medicine therapies.

Scientific Wellness	A new medical frontier to describe our ability to practice 21st Century healthcare that will focus on improving wellness for the individual, creating medicine that is preventive, personalized and participatory. Scientific wellness aims to improve health and prevent disease by combining personalized behavior coaching with DNA, blood testing, activity tracking, and other health and life measures. The foundation of scientific well are the 1000s of actionable possibilities that will arise from analyzing the BHG data against the entire world's medical literature.
Deep Phenotyping	A biomedical research approach of integrating genomic data with human phenotypic data, such as clinical, physiological, multi-omic, behavioral, and imaging data. Deep and accurate phenotyping enables using a smaller subset of patients to derive clinically meaningful and translational insights on disease etiology.

SPEAKER SHORT BIO

Dr. Hood received an MD from Johns Hopkins Medical School and a PhD from Caltech. He was a professor in biology at Caltech for 22 years and chair for 10 years, the founder and chairman of the first cross-disciplinary biology department of molecular biotechnology at the university of Washington Medical School for 8 years, and a co-founder and president for 18 years of the Institute for Systems Biology (ISB)—the first systems biology institution. He is in the US National Academies of Science, Medicine and Engineering—one of only 15 to be so honored. He and his co-workers invented the automated DNA sequencer that made the human genome sequence possible and 5 other instruments that serve collectively as the technological foundations of contemporary biology and molecular biology. Hood has published more than 900 papers, has 36 patents and 18 honorary degrees from leading institutions all over the world. He has published text books on biochemistry, immunology, molecular immunology, genetics and has just finished a text on systems biology. Dr. Hood is writing a book on 21st century medicine with Nathan Price, his long-time collaborator. He has won many national and international awards including the Lasker award, the Kyoto prize and the National Medal of Science. Dr. Hood has co-founded 17 biotech companies including AMGEN, Applied Biosystems, Rosetta and Arivale.