

# *What is Public Health Genomics and Why Should we Care?*

Muin J. Khoury, MD, Ph.D.

CDC National Office of Public Health Genomics



SAFER • HEALTHIER • PEOPLE™

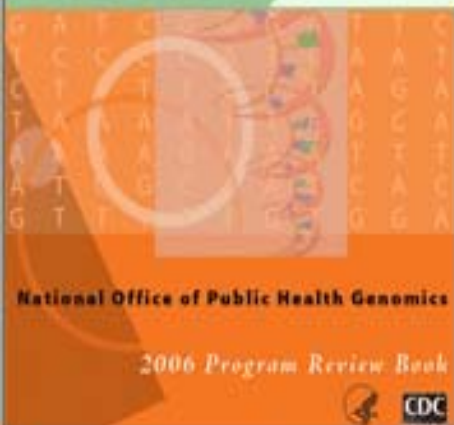




## National Office of Public Health Genomics

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1	2	3	4			
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### SPOTLIGHT



**CDC's National Office of Public Health Genomics (NOPHG)** is pleased to announce the 2006 Program Review Book is now available [online](#).

**Welcome** to the National Office of Español

Public Health Genomics (NOPHG), formerly the Office of Genomics & Disease Prevention (OGDP). This site provides updated information on how human genomic discoveries can be used to improve health & prevent disease. It also provides links to CDC wide activities in public health genomics.

- Message from [Dr. Muin Khoury](#) | [About NOPHG](#)
- [What's In A Name?](#)

#### MAIN MENU

- [NOPHG Home](#)
- [Weekly Update](#)
- [Frequently Asked Questions](#)
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#### Family History

[Family History Initiative](#) | [Publications](#)  
[Workshops](#) | [Resources and Tools](#) | [Links](#)



#### Genomics In Practice

[EGAPP](#) | [Genomics Centers](#) | [Genetic Testing](#)

#### FREQUENTLY ASKED QUESTIONS

- ▶ [FAQ's About Genomics](#)
- ▶ [Public Health Genomics](#)

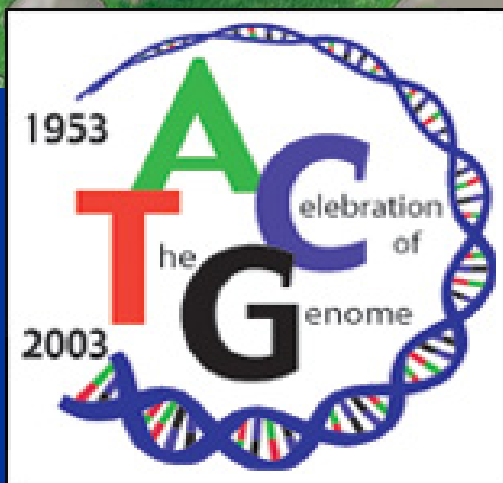
#### POPULAR PAGES

# Outline

- Welcome to the Genomics Era: Science and Hype
- Why Public Health?
- What is Public Health Genomics?
- Overview of the Series

# Rapid Developments in the “Omics” Age

URL of this page: <http://www.genome.gov/11007576>



## ARTICLES

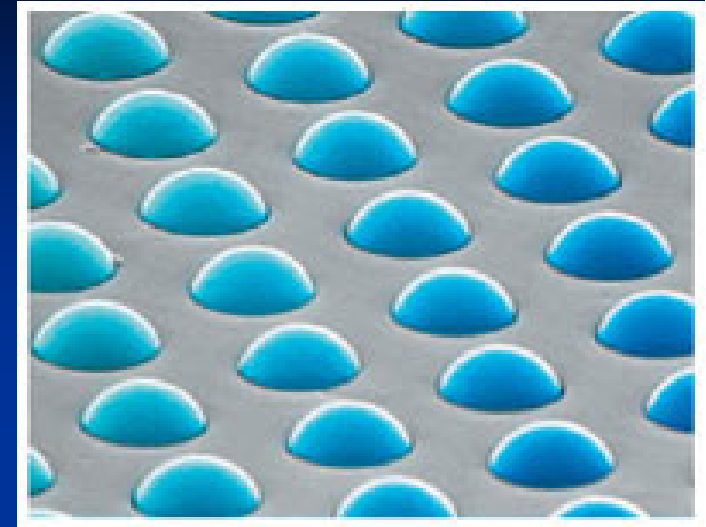
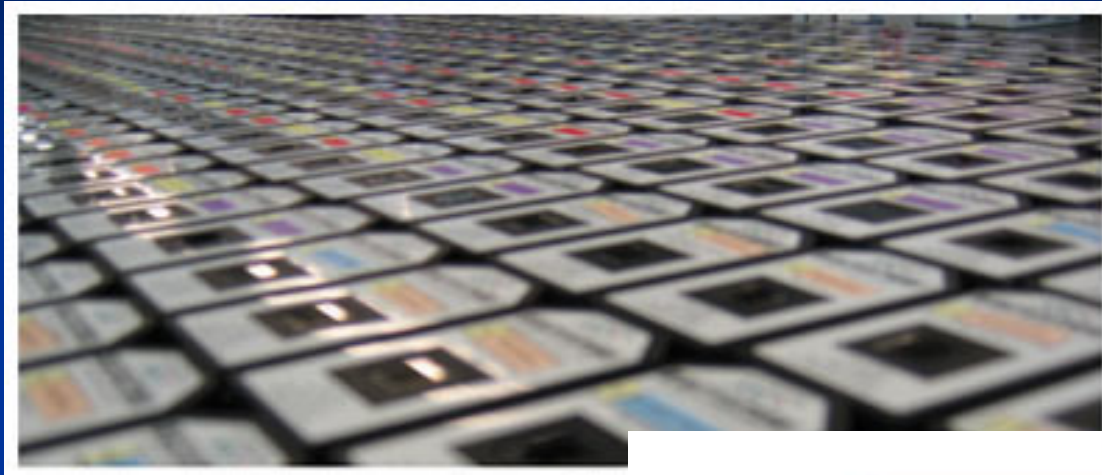
### A haplotype map of the human genome

The International HapMap Consortium\*

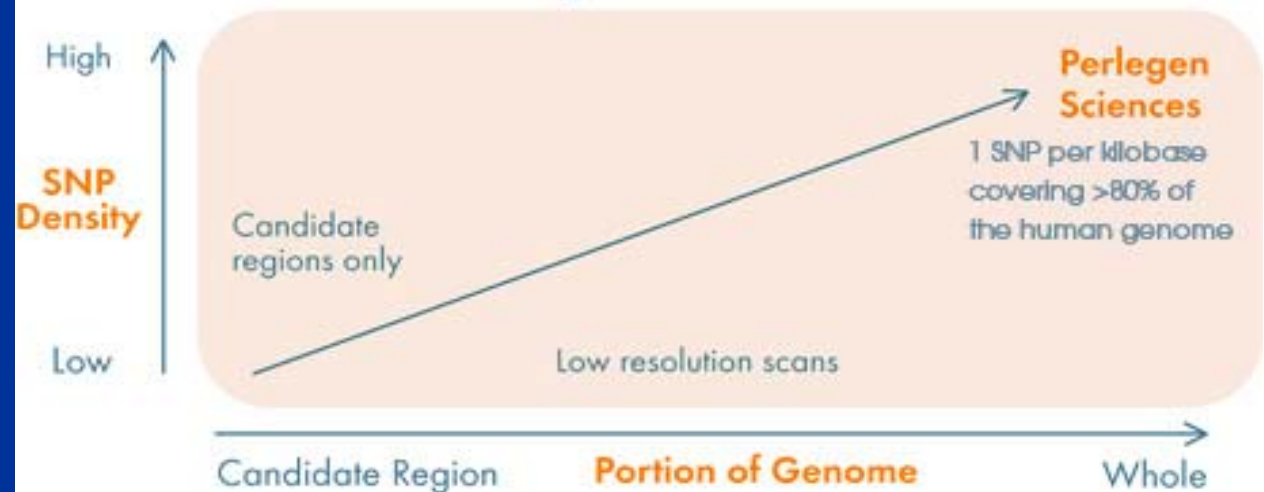
Inherited genetic variation has a critical but as yet largely uncharacterized role in human disease. Here we report a public database of common variation in the human genome: more than one million single nucleotide polymorphisms (SNPs) for which accurate and complete genotypes have been obtained in 269 DNA samples from four populations, including ten 500-kilobase regions in which essentially all information about common DNA variation has been extracted. These data document the generality of recombination hotspots, a block-like structure of linkage disequilibrium and low haplotype diversity, leading to substantial correlations of SNPs with many of their neighbours. We show how the HapMap resource can guide the design and analysis of genetic association studies, shed light on structural variation and recombination, and identify loci that may have been subject to natural selection during human evolution.



# *Chips and SNPs and Whole Genome Scans*



Unprecedented Scale



# The Era of Genome-Wide Association Studies

National Cancer Institute  
U.S. National Institutes of Health | www.cancer.gov

## CGEMS

Cancer Genetic Markers of Susceptibility

WELCOME BROWSE DATA BULK DATA DOWNLOAD SUPPORT FEEDBACK LOGIN/REGISTRATION

FOUNDATION FOR THE National Institutes of Health

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## GAIN Program

GAIN HOME PAGE  
► Partnerships  
► Overview

## GENETIC ASSOCIATION INFORMATION NETWORK (GAIN)

Genetic Association Information Network (GAIN) is a public-private partnership of the National Institutes of Health, Inc. (NIH), which will include corporations, advocacy groups, concerned individuals, and the National Institutes of Health. This initiative will take the next step in the search to understand the genetic risk for complex diseases. Through a series of whole genome scans, using samples from existing case-control studies of common diseases, the goal is to identify genetic pathways that make us more susceptible to disease and thereby facilitate discovery of new molecular targets for prevention, diagnosis, and treatment.

Address <http://www.wtccc.org.uk/>

WTCCC

Home

Links

Overview

Participants

Press Release [28 09 2005]

Data release and access policy

Guidelines for data use

Analysis data format

Simple data format

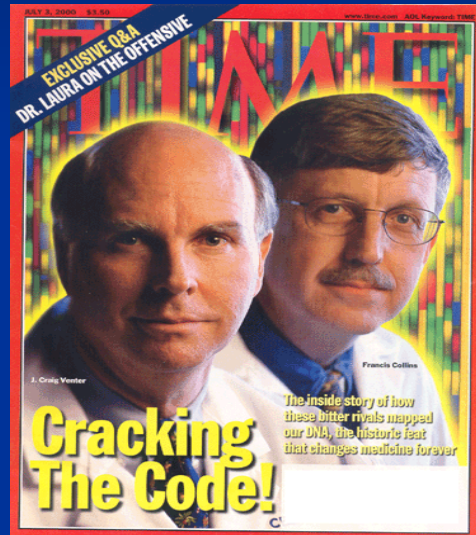
Data Access

## The Wellcome Trust Case Control Consortium

The Wellcome Trust Case Control Consortium (WTCCC) is a collaboration of 24 leading human geneticists, who will analyse thousands of DNA samples from patients suffering with different diseases to identify common genetic variations for each condition. It is hoped that by identifying these genetic signposts, researchers will be able to understand which people are most at risk, and also produce more effective treatments.

The WTCCC will search for the genetic signposts for tuberculosis, coronary heart disease, type 1 diabetes, type 2 diabetes, rheumatoid arthritis, Crohn's disease and ulcerative colitis, bipolar

# *Genomics is to the 21<sup>st</sup> century what infectious disease was to the 20<sup>th</sup> century...*



“...Genomics should be considered in every facet of public health: infectious disease, chronic disease, occupational health, environmental health, in addition to maternal and child health.”

Gerard S, Hayes M, Rothstein MA. J Law Med Ethics. 2002

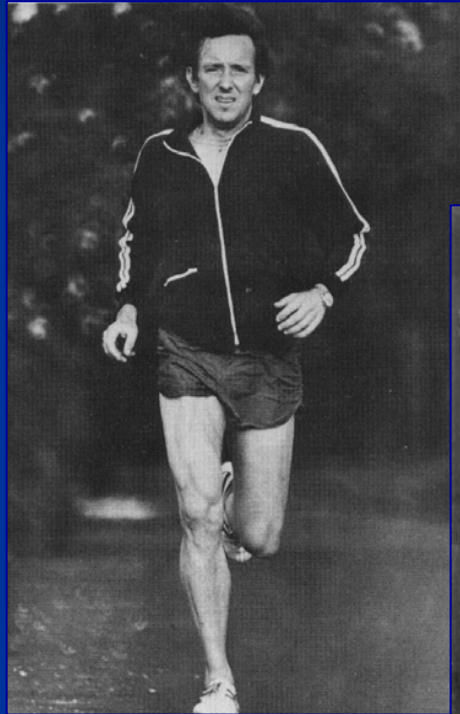
# *From Genetics to Genomics*

- Genetic Disorders
- Mendelian Disorders
- Disease burden: 5%
- Mutations/One Gene
- High Disease Risk
- Environment +/-
- “Genetic Services”
- Genetic Information
- All Diseases
- Disease Burden: 95%
- Variants/MultiGenes
- Low Disease Risk
- Environment ++
- General Practice



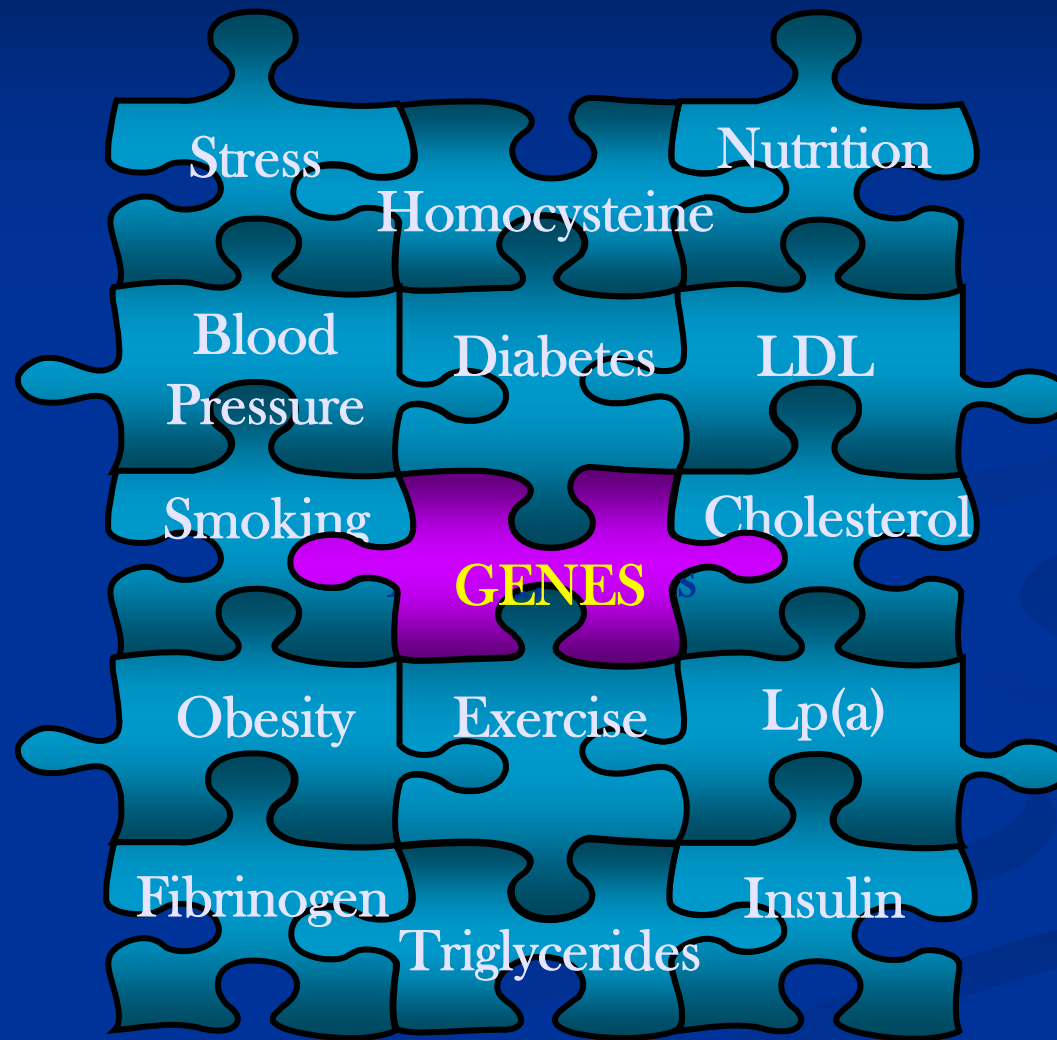
# *Human Diseases Result from Gene-Environment Interaction*

- “Some vegetarians with 'acceptable' cholesterol levels suffer myocardial infarction in the 30's. Other individuals...seem to live forever despite personal stress, smoking, obesity, and poor adherence to a Heart Association-approved diet”



**R.A. Hegele (1992)**

# Genetics and Cardiovascular Disease



## ***Examples of Recent Human Gene Discoveries: Implications for Practice and Prevention?***

- “Scientists identify gene mutation in autism” (December 18, 2006)
- Company identifies two genetic variations predisposing individuals to increased risk for psoriasis (December 14, 2006)
- “Can your genetic make-up predict what you should eat?” (December 19, 2006)
- “Genomic tests improve prediction of breast cancer response to chemotherapy, hormonal therapy” (December 18, 2006)

**SOURCE: CDC GENOMICS and HEALTH WEEKLY UPDATE**

**<http://www.cdc.gov/genomics/update/current.htm>**



# *Continuum of Genome-based Knowledge*

- Genetic diseases high penetrance
- Genetic diseases low penetrance
- Inherited common genetic variation
- Somatic genetic information
- Pathogen/vector genome information
- Gene expression profiles
- Protein markers
- Biological markers of all types
- Modern biology



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- Protein markers
- Biological markers of all types
- Modern biology

Narrow focus



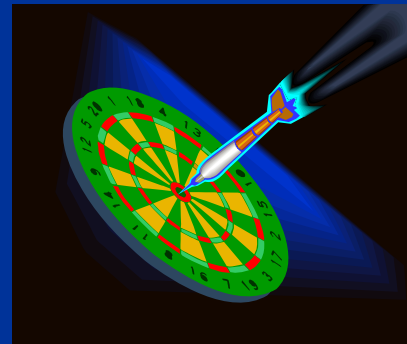
Broad focus

# *Vision for the Transformation of Medicine in the 21<sup>st</sup> Century*

*Predictive*



*Personalized*

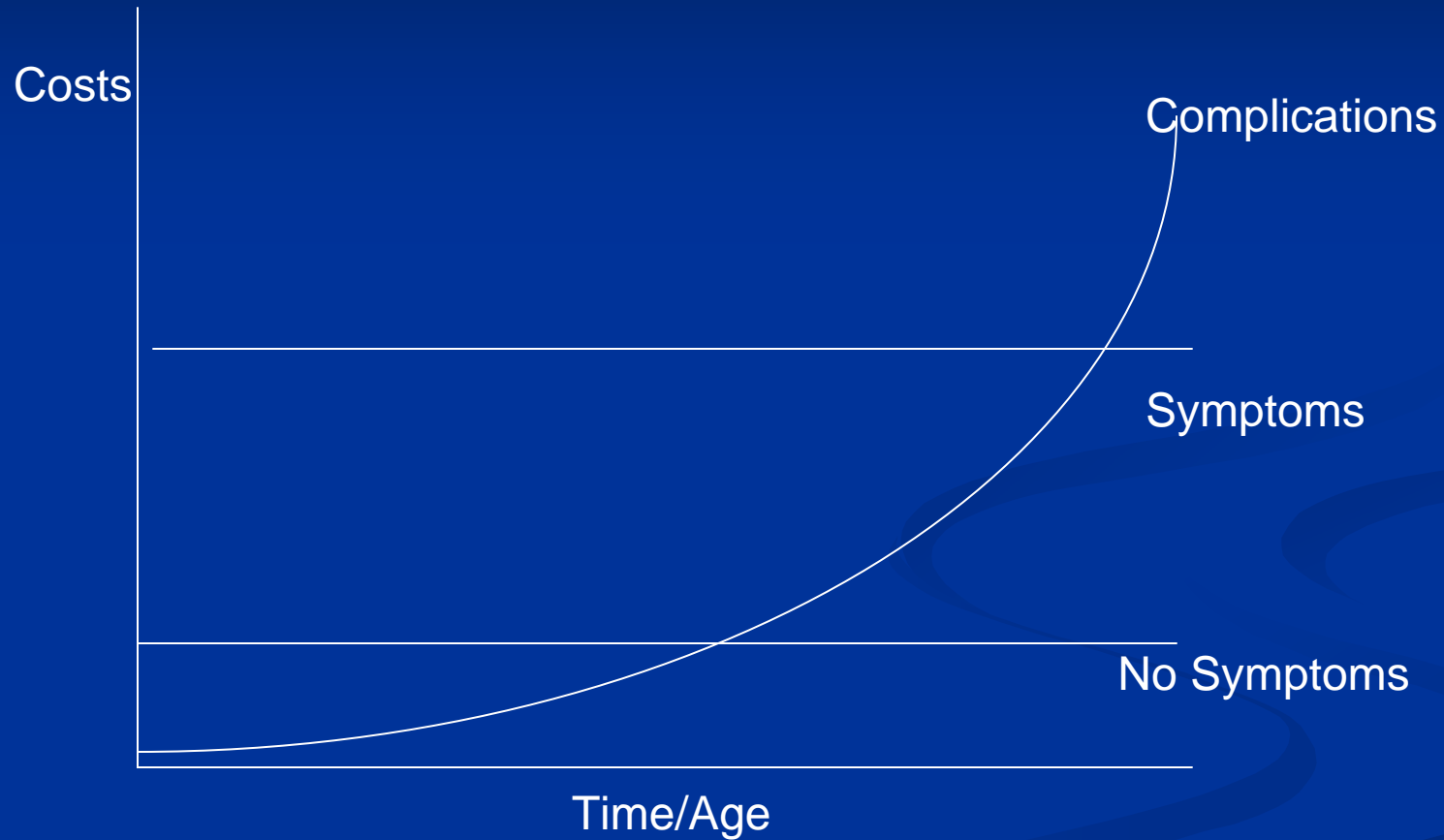


*Preemptive*

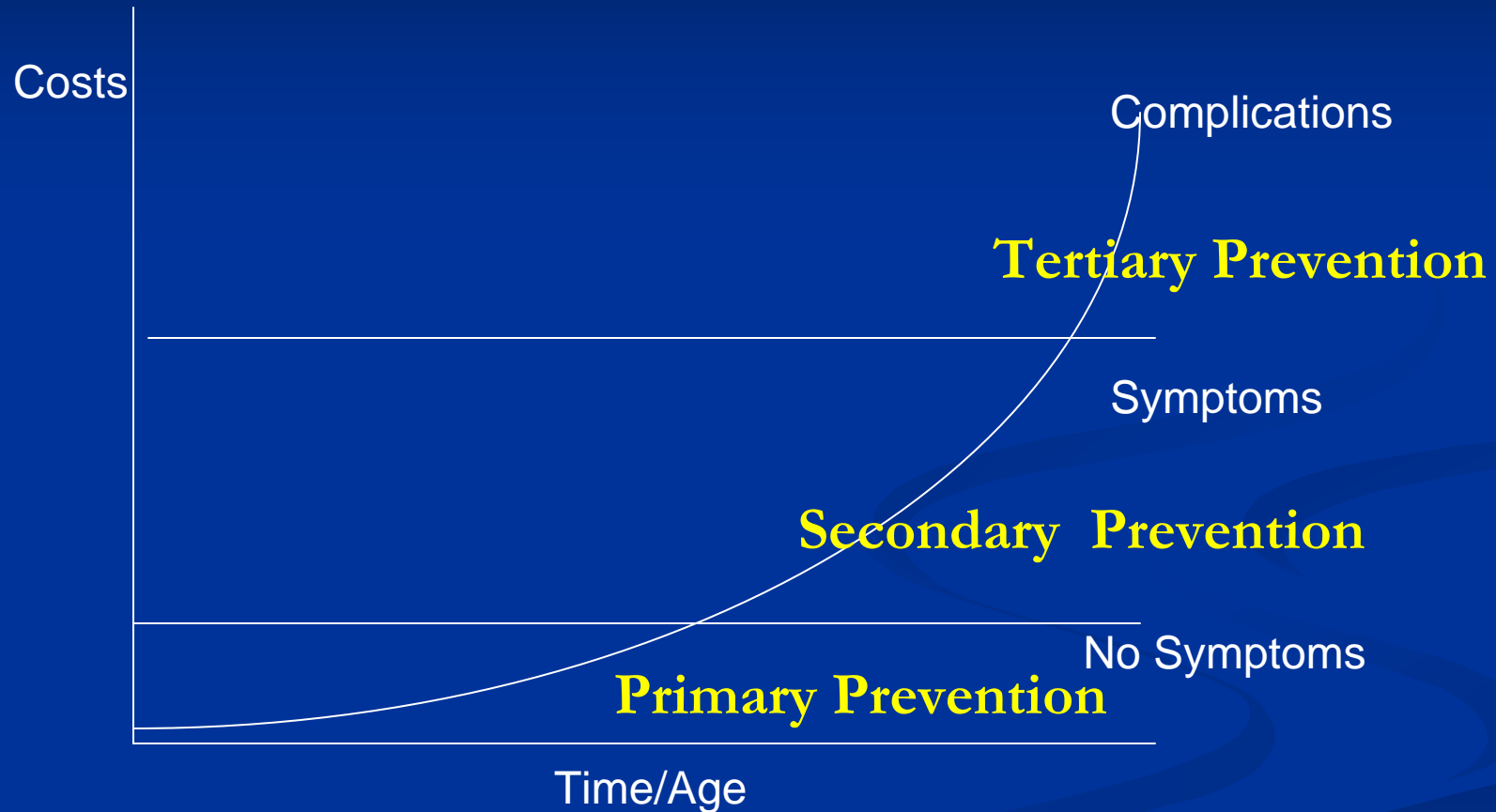


"I predict that comprehensive, genomics-based health care will become the norm with individualized preventive medicine and early detection of illnesses" (Zerhouni, 2006)

# Health Care Costs for Common Diseases by Stage of Disease



# Health Care Costs for Common Diseases by Stages of Prevention





## ***Gene-Based Medicine in 2010?***

■ Condition	Genes	RR	Lifetime
■ Prostate Ca	HPC1, 2, 3	0.5	7%
■ Alzheimer's	APOE,FAD3,XAD	0.3	10%
■ Heart disease	APOB,CETP	2.5	70%
■ Colon Cancer	FCC4,APC	4.0	23%
■ Lung Cancer	NAT2	6.0	40%

**Collins FC, New Engl J Med 1999;341:28-37.**

# *Gene-Based Medicine in 2010?*

## *Prevention Strategies*

- Increased Risk for
  - Heart disease
  - Colon Cancer
  - Lung Cancer
- Prevention Strategies
  - **Tertiary:** Cholesterol drugs + Lifestyle changes
  - **Secondary:** Increased surveillance for early detection
  - **Primary:** Behavior modification for smoking cessation

# “Gene Increases Diabetes Risk, Scientists Find”

(New York Times, January 16, 2006)

- “Scientists have discovered a variant gene that leads to a sizeable extra risk of Type 2 Diabetes and is carried by more than a third of Americans...An immediate practical consequence of the discovery would be to develop a diagnostic test to identify people who carry the variant gene. If people knew of their extra risk, they would have an incentive to stay thin and exercise”

Grant et al. Nat Genet Jan 2006

Address <http://bmj.bmjournals.com/cgi/content/extract/333/7567/509>

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BMJ 2006;333:509-510 (9 September), doi:10.1136/bmj.38953.598947.80

**Editorial**

**Predictive genetic testing for type 2 diabetes**

*May raise unrealistic expectations*

The first 150 words of the [full text](#) of this article appear below.

The discovery earlier this year that a variant of the TCF7L2 (transcription factor 7-like 2) gene is associated with type 2 diabetes was reported in a front page story in the *New York Times*.<sup>1 2</sup> The principal investigator, Kari Stefansson, told the newspaper that the discovery could lead to a diagnostic test to identify people who carry the variant gene. People who knew of their extra risk, he said, would be motivated to avoid the

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# *“Study Detects a Gene Linked to Alzheimer’s”*

New York Times, January 15, 2007

- “A variant gene involved in Alzheimer’s disease has been detected through study of Dominican families living in Manhattan, scientists are reporting **today...That raises the possibility of developing a drug...which would be expected to have a protective effect”**



# Outline

- Welcome to the Genomics Era: Science and Hype
- **Why Public Health?**
- What is Public Health Genomics?
- Overview of the Series

# *What Role of Public Health in Genetics and Vice Versa?*

*Holtzman NA, Comm Genet 2006*

- “The only genetic service for which a public health role is paramount is newborn screening”
- “There is little need for further integration of genetic services and education into public health especially in countries in which public and private health services are dichotomized.”

# “Dissecting Complex Disease: the Quest for the Philosopher's Stone?”

A. Buchanan et al. *Int J Epidemiol* 2006;35:562

- “If a major fraction of the billions spent on technological research were spent instead on simpler things like, yes, early health education to improve diet and promote exercise, the benefits could grossly dwarf even the greatest plausible genetic successes”

http://www.everydaychoices.org/

HOME EAT RIGHT GET ACTIVE DON'T SMOKE SEE YOUR DOCTOR GET MORE INFORMATION

**American Cancer Society**

**American Diabetes Association**  
Cure • Care • Commitment®

**American Heart Association**  
Learn and Live™

**Everyday Choices for A Healthier LIFE**  
Everydaychoices.org  
The American Cancer Society, American Diabetes Association and American Heart Association agree - you can significantly impact your health through your everyday choices. And your family and friends can provide the support you need to live a healthier life. Protect yourself today.

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# *What is Public Health?*

- “An effort organized by society to protect, promote, and restore the people’s health”
- [healthyamericans.org/docs/](http://healthyamericans.org/docs/)



# *What is Public Health?*

- Population focus
- Prevention
- Evidence-based



# *What is Public Health?*

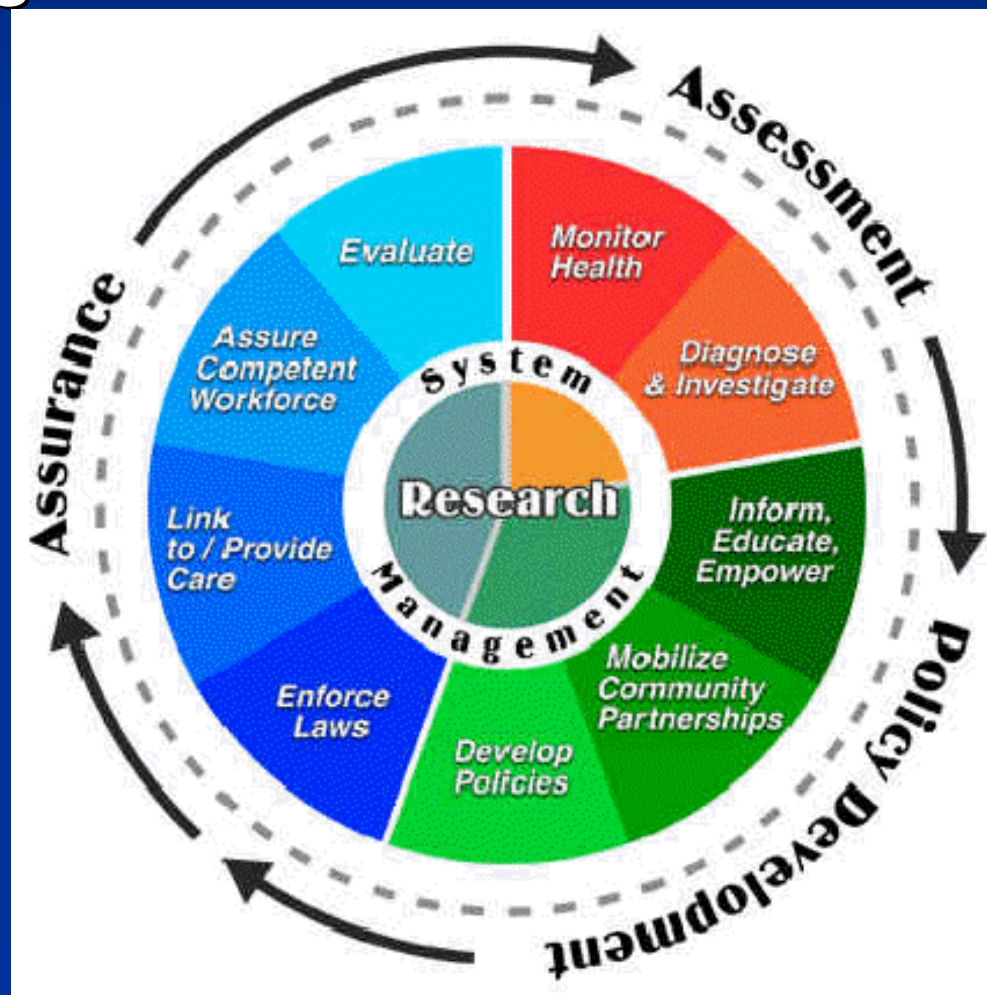
- Population focus
- Prevention
- Evidence-based
  
- Assessment
- Policy
- Assurance & Evaluation





# What is Public Health?

- Population focus
- Prevention
- Evidence-based
- Assessment
- Policy
- Assurance & Evaluation



# *Genomics and Public Health Practice: Two Major Contributions*

- Ensure that validated genetic information is used to improve health, especially in underserved populations

# ***”Clinical Research to Clinical Practice — Lost in Translation?”***

*C. Lenfant NEJM 2003;349:868*

**< 33% of patients with  
coronary artery  
disease are  
prescribed aspirin**

# ***“Clinical Research to Clinical Practice — Lost in Translation?”***

*C. Lenfant NEJM 2003;349:868*

**< 33% of patients with coronary artery disease are prescribed aspirin**

**“Let's be realistic: If we didn't do it with aspirin, how can we expect to do it with DNA?”**

# ***Genomics and Health Disparities*** ***(W Foege, 2005)***

- “The challenge to genomics is to overcome inequitable allocation of benefits, the tragedy that would befall us if we made the promise of genetics only for those who could afford it and not for all society”

**“Let's be realistic: If we didn't do it with aspirin, how can we expect to do it with DNA?”**

# *Genomics and Public Health Practice: Two Major Contributions*

- Ensure that validated genetic information is used to improve health, especially in underserved populations
- Protect the public from premature and inappropriate use of genetic information through information, education, policy and legislation



# “Genomic profiling to promote a healthy lifestyle: not ready for prime time”

Haga S et al. Nat Genet 2003

GENOVATIONS™  
Predictive Genomics for Personalized Medicine

Great Smokies Diagnostic Laboratory

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For Patients  
For Clinicians  
Lab Tests  
Education  
Resources

## Genovations™ is the advent of truly personalized healthcare.

By harnessing the ingenuity of new breakthroughs in genomic science with the power of preventive biomedicine, Genovations™ offers an innovative, advanced health care model for more effectively preventing and treating chronic disease.

Our predictive genomic profiles assess genetic variations in each person that, when combined with modifiable factors in the environment, may increase disease risk. This empowers physicians and patients to realize:

- Earlier, more effective preventive interventions—years before disease develops
- Precise, customized therapies that truly address each individual's needs

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## Facts for Consumers

PDF Version

### At-Home Genetic Tests: A Healthy Dose of Skepticism May Be the Best Prescription

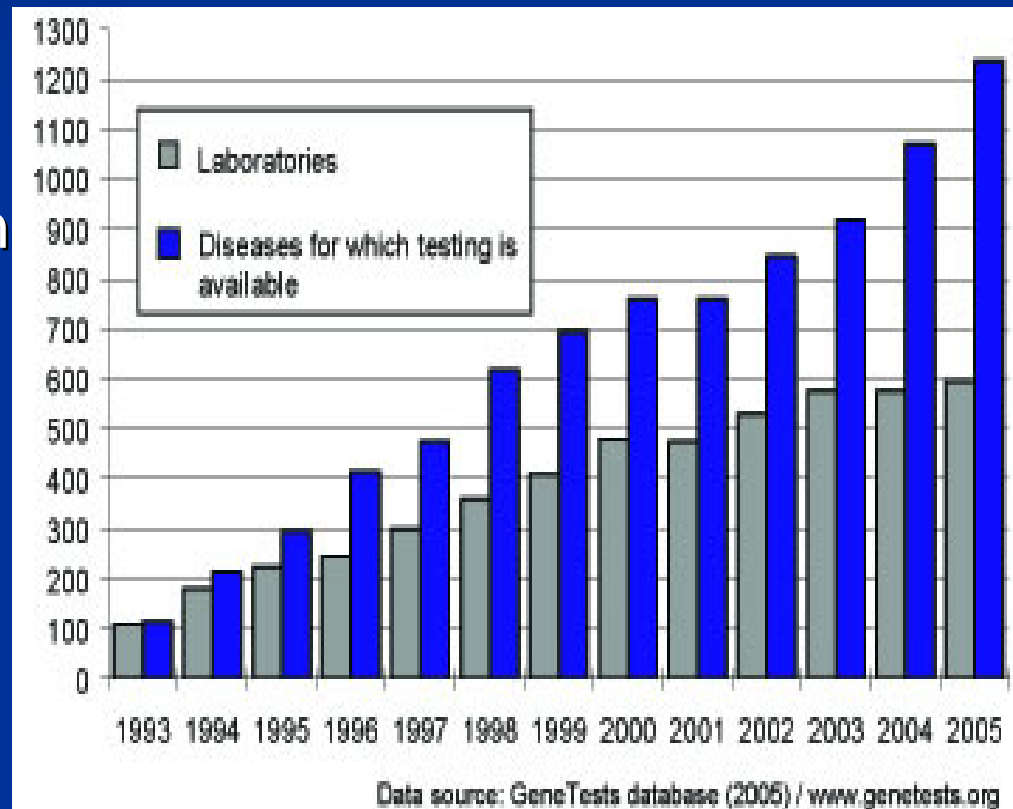
Could a simple medical test tell you if you are likely to get a particular disease? Could it evaluate your health risks and even suggest a specific treatment? Could you take this test in the privacy of your home, without a doctor's prescription or guidance? Some companies say genetic testing can do all this and more. They claim that at-home genetic testing can screen for diseases and provide a basis for choosing a particular diet, dietary supplement, lifestyle change, or medication. They sell their tests in supermarkets and drugstores, and they advertise their services in print, on television, and online.

The Federal Trade Commission (FTC) wants you to know the facts about the direct-to-consumers marketing of genetic tests. According to the Food and Drug Administration (FDA), which regulates the manufacturers of genetic tests; and the Centers for Disease Control and Prevention (CDC), which promotes health and quality of life, some of these tests lack scientific validity, and others provide medical results that are meaningful only in the context of a full medical evaluation. The FDA and CDC say that because of the complexities involved in both the testing and the interpretation of the results, genetic tests should be performed in a specialized laboratory, and the results should be interpreted by a doctor or trained counselor who understands



# Genomic Tests: a Public Health Issue

- Can potentially affect a lot of people (ie pharma cogenomics)
- Potential for enhancing and targeting prevention efforts
- Implementation and access
- Provider and public education
- Monitoring impact on population health



*Is There a Role for Public Health  
Sciences In Genomics?*

# Going Back to Gene-Based Medicine in 2010?

■ Condition	Genes	RR	Lifetime
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**Collins FC, New Engl J Med 1999;341:28-37.**

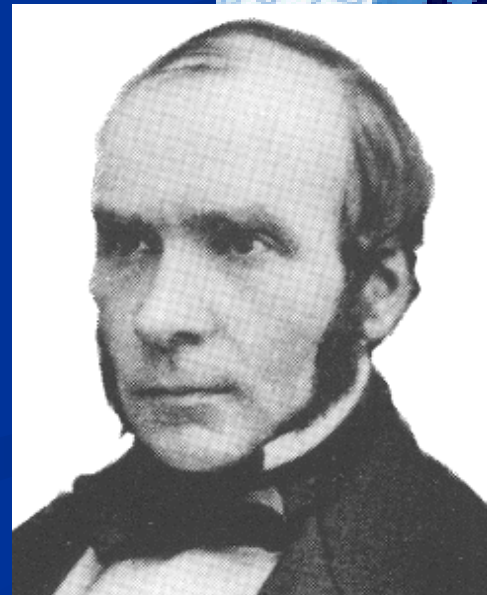
# *Gene-Based Medicine in 2010?*

## *Role of Public Health Sciences*

- Increased Risk for
  - Heart disease
  - Colon Cancer
  - Lung Cancer
- **Role of Public Health Sciences**
  - **Epidemiology**-Get the numbers
  - **Decision and policy analysis:** What's genetics value-added to population intervention or just family history?
  - **Behavioral research**- will information change behavior?
  - **Delivery research.** How will we get it to people?
  - **Outcome Research** -what's the impact?
  - **Economic research:** What's the cost?
  - **ELSI research.....**

# *Epidemiology in the 21<sup>st</sup> Century:* *“Calculation, Communication, and Intervention”* *Fleming and Koplan, AJPH 2000”*

- “The sequencing of the human genome offers the greatest opportunity for epidemiology since John Snow discovered the Broad Street pump”
- **Shpilberg et al. J Clin Epidemiol (1997)**





# Who Will Keep the Public Healthy? (IOM, 2002)

- Critical areas for public health education in the 21<sup>st</sup> century

Informatics

**Genomics**

Communication

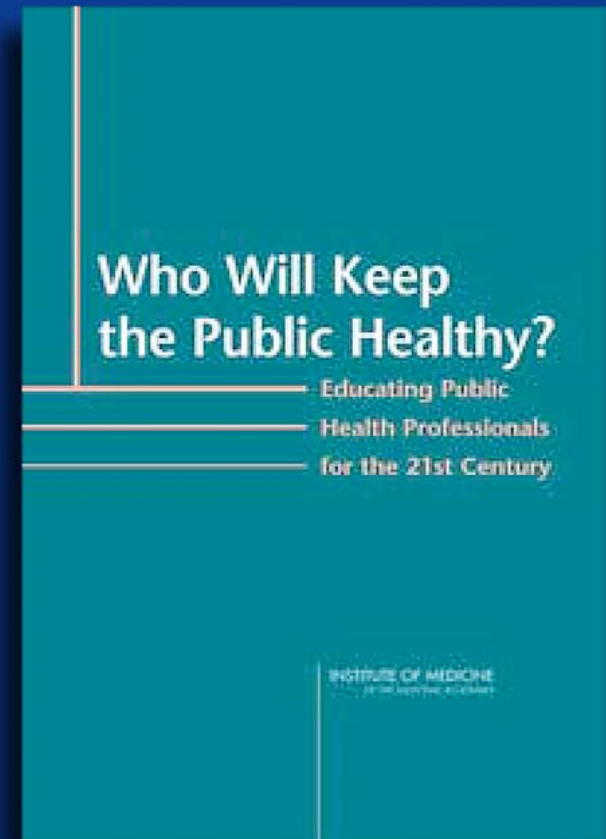
Cultural competence

Community-based research

Global health

Policy and law

Public health ethics



Institute of Medicine, 2002

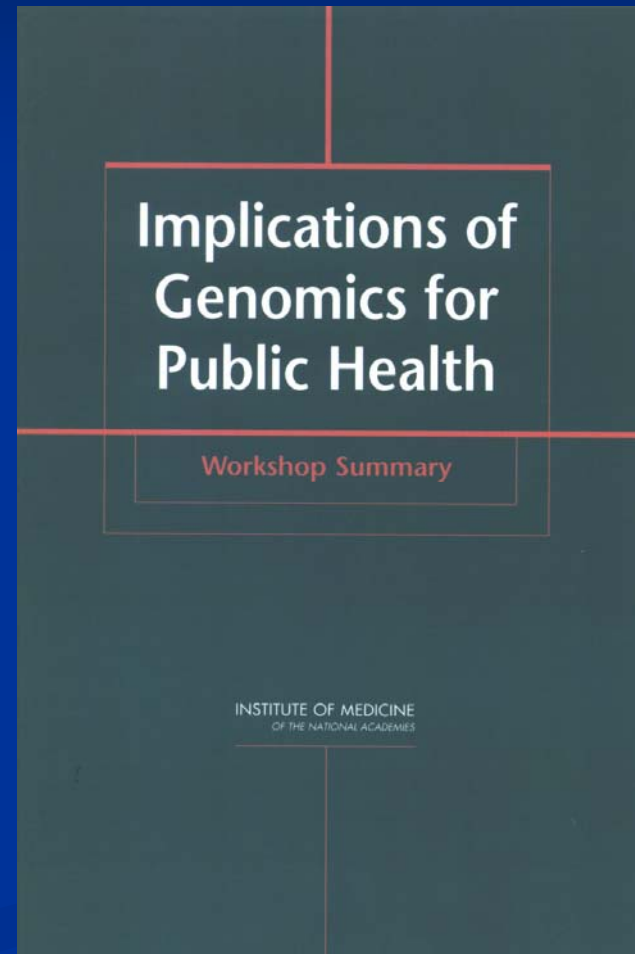
90% US public health schools teach policy but only 15% genomics

# Outline

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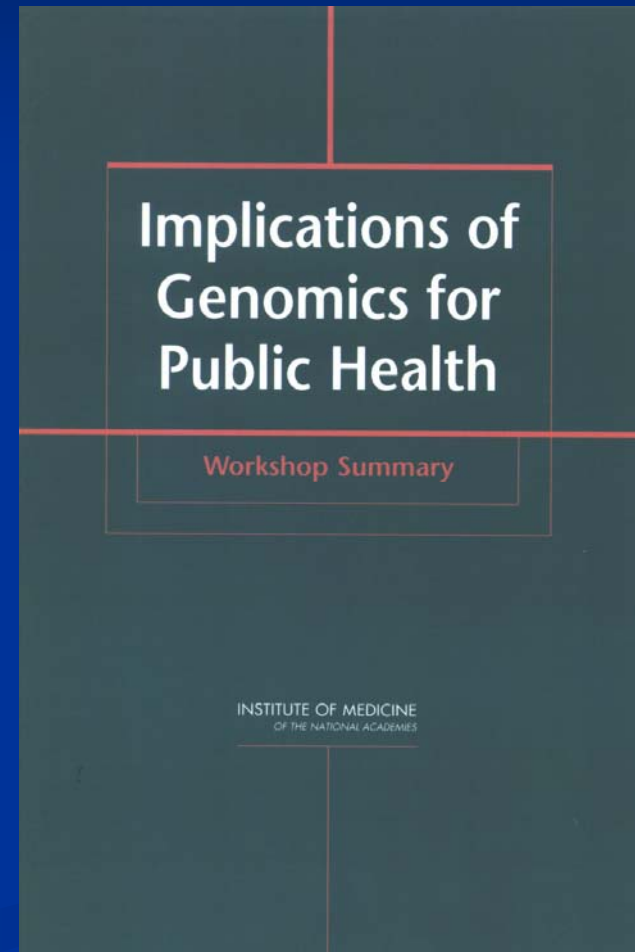
# ***What is “Public Health Genomics”?*** ***(IOM, 2005)***

- “An emerging field that assesses the impact of genes and their interaction with behavior, diet and the environment on the population’s health



# ***What is “Public Health Genomics”?*** ***(IOM, 2005)***

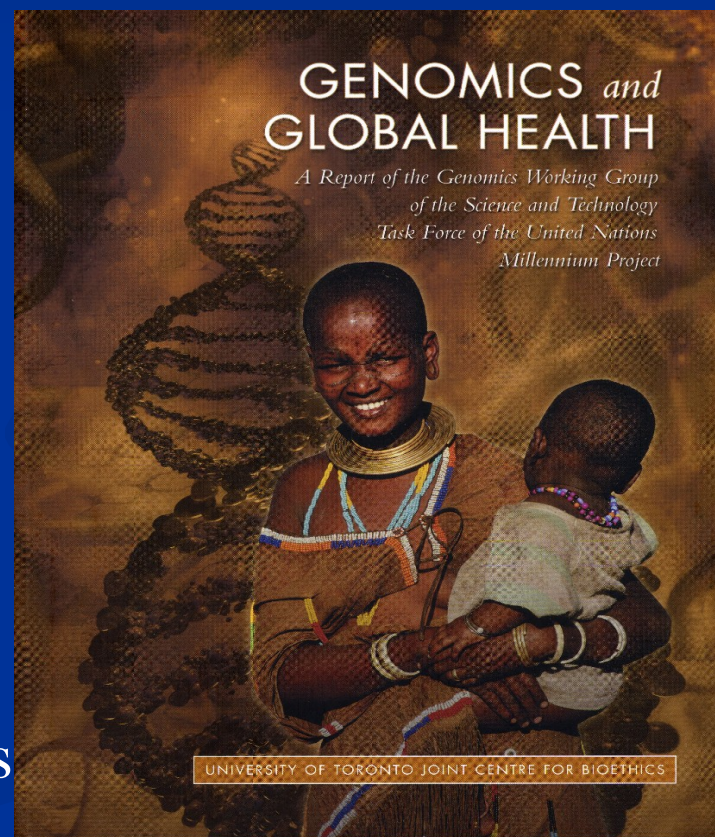
- Accumulate data on the relationships between genetic traits and diseases across populations
- Use this information to develop strategies to promote health and prevent disease in populations
- Target and evaluate population-based interventions



# *Genomics and Global Health: A Report of the Genomics Working Group of the Task Force on Science, Technology and Innovation, UN Millennium (2004)*

## Top 10 Biotechnologies

1. Molecular diagnostics
2. Recombinant vaccines
3. Vaccine/drug delivery
4. Bioremediation
5. Pathogen genome sequence
6. Female protection from STDs
7. Bioinformatics
8. Genetically modified crops
9. Recombinant therapeutic proteins
10. Combinatorial chemistry



# *“The Epidemiology Triangle” Revisited: Genome vs. Genome*



Host

Malaria

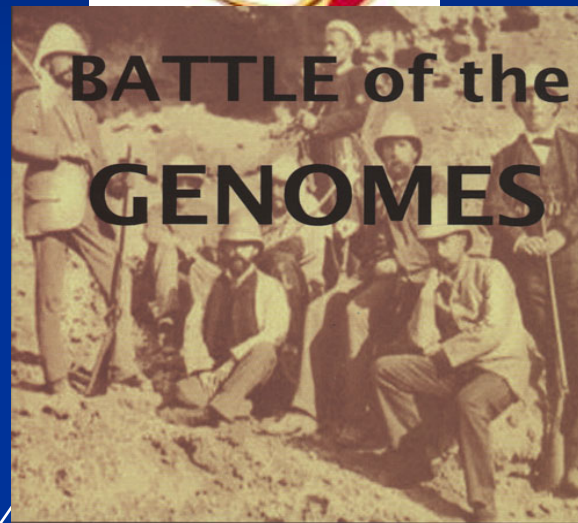
Agent


Environment





# *“The Epidemiology Triangle” Revisited: Genome vs. Genome*



The Struggle for Survival in a  
Microbial World  
  
H. M. Lachman, MD

Agent

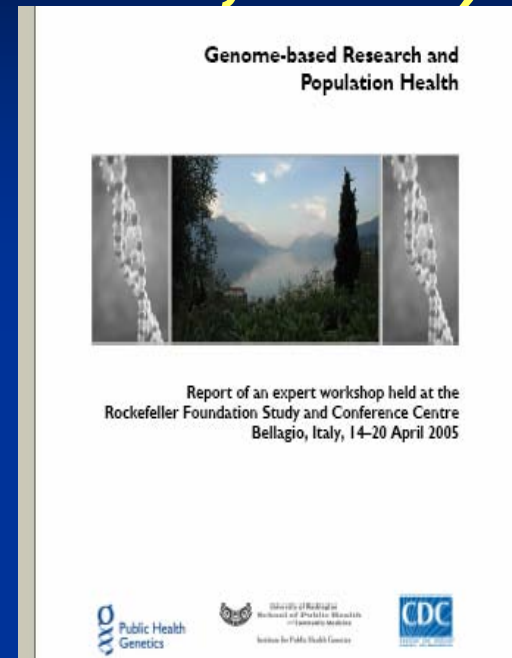


Environment



# What is “Public Health Genomics”? (Bellagio Statement, 2006)

- “A multidisciplinary field concerned with the effective and responsible translation of genome-based knowledge and technologies to improve population health”



July 2006 • Vol. 8 • No. 7

commentary

## The path from genome-based research to population health: Development of an international public health genomics network

Wylie Burke, MD, PhD<sup>1</sup>, Muin J. Khoury, MD, PhD<sup>2</sup>, Alison Stewart, PhD<sup>3</sup>, and Ronald L. Zimmern, MA, FFPHM<sup>4</sup> for the Bellagio Group<sup>5</sup>

The health benefits of the Human Genome Project have been widely anticipated. Experts predict a new era of individualized disease prevention based on testing for genetic susceptibilities,<sup>1</sup> and safer, more effective use of drugs based on

Which vision of the future should the prudent clinician believe: A cornucopia of healthcare innovations based on genomic research, or a stream of genetically-based interventions that fail to deliver value to the public? We argue that both visions are

**Genome-  
based  
Science and  
Technology**

**Improvement  
in  
Population  
Health**

**Genome-  
based  
Science and  
Technology**



**Improvement  
in  
Population  
Health**

## The “Grand Canyon” Gap

**Genome-  
based  
Science and  
Technology**



**Improvement  
in  
Population  
Health**

## The Bellagio Setting



**Genome-  
based  
Science and  
Technology**



**Improvement  
in  
Population  
Health**

## The Bellagio Group

**Population  
Sciences**

**Genome-  
based  
Science and  
Technology**

**Humanities  
and Social  
Sciences**

**Improvement  
in  
Population  
Health**



**Society**

**Population  
Sciences**

**Genome-  
based  
Science and  
Technology**

**Humanities  
and Social  
Sciences**

**Improvement  
in  
Population  
Health**

**Research**

Society

Population Sciences

Genome-based Science and Technology

Humanities and Social Sciences

Knowledge Integration

Within And Across Disciplines

Improvement in Population Health

Research



Society

Population Sciences

Genome-based Science and Technology

Humanities and Social Sciences

Knowledge Integration

Within And Across Disciplines

Informing Public Policy

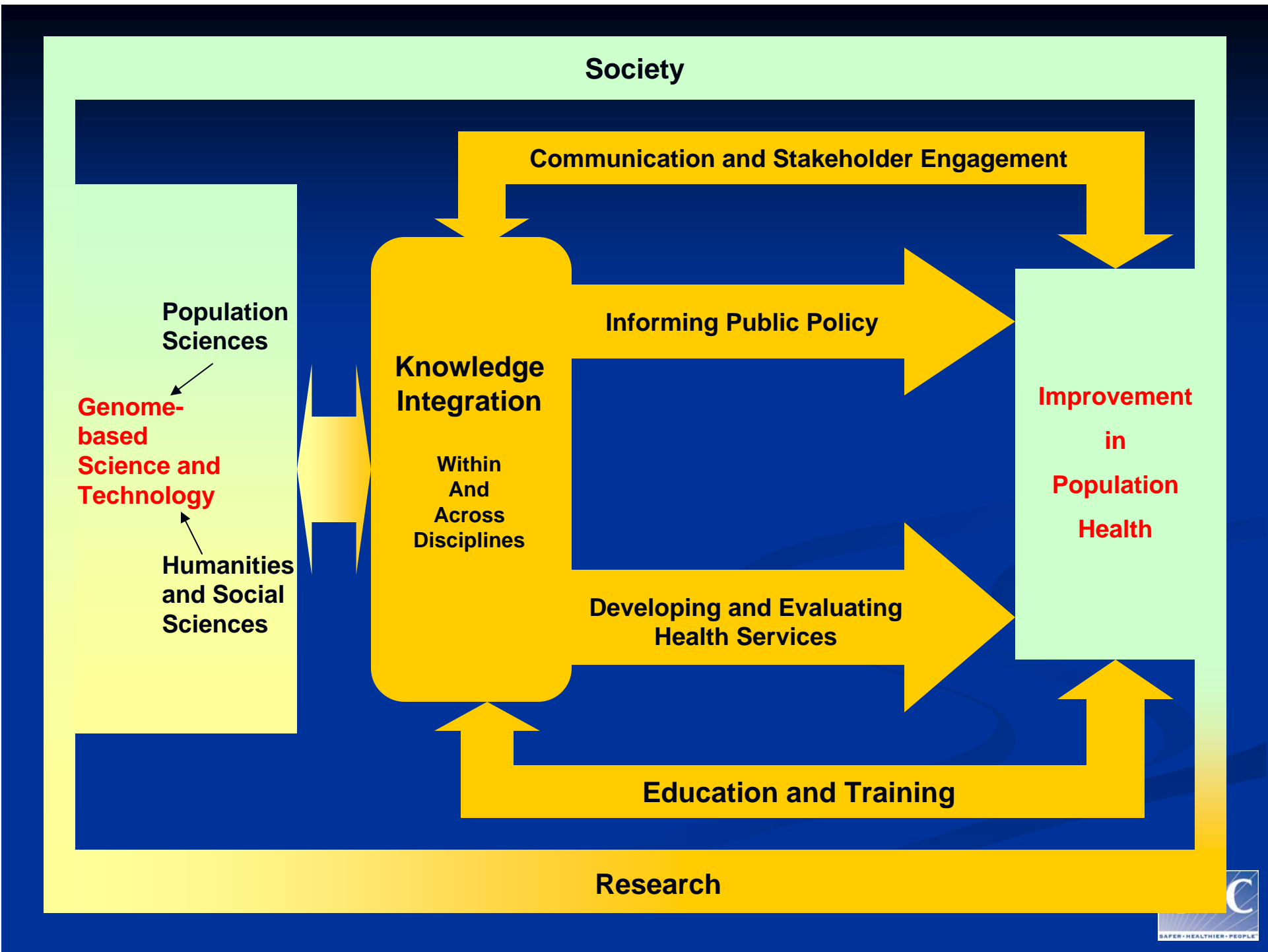
Developing and Evaluating Health Services

Improvement in Population Health

Research



SAFER • HEALTHIER • PEOPLE



# Society

Communication and Stakeholder Engagement

Population Sciences

Genome-based Science and Technology

Humanities and Social Sciences

Knowledge Integration

Within And Across Disciplines



Informing Public Policy

Improvement in Population Health

Developing and Evaluating Health Services

Education and Training

Research



# ***Knowledge Integration***

**The activity that we call  
knowledge integration is the  
driving force or 'engine house'  
of the enterprise**

**It is the process of selecting,  
storing, collating, analysing,  
integrating  
and disseminating information  
both within and across  
disciplines for the benefit of  
population health and  
includes methodological  
development**

**It is the means by  
which information  
is transformed  
into knowledge**

**Interdisciplinarity  
is a key feature**

# Activities of the Public Health Genomics Enterprise

## Informing Public Policy

- Legal, philosophical and social analysis
- Regulatory frameworks
- Engagement in the policy process
- Promoting relevant research
- International comparisons
- Working with governments



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## **Education and Training**

- Genetic literacy for health professionals
- Specific training of public health specialists
- Educational materials
- Courses, workshops and seminars

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## Developing and Evaluating Health Services

- Includes both preventive and clinical services
- Strategic planning
- Service organisation, manpower planning and capacity building
- Service review and evaluation
- Guideline development

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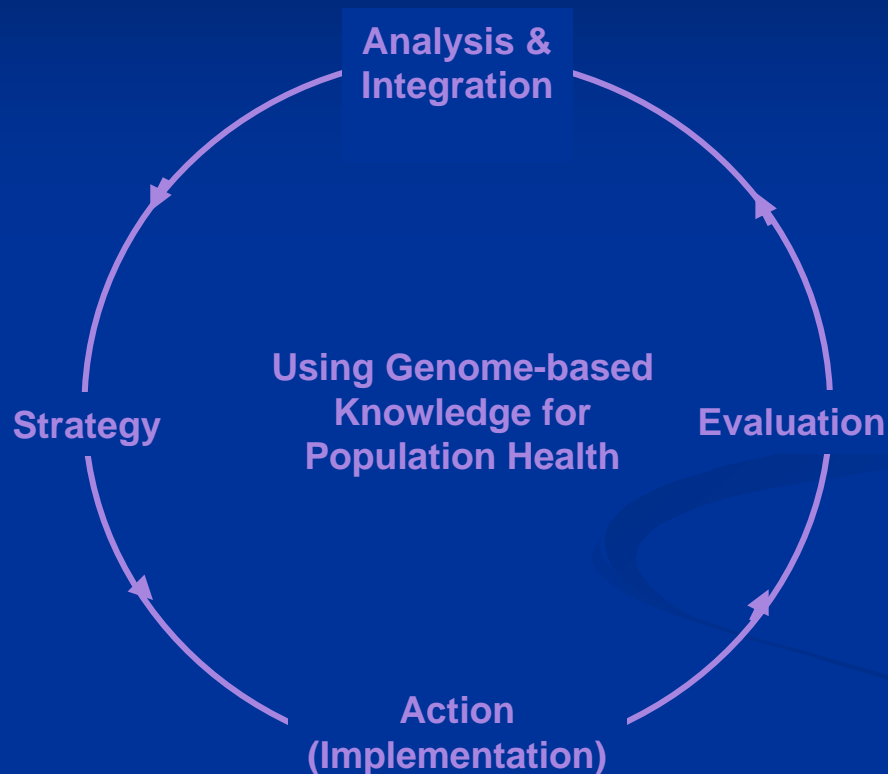
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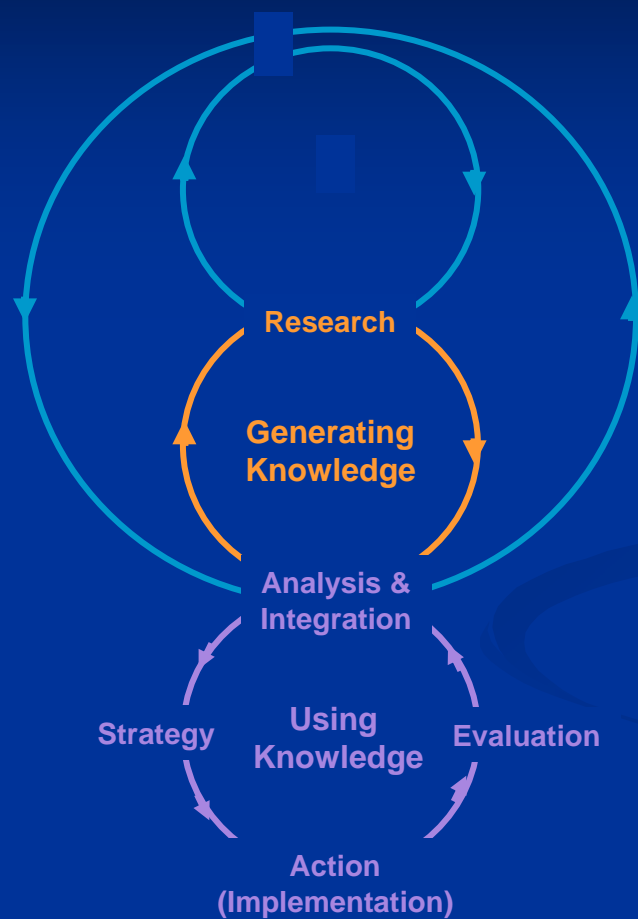
## Communication and Stakeholder Engagement

- General genetic literacy
- Public engagement
- Marketing the enterprise
- Commercial links

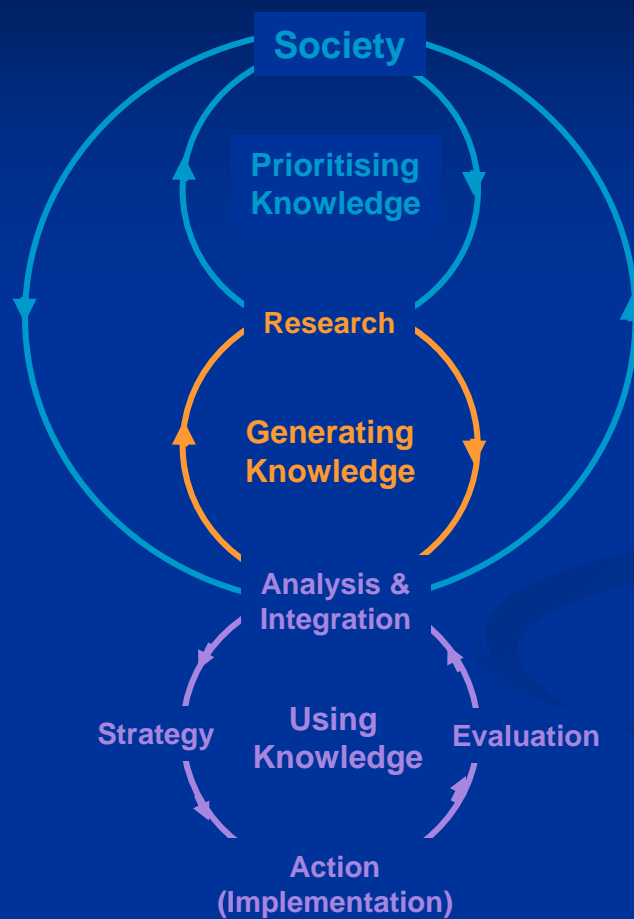
# *The Cycle of Public Health Practice (1)*



# *The Cycle of Public Health Practice (2)*



# The Cycle of Public Health Practice (3)



# *Outline*

- Welcome to the Genomics Era: Science and Hype
- Why Public Health?
- What is Public Health Genomics?
- **Overview of the Series**



**Society**

**Communication and Stakeholder Engagement**

**Population  
Sciences**

**Genome-  
based  
Science and  
Technology**

**Humanities  
and Social  
Sciences**

February 15, we will explore with Drs Bob Hoover from NCI and Teri Manolio from NHGRI the role of population sciences with a focus on epidemiology

**Education and Training**

**Research**

# Society

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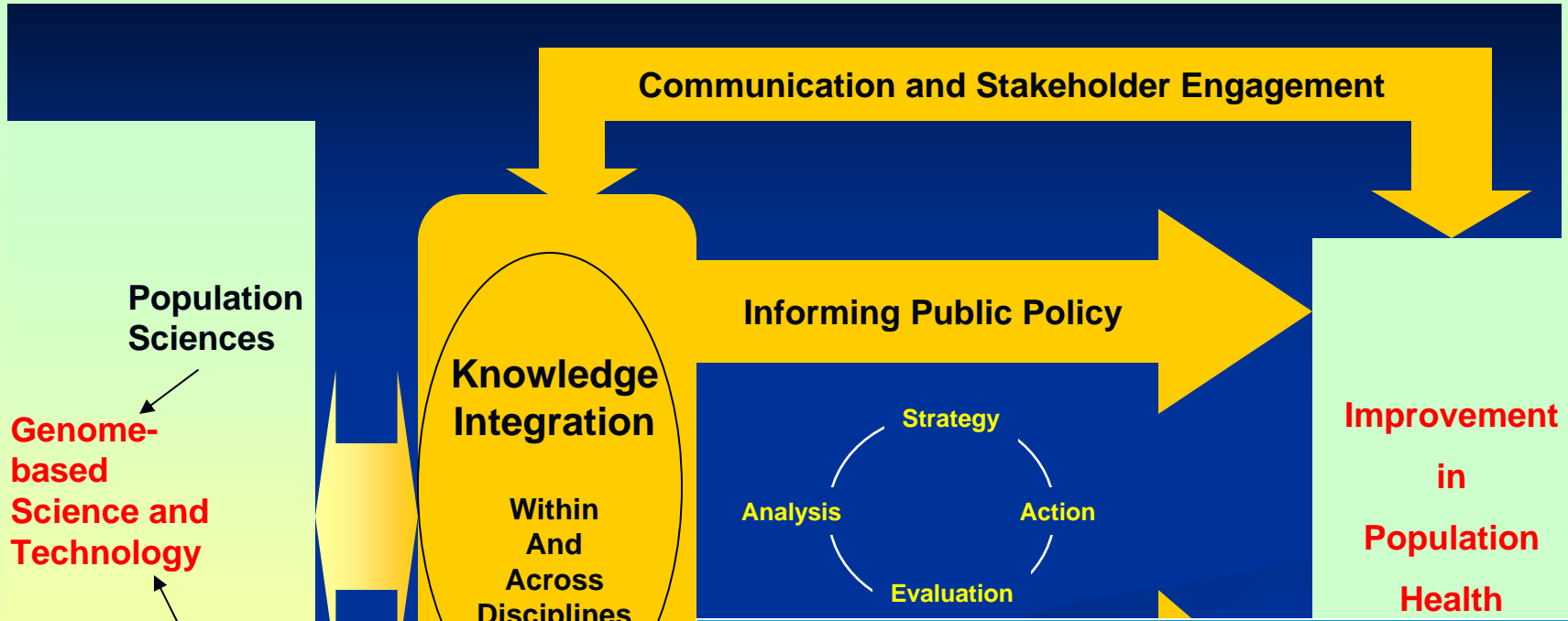
Humanities and Social Sciences

March 12 we will explore with Drs Colleen McBride from NHGRI and David Abrams from OBSRR the role of behavioral and social sciences

Education and Training

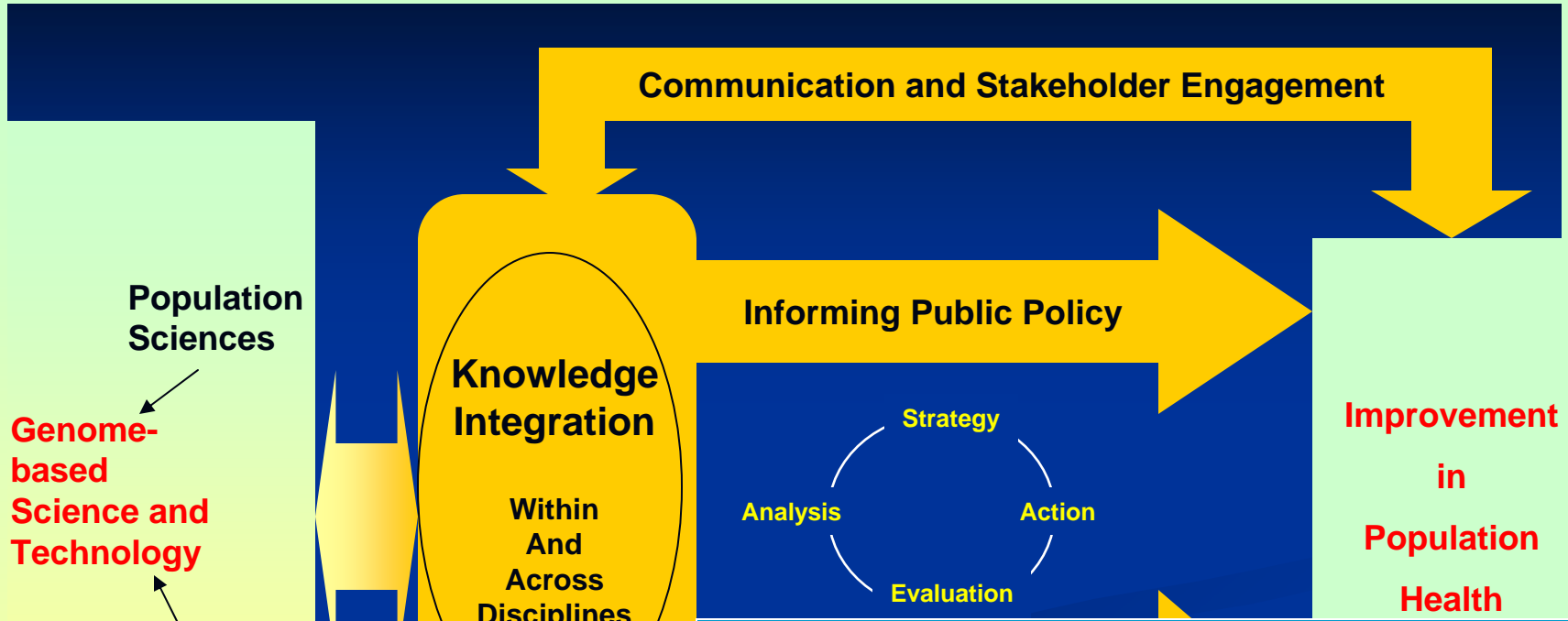
Research

# Society



April 19, we will explore with Dr Nat Rothman from NCI and myself the role of knowledge integration within the discipline of epidemiology

# Society



May 17, we will explore with Dr Linda Bradley from CDC and myself the role of knowledge integration across disciplines, with a focus on evaluation of genetic tests

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Developing and Evaluating  
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July 26 we will explore with Dr Jon Kerner from NCI and Kathy Hudson the next steps in translation process Including the role of professional organization, consumers and oversight



Society

Communication and Stakeholder Engagement

Population

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September 20, we will explore with Drs Louise Wideroff from NCI and myself how we monitor the impact of genomics on health through health services research and population surveillance

Improvement  
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Health

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Communication and Stakeholder Engagement

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October 18, we will explore with Drs Alan Guttmacher from NHGRI and Paula Yoon from CDC the special role of family history in improving population health



Improving and Evaluating  
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Finally, November 29, we will explore with Dr Charles Rotimi from Howard University and myself how can genomics close the gap between gene discovery, medicine and public health with a special emphasis on health disparities

**Improvement  
in  
Population  
Health**

**Research**

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# *The Public Health Genomics Enterprise*

**Genome-  
based  
Science and  
Technology**



**Improvement  
in  
Population  
Health**

**Closing the Gap Between Gene Human  
Genome Discoveries and Population Health**



Society

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Our next speaker, Dr Stephen Channock  
from NCI will give us a primer  
on Genome-based science  
and Technology

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Education and Training

Research

