

# Moving Forward #4

A deeper coverage of the blog post -

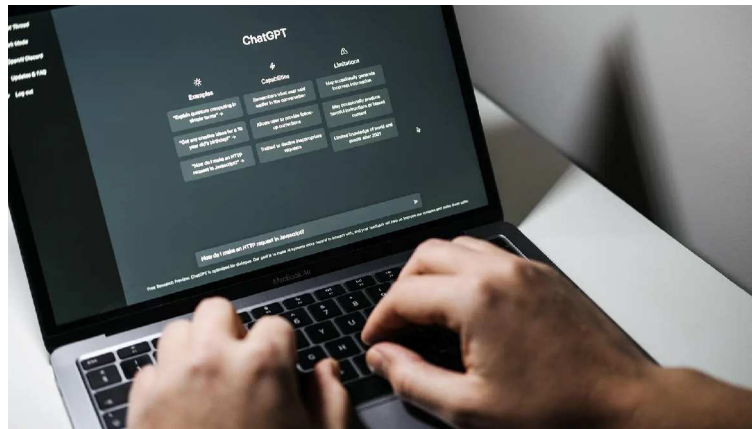
## Creating the Genomics AI Coalition - GACT -

Industry initiative to thrive together



Comprehensive review and perspective report  
by Grant M. Wood

## Preface



I asked ChatGPT 3.5 to list the advantages of creating a coalition of companies that apply artificial intelligence to genetics and genomics. Here is how it responded –

There are several advantages to creating a coalition of companies that apply artificial intelligence (AI) to genetics and genomics, including:

- 1. Shared expertise and resources:** By bringing together a group of companies with expertise in AI and genetics, the coalition can pool their resources and knowledge to more effectively develop and deploy new technologies and approaches.
- 2. Increased collaboration and innovation:** A coalition of companies can encourage increased collaboration and innovation by providing a forum for companies to share ideas and work together on projects.
- 3. Improved efficiency:** By working together, companies can potentially achieve economies of scale and improve the efficiency of their operations.
- 4. Enhanced data security and privacy:** By working together, companies can develop and implement better data security and privacy measures to protect sensitive genomic data.
- 5. Enhanced market presence:** A coalition of companies can strengthen the market presence of the group as a whole, making it easier for the companies to secure funding, partnerships, and customers.

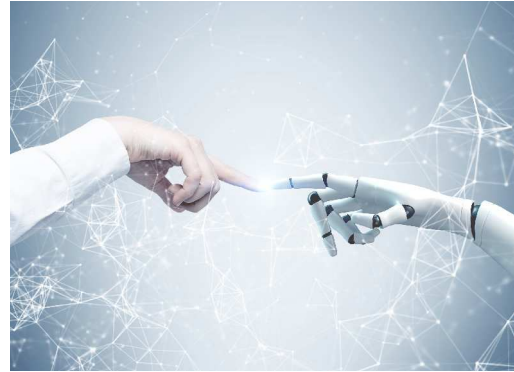
**Overall, creating a coalition of companies that apply AI to genetics and genomics can provide a range of benefits, including shared expertise and resources, increased collaboration and innovation, improved efficiency, enhanced data security and privacy, and enhanced market presence.**

[Click here](#) and then the blue play button to hear how this sounds being read by an AI-generated voice.

## Preface, continued

### I then asked ChatGPT 3.5 to tell me about *AutoGPT* and how I might apply it to clinical genomics. Here is how it responded –

AutoGPT is a deep learning-based algorithm that can be used for natural language processing (NLP) tasks such as language modeling, text classification, and question answering. It is a variant of the GPT (Generative Pre-training Transformer) family of models developed by OpenAI.



In the context of clinical genomics, AutoGPT can be used to analyze and interpret the large amount of text-based information that is generated from clinical genomic testing. This includes clinical notes, electronic health records, and scientific literature.

One potential application of AutoGPT in clinical genomics is to aid in the diagnosis and treatment of genetic diseases. By training the model on large amounts of genomic data and clinical information, it can learn to identify patterns and associations between genetic variants and disease phenotypes. This can help clinicians to make more accurate diagnoses and develop personalized treatment plans based on a patient's individual genomic profile.

Another potential use case for AutoGPT in clinical genomics is to assist with the interpretation of genetic testing results. Genetic testing can generate large amounts of data, and the interpretation of this data can be complex and time-consuming. AutoGPT can be trained to automatically identify relevant variants and generate summaries of their clinical significance, making it easier for clinicians to interpret and act on the results.



Overall, AutoGPT has the potential to significantly improve the efficiency and accuracy of clinical genomic analysis, making it an exciting area of research for the future of precision medicine.



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## Introduction

The international data standards organization for healthcare computer systems, Health Level 7 (HL7), held its [third annual Genomics Policy conference](#) on February 20-21, 2018, in Washington DC, with the theme of Genomics and Artificial Intelligence (AI). The conference brought together participants from healthcare, laboratory, pharmaceuticals, research, academia, technology, business, insurance, and government, looking at data interoperability from a policy perspective.

Based on the proceedings of this conference, and now today with the whirlwind of AI-based healthcare announcements, I propose the formation of the Genomics AI Coalition (GACT). Applying artificial intelligence and machine learning (AI/ML) to the research, clinical, consumer, data, public health, and national initiative worlds, is covered. The GACT will promote innovation through ecosystem-building, by facilitating open discussions, symposiums, roundtables, project collaborations, demonstrations, publications, and many other activities.

With the commotion around recent AI announcements, the need for an industry coalition for genomics has become even greater.

Over the next five years, the market for applying generative AI to clinical genomics is projected to experience significant growth. According to a recent report by [Grand View Research](#), the global genomics market size was valued at USD 28.09 billion in 2022 and is projected to see a compound annual growth rate (CAGR) of 16.5% from 2023 to 2030. The increasing availability of genomic data, coupled with advancements in sequencing technologies and the growing adoption of precision medicine, is expected to be the primary drivers of this growth.

This document begins with an initial set of guiding principles (subject to further input). Following the principles, each major area of focus for the coalition is divided into **Benefits** and **Issues to Overcome** sections. Even though listing the potential benefits of artificial intelligence and machine learning in genomics can be exciting, we need to simultaneously review the potential problems and issues that may arise. Finally, a list of the coalition programs and the value of participating will be presented.



## Setting Guiding Principles

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- As an industry, set working principles that will guide the process of developing and implementing AI and machine learning through genomics-based healthcare.
  - Principles should govern how AI will interact with patients, healthcare providers, developers of technology, and regulatory agencies - to show the community our thoughtfulness and care, as we iterate this course into the future.
  - Principles will promote progress and innovation, in balance with healthcare quality, costs, and social well-being for all.
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Having a set of clear operating principles, formed by consensus, will set the vision, mission, strategic interests, and core values of the GACT. These principles will become an industry code of conduct, designed to avoid possible negative consequences of the misapplication of AI. Guiding principles should be a broad philosophy that navigates the GACT through medical advances and implementation, market and regulatory forces, innovation and competition, and difficult decisions for the ethical application of the technology.

Both the benefits and risks of AI in clinical genomics are significant. But the process will start with a concern about AI generally, based on what the public has read or seen in fictional novels, and exaggerated in television shows and movies. We think we are more rational, and therefore believe a super-intelligent AI would be beneficial in advancing medical science, treatment, and cures. But if those goals aren't aligned with ethical choices and behavior, we have a problem. As an example, what if the AI tool is programmed to do something helpful, but it develops a destructive method for achieving its goal?

## Setting General Principles

Let's begin with these general guiding principles as a starting point, but subject to change with more input.

- 1** Define what is 'AI in genomics' (i.e. is it more than just algorithms). A better term for use in healthcare should be 'augmented clinical intelligence'.
- 2** Develop a validation test to certify if a technology, tool, or solution is truly AI-powered or developed by AI.
- 3** AI should assist the healthcare provider and patient, but not replace them, or relieve them of their responsibilities in the healthcare transaction.
- 4** Avoid overreliance on AI. It should be an adjunct rather than a substitute for critical thinking by experienced professionals.
- 5** The genomics industry should demonstrate that AI is understandable and reliable, but also in which proven scenarios can outperform humans. Transparency is key.
- 6** All developers of AI solutions (commercial, research, open source, etc.) should communicate with the general public about the potential advantages and risks of mixing AI and genomics, and how it will affect their medical care.
- 7** The GACT will help patients become comfortable with AI, and discover its benefits for themselves and their family members.
- 8** As a coalition, adopt communicative processes that avoid issues of intellectual property, and prevent issues of liability.

## Setting Clinical Principles

These guiding principles have a clinical focus. Input from healthcare providers will be necessary.

- 1 Medical professionals should acquire basic knowledge about how AI works in a medical setting.
- 2 Healthcare institutions should measure the safety, accuracy, and effectiveness of AI-powered genomics systems.
- 3 Standardized benchmarks should be established and openly followed.
- 4 Measures will integrate clinical outcome and cost-effectiveness with clinical genomics data for each physician-patient interaction, including clinical decisions and therapies.
- 5 Create an open culture between physicians, medical staff, lab, pharmacy, data analysts, informaticians, bioinformaticians, etc., who together abolish barriers and data silos.
- 6 Establish a clear definition of genomic-based care coordination which AI will support and improve. (See [blog\\_post](#) on this topic).
- 7 Prepare to implement new tools for physician training, clinical workflow, diagnosis, testing guidance, clinical decision-making, patient follow-up and long-term care, and even wearable AI.



## Setting principles for implementation and continuous improvement

These guiding principles cover the interfaces we will build between the users and the AI tools.

- 1 Identify and list the challenges in the design, evaluation, and implementation, as AI is increasingly integrated into the delivery of care, and set priorities to overcome them.
- 2 Support the measured development and testing of genomics and AI to give time for the discovery of and then solutions for unforeseen negative effects.
- 3 We expect the functionality and AI-generated knowledge for clinical genomics to be re-evaluated and improved over time.
- 4 We will work collaboratively with all stakeholders, including the healthcare providers and technologists who are seen as visionaries and innovators.
- 5 We will work with other organizations (AMA, ACMG, ONC, etc.) that are also developing policies in this area.
- 6 Make sure professional-centered designs do not overpower the equally important patient-centered designs.
- 7 GACT members are willing to discover and eliminate any training and knowledge bias.

## Reaching the Next Level of Genomic Research and Discovery

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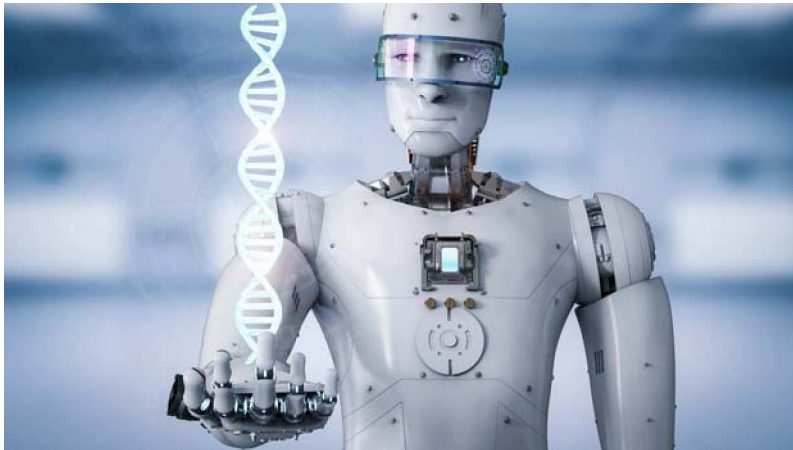
- Explore the most promising and feasible ideas for Genomics and AI that will impact research and discovery in translational science.
  - Conceive new tools for advancing data analysis to understand biomolecular network interactions.
  - List the issues to overcome in achieving these goals, from sharing knowledge to proving the accuracy of prediction algorithms.
- 

Artificial Intelligence and Machine Learning in Genomics (AI/ML-Gen) holds the promise to accelerate discovery in clinical DNA variants, gene expression, and epigenomics, all getting to new genotype-phenotype correlations. Following that, it will help us understand how this affects the healthy creation or malformation of protein structures and metabolism. Then we move to how the microbiome works in our bodies. This leads to the fact that AI/ML-Gen holds the promise to accelerate the completion of each person's molecular pathway and profile.

The hope is that AI/ML-Gen will expand the researcher's capabilities in developing new knowledge beyond our current ability and velocity to do so. For example, many expect machine learning to advance clinical variant interpretation to the point where there are no longer variants classified as 'uncertain significance'.

It is also hoped that AI/ML-Gen can produce more accurate relevance rankings of laboratory findings, so that genetic testing results behave more like a search engine and less like a long checklist.

## Benefits of Genomics AI in Research and Discovery



### Data analysis

AI/ML-Gen can speed up and increase the accuracy of the data analysis process, which is currently heavily manual and subjective, and is the biggest bottleneck in clinical genomics discovery and translation. It should expand the ability to analyze whole genome sequencing (WGS) in cases with uncertain phenotype/genotype, followed by the ability to pull out likely or potential pathogenic variants of many variants found. Also, machine learning can offer better statistical models for teasing out the heritable component of disease risk and response to therapy, especially on larger scales. This achievement, of course, will depend on solving issues of data aggregation and sharing (which are detailed in a later section).

### Rare disease

Current genomic research is focused on improving our understanding of rare disease. There is genomic data on thousands of unsolved rare disease patients. We need to be able to match other unsolved cases when we don't have a clear gene candidate. AI/ML-Gen could speed up and increase the accuracy of the analysis of genomic data and the data analysis process, which is currently heavily subjective, not automated, and a restrictive bottleneck in clinical genomics.

### Research processes

Another application is in solving key clinical trial challenges, such as better protocol design, patient enrolment and retention, genomic data analysis, and identifying treatment efficacy. AI/ML-Gen may provide advanced data analytics, visualization, image analysis, and natural language processing, while leveraging virtual reality in clinical research. Enhancing these processes, as an example, could improve the ability to integrate many variants with very small effects to generate an overall integrated disease and disease comorbidity risk, which is a major goal of clinical research.

## Benefits of Genomics AI in Research and Discovery

### Networks and network interactions

A new area of research involves understanding gene regulatory and biomolecular networks. A paper titled [An Expanded View of Complex Traits: From Polygenic to Omnigenic](#) explains the hypothesis in this manner: "For complex traits, association signals tend to be spread across most of the genome, including near many genes without an obvious connection to disease. We propose that gene regulatory networks are sufficiently interconnected such that all genes expressed in disease-relevant cells are liable to affect the functions of core disease-related genes and that most heritability can be explained by effects on genes outside core pathways. We refer to this hypothesis as an 'omnigenic' model." AI/ML-Gen will be a critical tool to advance the knowledge and workings of these networks.

### Genes and environment

How genes are expressed, and especially the environmental effects, remains difficult to pinpoint and prove. AI/ML-Gen may be able to consume seemingly unrelated data to discover new causes and effects. It may also help us understand how genes coordinate their actions, and how they adapt (or mutate) their regulation to a constantly changing environment.

### Product development

Product developers and innovators are already using AI/ML-Gen to advance drug development for pharmacogenomics, and even in more leading-edge areas such as gene therapy. Investment in this technology will promote chances for both medical and market success, and while proving its efficacy, it could reduce healthcare costs. Early thinking seems to be breaking old boundaries, as AI/ML-Gen can link with other medical advances, such as genetic prediction for surgical or physical therapy success.

### Data standards for research

The Global Alliance for Genomics and Health (GA4GH) has created open standards in their [Genomic Data Toolkit](#) for genomic data sharing internationally, and an updated Pedigree conceptual model. Other related standards include those developed by the Clinical Data Interchange Standards Consortium ([CDISC](#)), which is a standards-developing organization dealing with medical research data linked to healthcare. There are many other research-related ontologies and nomenclatures. The HL7 standards are reviewed in the next section on clinical applications.

## Benefits of Genomics AI in Research and Discovery

### **Issues to overcome**

Those involved in research, especially clinical trials, have noted for many years that the most problematic step is the difficulty in identifying study participants and obtaining patient consent. Following enrollment, managing data rights and ownership, and returning results to study participants, are emerging as new issues. And the public's fear of harm, or not seeing the benefit to themselves, may hinder research participation.

### **Knowledge bases**

Keeping public reference knowledge bases updated is a serious task. Currently, there is a delay of several months in many well-curated genomic-related knowledge bases, and crowd-sourced tools lack the accuracy or clear annotation of evidence levels. The result is an expanding number of knowledge bases that need to be discoverable on the network.

### **Classical genetics**

Many current research modalities and systems, such as those used in pharmacogenomics, only work when we already have a gene candidate in mind. In order to do this, some of the issues in classical genetics are: 1) the importance of specialized variant calling strategies to determine the rsID of pathogenic variants, 2) the prediction of missense variant pathogenicity, 3) determining polymorphism locations, alterations in nucleotide and amino acid sequences, as well as minor allele frequencies, and 4) the need to predict structural changes based on biochemistry and the literature.

### **Data and algorithms**

Other challenges include how we identify predictors of disease and outcomes, and how these algorithms are validated. This is particularly complex. It requires using data beyond genomics, EHR, and insurance claims, to know how to incorporate environmental, social, and consumer data to better understand the link between genomics, behavior, and outcomes. As research requires a wide range of structured and unstructured data, many of the same issues listed in the section on data aggregation and sharing apply to this section on research and discovery.



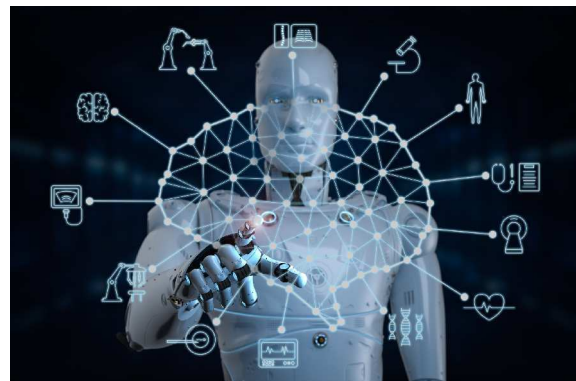
## Advancing Clinical Applications for Genomics-Based Care

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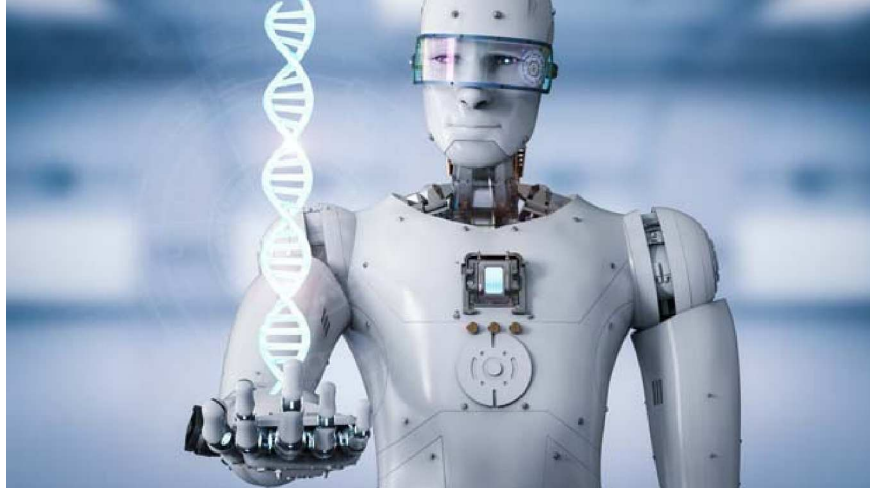
- Explore the most promising and feasible ideas for Genomics and AI in clinical applications over the next few years that will augment clinicians in health care delivery.
  - Cover the critical topics of standards, the patient molecular profile, and patient care coordination.
  - Identify critical areas to solve existing or future genomic data and standards requirements.
  - List the issues to overcome in achieving these goals from interoperability to reimbursement.
- 

The process of clinical translation of the discoveries coming out of research can be greatly enhanced with AI-based tools for the healthcare provider. These tools will cover a wide range of use cases, from enhanced disease prediction and predictions for treatment outcomes, faster and more accurate diagnosis and effects of co-morbidities, well-informed and targeted care protocols with real-time analysis of improved patient quality, more accurate reading of radiological images, and advanced algorithms to advance clinical decision support and patient care coordination.

AI/ML-Gen will expand this list to many other areas in clinical workflow, doctor-patient communication, automated patient documentation, other doctor and nurse interfaces with patient electronic medical record (EHR) systems, recommendations for clinical trials, and optimizing financial issues for all parties.



## Benefits of Genomics AI in Clinical Applications



### **Innovative clinical applications**

We must first start with having discrete genetic/genomic results in the EHR to use at the point of care, and also available to use over the lifetime of the patient. When this becomes standard of care, we will use AI/ML-Gen tools to extract clinically relevant and actionable information from the diversity of data sources, including clinical or phenotypic data, genetic data, and family health history data, which makes a powerful place to begin developing the augmented intelligent applications for the hospital and clinic.

Innovation in this space will continue to expand as the clinical world begins using patient-generated and other unstructured data not previously considered. Pulling the right information at the right time to improve physician workflow, e.g., predicting when a genetic test, or a new interpretation of an existing sequence, might be relevant for a particular patient.

Expanding this capability could include factoring in insurance coverage and policies, extracting the necessary information to allow insurers to make coverage decisions, and finally, guiding clinicians to the right follow-up care plan that incorporates important factors beyond just test results. This would greatly advance the doctor-patient relationship, having clinical pathways that are populated at the point of care, integrated with clinical and genomic results, and with other social and financial parameters unique to that patient or patient population.

## Benefits of Genomics AI in Clinical Applications

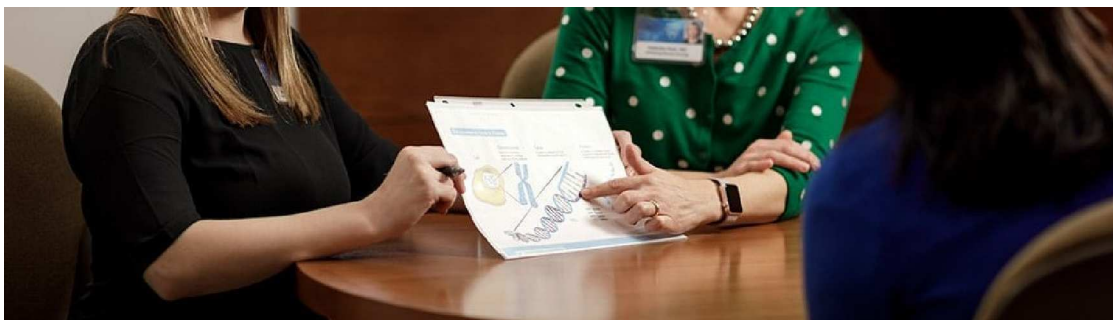
### Clinical decision support

A major area for the application of AI/ML-Gen is clinical decision support (CDS). Such a clinical tool will augment the knowledge of the clinician using genetic testing, including the pre-analytic, analytic, and post-analytical clinical phases: determining when a particular or combination of molecular tests can answer a clinical question, taking steps to perform the analysis of the sequence(s), and reporting and interpreting the genetic test results. For the latter, variant interpretation requires a comprehensive and accurate knowledge base, with clear annotations and evidence levels for actionable variants, that is updated in a timely manner.

AI/ML-Gen enhanced CDS will improve the utility of all types of testing, including carrier, prenatal, newborn, predictive, presymptomatic, and diagnostic testing, with improved analysis, resulting in advanced patient care. AI/ML-Gen will expand the capabilities of CDS through other tools like [SMART on FHIR](#) apps and Infobuttons, and as CDS tools become integrated across all clinical systems, regardless of the system platform.

### Genetic counseling

The opportunities for developing AI/ML-Gen-based tools for genetic counselors are great. We do, however, need to start with widely available family health history applications that allow patients to enter their own information, share it with their relatives, and have the data available to all healthcare providers, especially genetic counselors. The data collected through genetic/genomic testing is more powerful in the context of a family health history. The goal would be to integrate family history and genomic data earlier in life, in order to take advantage of their predictive power.





## Benefits of Genomics AI in Clinical Applications

Genetic counselors desperately need patient management, test tracking, and risk analysis tools designed for their specific workflow. Both doctors and genetic counselors, working together, need tools for the development of treatment plans after testing, interpretation, and diagnosis. This should also include patient education tools that assist in the patient's desire for self-knowledge about their DNA. AI/ML-Gen technologies already exist that can augment the counselor's workload through voice assistant applications that answer basic questions through chatbots.

### **Patient polyomic or molecular profiles**

The creation and interoperability of a patient's polyomic or molecular profile are critical. Polyomics (or multi-omics) combine all relevant genome and post-genome technologies, such as genomics, proteomics, transcriptomics, metabolomics, and microbiomics. AI/ML-Gen can help assemble, format, curate, and integrate the data, from multiple sources. With the profile completed, discovery, analysis, and clinical use powered by AI/ML-Gen are ready to reach new levels.

### **Genomic-based care coordination**

The area of patient care coordination is constantly being evaluated and improved. When we add genetic/genomic services to the mix, services provided by the primary and specialty care doctors, and including nursing and many other ancillary services, then coordination becomes key in providing patient-centered genetic/genomic-based care. When that coordination is operating efficiently, the patient can receive optimal genomics-based care throughout their lifespan. (See the earlier blog post [Patient-centered genomics-based care requires real genomics-based care coordination](#)).







## Benefits of Genomics AI in Clinical Applications

### System, application, and data interoperability

Another issue is the lack of interoperability between EHRs and other clinical systems at the level of discrete genomic results. PDF reports must be accompanied by the underlying data. Mechanisms are needed for evaluating the data quickly and providing answers back to the doctor and patient. There must be a proficient process to move new products, which are fully interoperable, into the informatics space related to EHR and lab sequencing data systems. A standards-based API, [SMART on FHIR](#) apps, is a framework to be followed.

Going deeper, integrating variants with small effects into an overall risk model requires responsive computer support. Also, there is a significant need to standardize the very heterogeneous clinical terminologies, vocabularies, and semantics, across all existing medical silos, which has hindered interoperability for a very long time.

### Clinical workflow

New AI/ML-Gen-based tools will most certainly disrupt current workflow processes. Because of this, application developers must show the clinical value of the change. And if workflow efficiency isn't significantly improved, physicians and other healthcare providers will not even consider the technology.

### Reimbursement and cost

We need to continue to reduce the costs of whole genome sequencing to below \$100, but more importantly, we need to achieve faster sequencing turnaround times. Clear coverage policies, automated prior-authorization, and timely reimbursement by insurers are ongoing issues that continue to evolve.



## Advances for Healthcare Consumers Managing Their Genetic-Based Care

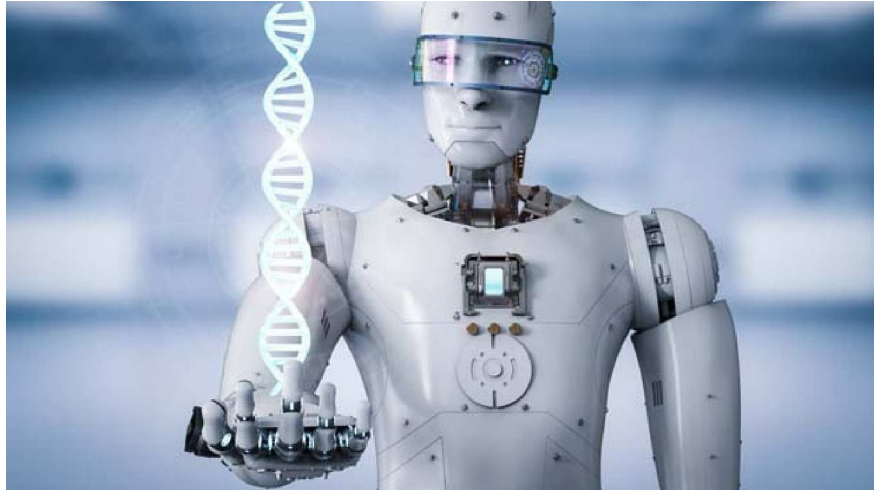
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- Brainstorm the most promising and feasible ideas for Genomics and AI in patient and healthcare consumer applications as part of an emerging ecosystem.
  - Consider new concepts of participatory health, to a medical record for the patient lifespan.
  - List the issues to overcome in achieving these goals, such as patient care centeredness and patient data ownership.
- 

An obvious starting point for the patient and AI are personalized health recommendations and management. By combining genomics-based consumer health apps with AI, individuals could receive the promised 'precision' in their medical care. AI could analyze an individual's genomic data and provide insights into how their unique genetic makeup affects their risk for certain diseases, such as cancer, heart disease, or Alzheimer's. This information could be used to create tailored wellness plans for diet, exercise, and other lifestyle changes that could improve their overall health.

Other AI features in patient-facing apps could include risk assessment and early detection of diseases, and improved treatment outcomes with guided patient instructions. AI could help to make healthcare more efficient by reducing the amount of time that healthcare providers spend on manual data analysis and decision-making. By automating these processes, AI could free up healthcare providers to focus on more complex tasks, such as patient communication, the social determinants affecting the patient, and patient desires in treatment planning.

## Benefits of Genomics AI in Consumer Health Applications



### Participatory Health

With market pressures coming from multiple stakeholders, healthcare is changing in regard to the power of the patient as a consumer to engage in control of their medical experience. Participatory health is a profound shift in expectations of the health delivery system—one that is more responsive and convenient, focusing more on wellness and well-being than just sick care, and utilizing self-direction and personalized services.

A significant opportunity for innovation will be to use AI/ML-Gen to build apps that help the consumer navigate the healthcare landscape. Imagine an intelligent healthcare adviser that walks a patient through the whole process: linking appointments, scheduling tests, understanding test results, moving between healthcare providers and facilities, and providing cost information and assistance with payment transactions.

The app would encompass healthcare provider information in advance of a clinical visit, i.e., wait times, patient satisfaction, patient quality, and outcomes analysis, as well as the provider's comprehensive digital capability (interoperable EHR, patient-accessible scheduling, online prescription refill, telehealth, access to external patient social, environmental, family health history, and genomic data, etc.). Apps would be interoperable so intelligent services could connect with each other.

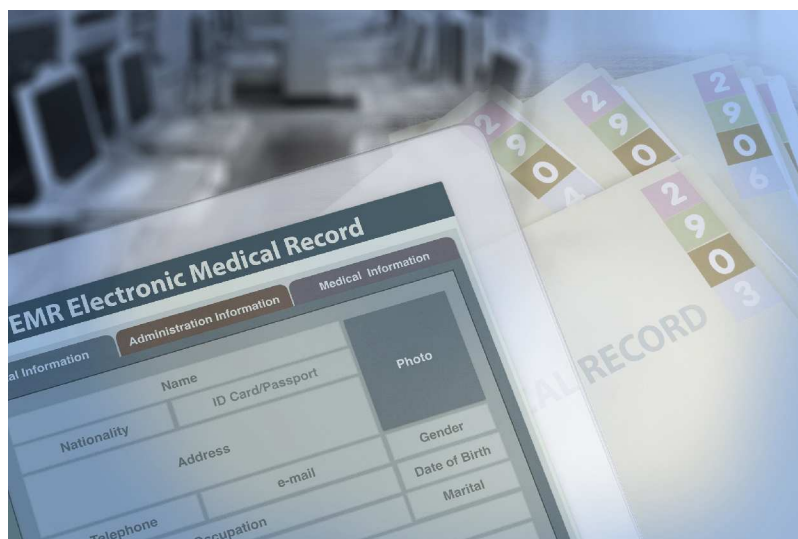
Participatory health can reach beyond the patient's care beyond their local area. Telehealth is growing, and with AI/ML-Gen tools like voice assistants, chatbots, and other helpful agents, patients can find expertise anywhere. Families with heritable disorders can also interact with a 'families like mine' social network. This could even benefit families across geographical boundaries and different nations.

## Benefits of Genomics AI in Consumer Health Applications

### Medical record for the patient lifespan

A patient's longitudinal medical record should be recorded and managed over the patient's lifetime. Whether in a single record, or a linking of multiple records, it should be complete, accurate, and available to any patient-controlled app (e.g., family health history applications). This record would enable preventive care through patient risk stratification, intelligent screening, and post-test monitoring, from conception to death.

AI/ML-Gen will contribute to what's new on the horizon. This will be the integration of data from wearables, devices that produce data in real-time, lifestyle management and monitoring, data from the Internet of Things, and even that magic toilet we hear about. AI/ML-Gen could collect, organize, and analyze this data against our molecular profile, so that the new insights can be used in clinical decision-making. AI/ML-Gen can assist in easier and more efficient identification, enrollment, and participation in research and clinical trials. The study results can be quickly fed back into the patient's longitudinal record for immediate or future benefit.



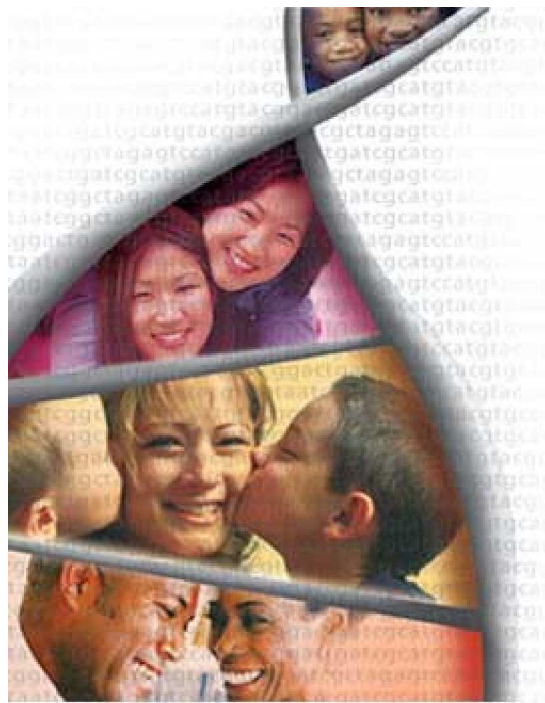
## Benefits of Genomics AI in Consumer Health Applications

### Condition and behavior management

In addition to the risk awareness, early screening, and detection mentioned previously, AI/ML-Gen will help us add advanced targeted drug delivery, management, and adherence. This will include ingestible sensors that track the effectiveness of the medications.

AI/ML-Gen could assist patients and their providers with predictions of the onset of medical conditions (cancer, cardiovascular diseases, Type 2 diabetes, organ failure, neurological disorders, Alzheimer's, hospital readmissions, etc.). It could also assist with chronic disease management, physical therapy response, nutritional guidance, and trauma recovery.

A significant amount of investment capital is moving towards developing the next level of personal apps for healthcare consumers, patients, and providers, to utilize and apply the results of clinical genomics for wellness and enhanced quality of life. That is why this list of AI/ML-Gen benefits in this section is not comprehensive of the healthcare experience, but only an attempt at highlighting the expanding world of commercial patient apps, products, and services.





## Benefits of Genomics AI in Consumer Health Applications

### **Issues to overcome**

The issues to overcome for patients and healthcare consumers begin with the usual suspects: patient education, including genetics, consumer literacy, community and family culture, false information and beliefs, and access to care based on local economics. Then there are the technical issues of access to computers, devices, smartphones, and Internet connectivity. Of course, there is the business issue of the willingness of the healthcare delivery system to partner with their customers.

### **Patient-centered services**

We also have a lack of patient-centered genetic/genomic services in healthcare systems, as most services are still specialty-centric. A centralized data (sequence) repository for the patient's genome, or their complete molecular profile, still does not exist. Performing whole genome sequencing for all patients has not yet become the standard of care, bringing with it the promise of personalized health recommendations, early detection, and precision treatment.

### **Data access**

Issues beyond the control of the healthcare consumer are access to their medical record in the EHR, access to lab results, and their own insurance claims data. This lack of access extends to data that was collected through participation in a research study or a clinical trial. Then there is the lack of integration of the diverse sources of data, and the entrenched business models and financial incentives that hinder the creation of the longitudinal record.

### **From standards to security**

As in the clinical world, data standards affect the patient and healthcare consumer world. AI/ML-Gen will have to map data to different models, standards, vocabulary (medical versus common terms), and structures. This then leads to issues of data governance, privacy, security, de-identification, and the challenges with HIPAA and GDPR.



## Patient Portal

## Solving Issues in Data Aggregation and Sharing

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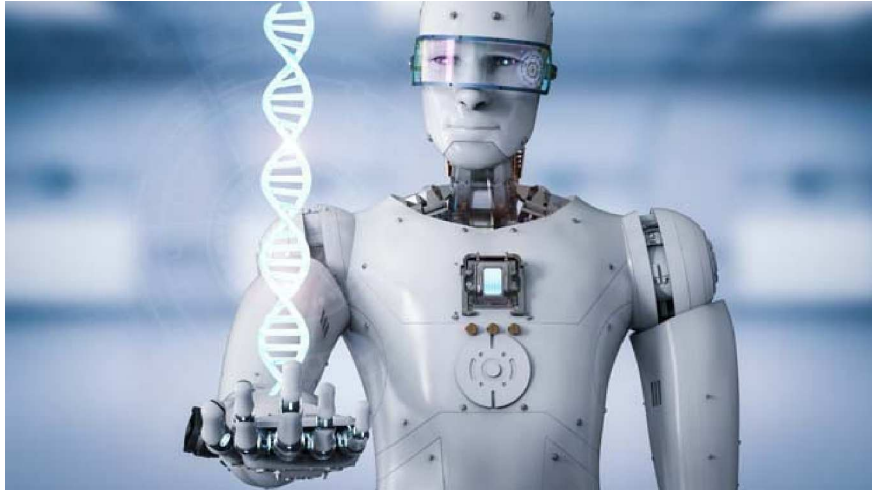
- Identify specific data sets critical for making the analysis of Genomics and AI possible and successful – including data sets that are currently in silos, not currently collected, and that need to be combined.
  - Explore the utility creating a federated system to link data sources.
  - List the issues to overcome in achieving these goals, such as data regulation, privacy, consent, ownership, and even data dictionaries and harmonization.
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Personalized treatment recommendations informed by genomic data are increasing for a broad range of clinical conditions. Applying machine learning to CDS algorithm development is the innovation that is taking intelligent treatment recommendations to new levels. However, key to this next achievement is the ability for AI/ML-Gen engines and tools to access and consume larger and more expansive data sets.

The first step is to identify and architect a federated system that would enable the linking of data

sets required to create the patient multi-omic molecular profile, including, but not limited to genomic (NGS, GT), proteomic (mass spec), gene expression (protocols and standards), metabolic (mass spec), transcriptome, and microbiome (16S, shotgun, data processing). AI/ML-Gen tools would help discover, validate, curate, annotate, and govern (e.g., gatekeeper security by tracking source, providence, and access, while operating a consent engine), and manage the business models of the envisioned federated system.

## Building Data Models to Benefit Genomics AI



### Data sources

The data sources would include family health history data, possibly mixed with updated genotype/phenotype correlations, and other combinations of clinical, research, curated, and patient data sets, which contribute to that 'expanded' context. The integration of real-world information from wearables, home care devices, and patient-reported outcomes, includes data that is collectively considered in clinical decision-making. Going further, if a person's health is driven by behavior, and we don't have behavioral data (which is not to be confused with important mental health data), then we won't understand health holistically. We will not be able to truly predict and understand health status, and interpret the complexity of the patient's network of health-controlling biological systems.

This federated system will build upon efforts around population analytics. An opportunity here is for AI/ML-Gen tools to develop primary and control data with broad ethnic and geographic diversity, combining both those with unmixed and very mixed ancestry. The data generated by national genomics and health studies will be a feast for AI/ML-Gen if shared. And in addition to national and public health databases, we can include disease-specific databases and registries, healthcare system and medical office databases, direct-to-consumer testing data, health data generated in non-traditional care settings like Walmart or Walgreens, health insurance claims data, and data collected by clinical trials, free health clinics, employer health offices, schools, etc.

## Building Data Models to Benefit Genomics AI

AI/ML-Gen could help us build (dare I say perfect) synthetic cohorts for a wide range of applications, from research analytics to clinical trial regulatory purposes to the development of new products and treatments. The goal is to develop the foundation, environment, and processes that facilitate the sharing of discoveries for the diagnosis, treatment, and cure of future patients.

### Knowledge base networks

The ability to do whole genome sequencing in cases with an uncertain phenotype/genotype, followed by the ability to pull out likely or potential pathogenic variants of many variants found in the sequence, would be a great advance. Therefore, the next innovation needs to be self-sustaining and grow knowledge-base networks that, through a feedback loop, provide always advancing medical care for that 'next' patient. This can only be possible if all the needed data is aggregated, linked, curated, and shared.



## Building Data Models to Benefit Genomics AI

### **Issues to overcome**

A big intersection resides in the need for a very well-defined mechanism to get the variant data into the genomic repository so that the data can be mined effectively. Currently, this mechanism seems poorly defined and cumbersome. A streamlined, standardized process is needed. We recognize there are multiple data formats that will be used, but standardizing them would be very helpful. The lack of widely adopted standards (like CDISC) means that curation will remain a barrier to advancing translational and medical science.

Data privacy and security issues will need to be solved. HIPAA, GDPR, and other state, provincial, or federal regulations need to be rewritten to address the need to share data. Data blocking will be the AI/ML-Gen killer. In some jurisdictions, we need to provide protections for pre-existing conditions in health insurance. If this safeguard is removed, participation in data-sharing efforts will decrease out of fear. Patients raised this concern during healthcare policy and health insurance debates in Congress.

### **Ownership and consent**

Patient data ownership and control would overcome this brick wall. But the necessary managed consent processes and tools should be developed and required. Informed consent involves an education and information exchange between the data owner (or guardian), and the various stakeholders and uses of the data.

We need to explore how AI/ML-Gen and related technologies can address some of the challenges around data harmonization (retrospectively), the application of standards (ontologies and data dictionaries—prospectively), and the structuring of data (natural language processing and/or manual curation). And finally, we need to solve the issues of the lack of shared attributes, the handling of longitudinal data, social information, etc.



## Public Health, National Genomic Initiatives, and Global Implementations

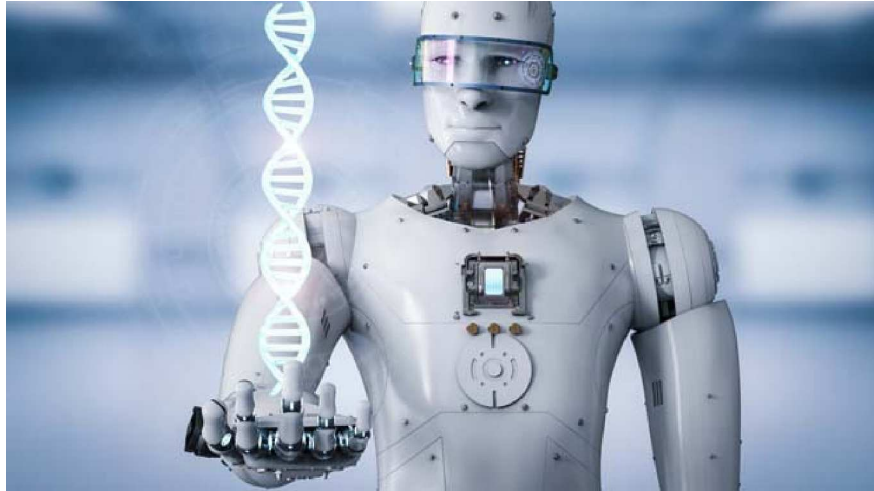
- List benefits and issues of Genomics and AI in public health, national genomic initiatives, and global implementation.
- Review benefits and issues to overcome under each group.
- Acknowledge great opportunities for partnerships with established non-profit and philanthropic organizations.

Public health agencies are asking for funding to develop the infrastructure to support genomic-related population research. This includes patient registries and population datasets to conduct studies that assess gene-environment interactions. As one example, analyzing the results of metabolic and genomic screening using AI/ML-Gen tools could benefit healthy newborns, which is the best place to start for population health strategies.

Whole genome sequencing from birth (or even during gestation) can provide early insight into the risk of developing medical conditions that may be modified by environmental exposure over time. AI/ML-Gen in population health surveillance could warn of exposures that are risky for specific subpopulations. Risk assessment and risk adjustment tools designed at the population level could help inform the assessment back down to the individual level.



## Benefits of Genomics AI in Public Health



The list of AI/ML-Gen applications in public health is quite long. This includes opportunities for the avoidance of passing on heritable diseases by informing reproductive options and decisions, pathogen outbreak prediction, detection, and containment, food identity and safety, and population nutrition.

The integration of genomics into public health strategies will include the wider context of other determinants of health, such as the physical and educational environments, as well as behavioral, socioeconomic, and social support factors. Applying AI/ML-Gen could lead to advanced population-based interventions, and ultimately, improve population health outcomes.

### **Issues to overcome in public health genomics**

The biggest problem is the lack of infrastructure for population genomic screening, and for all the other areas of population health described above. Public health agencies may not be linked, such as state or provincial agencies, which would require the mining of siloed data systems. Also, public tools are not in place to collect and use family health history data for population health analysis, although the agencies have always been very supportive of its promotion through many programs. Then there's the question of protection from pre-existing genetic conditions, especially as sequencing is done earlier in life.

Issues like cultural and belief systems that may hinder support from some subpopulations will always need to be addressed. So as long as there are opportunities here for many more ideas, any solution will still take commitment and lots of work, with large doses of the human touch.

## Benefits of Genomics AI in National Initiatives

According to the Global Alliance for Genomics and Health's (GA4GH) [Catalogue of Genomic Data Initiatives](#), there are 105 research projects and consortium network initiatives around the world. In addition to these activities, there are at least 20 national genomics initiatives. The initiatives usually consist of partner organizations, including hospitals, research institutes, universities, and maybe a few commercial entities. Each initiative wants to implement new discoveries into clinical practice, reduce healthcare costs, and help citizens have healthier lives. But each, however, also has economic goals around developing national expertise and reaching new levels of innovation in the life sciences and AI.

AI/ML-Gen could build upon the dozens of existing tools for collaboration between these initiatives. The GA4GH [Matchmaker Exchange](#) tool is a great example. Serious opportunities exist for AI/ML-Gen to solve undiagnosed and rare disease questions that are a focus of many of these initiatives. New tools for biobanks and the ability to access them and other national data, especially over time, would be a benefit. And as was discussed in the data sharing section, AI/ML-Gen tools like larger datasets. Database co-development through strategic collaboration would provide long-term benefits.

### **Issues to overcome in national genomic initiatives**

Genotypic-phenotypic data sharing across national boundaries is certainly at the top of the issue list, which would require legislative, regulatory, and ethical perspectives and solutions. Generally, citizens want protection of their privacy from both the government and their suppliers, but too many safeguards could hinder the development of new knowledge. Then there are the issues of public trust and attitudes toward participation, with citizen data ownership and the return of results raising big questions (or big opportunities). And finally, all of these initiatives must serve their national interests.

Each initiative will struggle with the level of curated datasets, common data models, and the use of standardized methods. A key challenge will be the commitment to and development of the architecture and underlying technology stack of a genome-phenome database. Architects must plan for the lack of knowledge of how such a database will be used in the future. But mostly, these government-back initiatives must show value to the taxpayers.



## Benefits of Genomics AI in Global Implementations

Global implementations, especially in lower- and middle-income countries (LMICs), would benefit from AI/ML-Gen. The first advantage would be in bio-surveillance, getting to a quicker identification and analysis of infectious diseases. Other applications would help in countries with the high incidence of birth defects, cancer, heart disease, thalassemia, chronic respiratory illness, blood disorders, vision problems, and diabetes. Many of the benefits mentioned above in the public health section also apply to this section, but with fewer resources.

AI/ML-Gen could help LMICs skip the ‘first world’ medical infrastructure like they skipped the landline infrastructure for mobile services. Besides bringing medical advances to LMICs, AI/ML-Gen could help with the Sustainable Development Goals of the World Health Organization (WHO), which include achieving food security, improving nutrition, and ending hunger. And as mentioned in the healthcare consumer section, families like mine with social networks could benefit families across different nations, and better understand genetic population movements over time.

### Issues to overcome in global genomic implementations

Deployments in LMICs are subject to funding and resource challenges. Technology availability and infrastructure have to be considered. Workforce training and skill development will require investment. There are several organizations already on the ground that could be excellent solution partners, like H3Africa, Bio Ventures for Global Health BVGH, and PATH. For implementing genetic-based care, I suggest we start with family health history.



## Establish a New Coalition with Partnerships to Move This Forward - Key Components and Collaborations

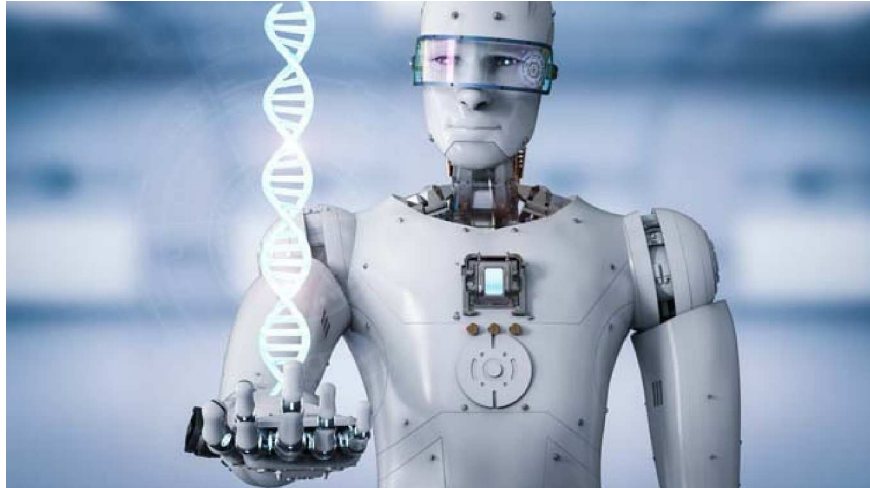
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- Create a new grassroots industry coalition that will promote the trusted implementation of AI/ML-Gen in all aspects of translational and clinical genomics.
  - List the benefits of coalition participation and breadth of GACT activity.
  - Complete list of potential stakeholders and strategic partnerships that will drive new collaborations and mutually beneficial projects.
  - Review the coalition issues to overcome.
- 

At healthcare IT industry conferences like HIMSS and in the healthcare technology industry press, the claims of products that are AI-powered are running wild. We are quickly reaching the pinnacle of the hype curve. The time is right to organize the GACT to collectively define, educate, promote, and successfully implement AI/ML-Gen knowledge and tools. The early members of the GACT will be very influential in its long-term success.

The GACT will represent the interests of the subsection of the healthcare AI industry that focuses on the translational and clinical areas of human genomics. The coalition will support the needs of the members on a variety of policy issues, help construct the needed data infrastructure, and help solve the healthcare data interoperability issue. The coalition will need early adopters—those that are incentivized to find solutions for the common good.

## Benefits of a Genomics AI Coalition



The GACT will expand its efforts through partnerships with similar industry groups that share goals on policy and technology progress. A coalition between the genomics and AI industries offers a unique opportunity to unlock the true potential of both fields. By combining the power of genomic data with the analytical capabilities of AI, this partnership can lead to groundbreaking advancements and be at the forefront of revolutionizing healthcare. Our philosophy is that coalitions enable their members to leverage their networks, learn about developments that shape issues that affect the industry, and work together for shared goals of business growth and innovation.

### **GACT members could cover a wide range of stakeholders:**

- Healthcare systems and providers
- Physician specialty organizations
- Genomic sequencing labs
- Health insurance payers
- Technology, commercial developers, EHR vendors
- AI machine learning tools, population analytics tools
- Venture capital, private investors, funders
- Commercial and academic research
- Industry research like KLAS, CBInsights
- Conference organizers
- Government groups like ONC, NHGRI, ARPA-H, NIH, FDA, CMS

## GACT Major Initiatives and Activities

The following is a list of 11 activity areas for members of the GACT.

### Activity area #1



#### GACT conferences

- Convene and report on meetings
- Determine, run, and report on ad hoc task projects
- Display member solutions, demos
- State of the industry reports
- Mutually beneficial competitions
- Sub-group discussions around a specific topic
- Participate with HIMSS, Bio-IT World, and other industry conferences

### Activity area #2



#### Focused Roundtables

- Economic incentives/reimbursement
- FHIR Genomics, GA4GH, creating standards
- How to get FHIR implementation guidance
- HIPAA, GDPR and genomic data
- Internationalization/global issues
- Applied machine learning techniques in genomics
- Role in gene editing, synthetic biology
- The opportunities for generative AI

## GACT Major Initiatives and Activities

### Activity area #3

#### → Hold roundtables with stakeholders in the various industry areas

- Research applications
- Clinical applications
- Patient/consumer applications
- Data aggregation
- Public health, national, and global initiatives

### Activity area #4

#### → Strategic partnerships and ecosystem development

- Define the ecosystem
- Collectively build the infrastructure and standards that allow linking of AI applications
- Determine critical partnerships
- Perform market surveys

### Activity area #5

#### → Connectathons and shared proof-of-concept pilots

- Hold connectathons that work on shared problems
- Define and run proof of concept pilots
- Feedback new knowledge to the ecosystem
- Create an industry accerator for projects of mutual benefit

## GACT Major Initiatives and Activities

### Activity area #6



#### Participating with Standards Organizations

- HL7 International, HL7 Clinical Genomics Workgroup (FHIR Genomics specification, Domain Analysis Model)
- GenomeX
- GA4GH Genomics toolkit
- ISO Genomics group
- CDISC
- ClinGen, CPIC, etc.
- Nomenclatures like HGVS

### Activity area #7



#### Collaborating and Influencing Genomics Groups

- American Medical Association (AMA)
- American Medical Informatics Association (AMIA)
- National Human Genome Research Institute (NHGRI)
- The World Health Organization (WHO)
- Global Alliance for Genomics and Health (GA4GH)
- Global Genomic Medicine Collaborative (G2MC)
- European and other geographical groups

## GACT Major Initiatives and Activities

### Activity area #8

#### ➔ Policy, Advocacy, and International Opportunities

- Facilitate federal inter-agency dialogue and congressional education with a clear, unified voice
- Represent members needs and interests on regulatory matters
- Create a GACT policy group
- Develop processes and activities that are multinational
- Develop processes and activities that focus on low- and middle-income countries

### Activity area #9

#### ➔ Participate with other Healthcare AI initiatives

- Alliance for Artificial Intelligence in Healthcare
- Society of Artificial Intelligence in Medicine & Healthcare
- Partnership for AI, Automation and Robotics in Healthcare
- AIMed
- Coalition for Health AI
- Consumer Technology Association's new initiative on artificial intelligence
- Healthcare.ai

## GACT Major Initiatives and Activities

### Activity area #10



#### Horizon scanning - The following are not specific to AI genomics, but play an influential role -

- U.S. Department of Health and Human Services (HHS) asked JASON to consider how AI will shape the future of healthcare. JASON published their report in December of 2017. One of their recommendations is to embrace the crowdsourcing movement to support AI development and data generation.
- The CMS Artificial Intelligence (AI) Health Outcomes Challenge is an opportunity for innovators to demonstrate using AI tools for specific problems. One solution predicted unplanned hospital admissions and adverse events. We should learn if these have a genetic component.
- Get out in front of new FDA regulations that will affect genomics and AI. The FDA has announced a new program with a goal to promote the development of a safe and effective artificial intelligence ecosystem in healthcare. The FDA claims it will exchange its traditional regulatory approaches for a faster model that offers more flexibility for the fast-paced advancement of AI and machine learning.

### Activity area #11



#### General Coalition Activities

- Advisory committee
- No work groups, but targeted ad hoc task groups with time limits
- Online community
- Member highlight, newsletter
- Joint publications, white papers
- Expert access and advice, implementation
- Launch and continually promote the new coalition with press releases, marketing and messaging



## Benefits of a Genomics AI Coalition

### Coalition issues to overcome

After investigating membership interest, funding for the GACT is the first order of business. What will attract early members and then continue membership growth? Different member organizations will have different interaction preferences. Questions on sharing community discoveries and intellectual property while protecting the IP of individual organizations must be answered.

We know that member organizations may have differing definitions of AI/ML-Gen. Everybody wants to say they do AI. But GACT must not contribute to the hype but look beyond the hype curve. How do we go about resolving differing opinions on ethical questions and policy positions? Issues to overcome will span global differences, creating effective partnerships, and developing that all-encompassing ecosystem.

Is this a real healthcare thing or a Silicon Valley thing? What are the scalability barriers? Will the need for high investment returns and intense competition stop a successful coalition? There will be many hurdles on the way to reaching critical mass, but not if we keep the patient as the focus.



## Call to Action

→ To fully realize the potential of genomics and artificial intelligence, it is crucial that all industry stakeholders come together to form a coalition dedicated to advancing these technologies in a transparent and trustworthy manner while pushing the state-of-the-art. We need this alliance to help establish best practices, encourage collaboration and knowledge sharing, and drive innovation. Therefore, it is imperative that companies involved in these fields work together to overcome challenges and maximize the impact of this new frontier in medicine.

We really want to see these actions happen. Your input and ideas will determine the next steps and the development of each action strategy. Progress will be tracked in future posts. [This blog](#) is not designed for passive readers. If you agree with these actions, let's work together to make them happen. We will pursue these and future call-to-actions over time until we can verify that they have been achieved. Stay tuned!

Join this [Call-to-Action](#), and email ideas, efforts, and results to [moveforward@genomics.network](mailto:moveforward@genomics.network)

You can find the blog post [here](#), and download the Factsheet [here](#).



## Conclusion

This document should not be viewed as a comprehensive coverage of all the possibilities for applying artificial intelligence and machine learning to the world of research and clinical genomics. We have presented some ideas and opportunities to develop intelligent solutions for research, clinicians, patients, public health, national initiatives, and global implementation. We covered critical topics in data availability and aggregation. We started by framing all this activity under our guiding principles.

In the healthcare industry, AI is already making improvements in the delivery, treatment, and efficient reimbursement of care. The question is: Are we at a turning point for clinical genomics? And what constitutes a turning point? By leveraging the power of AI to analyze vast amounts of genomic data, healthcare providers and individuals can gain valuable insights into their health risks and conditions, allowing for personalized recommendations, early detection of diseases, and improved treatment outcomes. The combination of artificial intelligence with genomics-based clinical and consumer health apps has enormous potential to revolutionize healthcare.

Within this market, the application of AI to genomics is expected to be one of the fastest-growing segments, growing at a compound annual growth rate of 44.9% to reach \$45.2 billion by 2026. Much of this will happen because patients are demanding more convenient, effective, and affordable healthcare. So, what will the world of healthcare look like when we reach these goals? What happens when we add synthetic biology? What is our vision for the next 10 years? The GACT will bring us there together in much better shape than if we go forward individually.

