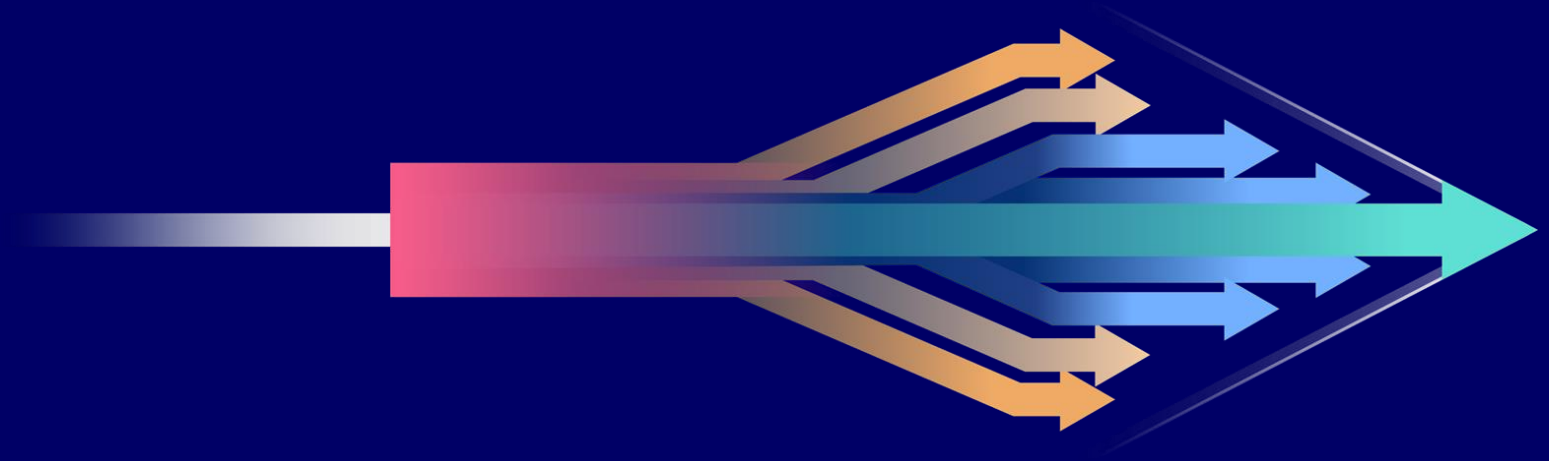


The Forefront of Genomics®

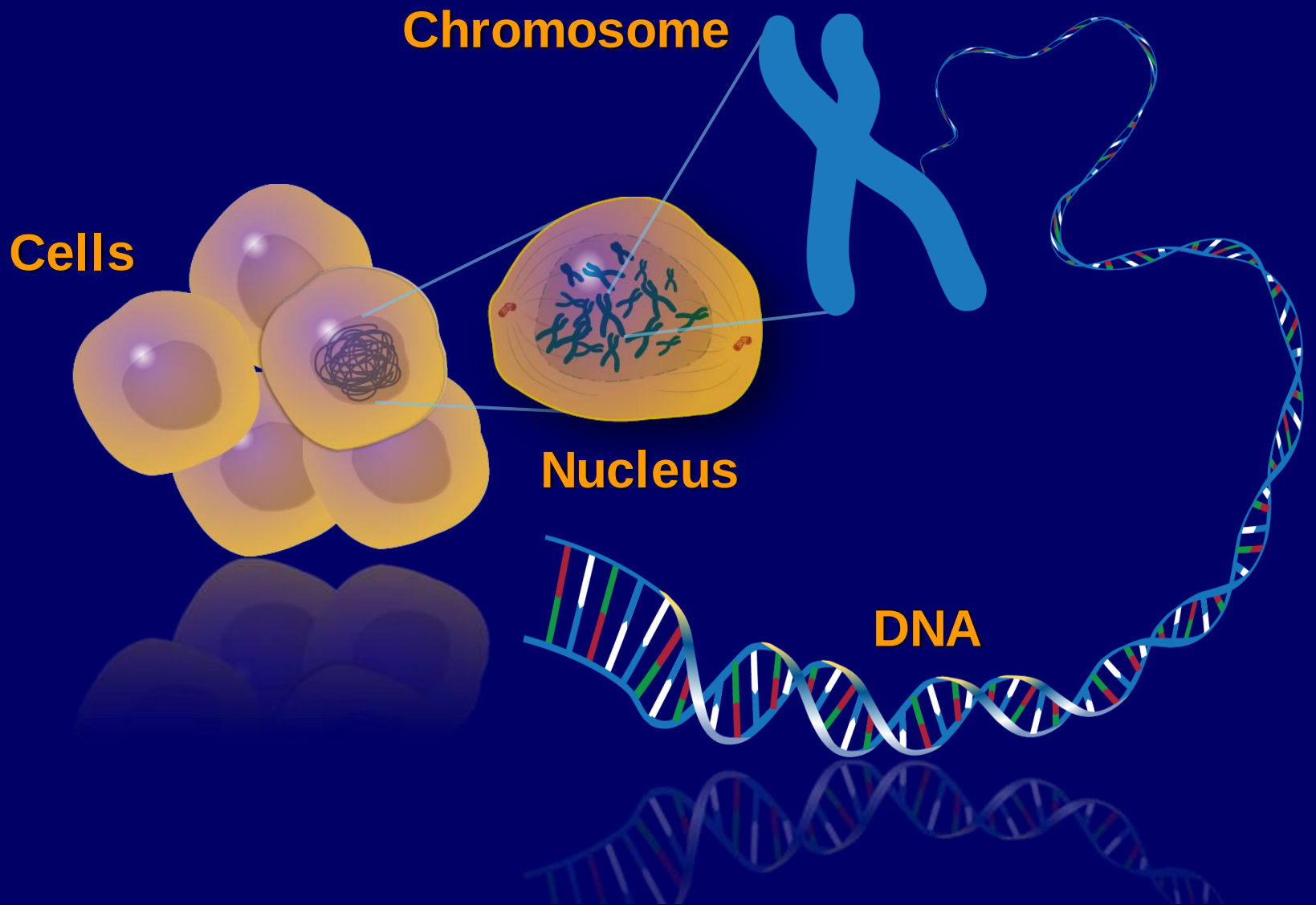
Strategic Vision for Improving Health at *The Forefront of Genomics*

Eric Green, M.D., Ph.D.

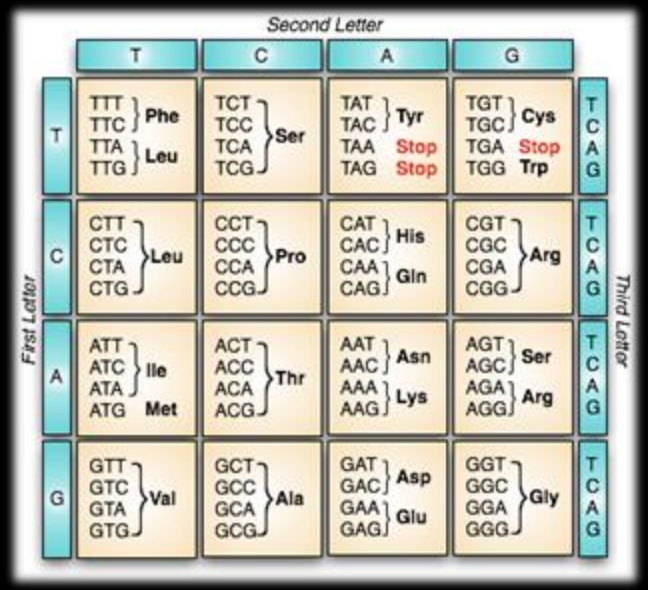
Director, NHGRI

National Human Genome Research Institute

Genomics: Some Basics

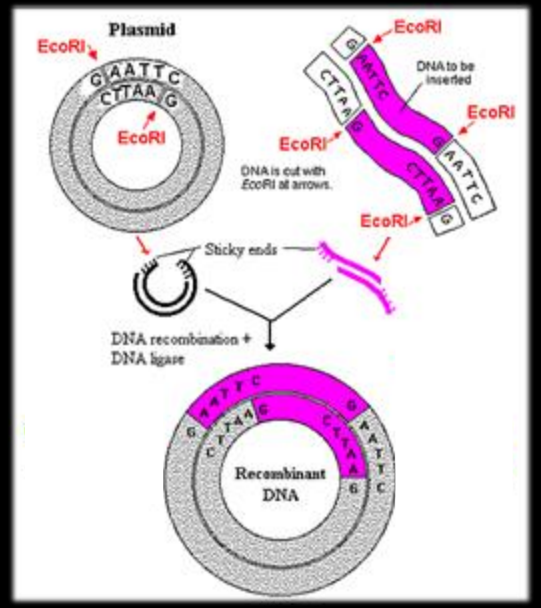


1960’s



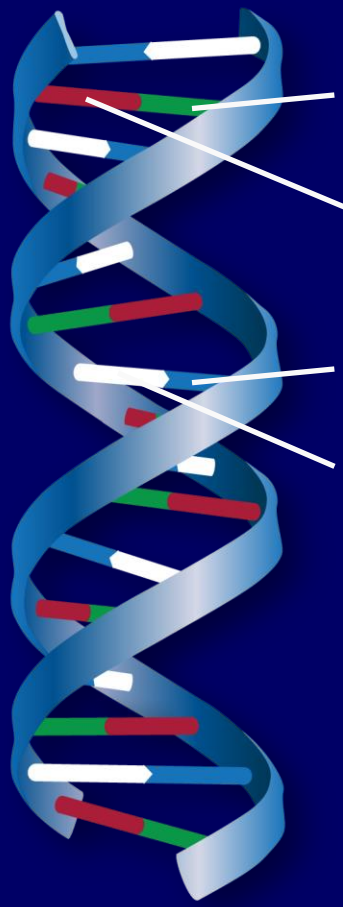
The Genetic Code

1980’s



DNA Cloning

The DNA Alphabet

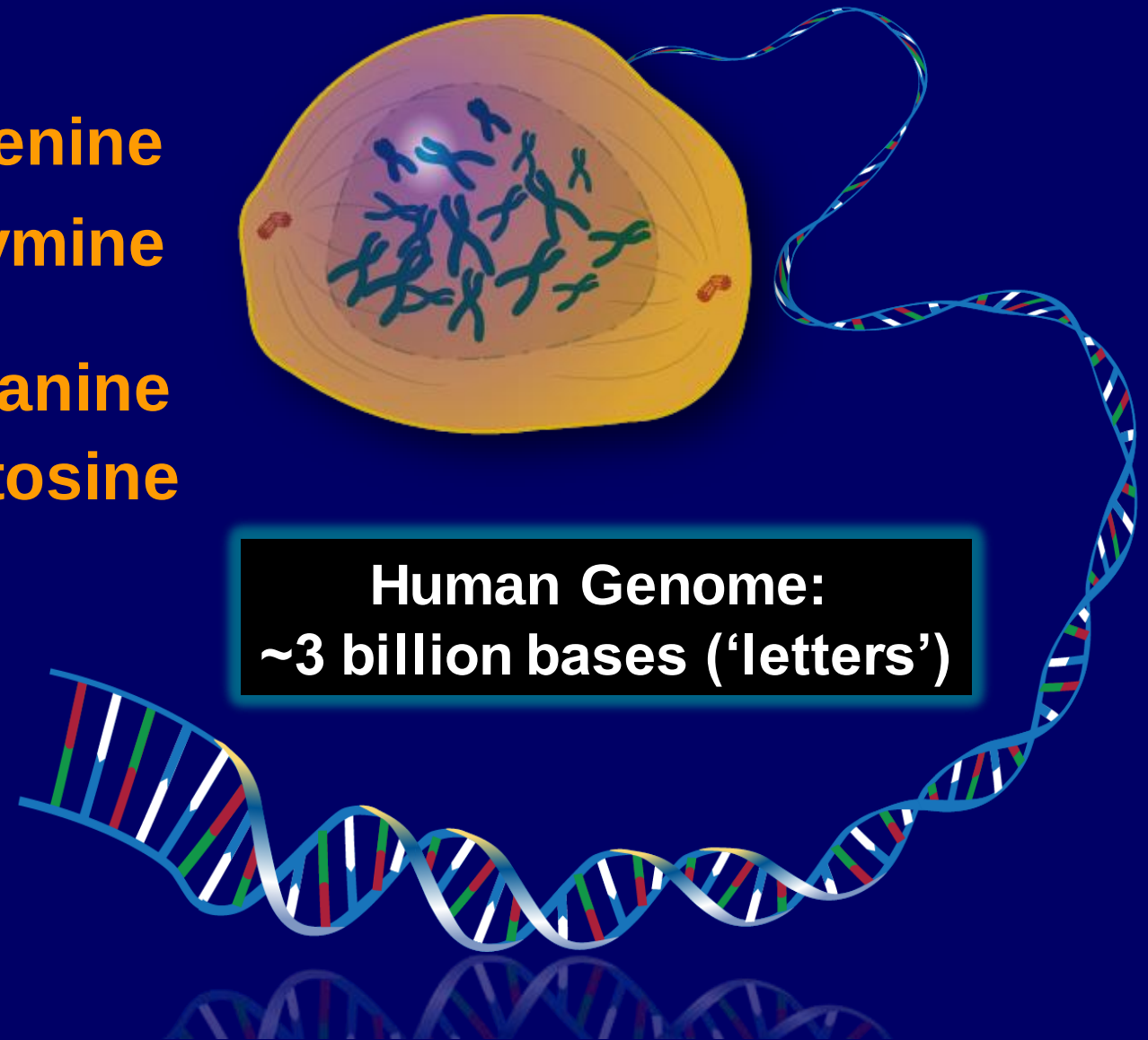


A Adenine

T Thymine

G Guanine

C Cytosine



Human Genome:
~3 billion bases (‘letters’)

The Origin of “Genomics”: 1987

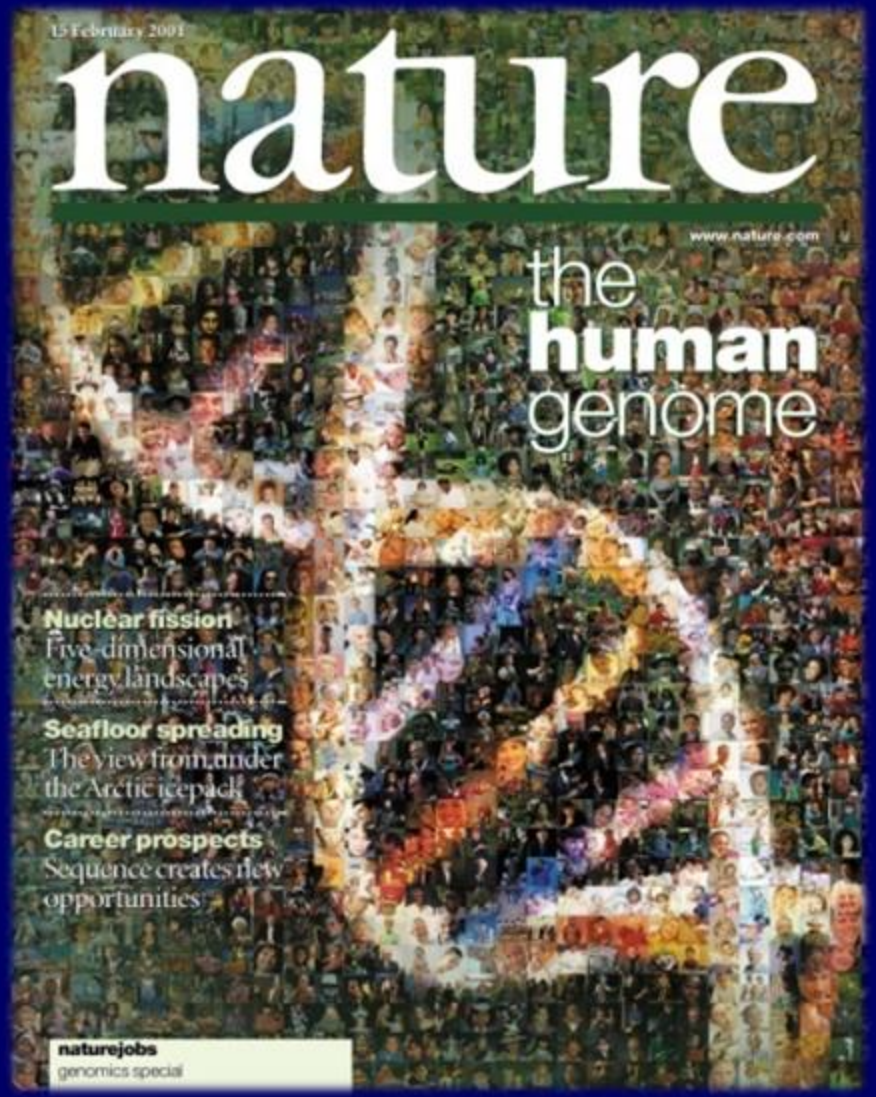
EDITORIAL

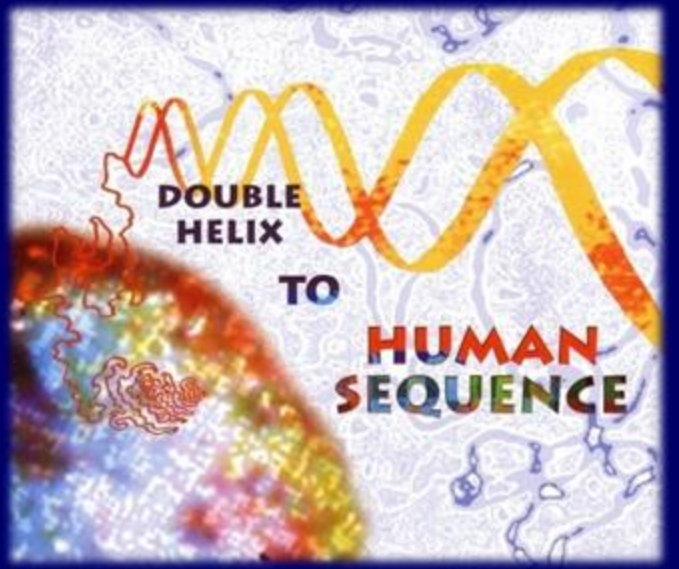
A New Discipline, A New Name, A New Journal

Genomics **(1987)**

“For the newly developing discipline of [genome] mapping/sequencing (including the analysis of the information), we have adopted the term GENOMICS…

Human Genome Project: 1990-2003





genome.gov/HGP

The Signature Accomplishment of the Human Genome Project was Sequencing the ~3 Billion Letters of the Human Genome

The international journal of science / 11 February 2021

nature

GENOME REVOLUTION

How 20 years of the human genome sequence have helped reshape science

Coronavirus
The power and pitfalls of rapid tests for COVID-19

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Microhabitats save mammals, but not birds, from warming pp. 553 & 633

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Science

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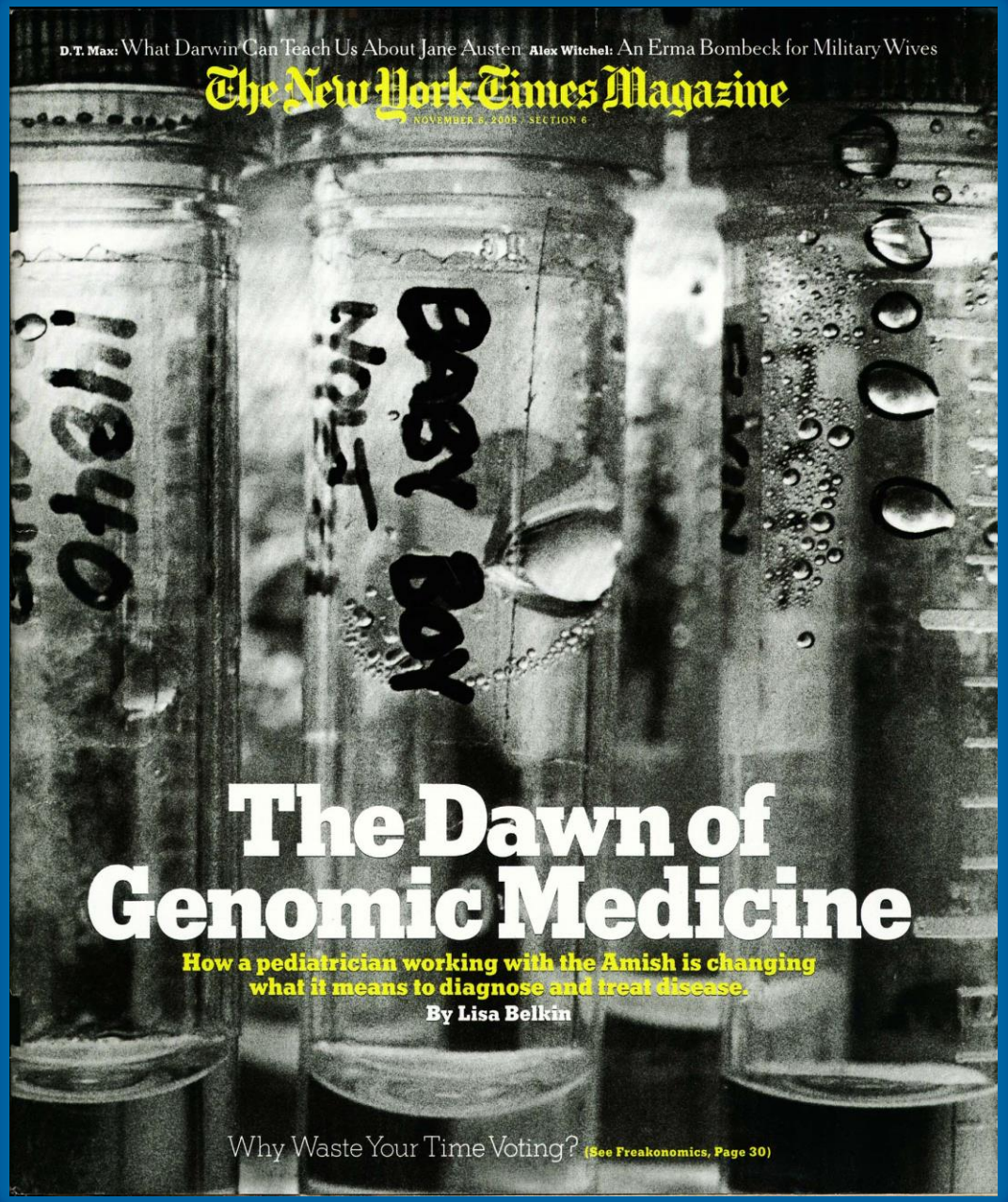
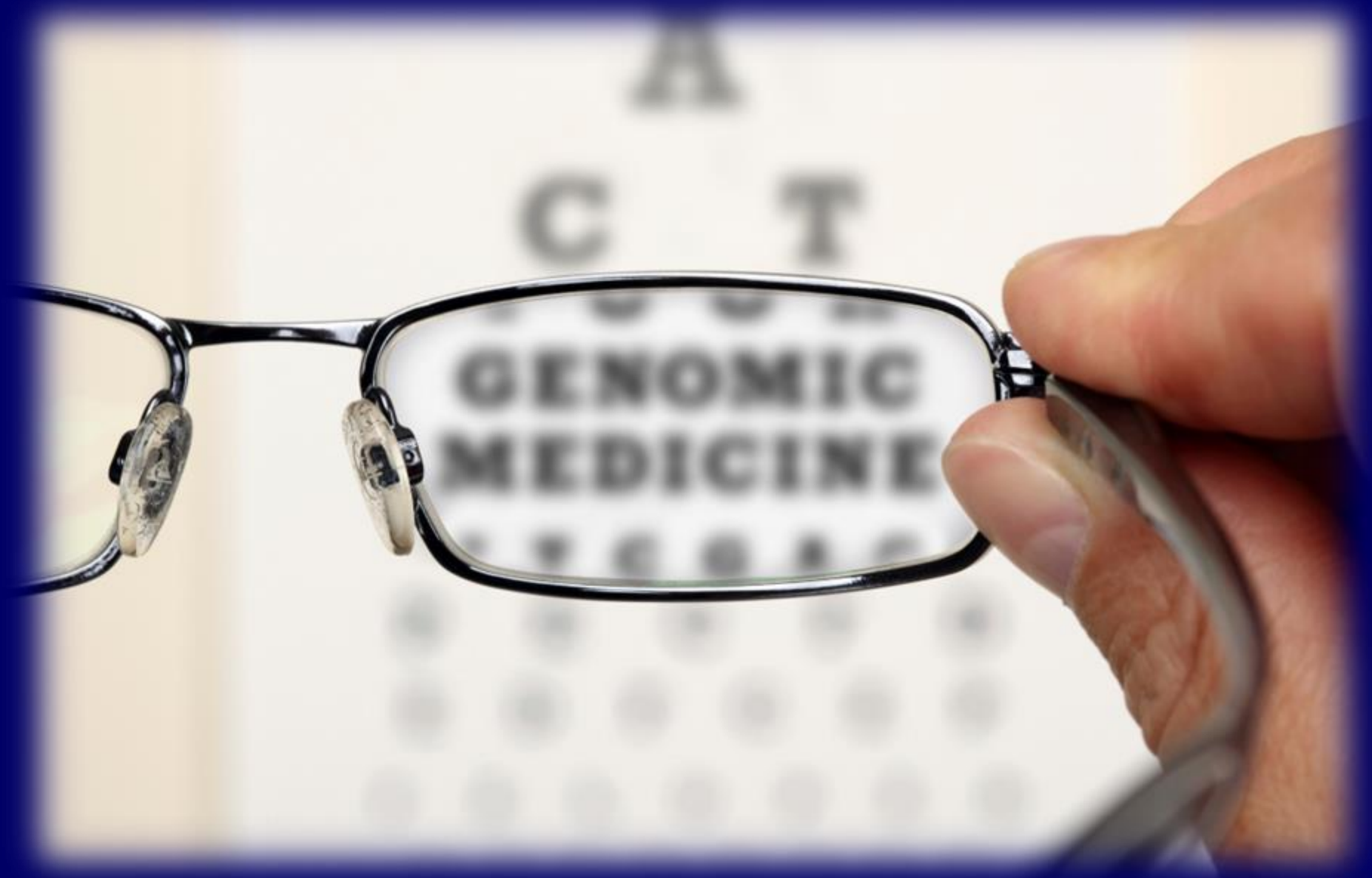
SPECIAL ISSUE

HUMAN GENOME AT


D.T. Max: What Darwin Can Teach Us About Jane Austen Alex Witchel: An Erma Bombeck for Military Wives
The New York Times Magazine
NOVEMBER 6, 2008 · SECTION 6
The Dawn of Genomic Medicine
How a pediatrician working with the Amish is changing what it means to diagnose and treat disease.
By Lisa Belkin
Why Waste Your Time Voting? (See Freakonomics, Page 30)


Science
24 October 2003
Vol. 302 No. 5645
Pages 517–728 $10
Genomic Medicine
American Association for the Advancement of Science

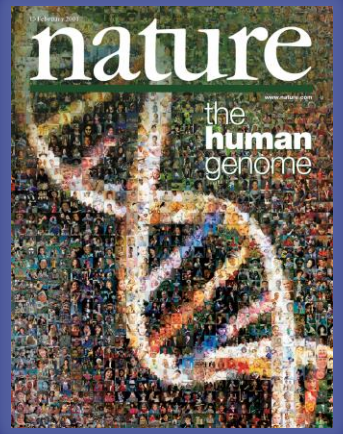
Bringing Genomic Medicine Into Focus



Genomic Medicine

An emerging medical discipline that involves using genomic information about an individual as part of their clinical care (e.g., for diagnostic or therapeutic decision-making) and the other implications of that clinical use

The Journey to Genomic Medicine

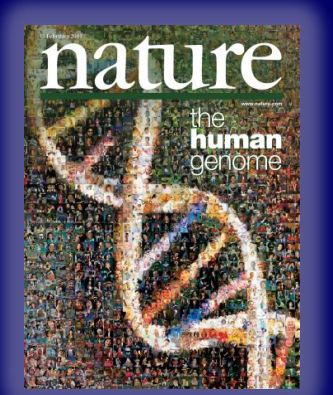


Human Genome Project

Realization of Genomic Medicine

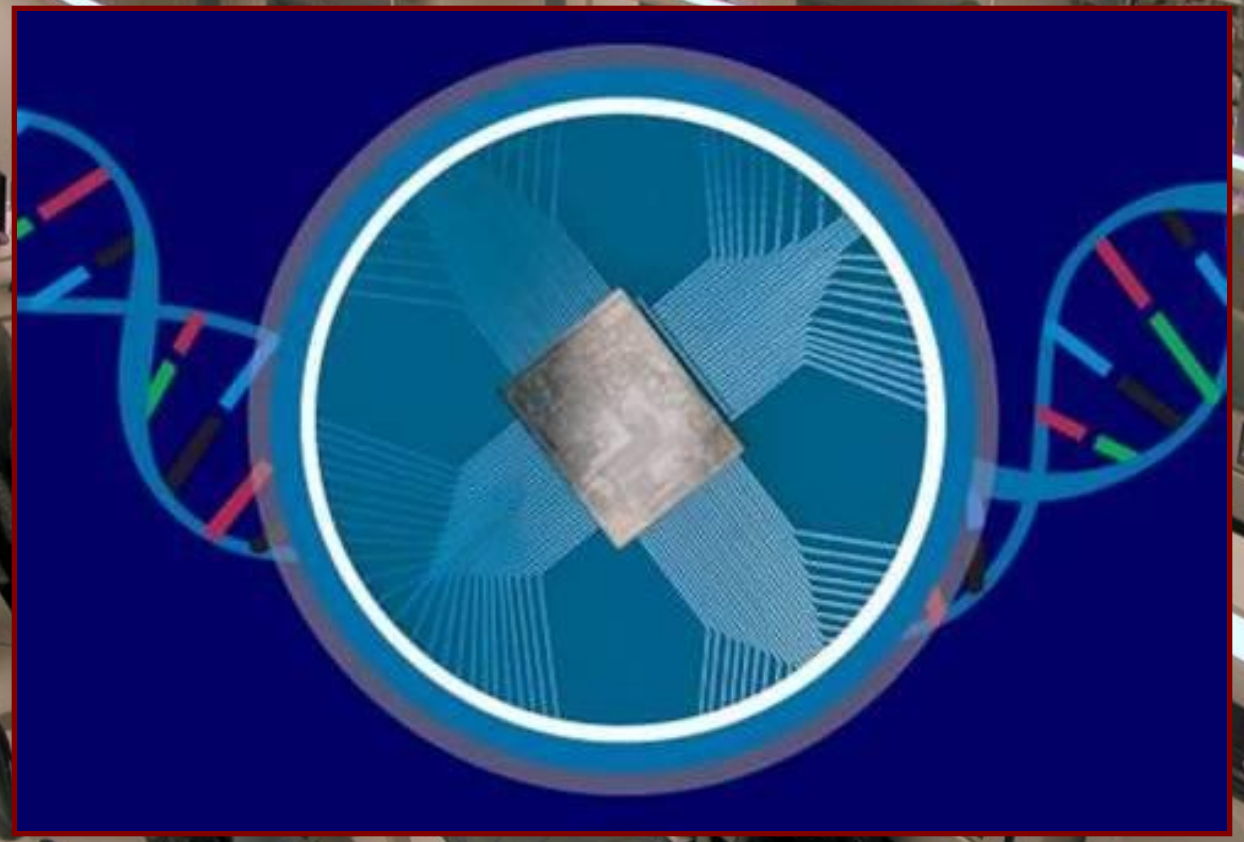
Human Genome Sequence

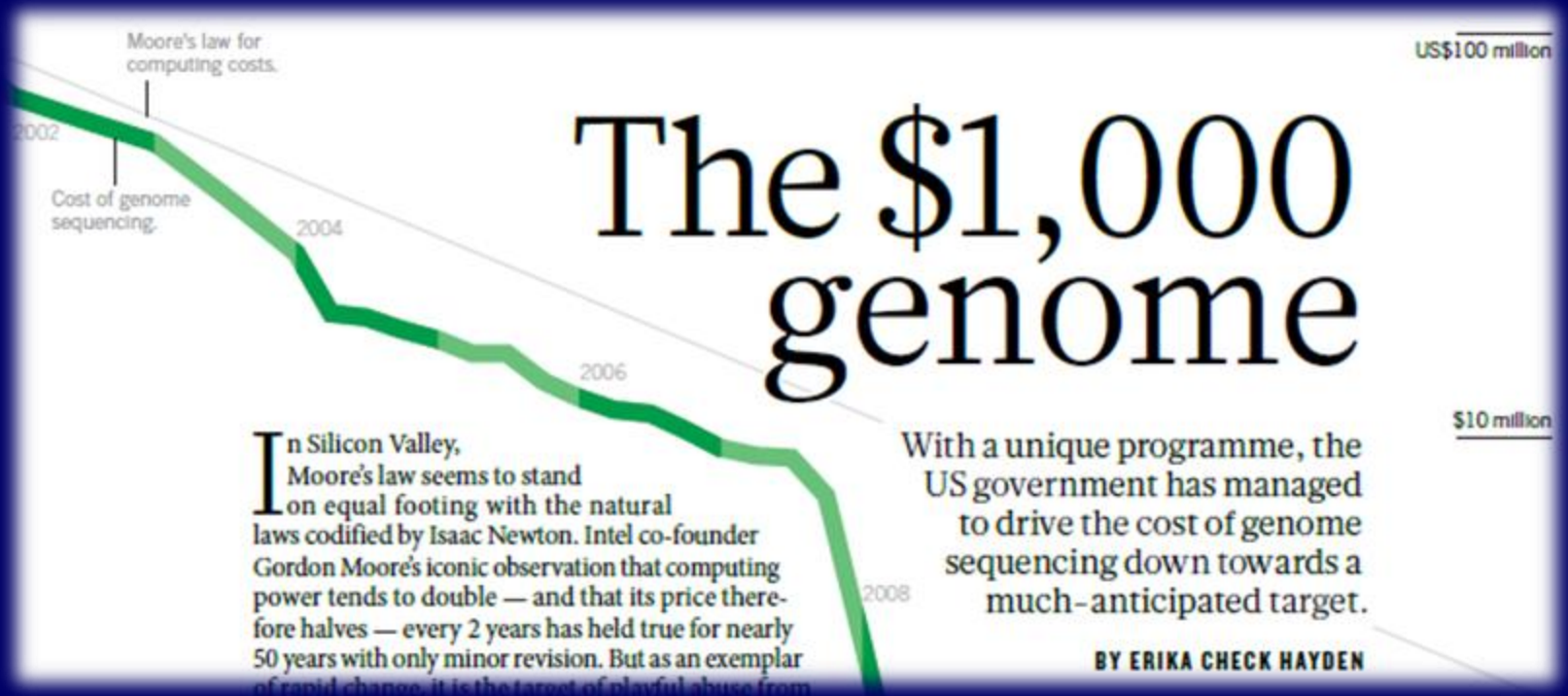
~$1,000,000,000



~$1,000

“The $1000 Genome”



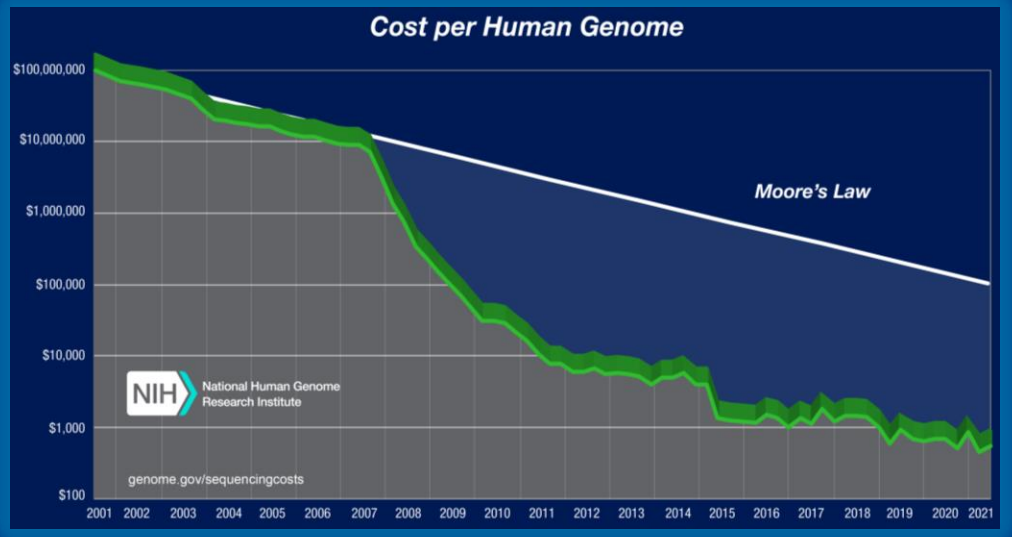


The $1,000 genome

In Silicon Valley, Moore's law seems to stand on equal footing with the natural laws codified by Isaac Newton. Intel co-founder Gordon Moore's iconic observation that computing power tends to double — and that its price therefore halves — every 2 years has held true for nearly 50 years with only minor revision. But as an exemplar of rapid change, it is the target of playful abuse from

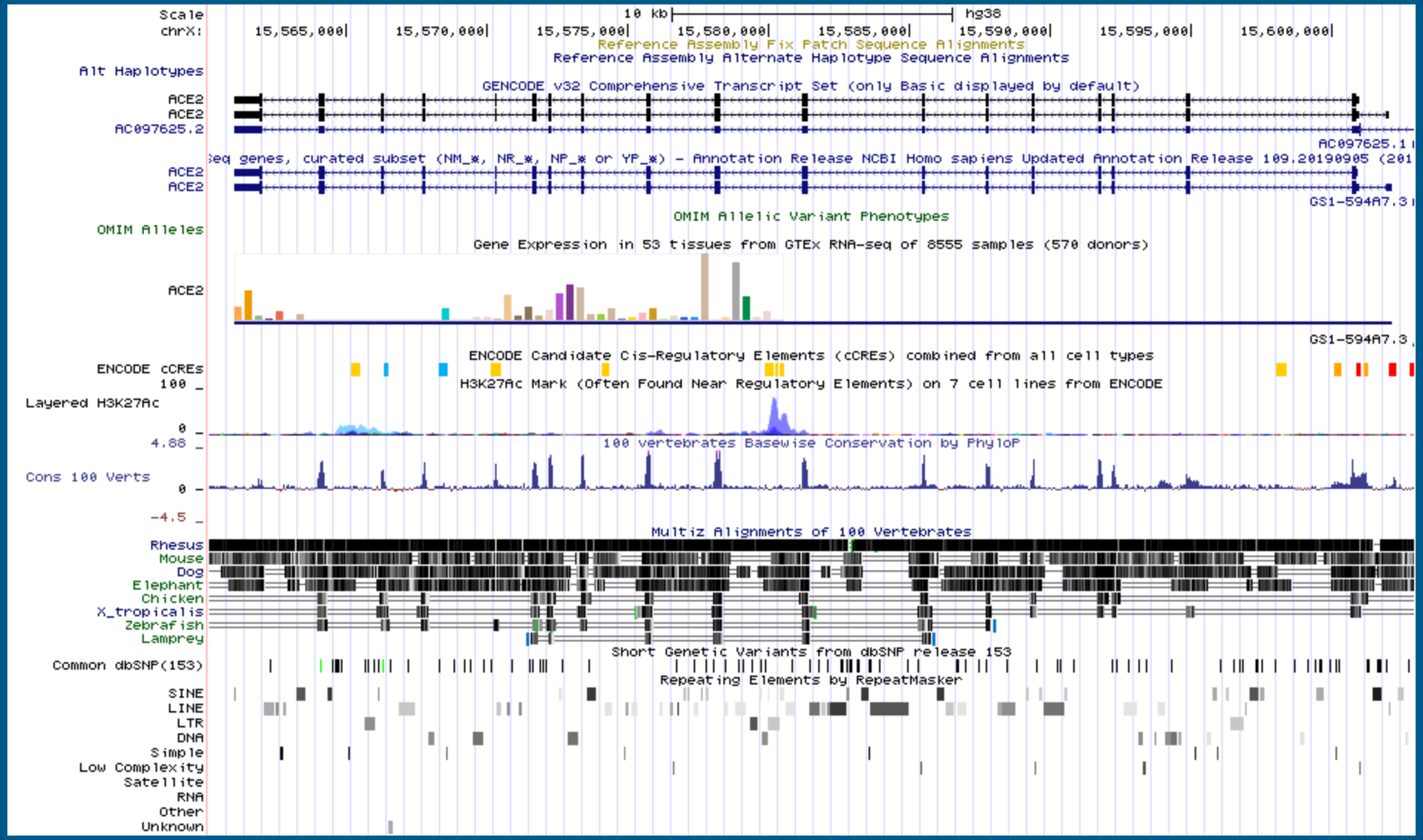
With a unique programme, the US government has managed to drive the cost of genome sequencing down towards a much-anticipated target.

BY ERIKA CHECK HAYDEN

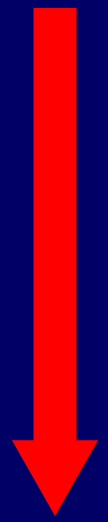


Human Genome Variation

Human Genome Function

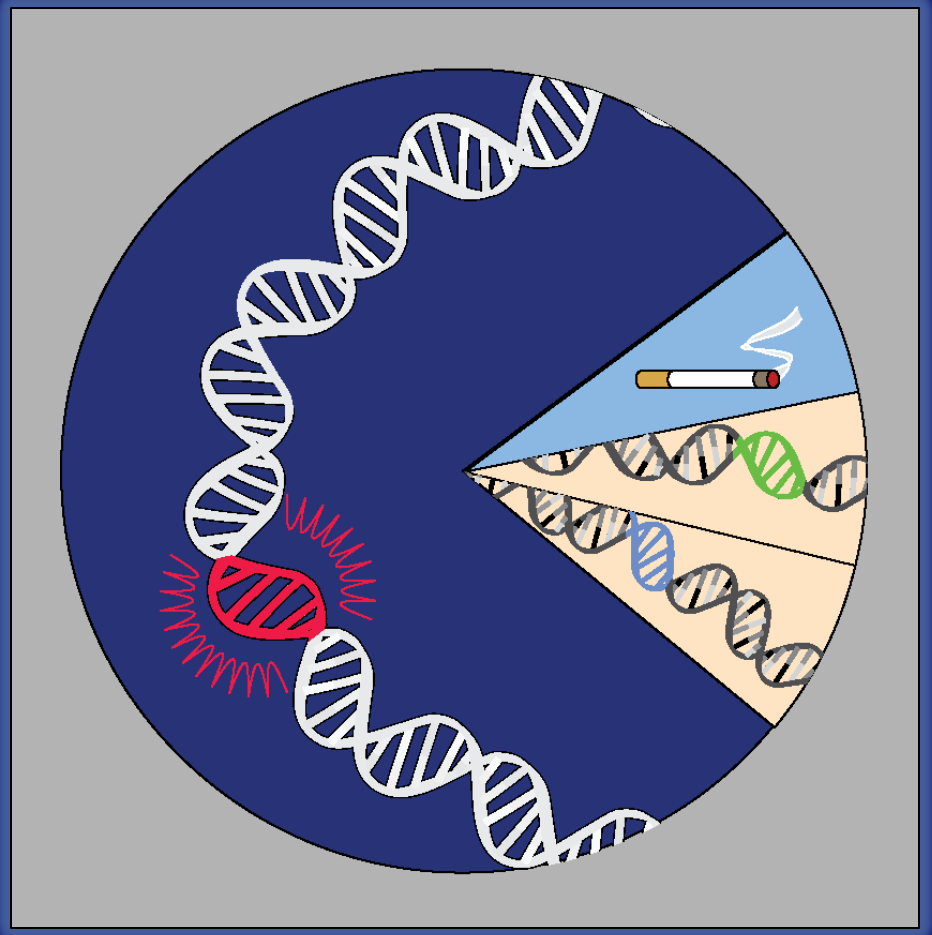


Some Genomic Variants

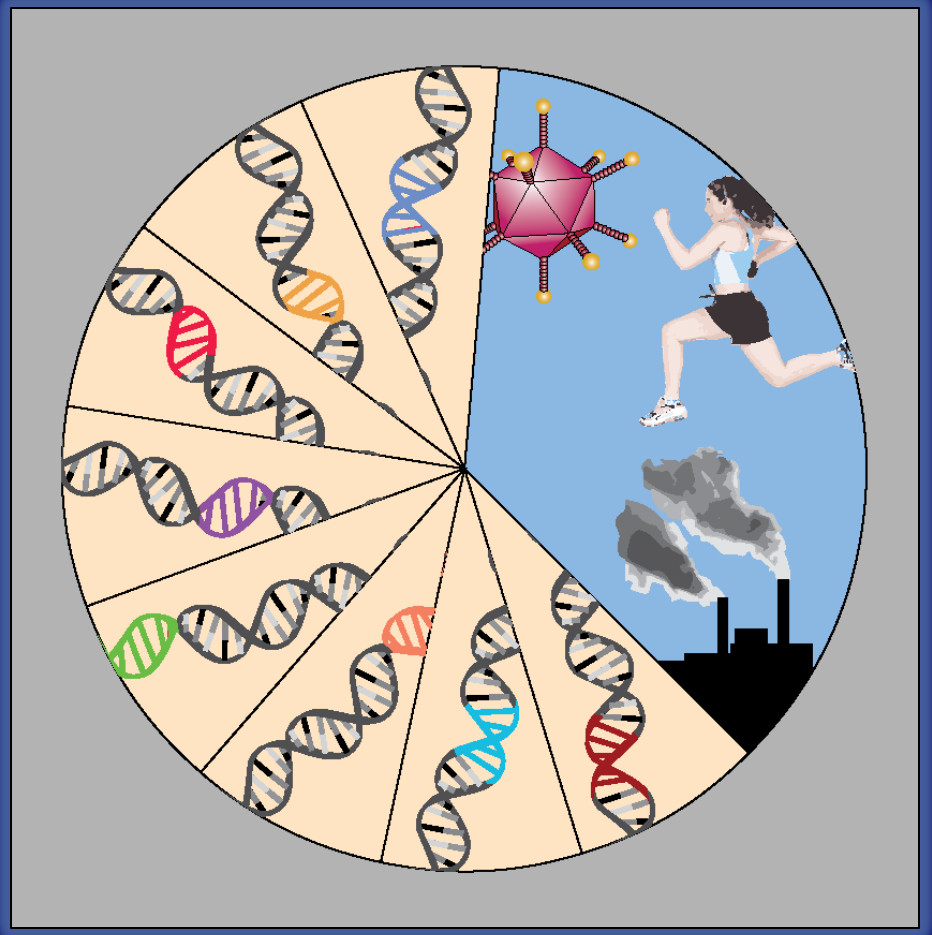


Traits
(i.e., Phenotypes)

Genomic Architecture of Genetic Diseases



Rare, Simple, Monogenic, Mendelian…



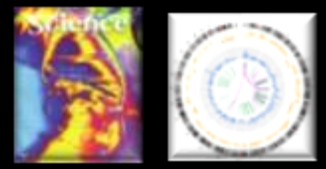
Common, Complex, Multigenic, Non-Mendelian…

Manolio et al., J Clin Invest (2008)

Bringing Genomic Medicine Into Focus

Genomic Medicine Implementation

Cancer Genomics



Rare Genetic Disease Diagnostics

Prenatal Genomic Testing

Pharmacogenomics

Genomic Risk Predictions for Common Diseases

???

Celebrating 3+ Decades of Genomics

- Human Genome Sequenced for First Time by the Human Genome Project
- Cost of Sequencing a Human Genome Reduced >1 Million-Fold
- Millions of Human Genomes Sequenced
- Profound Advances in Understanding How the Human Genome Functions
- Significant Advances in Unraveling the Genomic Bases of Human Disease
- Vivid Examples of Genomic Medicine Now Emerging

But Genomics Still Faces Big Challenges

Clinically Understanding a Patient's Genome Sequence Remains Difficult

Genomics is Becoming Profoundly Relevant in Society, Especially Healthcare

There is a Lack of Diversity in Genomics

Must Understand Roles of Both Genomic and Non-Genomic Factors in Human Health and Disease

The Reality of Genomics as a Field

The **Forefront** of **Genomics**®

2020 NHGRI Strategic Vision

Perspective

Strategic vision for improving human health at The Forefront of Genomics

https://doi.org/10.1038/s41586-020-2817-4
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Check for updates

Eric D. Green[1]✉, Chris Gunter[1], Leslie G. Biesecker[1], Valentina Di Francesco[1], Carla L. Easter[1], Elise A. Feingold[1], Adam L. Felsenfeld[1], David J. Kaufman[1], Elaine A. Ostrander[1], William J. Pavan[1], Adam M. Phillippy[1], Anastasia L. Wise[1], Jyoti Gupta Dayal[1], Britny J. Kish[1], Allison Mandich[1], Christopher R. Wellington[1], Kris A. Wetterstrand[1], Sarah A. Bates[1], Darryl Leja[1], Susan Vasquez[1], William A. Gahl[1], Bettie J. Graham[1], Daniel L. Kastner[1], Paul Liu[1], Laura Lyman Rodriguez[1], Benjamin D. Solomon[1], Vence L. Bonham[1], Lawrence C. Brody[1], Carolyn M. Hutter[1] & Teri A. Manolio[1]

Starting with the launch of the Human Genome Project three decades ago, and continuing after its completion in 2003, genomics has progressively come to have a central and catalytic role in basic and translational research. In addition, studies increasingly demonstrate how genomic information can be effectively used in clinical care. In the future, the anticipated advances in technology development, biological insights, and clinical applications (among others) will lead to more widespread integration of genomics into almost all areas of biomedical research, the adoption of genomics into mainstream medical and public-health practices, and an increasing relevance of genomics for everyday life. On behalf of the research community, the National Human Genome Research Institute recently completed a multi-year process of strategic engagement to identify future research priorities and opportunities in human genomics, with an emphasis on health applications. Here we describe the highest-priority elements envisioned for the cutting-edge of human genomics going forward—that is, at 'The Forefront of Genomics'.

Beginning in October 1990, a pioneering group of international researchers began an audacious journey to generate the first map and sequence of the human genome, marking the start of a 13-year odyssey called the Human Genome Project[1–3]. The successful and early completion of the Project in 2003, which included parallel studies of a set of model organism genomes, catalysed enormous progress in genomics research. Leading the signature advances has been a greater than one million-fold reduction in the cost of DNA sequencing[4]. This decrease has allowed the generation of innumerable genome sequences, including hundreds of thousands of human genome sequences (both in research and clinical settings), and the continuous development of assays to identify and characterize functional genomic elements[5,6]. These new tools, together with increasingly sophisticated statistical and computational methods, have enabled researchers to create rich catalogues of human genomic variants[7,8], to gain an ever-deepening understanding of the functional complexities of the human genome[9], and to determine the genomic bases of thousands of human diseases[9,10]. In turn, the past decade has brought the initial realization of genomic medicine[11], as research successes have been converted into powerful tools for use in healthcare, including somatic genome analysis for cancer (enabling development of targeted therapeutic agents)[12], non-invasive prenatal genetic screening[13], and genomics-based tests for a growing set of paediatric conditions and rare disorders[14], among others.

In essence, with growing insights about the structure and function of the human genome and ever-improving laboratory and computational technologies, genomics has become increasingly woven into the fabric of biomedical research, medical practice, and society. The scope, scale, and pace of genomic advances so far were nearly unimaginable when the Human Genome Project began; even today, such advances are yielding scientific and clinical opportunities beyond our initial expectations, with many more anticipated in the next decade.

Embracing its leadership role in genomics, the National Human Genome Research Institute (NHGRI) has developed strategic visions for the field at key inflection points, in particular at the end of the Human Genome Project in 2003[15] and then again at the beginning of the last decade in 2011[16]. These visions outlined the most compelling opportunities for human genomics research, in each case informed by a multi-year engagement process. NHGRI endeavoured to start the new decade with an updated strategic vision for human genomics research. Through a planning process that involved more than 50 events (such as dedicated workshops, conference sessions, and webinars) over the past two years (see http://genome.gov/genomics2020), the institute collected input from a large number of stakeholders, with the resulting input catalogued and synthesized using the framework depicted in Fig. 1.

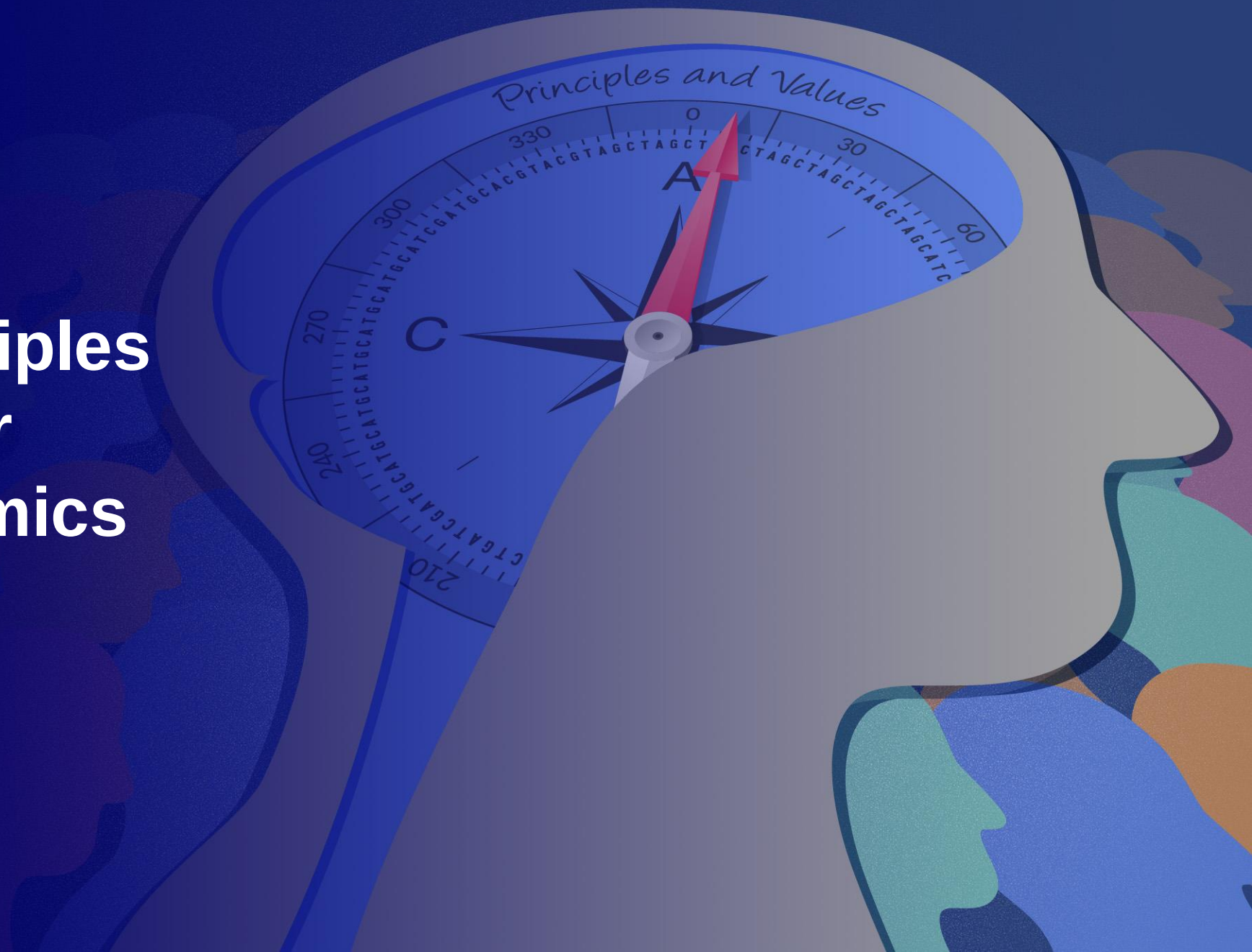
Unlike the past, this round of strategic planning was greatly influenced by the now widely disseminated nature of genomics across biomedicine. A representative glimpse into this historic phenomenon is illustrated in Fig. 2. During the Human Genome Project, NHGRI was the primary funder of human genomics research at the US National Institutes of Health (NIH), but the past two decades have brought a greater than tenfold increase in the relative fraction of funding coming from other parts of the NIH.

[1]National Human Genome Research Institute, National Institutes of Health, Bethesda, MD, USA. ✉e-mail: egreen@nhgri.nih.gov

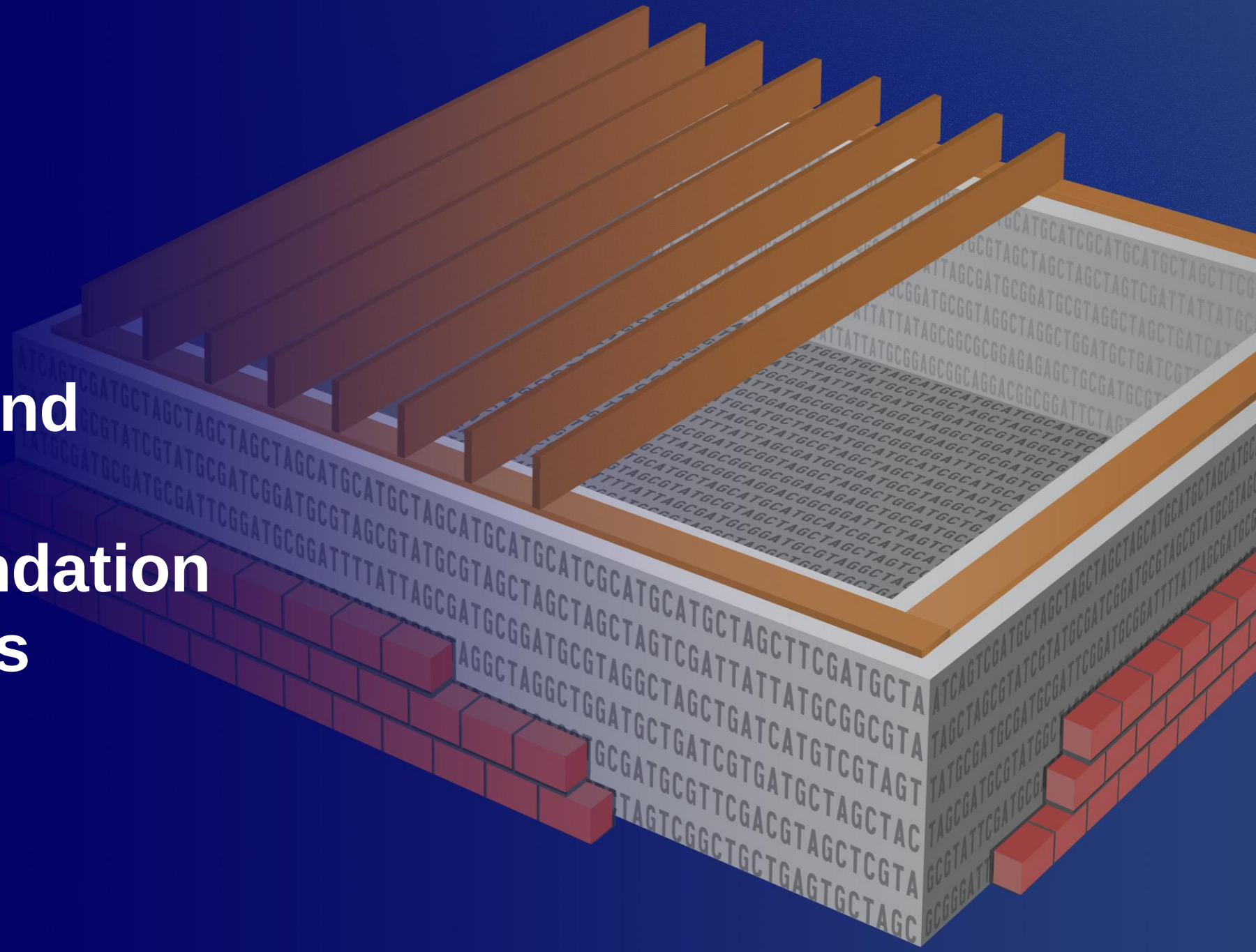
genome.gov/2020sv

Nature (2020)

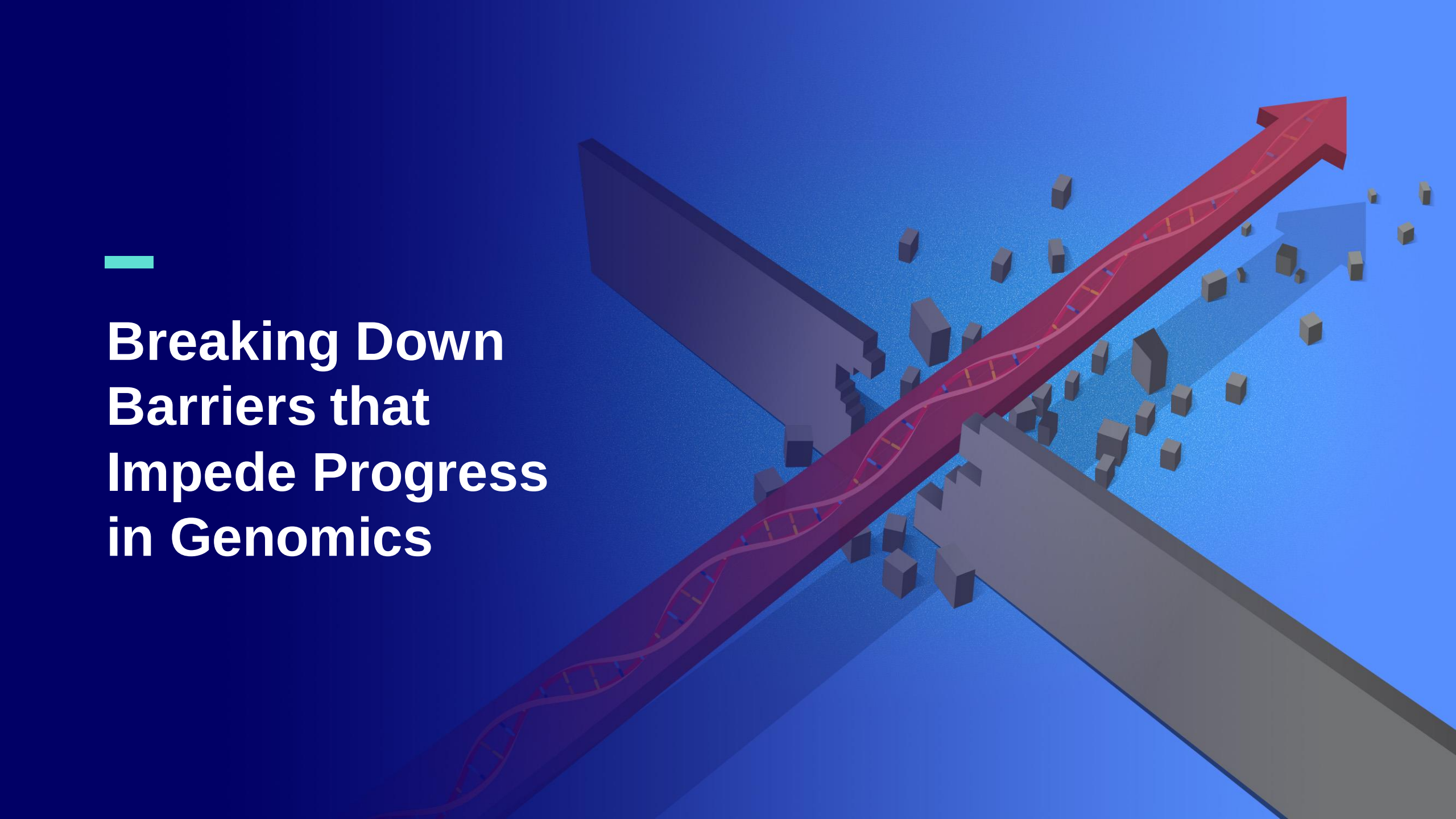
Guiding Principles and Values for Human Genomics



Sustaining and Improving a Robust Foundation for Genomics



Breaking Down Barriers that Impede Progress in Genomics



Compelling Genomics Research Projects in Biomedicine


330
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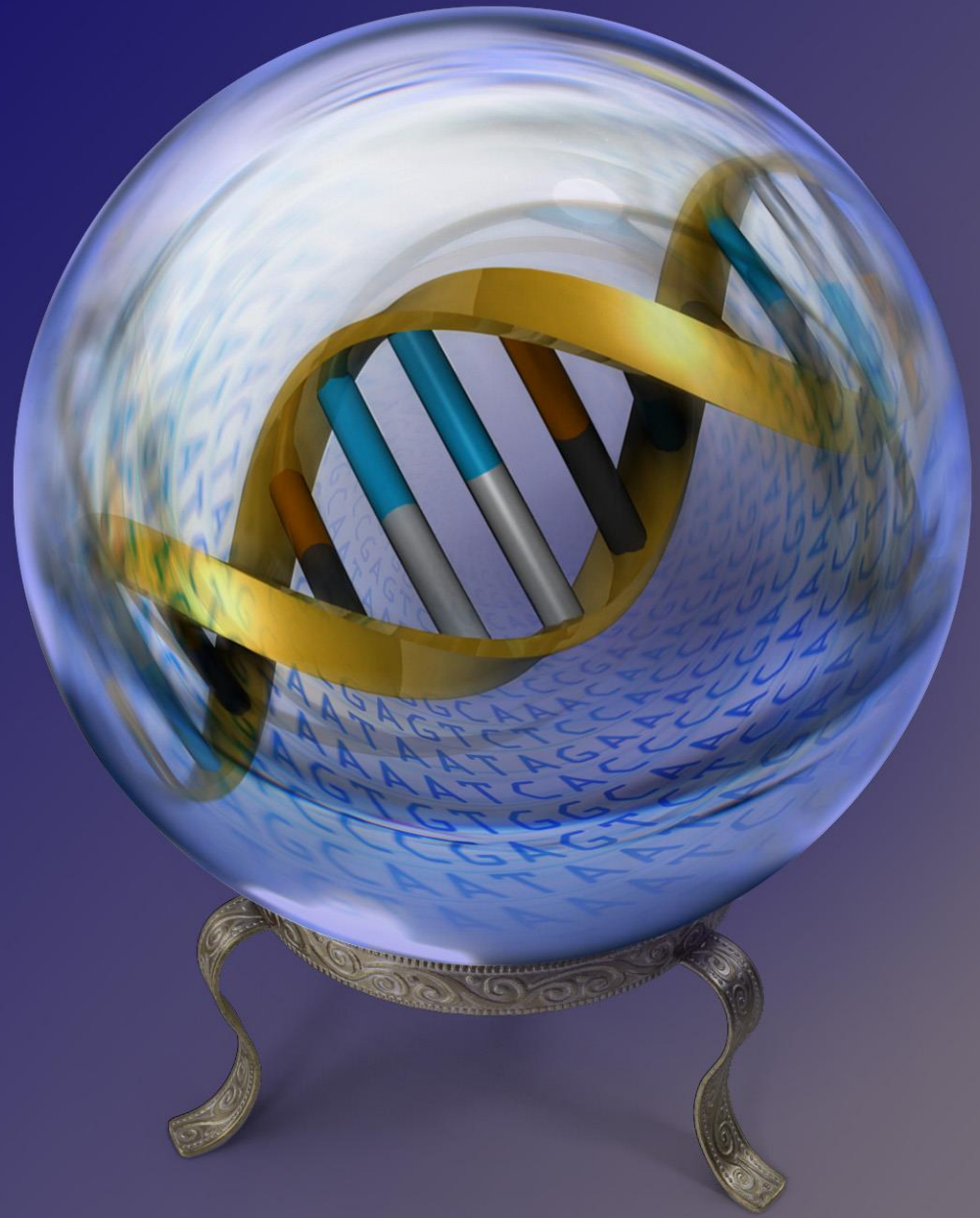
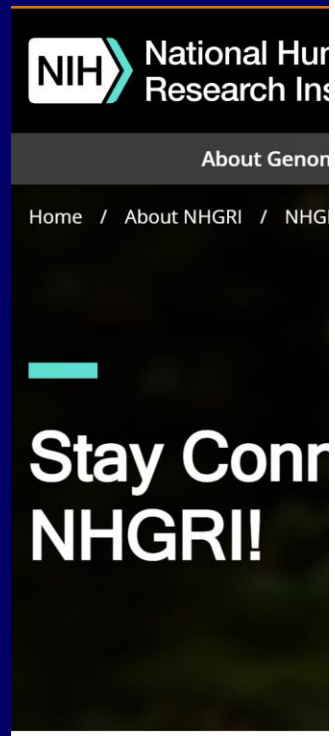
C

Bold Predictions for Human Genomics by 2030



‘One-Stop-Shop’ to Stay Connected

genome.gov/stayconnected



Podcasts

DNA TODAY PODCAST (APRIL 26, 2022)
Eric Green on the Complete Human Genome Project ›

AMERICAN METAPHOPHOSIS (MARCH 30, 2021)
The Butterfly Effect ›

TRAILBLAZERS WITH WALTER ISAACSON (DECEMBER 15, 2020)
Genomics: Rewriting Our Health ›

GENETICS UNZIPPED (OCTOBER 22, 2020)
The Past, Present and Future of the Human Genome Project ›

There are many ways
of the major sites that

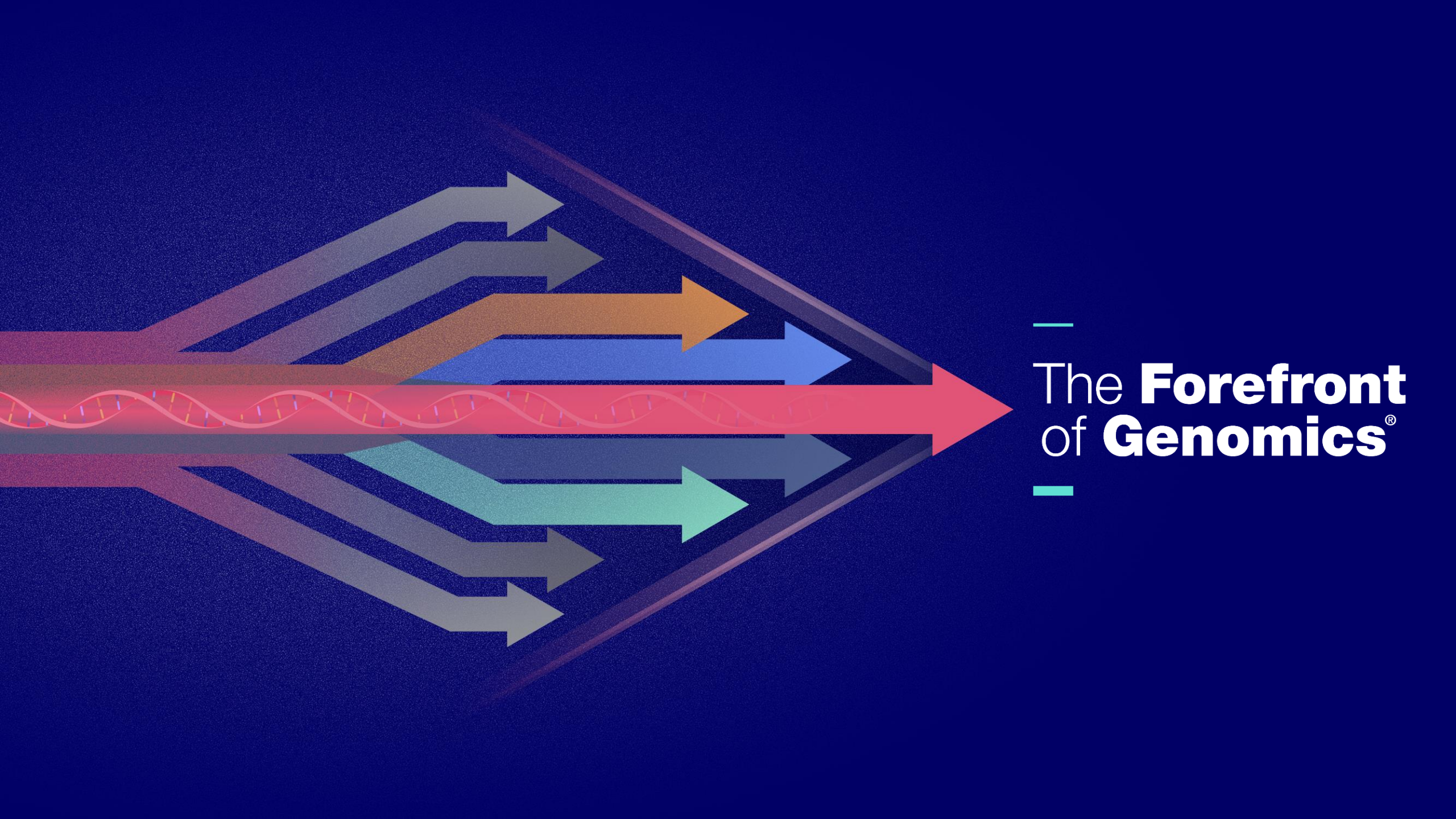
Op-Eds/Commentaries

Completing the Human Genome Sequence (Again)
Scientific American, March 31, 2022

An Anti-racist Action Plan for Studying the Human Genome
The Hill, September 16, 2021

A Vision for the Next Decade of Human Genomics Research
Scientific American, October 28, 2020

Questions?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