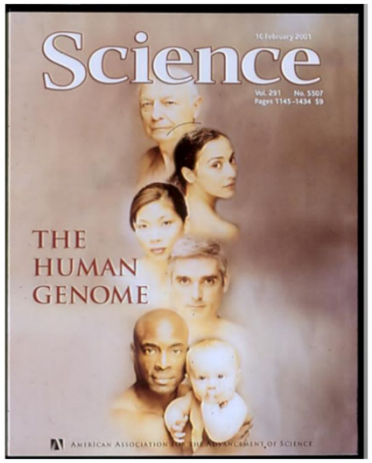
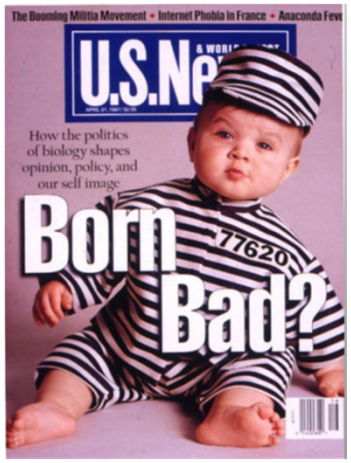
The Use of Genetic Testing in the Courtroom

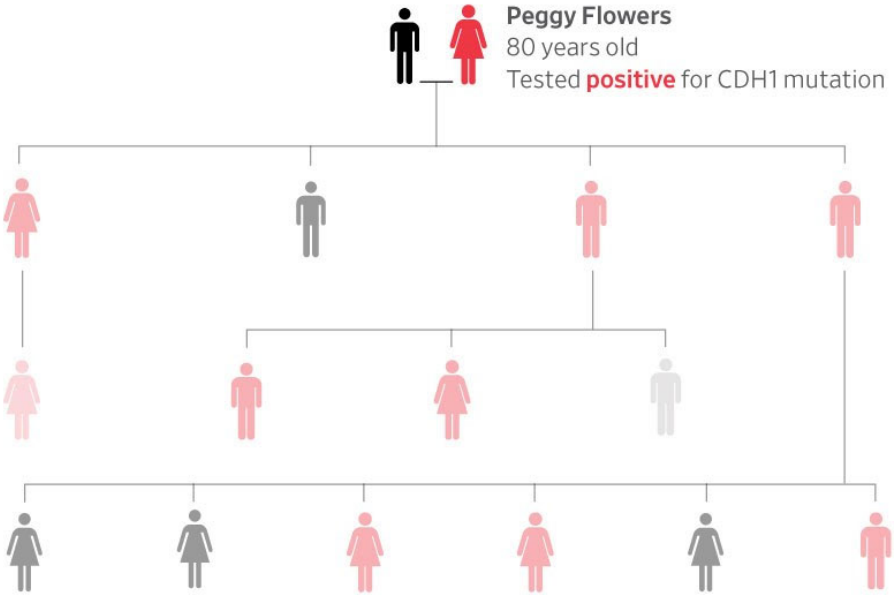

Science
16 February 2001
Vol. 291 No. 5507
Pages 1145–1434 $9
THE HUMAN GENOME
AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE


nature
the human genome
Nuclear fission
Five-dimensional energy landscapes
Seafloor spreading
The view from under the Arctic ice
Career prospects
Sequence creates new opportunities


THE ANGELINA EFFECT
Angelina Jolie's double mastectomy puts genetic testing in the spotlight. What her choice reveals about calculating risk, cost and peace of mind
BY JEFFREY KLUGER & ALICE PARK


The Booming Militia Movement • Internet Phobia in France • Anaconda Fev
How the politics of biology shapes opinion, policy, and our self image
Born Bad?
77620


Egypt Divided / Pot's Big Moment / Best of 2012
TIME
Want to Know My Future?
Asthma
Cancer
Parkinson's
Obesity
New genetic tests can point to risks—but not always a cure

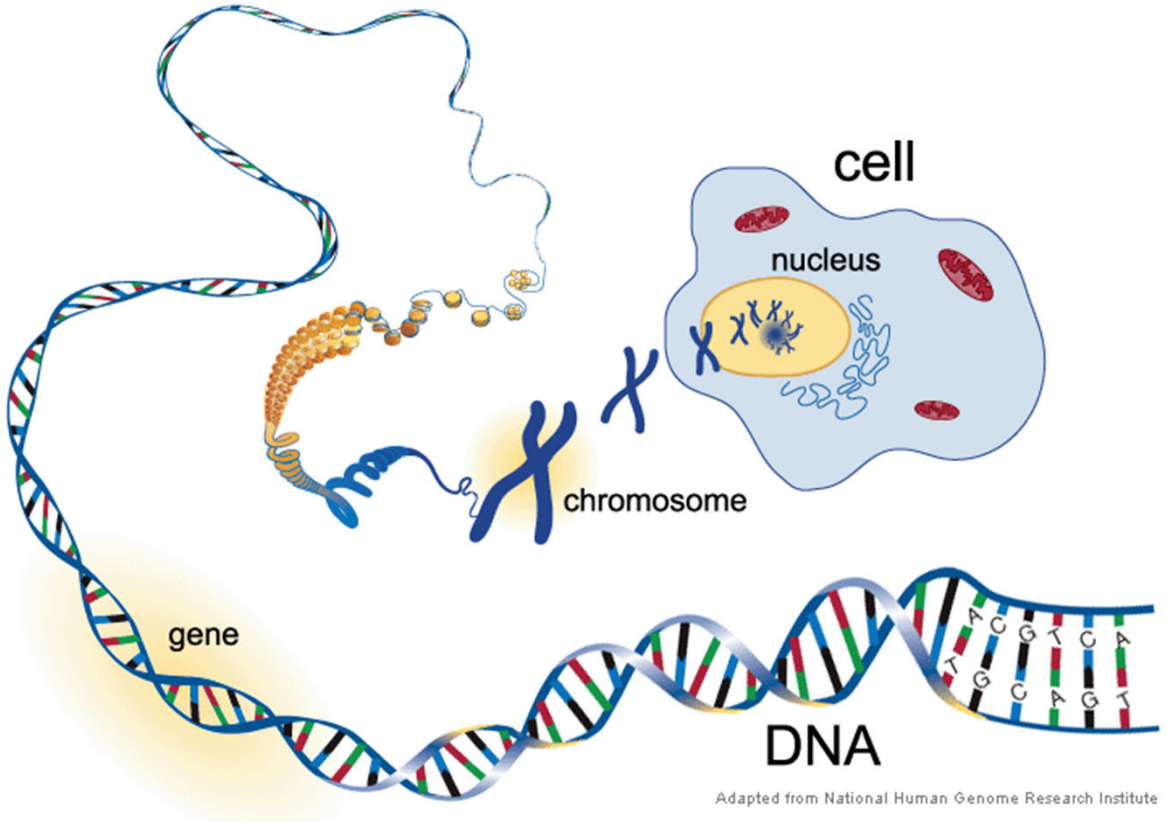

Peggy Flowers
80 years old
Tested positive for CDH1 mutation

"Every disease has, in addition to environmental influences, genetic components that collectively determine the likelihood of a specific disease, age of onset, and severity."

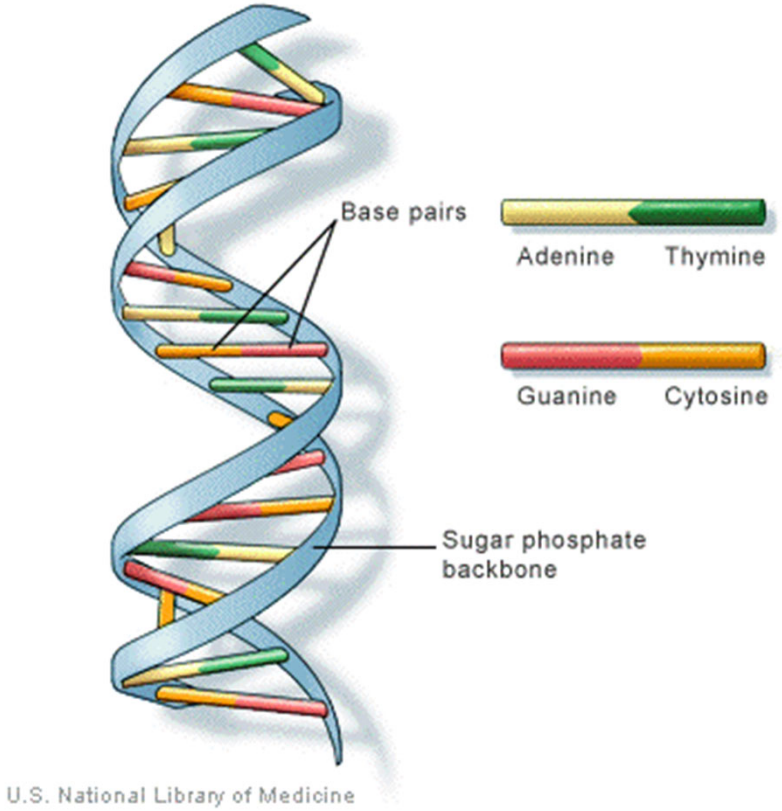
- S. Donlon, MS, "Genetics: The Future of Medicine." Available at http://www.queensmedicalcenter.net/services/90-genetics-the-future-of-medicine (25 March 2013)

Genetics Fundamentals

The Human Genome

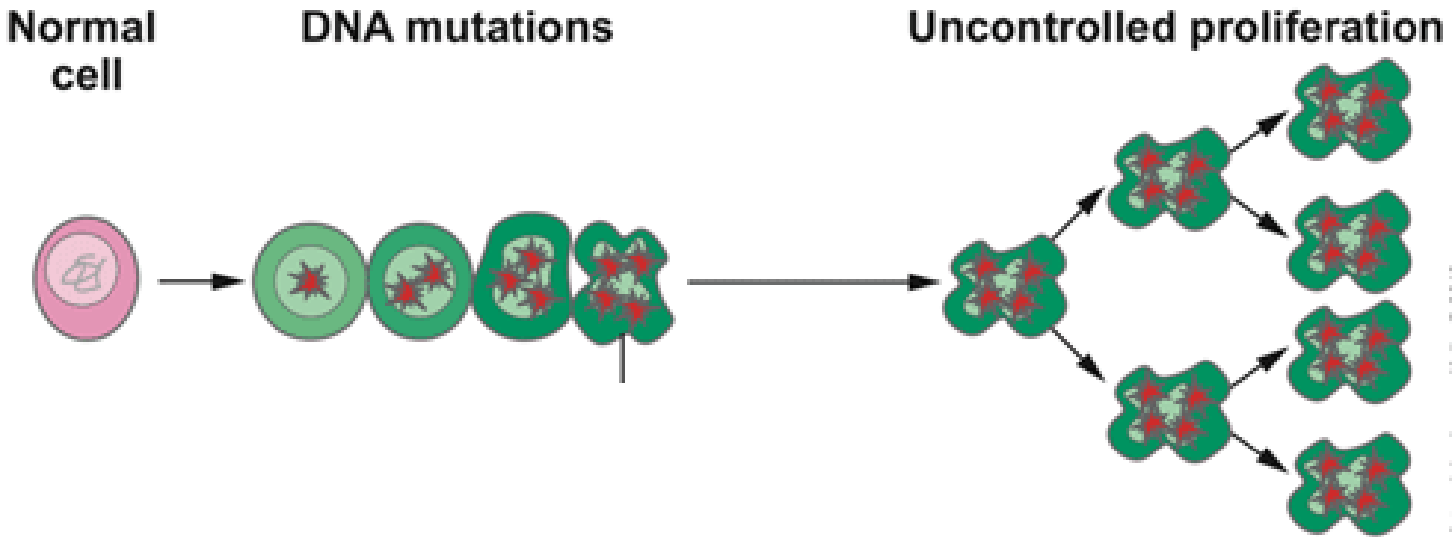


DNA



U.S. National Library of Medicine

Cancer is a Disease of the Genome



Germline vs. Somatic Mutations

Germline Mutations

Present in egg or sperm

Inherited from mother or father

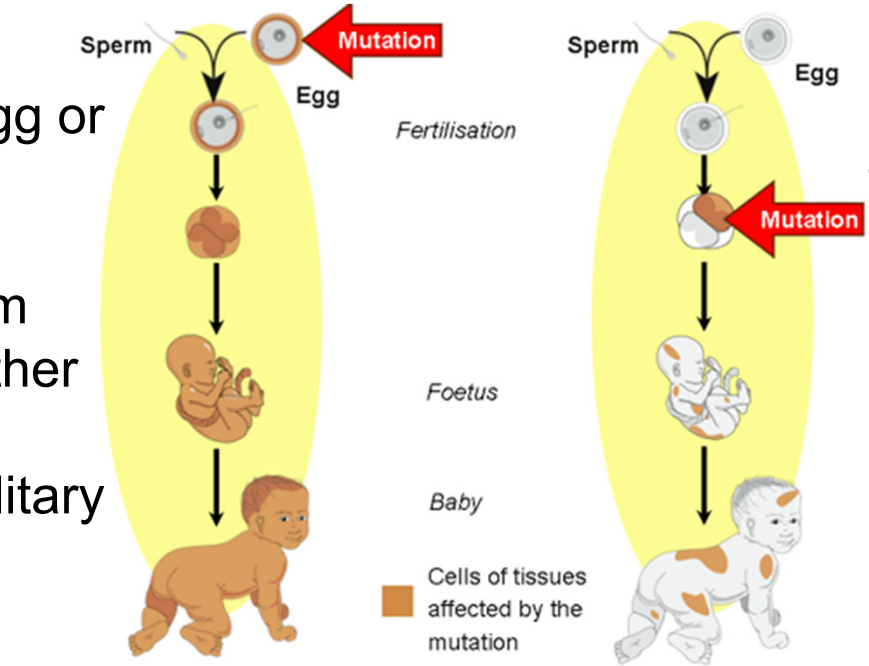
Cause hereditary cancer syndromes

Somatic Mutations

Occur in cancer tissues

Non-heritable

Later onset



Gametic mutations are inherited and occur in the testes of males and the ovaries of females.

Somatic mutations occur in body cells. They are not inherited but may affect the person during their lifetime.

Multiple Genetic Mutations that Drive Cancer
(Independent of Exposure)

Exposure	Disease (Injury)	Some Relevant Genomic Mutations
Benzene	Acute myeloid leukemia (AML)	Chromosomal Translocation (5 →7) (AML) Chromosomal Translocation (15→17) (APL) *RUNX1, CEBPA*
Ionizing Radiation	AML Mesothelioma	*RUNX1, CEBPA, GATA2, TERT, TERC* *CDKN2A*; gene expression profiles
Asbestos / Talcum Powder	Mesothelioma Ovarian Cancer	*BAP1, TP53, CDKN2A, NF2* *BRCA1, BRCA2* *GSTT1, GSTM1* (many others)
Roundup	Lymphoma	*IG4, RAG1, TP53, MEF2B* (many others)
SSRIs / Other Drugs	Autism	*PRKCB1, SHANK3, TAOK2, NRXN1, PTEN* (many others)

High Rate of Germline Mutations in Early-Onset Cancers

- 21% of patients with early-onset cancers had germline mutations
- Most frequent mutations in patients with early-onset cancers:
  - ✓ *BRCA1*
  - ✓ *BRCA2*
  - ✓ *ATM*
  - ✓ *CHEK2*
  - ✓ Lynch syndrome-associated genes

AACR
American Association for Cancer Research®

Source: https://www.aacr.org/about-the-aacr/newsroom/news-releases/young-adults-with-cancer-may-harbor-germline-mutations/

Genetic Predisposition vs. Susceptibility

Genetic Predisposition vs. Susceptibility

Genetic Predisposition

- A genotype that increases likelihood of developing a disease state
- No toxin required
- Not every carrier of a predisposing genetic variant(s) will get the disease
- Generally supports the defense position

Genetic Susceptibility

- A genotype that increases the likelihood that a toxin will cause a disease state
- Individuals can be susceptible or resistant (have genetic protective factors)
- Generally supports the plaintiff position

Genetic Predisposition vs. Genetic Susceptibility

Pro-Plaintiff	Intermediate	Pro-Defense
• Exposure to toxin increased likelihood of disease • Toxin-induced mutation • Eggshell Plaintiff	• Inherited mutation **may** increase susceptibility • Inherited mutation **may** predispose toward injury	• Inherited mutation caused the injury • Independent of toxin • Powerful alternative cause argument

Pure Susceptibility ⟵ Genetic Evidence ⟶ **Pure Predisposition**

Obtaining Genetic Testing

OBJECTIONS TO GENETIC TESTING

- Privacy interest in genetic information is well established:

"Courts have … recognized that DNA contains an extensive amount of sensitive personal information beyond mere identifying information, and people therefore have a strong privacy interest I controlling the use of their DNA." *County of San Diego v. Mason*, 209 Cal. App.4th 376 (2012)

- Right to genetic testing in tort litigation governed by same rules as other medical examinations

OBJECTIONS TO GENETIC TESTING

- **FRCP 35**

Order for an Examination. (1) *In General.* The court where the action is pending may order a party whose mental or physical condition—including blood group—is in controversy to submit to a physical or mental examination by a suitably licensed or certified examiner.

OBJECTIONS TO GENETIC TESTING

- Party seeking testing must show “good cause”
- Good cause not defined precisely:
  - More than general relevance; greater showing than other discovery rules
  - Movant must show “specific facts” justifying discovery
  - Requires “discriminating application” by judge
  - Should not be routinely granted
- Courts examine:
  - Expert description of need for testing
  - Link between condition and specific genetic mutation(s)/likelihood of discovering relevant information

OBJECTIONS TO GENETIC TESTING

- Malpractice action alleging brain damage from negligence during delivery
- Defendant sought whole exome sequencing (WES) to identify genetic causes of brain impairment
- "The testimony of defendant's expert…that some unidentified and unspecified genetic condition may be a cause or contributing factor to X.S.F.'s condition is insufficient to place the near entirety of X.S.F.'s genetic information at issue, especially in the face of competing testimony by [plaintiff's expert] that it is unlikely that X.S.F.'s brain damage has a genetic cause."
  - *Fisher v. Winding Waters Clinic*, 2017 U.S. Dist. Lexis 19691 (D. Ore.)

OBJECTIONS TO GENETIC TESTING

- Recent state court case alleging mesothelioma from asbestos in talc
- Defendant must show that information sought is “directly relevant” to the claim and “essential to the fair resolution of the lawsuit”
- Court granted permission to test existing pathology material (BAP-1 immunostaining)
- But additional testing would require “stronger showing of direct relevance” to include:
  - More evidence product did not contain asbestos
  - More specific scientific basis for relationship between BAP-1 genetic defect and causation of mesothelioma or susceptibility to mesothelioma
    - *O’Hagan v. Johnson & Johnson et al.*, No.RG19019699 (Alameda Sup. Ct.)

OBJECTIONS TO GENETIC TESTING

FRCP 35

- Order must specify “time, place, manner, conditions, and scope of the examination, as well as the person who will perform it”
- Party requesting examination must produce the examiner’s report (and examined party must produce all earlier or later examinations of same condition)
- Examiner’s report must be in writing and include diagnoses, conclusions and results of any tests

Ethics Related to Genetic Testing

Questions re Compelled Genetic Testing of Plaintiffs

- Plaintiffs' right not to know?
- Does plaintiffs counsel have duty to warn plaintiff of possibility of genetic testing before filing case?
- Who counsels plaintiffs on implications of genetic test results for plaintiffs and their families?
- What happens when plaintiff has sequenced entire genome?

Ethical Issues Related to Genetics

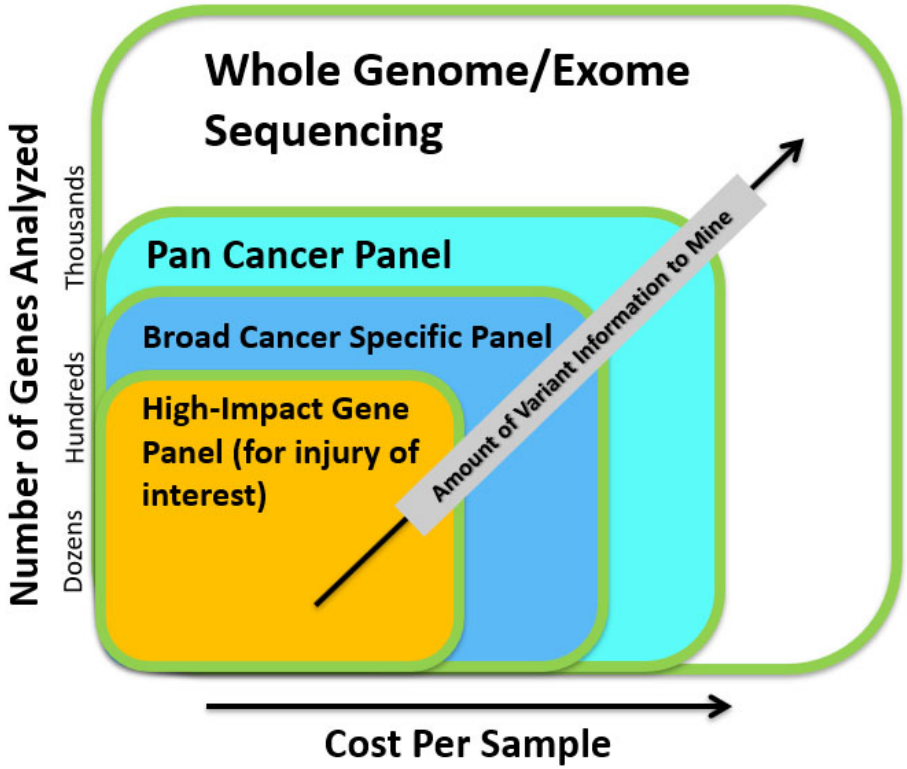
- Privacy and confidentiality; invasion of privacy
- Discovery of potentially harmful genetic variants – what to do with the information (secondary findings)
- Disclosure of information to high-risk relatives?
- Disclosure of results to employers, insurers?
- Discrimination issues

Costs and Types of Sequencing

Implementing Genetic Data in Litigation

- **Plaintiff Medical Records**: Scour plaintiff medical records for pre-existing genetic testing
- **Published Science**: Utilize the published scientific and medical literature to:
  - ✓ Cross examine plaintiff experts to establish doubt
  - ✓ Provide alternative causation in defense case
- **Genetic Sequencing**: Identify the genetic cause of a plaintiff's injury through genetic sequencing
  - ✓ Gene panels
  - ✓ Whole exome sequencing
  - ✓ Whole genome sequencing

What Does Genetic Sequencing Cost?

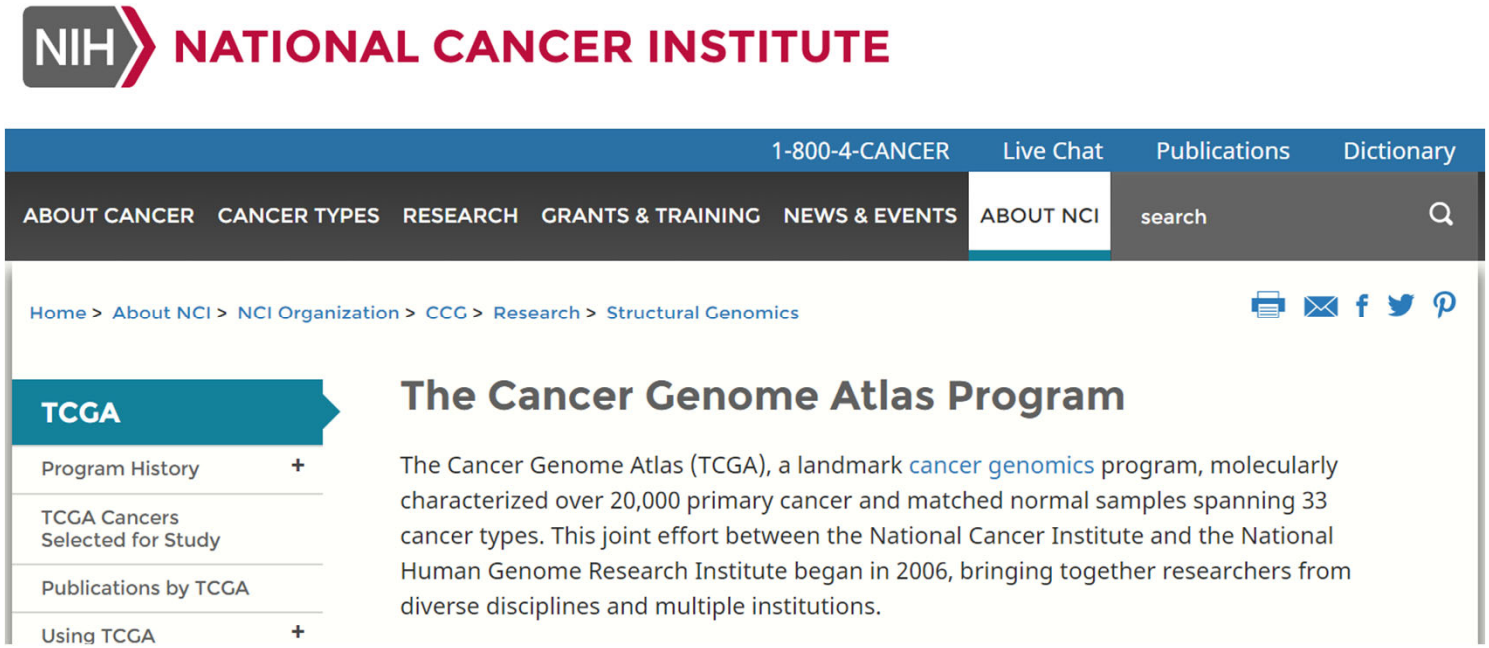


Admissibility and Causation

Toxic Tort Applications of Genetics

- Heightened Duty ("Eggshell skull")
- No Duty ("Idiosyncratic response")
- Causation
  - General causation
  - Specific causation
- Alternative Causation
- Duty to warn
- Class certification
- Damages

Genetics can shape the causation question



Genetics can shape the causation question

- Example: Glioma and radiofrequency emissions
  - Plaintiff alleges that RF emissions from a cell phone caused glioma
  - Specific genetic mutations that lead to glioma were identified in TCGA program
  - Defense expert: “Plaintiffs’ experts do not (1) discuss or acknowledge integrated genomics; or (2) provide published data that identify studies finding that EMF initiates or promotes a biological process that leads to alteration or mis-expression of the specific genes that are the driver or passenger genes in the biology of gliomas.”

Genetics can shape the causation question

- Plaintiff alleged birth defects caused by Depakote
- Successful motion to exclude specific causation testimony for failure to properly rule out potential genetic causes despite prior testing
- Court noted several references in medical records to advancements in genetic testing and potential for additional testing to reveal more information about genetic causes
  - *NK v. Abbott Labs*, 2017 U.S. Dist. Lexis 77461 (EDNY)

Genetics can shape the causation question

- Plaintiff alleged Hirschsprung's disease from coal ash waste exposure
- RET gene mutations linked to Hirschsprung's disease
- Plaintiff challenged geneticist's opinion because particular sub-genetic location of defect on the RET gene (exon 20) had not been linked to Hirschsprung's
- Court admitted opinion based on link to defects in the region (intracellular tyrosine kinase tail) even though exon 20 had not been described
  - *Pallano v. AES Corp.*, 2015 Del. Super. Lexis 1021

Will Biomarkers Be Required to Prove Exposure?

- “[T]here are biological tests (biomarkers) that measure the levels of chemicals in the body to reveal whether these levels can exceed expected or accepted levels. …. [B]ecause no such tests were performed on Mr. Cord, ‘it is impossible to determine to a medical certainty’ whether Mr. Cord's exposure, absorption or toxicity to benzene or other chemicals exceeded normal and expected levels. In other words, existing tests were available to measure whether Mr. Cord in fact had excessive exposure to benzene and other chemicals, but plaintiffs' experts did not use them.” Cord v. City of Los Angeles (Cal. App. Sept. 30, 2004).

Genetic Biomarker of Exposure

- *In re TMI Litigation*
  - Plaintiffs lacked data quantifying exposure from TMI accident; instead relied on "biological indicators of radiation dose" (dicentric chromosomes)
  - 3rd Circuit holding: Dicentric chromosomes provide a valid and reliable quantitative dosimeter of exposure; but not 15 years after exposure
  - Measurement of translocations using FISH would have provided "a valid and reliable scientific methodology" even 15 years later

Susceptibility Genes: Causation

- *In re Hanford Nuclear Reservation Litigation,* 1998 WL 775340 (E.D. Wash. 1998)
  - Court required class of P's to show doubling of risk to survive summary judgment
  - P expert added 5-fold genetic susceptibility factor in calculating doubling dose
  - Problems: (i) not everyone genetically susceptible; (ii) no attempt to identify those who may be genetically susceptible

Susceptibility Genes: Causation

- *Easter v. Aventis Pastuer, Inc.,* 2004 WL 3104610 (E.D. Tex.)
- Plaintiffs alleged that thimerosal in defendant's vaccines caused their son's (Jordan Easter) autism
- Plaintiffs contended that "some children are genetically susceptible to mercury poisoning and cannot excrete or otherwise eliminate the mercury in the vaccine preservative"
- Genetic testing subsequently revealed that Jordan did not have the pertinent genetic susceptibility
  - Court: Plaintiff concedes that he "cannot prove, in Jordan's case, that his autism was caused by thimerosal . . . because Jordan does not meet the genetic profile for children who . . . are at increased risk for developing autism by thimerosal." This concession was "the beginning and the end" of plaintiff's claim.

Susceptibility Genes: Failure to Warn

- Manufacturer of lyme disease vaccine (LYMErix) sued for failing to warn that 30% of population has genotype (HLA-DR4+) which places them at risk of developing “treatment-resistant Lyme Arthritis”
- *Cassidy v. SmithKline Beecham*
  - Plaintiffs argued that manufacturer should have recommended genetic test prior to vaccination
  - Case settled; vaccine taken off market

Susceptibility Genes: Class Certification

- Certification of a class in a class action requires "predominance" of common issues within class
- Genetic heterogeneity in susceptibility to defendant's product could be used to argue against class certification
- *E.g., Mahoney v. R.J. Reynolds* (Oct. 2001)
  - Certification of class of Iowa smokers denied in part because of differences within class in genetic susceptibility to tobacco smoke requires individualized proof of causation

Genetic Biomarkers: "Latent Injury"

- Many at-risk plaintiffs who have been exposed to toxic substances seek compensation before clinical disease has manifested
  - Increased risk of injury
  - Fear of disease
  - Medical monitoring
- Arguments pro and con recognizing such claims?
- Genetic biomarkers of exposure or effect may provide "present injury" needed to support such claims
  - Courts are divided on whether subclinical genetic effects are "present injury"

Policy and Normative Issues

- Strong incentives for premature use
- Need for validation of biomarkers (reliability, relevance)
- Jury comprehension
- Opening litigation floodgates to latent disease and multigenerational claims?

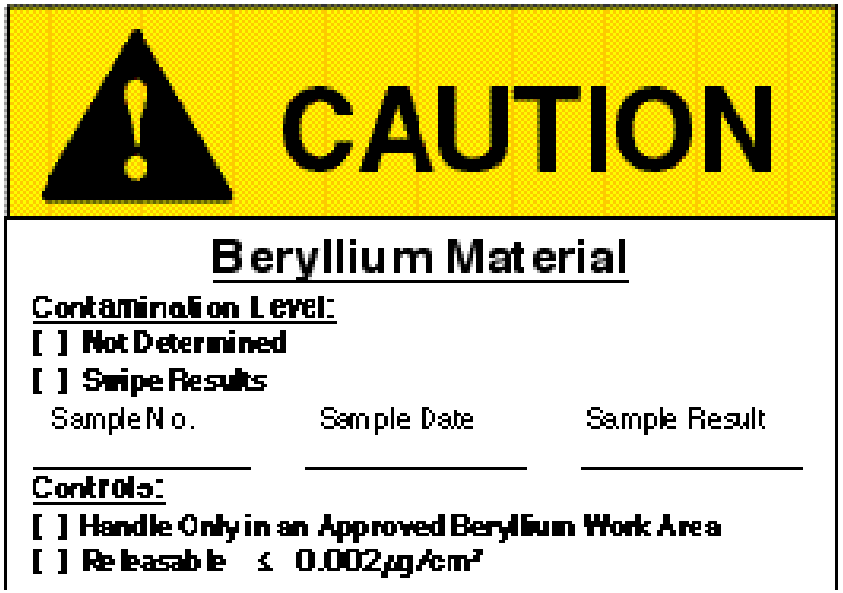
Expansive Liability?

- As capability to identify agents causing injury and risk in the human body expands with genomic and other biomarkers, much higher percentage of illnesses may be litigated.
  - Currently can only identify a small percentage of illnesses and deaths caused by environmental (defined broadly) exposures
  - Even smaller percentage currently justiciable

New Legal and Corporate Duties?

- "The company's risk management structure should include an ongoing effort to assess and analyze the most likely areas of future risk for the company, including how the contours and interrelationships of existing risks may change and how the company's processes for anticipating future risks are developed. This includes understanding risks inherent in the company's strategic plans, risks arising from the competitive landscape and the potential for technology and other developments to impact the company's profitability and prospects for sustainable, long-term value creation. Anticipating future risks is a key element of avoiding or mitigating those risks before they escalate into crises."
  - Wachtell, Lipton, Rosen & Katz, Risk Management and the Board of Directors (March 2018)

Proliferation of Genetic Warnings/ Failure to Warn Lawsuits?



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- Our Future, Our Environment: Welcome
- Beyond the Internet
- Rosetta Stone
- Nature's Services
- Consumer Power
- New World, Old Order
- Game Changers
- Manufacturing Anywhere

Plaintiffs in the Post-Genome Era

Proof by Genetic Assay in 2007

The plaintiff sat nervously as the jury filed backed into the courtroom. This jury was about to announce an award that would have been inconceivable only five years earlier. There were over 8,000 others who had been exposed to the same contaminant as they had. Like the plaintiff, four of these others were afflicted with bladder cancer. Unlike the plaintiff they lacked a key piece of evidence connecting their cancer with the actions of the defendant. They lacked the genetic variant that rendered this successful plaintiff, Mike Harlan, highly susceptible to cancer following exposure to the arsenic that had appeared in the local drinking water.

"To the extent that a person's genes are responsible for the risks they face, what duty should they have to either alter those genes through genetic therapy, or alter their behavior to minimize their risk?"

Case Study

Case Study

- 47-year-old female plaintiff
- Diagnosed with peritoneal mesothelioma at age 45
- Husband worked for Acme Industrial Co and claimed asbestos exposure
- Industrial hygienist testimony of low levels of airborne asbestos on premises
- Plaintiff washed husband's clothes and alleges asbestos exposure (i.e., take home exposure)
- Defense seeks to utilize genetics to defeat asbestos-mesothelioma link

Case Study – Legal Practical Tips

Ideal Case to Implement Genetic Defense

Criteria	Yes	No
Young age of onset?	✓	
Evidence/record/mode of exposure?		✓
Lifestyle/behavioral risks?	✓	
Family medical history of related diseases?	✓	
Previous genetic diagnostics?	✓	
Tissue sample availability? (for sequencing only)	✓	

Practical Considerations

01

Perform careful medical record review for genetic data

02

Look for ancestry/family history of cancer – cancer predisposition syndrome

03

Use model data to demonstrate role of genetic mutations in causation

04

Consider genetic sequencing on plaintiff

- E.g., mesothelioma gene panel
- Whole Exome

05

Develop comprehensive genetic strategy

Case Study - Jury Instructions

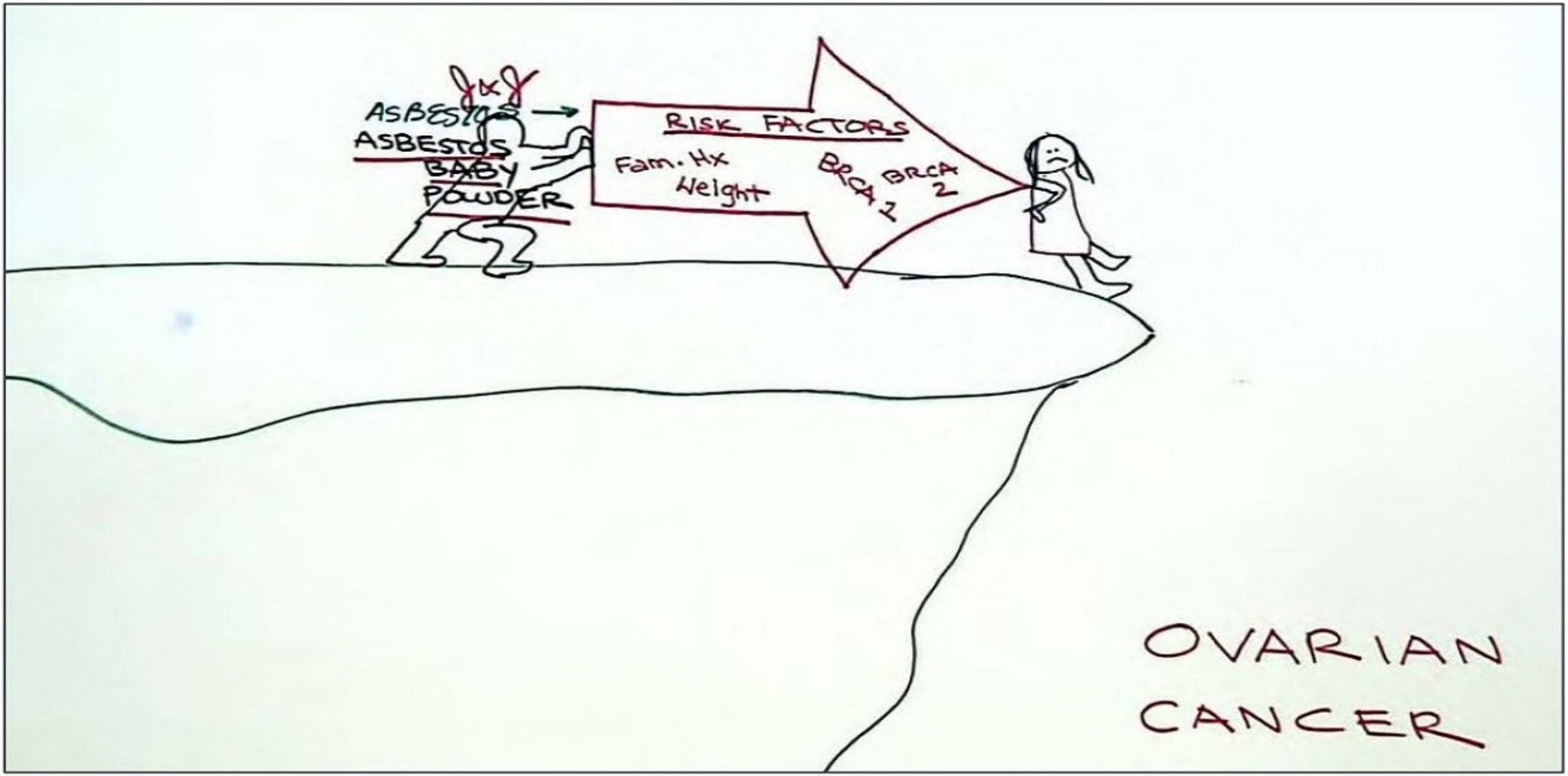
SUBSTANTIAL FACTOR

"A substantial factor in causing harm is a factor that a reasonable person would consider to have contributed to the harm. **It does not have to the only cause of the harm.**"

"A person's negligence may combine with another factor to cause harm. If you find that defendant's negligence was a substantial factor in causing [Plaintiff's] harm, then that defendant is responsible for the harm. **[Defendants] cannot avoid responsibility just because some other person, condition, or event was also a substantial factor in causing [Plaintiff's] harm.**"

SUBSTANTIAL FACTOR

"The last requirement for holding a defendant liable is that the defect, whatever you find it to be, must have been a proximate cause of the injury. By proximate cause is meant that the defect in the product was a substantial factor which singly, or in combination with another cause, brought about the injury."


ASBESTOS
ASBESTOS
BABY
POWDER
RISK FACTORS
Fam. Hx
Weight
BRCA 1
BRCA 2
OVARIAN
CANCER

Is Every Risk Factor a Cause?

Dr. Marks provided a second possible explanation of her consideration of alternative causes by testifying that "[a]ll the [risk] factors [for diabetes] work together." Here Dr. Marks appears to be contending that since diabetes can have multiple concurrent causes, she need not analyze the role played by each cause.

An expert, however, cannot merely conclude that all risk factors for a disease are substantial contributing factors in its development. The fact that exposure to [a substance] may be a risk factor for [a disease] does not make it an actual cause simply because [the disease] developed.

- *Guinn v. AstraZeneca Pharm. LP*, 602 F.3d 1245, 1255 (11th Cir. 2010).

Attacking Substantial Factor

- Make it a scientific, not a legal issue
- Challenge plaintiffs' experts to:
  - Define "substantial factor"
  - Define methodology for addressing substantial factor
  - Opine whether the disease would have occurred anyway
  - Define and rank all causes
  - Assign probabilities to each cause
  - Explain any "differential diagnosis" – what was ruled in/out and why
  - Agree with the principles - medicine has tools for comparing risks; risk factors can be assigned strengths (sometimes through dose)

Case Study - Scientific Considerations

Why is There Such Great Variability in Mesothelioma Susceptibility?

Published in final edited form as:
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Germline *BAP1* mutations predispose to malignant mesothelioma

Joseph R. Testa[1,*], **Mitchell Cheung**[1], **Jianming Pei**[1], **Jennifer E. Below**[2], **Yinfei Tan**[1], **Eleonora Sementino**[1], **Nancy J. Cox**[2,3], **A. Umran Dogan**[4,5], **Harvey I. Pass**[6], **Sandra Trusa**[6], **Mary Hesdorffer**[7], **Masaki Nasu**[8,9], **Amy Powers**[8], **Zeyana Rivera**[8,9], **Sabahattin Comertpay**[8,9], **Mika Tanji**[8,9], **Giovanni Gaudino**[8], **Haining Yang**[8,10], and **Michele Carbone**[8,*]

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NIH-PA Author Manuscript

"Some individuals develop mesothelioma following exposure to small amount of asbestos, while others exposed to heavy amounts do not."

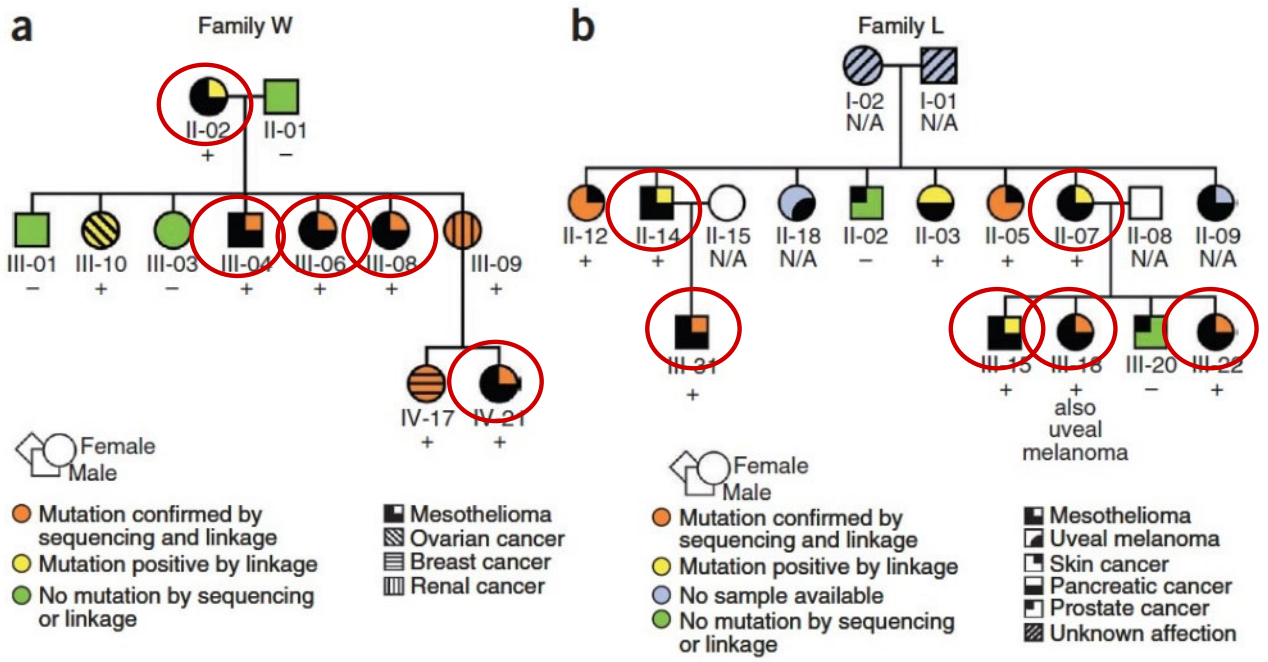
and because mesothelioma clustering is observed in some families[1], we searched for genetic predisposing factors. We discovered germline mutations in *BAP1* (*BRCA1-associated protein 1*) in two families with a high incidence of mesothelioma. Somatic alterations affecting *BAP1* were observed in familial mesotheliomas, indicating biallelic inactivation. Besides mesothelioma, some *BAP1* mutation carriers developed uveal melanoma. Germline *BAP1* mutations were also found in two of 26 sporadic mesotheliomas: both patients with mutant *BAP1* were previously diagnosed with uveal melanoma. Truncating mutations and aberrant BAP1 expression were common in

*Correspondence should be addressed to J.R.T.(joseph.testa@fccc.edu) or M.Ca. (mcarbone@cc.hawaii.edu)..

AUTHOR CONTRIBUTIONS

J.R.T. led the team at FCCC (M.Ch., J.P., Y.T., E.S.) that first identified and characterized the *BAP1* mutations and genomic alterations in each of the two mesothelioma families, performed the splicing and functional assays, and discovered *BAP1* mutations in sporadic tumors and cell lines. N.J.C. designed and directed the genetic linkage analyses studies performed by J.E.B. H.I.P. treated many of these patients and together with S.T. and M.H. provided the tumor samples, DNA, and clinical information. A.U.D. performed the mineralogical studies. M.Ca. conceived the project, assembled the families and the entire research group, diagnosed mesotheliomas, and led the team at UHCC (M.N., A.P., Z.R., S.C., M.T., G.G., H.Y.) that confirmed the mutations in the two

Germline Mutations Predispose Families to MM in the Absence of Asbestos Exposure



Testa JR, et al. Germline BAP1 mutations predispose to malignant mesothelioma. Nat Genet. 2011 Aug 28;43(10):1022-5.

Genetically Engineered Models (Knockout Mice)

GEM Technique Allows **Experimental** Evaluation of Role of **Specific Genes** in Cancer

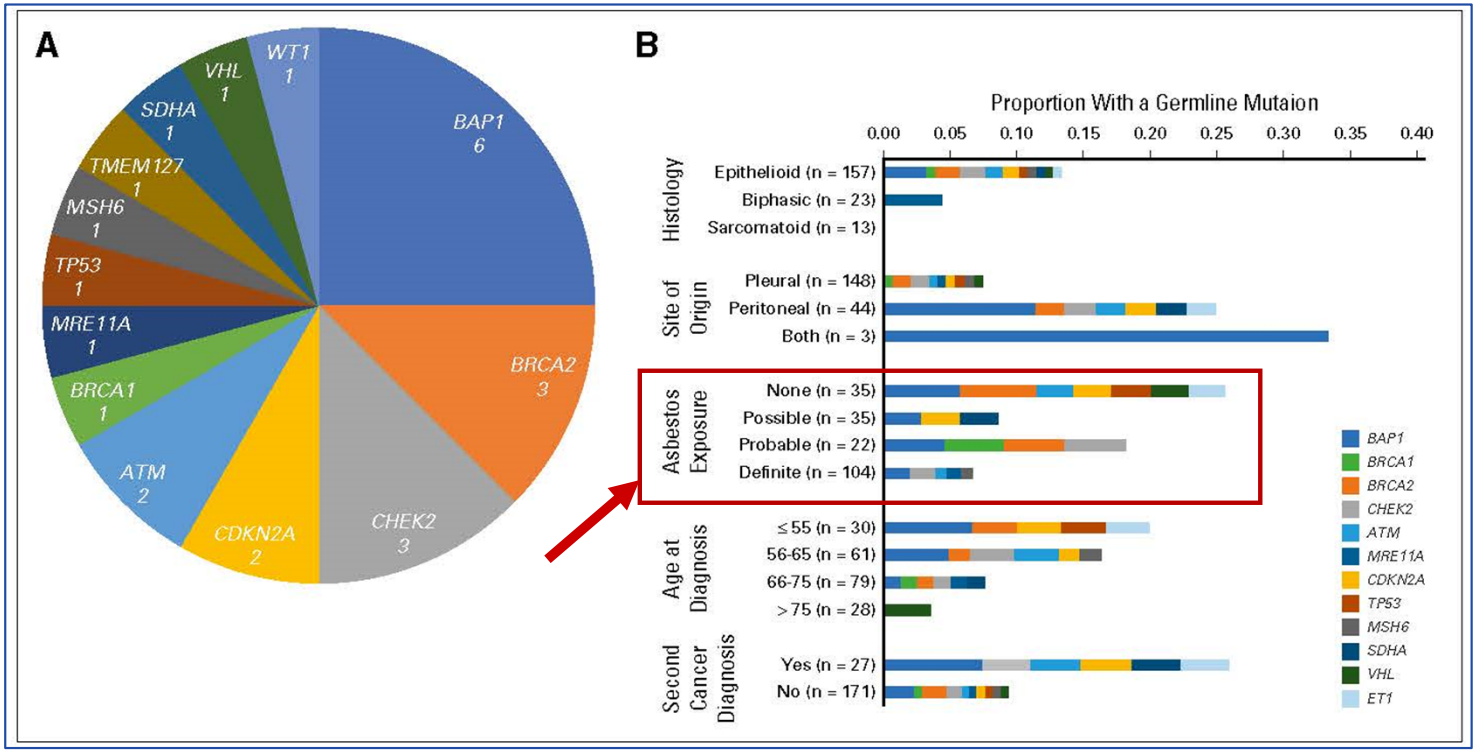
Deleting Multiple Genes Induces Mesothelioma

In Absence of Asbestos Exposure

Study Year	Deleting Genes Drives Mesothelioma
2008	NF2; P53; INK4A
2014	TSC1; TP53
2015	NF2; INK4A; ARF; BAP1
2016	BAP1
2018	PTEN; P53
2018	NF2; CDKN2A; BAP1
2019	NF2; CDKN2A; BAP1

Individuals with MM and No Asbestos Exposure

Multiple Rare Genetic Mutations



Panou *et al*., 2018; Hassan *et al*., 2019 *etc*.

Genetic Mutations Drive Mesothelioma

What the Scientists Say

"Together, these studies provide compelling evidence that there is a subset of MMs **that developed in carriers of pathogenic germline mutations**." (Pastorino, 2018)

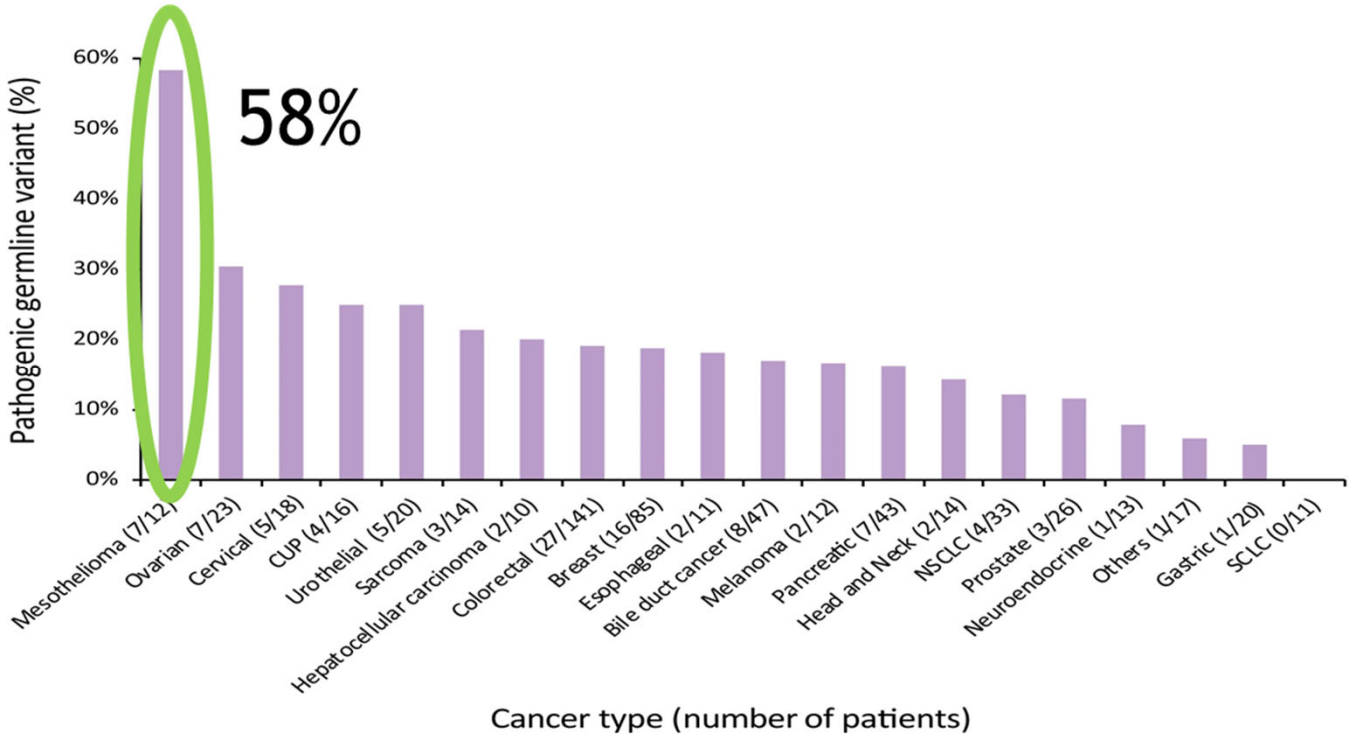
"Our study lends further support for **the role of aberrations in DNA damage repair genes in the pathogenesis of malignant pleural mesotheliomas**…" (Guo, 2019)

"Genomic analysis has defined the spectrum of **molecular alterations that drive pleural mesothelioma**." (Joseph, 2017)

"**The genetic landscape of end-stage human MPM is now well-defined**." (Farahmand, 2020 [Preprint])

"Multiple BAP1-deficient cancers that developed in a single patient suggest the **newly identified germline variant of BAP1 gene to be pathogenic…**." (Shinozaki-Ushiku, 2020)

Mesothelioma has the Most Pathogenic Germline Mutations Among All Tumor Types

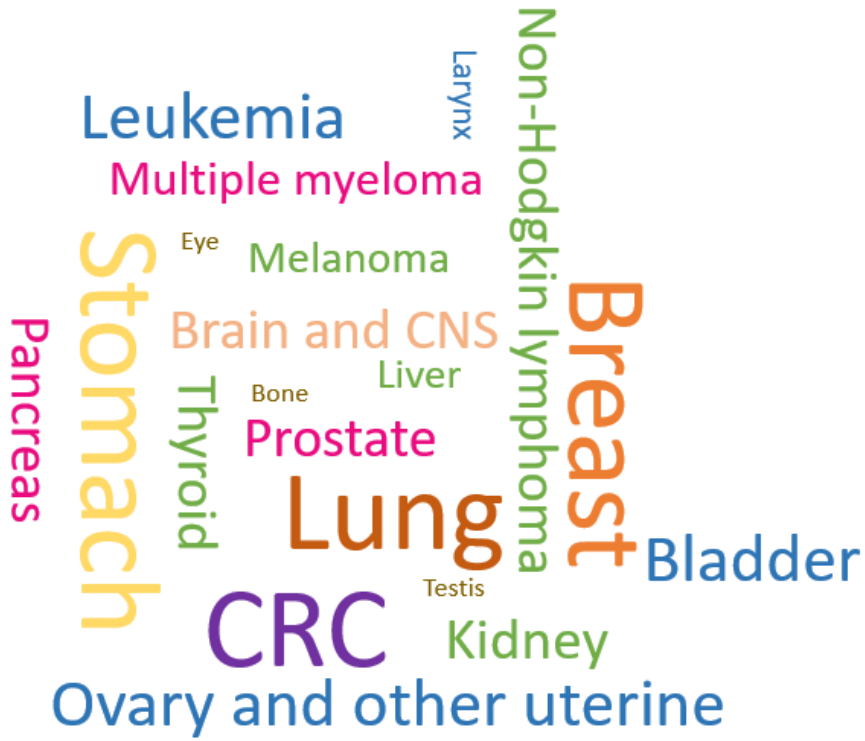


Bertelsen et al., 2019

Genetic Mutations Cause Cancer

Mesothelioma is Like Any Other Cancer

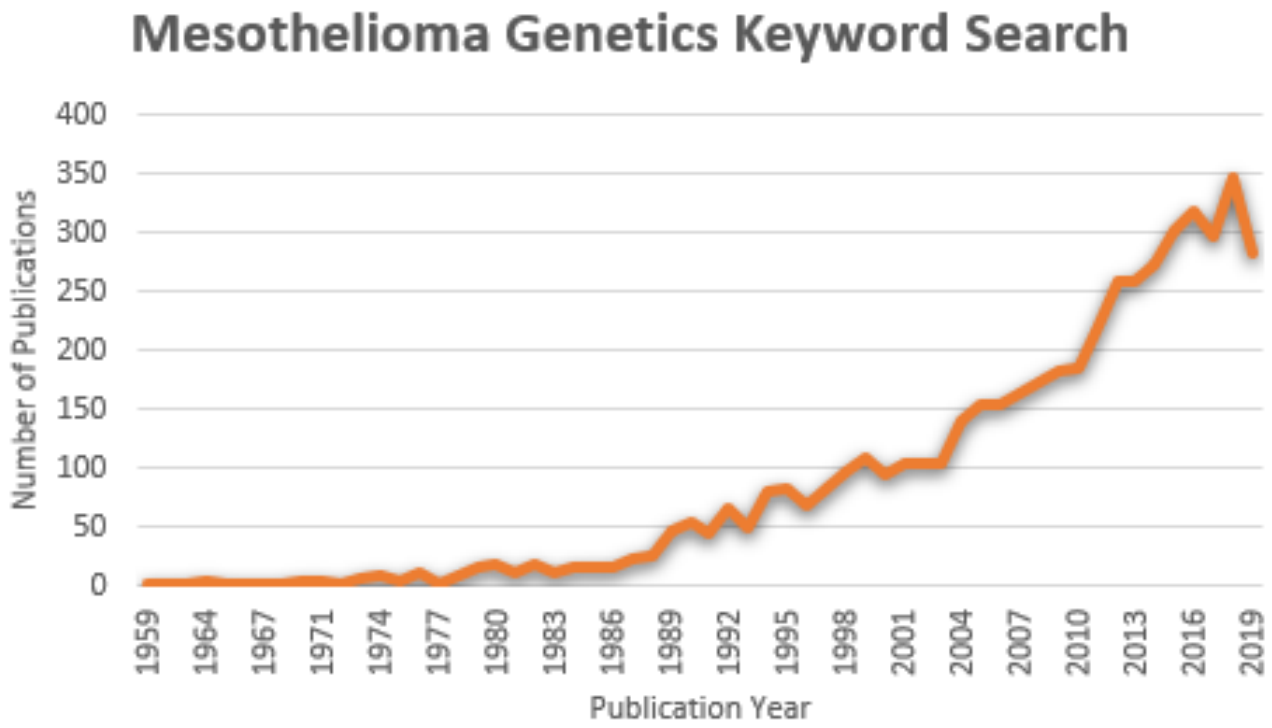
All Other Cancers



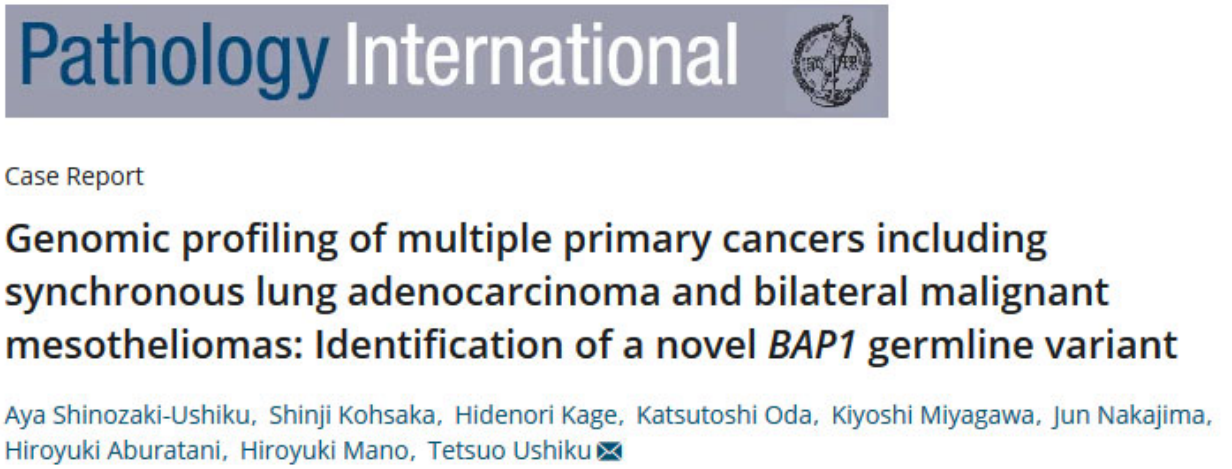
Mesothelioma

Staying Up to Date With the Science

Science is Moving Very Rapidly



Just This Week…



Pathology International

Case Report

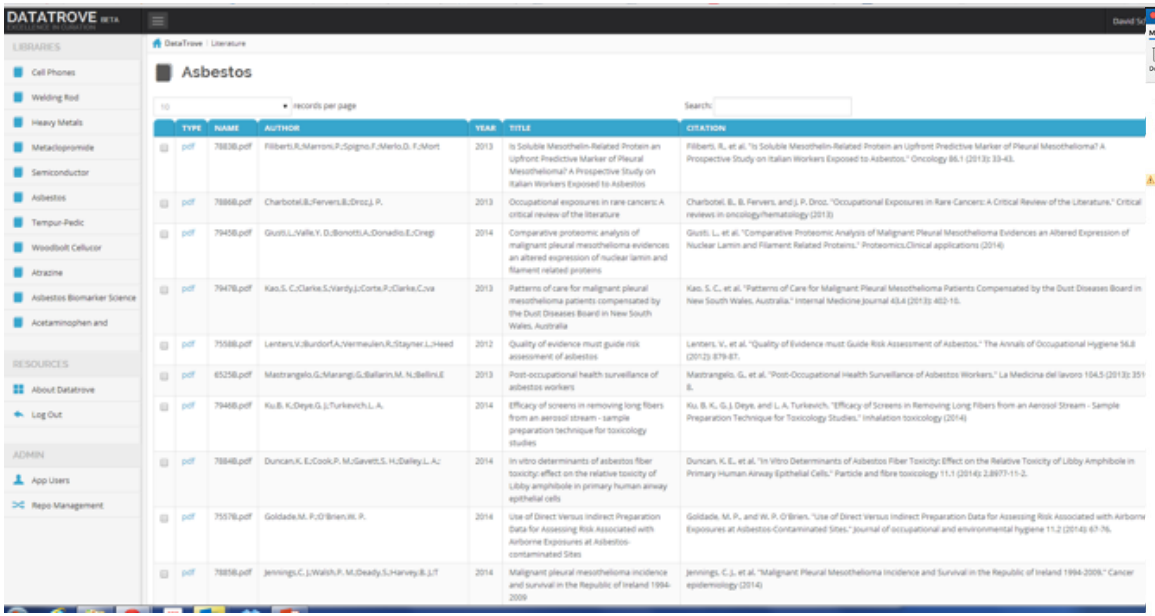
Genomic profiling of multiple primary cancers including synchronous lung adenocarcinoma and bilateral malignant mesotheliomas: Identification of a novel *BAP1* germline variant

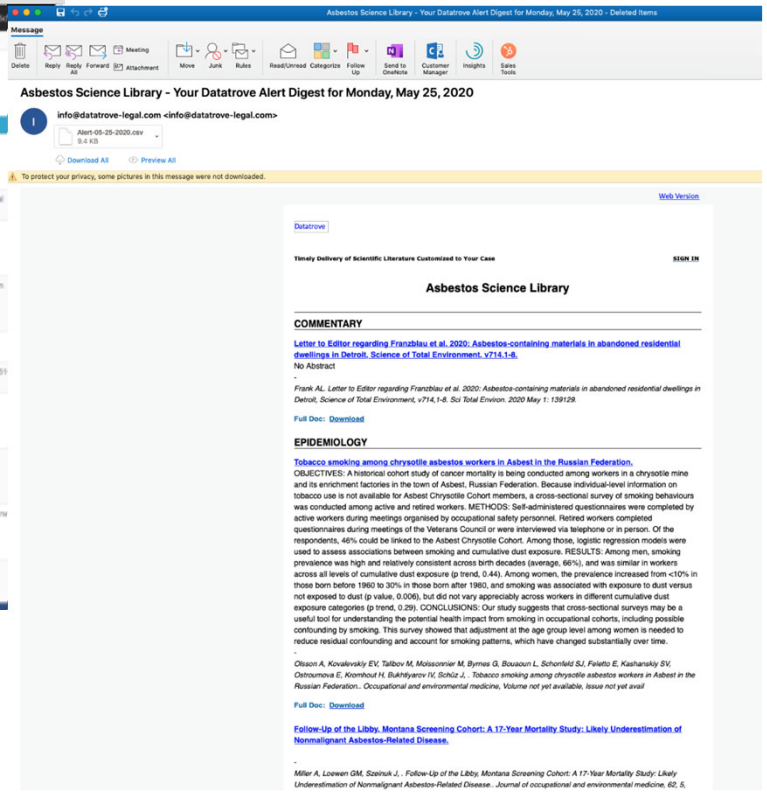
Aya Shinozaki-Ushiku, Shinji Kohsaka, Hidenori Kage, Katsutoshi Oda, Kiyoshi Miyagawa, Jun Nakajima, Hiroyuki Aburatani, Hiroyuki Mano, Tetsuo Ushiku

- Case Study: Mesothelioma and other cancers (in the absence of asbestos exposure)
- Novel *BAP1* germline mutation – never before seen
- Evidence that *BAP1* mutations can drive cancer

Stay Up-to-Date with the Science

The DataTrove Platform





Conclusions and Q&A

END