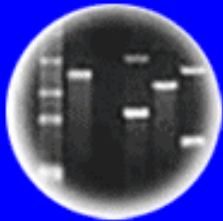


DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow

# HC70A, PLSS530, & SAS70A Winter 2014 Genetic Engineering in Medicine, Agriculture, and Law

**Professors Bob Goldberg,  
Channapatna Prakash, & John Harada**

## Lecture 1 The Age of DNA: What Is Genetic Engineering-Part One

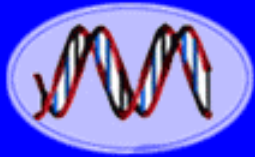
*Please Turn Off Your Cell Phones!!*

**UCLA**



**UC DAVIS**  
UNIVERSITY OF CALIFORNIA

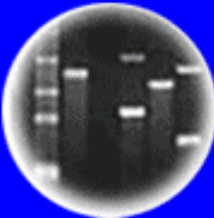
# THEMES



DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting

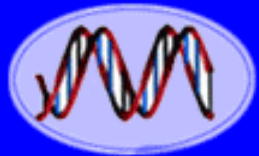


Cloning: Ethical Issues  
and Future Consequences



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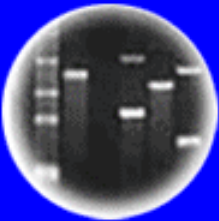
1. The Age of DNA, Genomics, Genetic Engineering & Synthetic Organisms
2. What Do Genes Look Like - DNA Demonstration
3. How Was Modern Genetic Engineering Invented & What Is the Genetic Engineering Process?
4. Why Use Genetic Engineering?
5. How Has Genetic Engineering Affected Our Lives?
6. How Has Genetic Engineering Created New Ethical and Legal Issues?
7. Is DNA Part of Our Culture - Some Examples



DNA  
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Entire Genetic Code  
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DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences

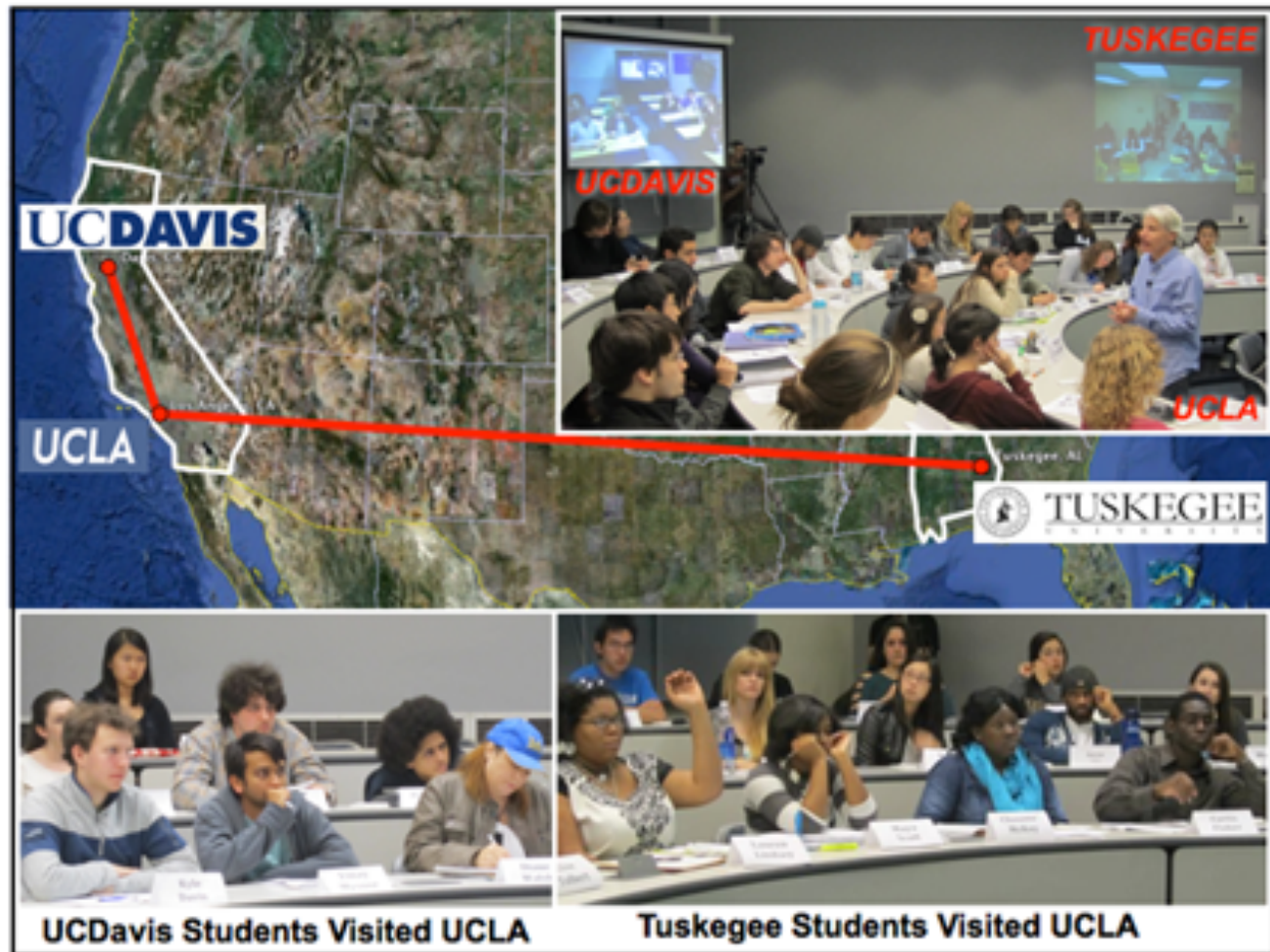


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# *The Long Distance Connection!*

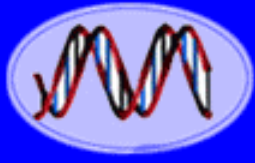
## *HC70A, SAS70A, & PLSS530*

### *Winter 2014*



*A Model For Cross-Campus  
Interactive Learning*

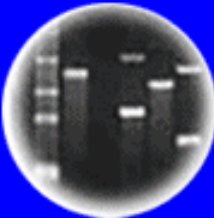




DNA  
Genetic Code of Life



Entire Genetic Code  
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DNA Fingerprinting



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## *Genetic Engineering and DNA in the News.....*

**In Girl's Last Hope, Altered Immune Cells Beat Leukemia**

DNA-swap technology almost ready for fertility clinic

**Gene therapy trial 'cures children'**

**Court: Human genes cannot be patented**

**Supreme Court Supports Monsanto in Seed-Replication Case**

**Supreme Court OKs DNA swab of people under arrest**

**FDA expected to approve Genetically Modified Salmon**

**Genetically altered 'Arctic' apples may be headed to market**

NOVEMBER 7, 2012, 9:21 AM



**California Votes No on 37: Flawed Proposition on Food Labeling**

**Washington state voters reject labeling of GMO foods**

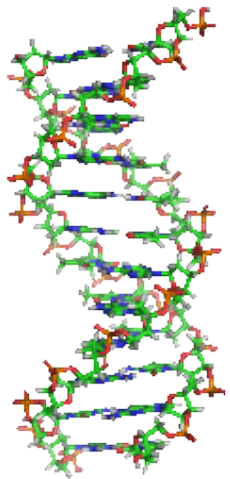
*.....and Politics*



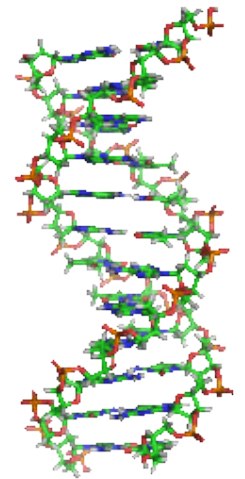
# *DNA is Part of Our Culture and Embedded in Society!!*



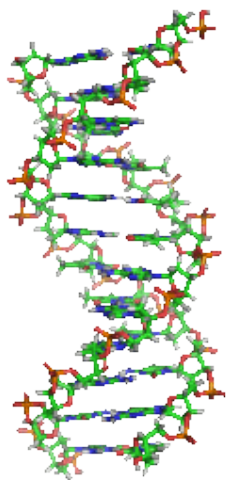
***"It's In Our DNA!"***



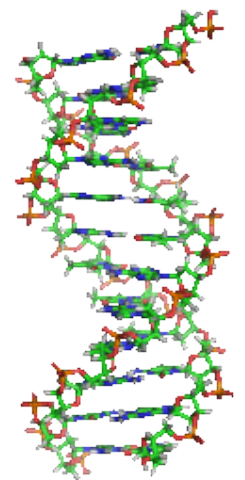
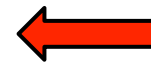
Not Surprising Because  
We Live in  
The Age of DNA!



Genetic Engineering Is  
Manipulating DNA!

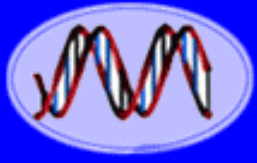


*By Classical Breeding  
or in a Test Tube  
It's All the Same!*



# What Does Your DNA Look Like?

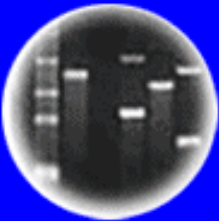
Have You Ever Seen or Touched Your Genes???



DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



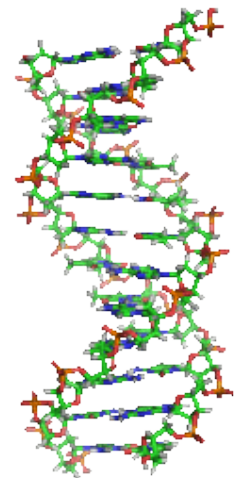
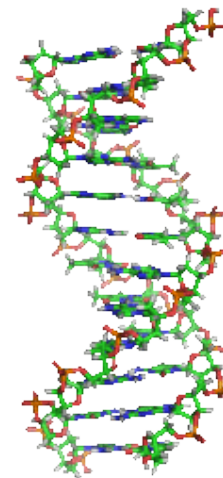
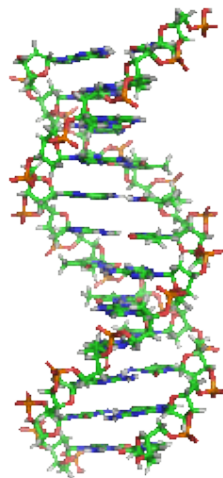
DNA Fingerprinting



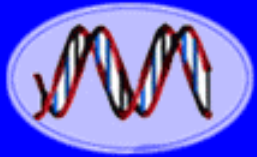
Cloning: Ethical Issues  
and Future Consequences



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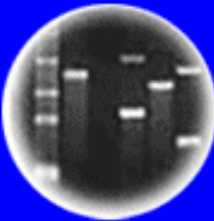




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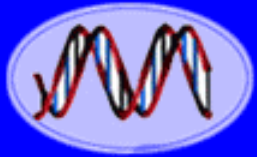
Cloning: Ethical Issues  
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## We Live in the Era of....

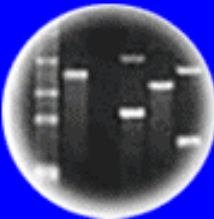
- Genes & DNA
  - Genomics & Whole Genome Sequencing
  - Genetic Engineering of Microbes, Plants Animals, & Humans!
  - A \$200B Medical and Agricultural Biotechnology Industry Using Genetic Engineering Technology and Proprietary Gene Patents, and Processes
  - Synthetic Microbes Made Using Genetic Engineering by "Man"
  - Personalized Genomes and Ability to Identify Any Individual or Disease Using DNA
  - Stem Cells, Mammalian Reproduction, & Cloning
- And the INTEGRATION of These Technologies!!



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# It All Started 40 Years Ago With the Invention of Genetic Engineering

*Proc. Nat. Acad. Sci. USA*  
Vol. 70, No. 11, pp. 3240-3244

November 1973

*This is the 40<sup>th</sup> Anniversary of Genetic  
Engineering's Origins*

## **Construction of Biologically Functional Bacterial Plasmids *In Vitro***

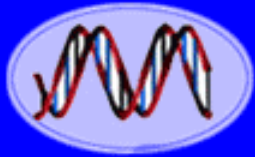
(R factor/restriction enzyme/transformation/endonuclease/antibiotic resistance)

STANLEY N. COHEN\*, ANNIE C. Y. CHANG\*, HERBERT W. BOYER†, AND ROBERT B. HELLING†

\* Department of Medicine, Stanford University School of Medicine, Stanford, California 94305; and † Department of Microbiology, University of California at San Francisco, San Francisco, Calif. 94122

*Communicated by Norman Davidson, July 18, 1973*

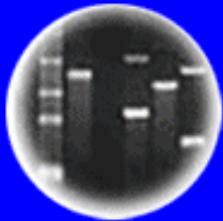
*It is Not a New Technology....In Fact, To  
Those of Us Who Have Done This Our  
Entire Careers, It is an OLD technology!!*



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Cloning: Ethical Issues  
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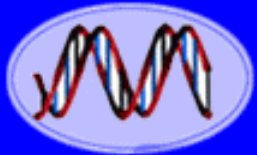
## Genetic Engineering.....

**Is the Most Revolutionary Technology in  
Biology to Have Been  
Invented in Human History!**

**Has Generated the Vast Majority of  
New Biological Knowledge Over the  
Past 40 Years From Experiments in  
Biology Laboratories Around the Globe**

**Has Changed Our Lives Dramatically!**

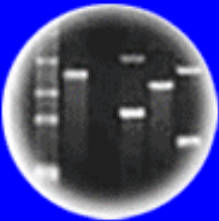




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# How Was Genetic Engineering Invented? &

# How Did It Lead To Remarkable Advances With DNA? *Genetic Engineering 1.0*

*Proc. Nat. Acad. Sci. USA*  
Vol. 70, No. 11, pp. 3240-3244, November 1973

## **Construction of Biologically Functional Bacterial Plasmids *In Vitro*** (R factor/restriction enzyme/transformation/endonuclease/antibiotic resistance)

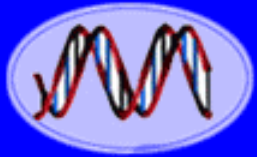
STANLEY N. COHEN\*, ANNIE C. Y. CHANG\*, HERBERT W. BOYER†, AND ROBERT B. HELLING†

\* Department of Medicine, Stanford University School of Medicine, Stanford, California 94305; and † Department of Microbiology, University of California at San Francisco, San Francisco, Calif. 94122

*Communicated by Norman Davidson, July 18, 1973*

## **DNA cloning: A personal view after 40 years**

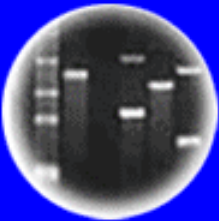
Stanley N. Cohen<sup>1</sup>    Proceedings National Academy of Sciences, September 24, 2013



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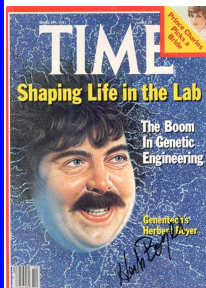
Plants of Tomorrow

# Genetic Engineering Started in a Hawaii Delicatessen 40 Years Ago....

With An Unexpected “Eureka”  
Moment Dealing With Two Unrelated  
Areas of Study:

1. The Mechanism of Bacterial  
Antibiotic Resistance

2. How Novel Enzymes That Protect  
Bacteria From Destruction By  
Viruses “Cut” DNA Into Pieces



TIME, March, 1981

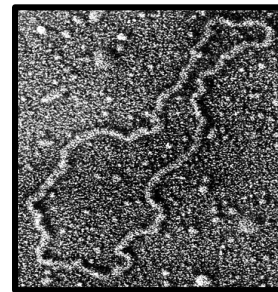




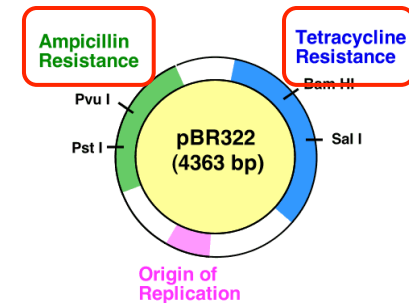
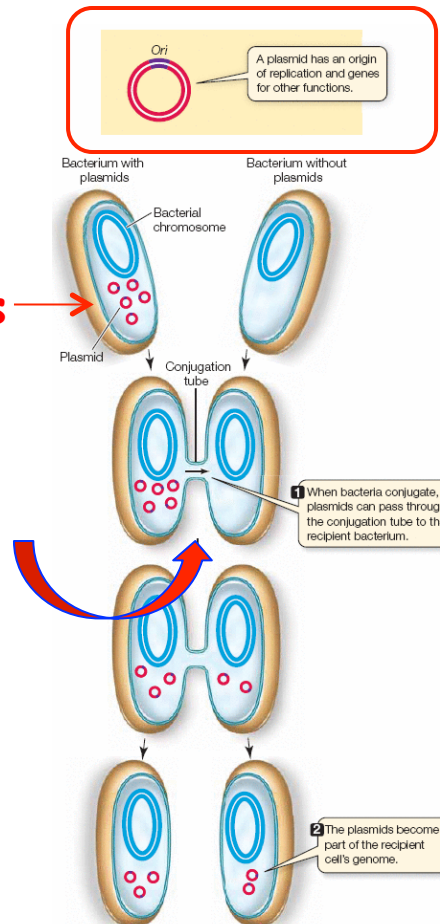
# Plasmids Are Circular Self-Replicating DNA Molecules in Bacterial Cells That Carry Antibiotic Resistance Genes



Stanley Cohen



Plasmids

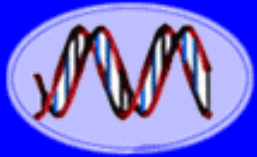


Plasmids Can Move From Cell to Cell Spreading Antibiotic Resistance Genes in Bacterial Populations!

Plasmids Defend Bacteria Against Antibiotics!



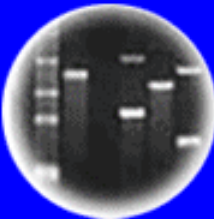
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DNA Fingerprinting



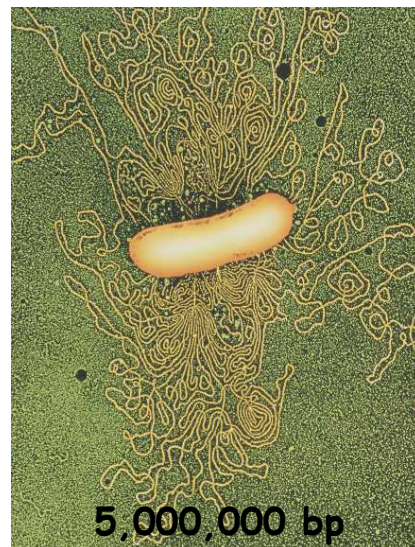
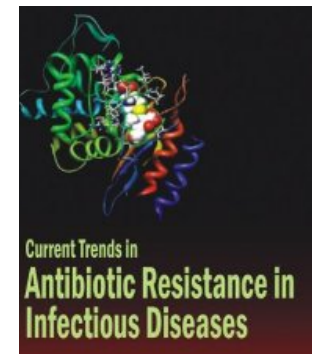
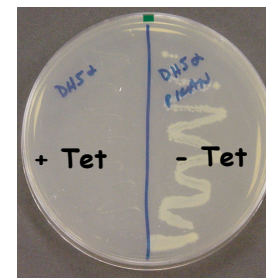
Cloning: Ethical Issues  
and Future Consequences



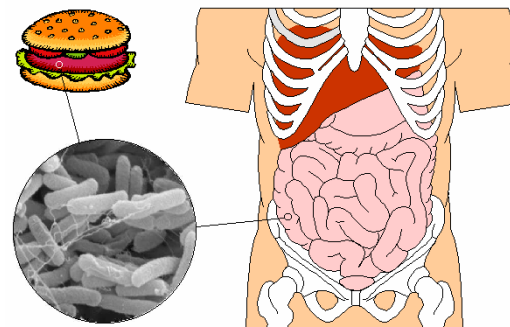
Plants of Tomorrow



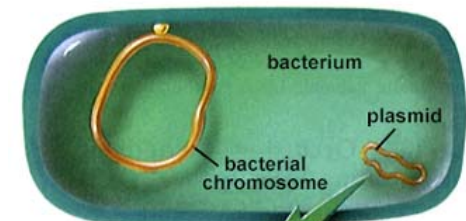
*E. coli*



5,000,000 bp



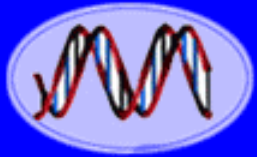
*E. coli* in Gut



Plasmid

1  $\mu$ m

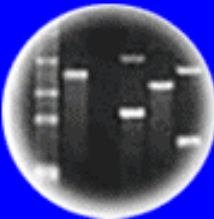
5,000 bp



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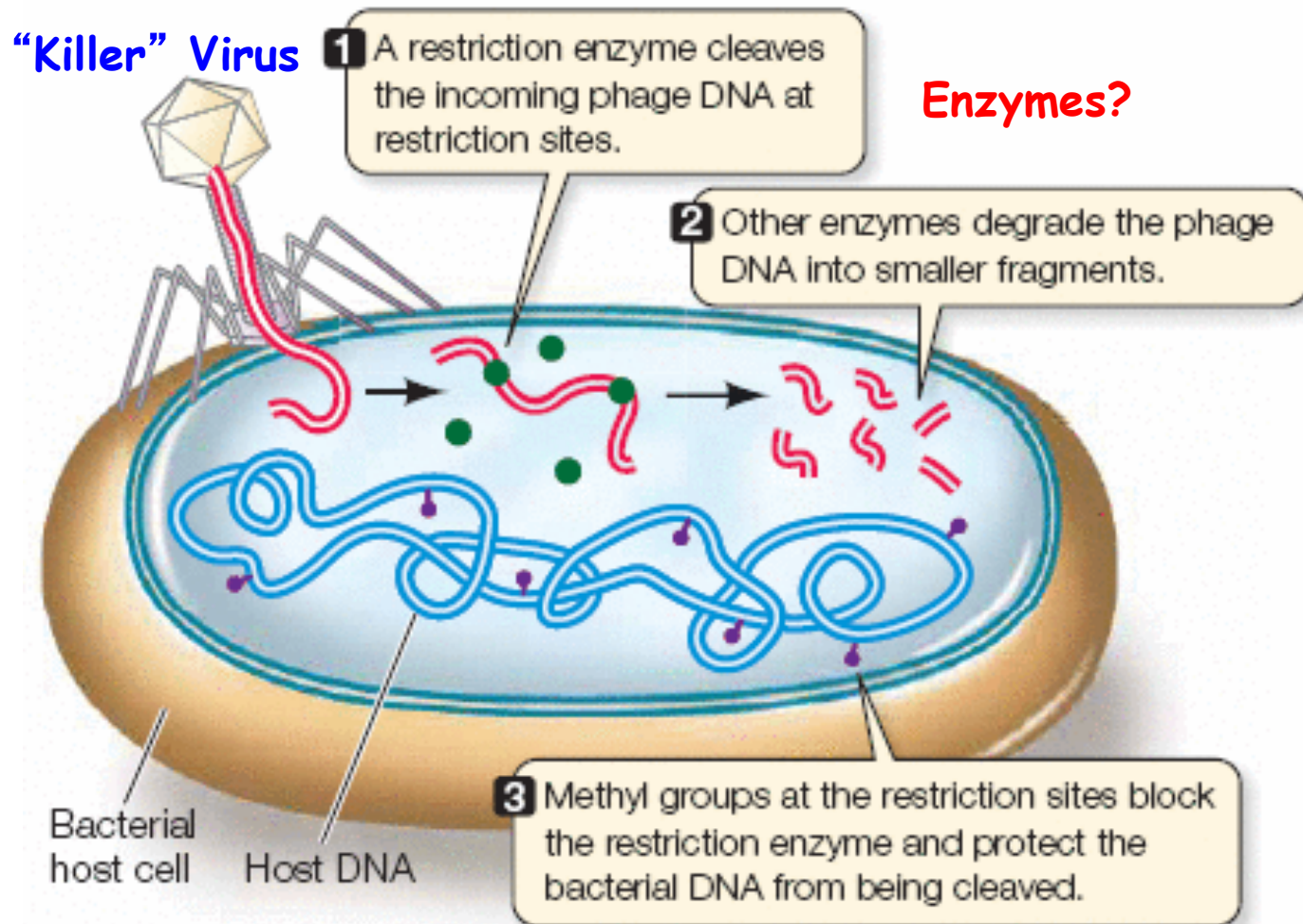
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# Restriction Enzymes Are Proteins That “Cut” DNA Into Pieces



Herb Boyer

“Killer” Virus



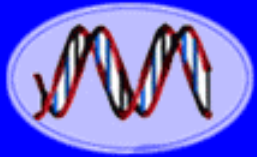
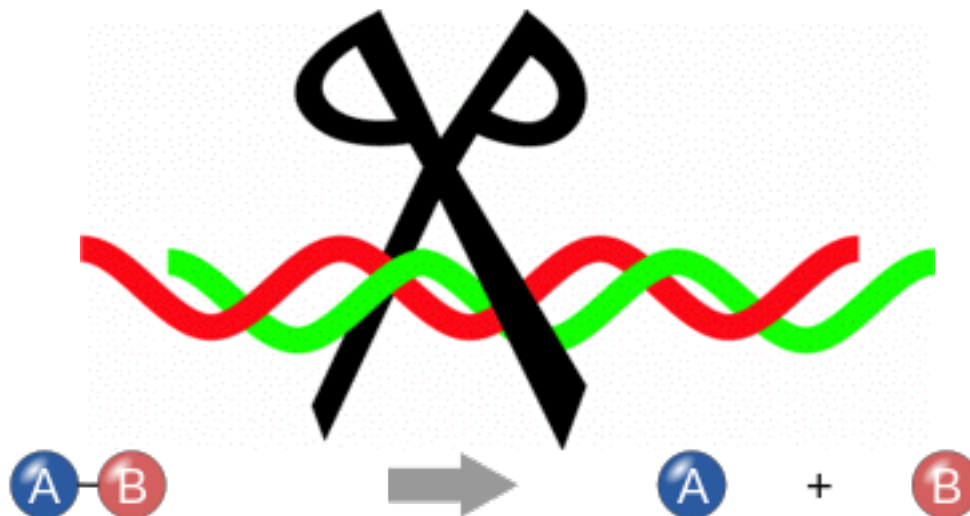
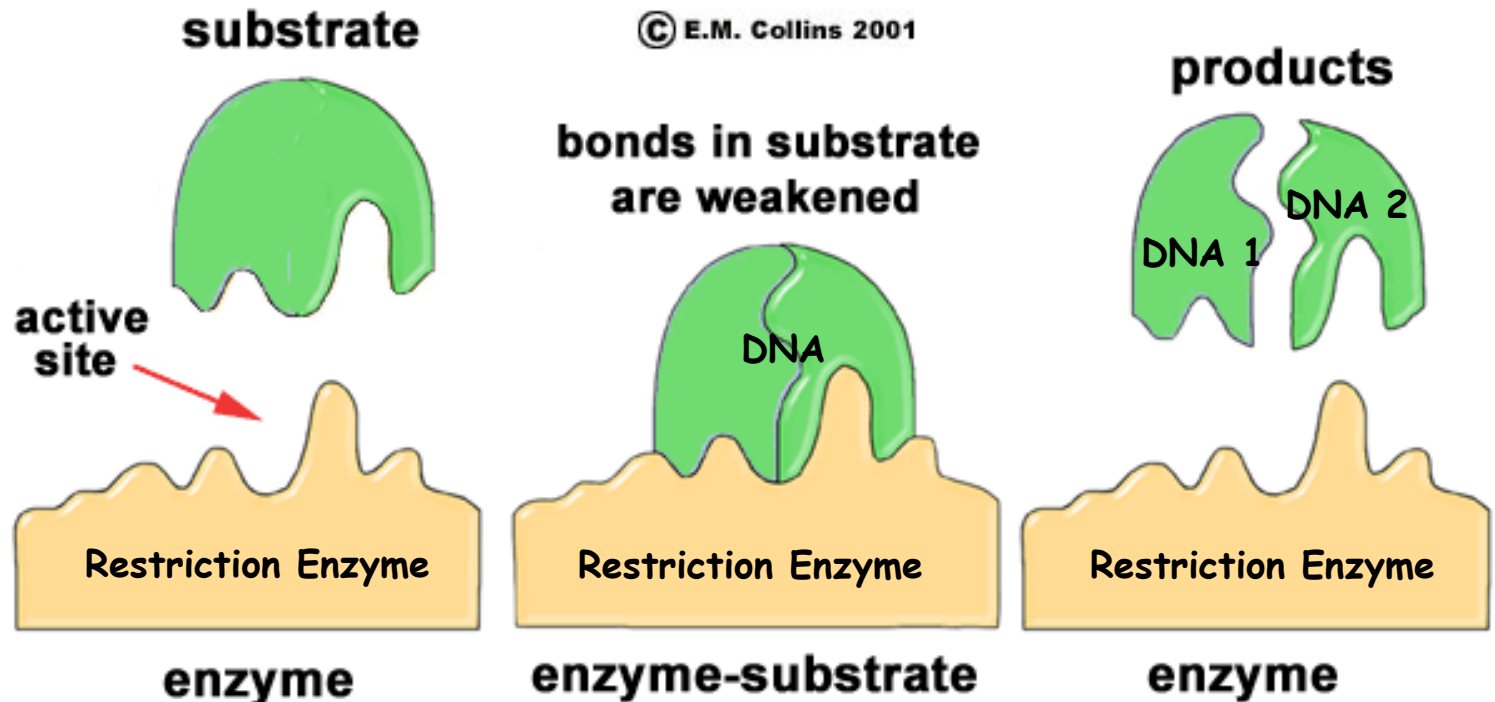
Enzymes?

Restriction Enzymes Protect  
Bacteria From “Killer”  
Viruses!



# Enzymes Are Proteins That Catalyze or Facilitate Chemical Reactions

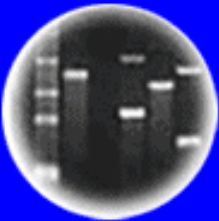
© E.M. Collins 2001



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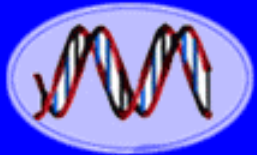
Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow



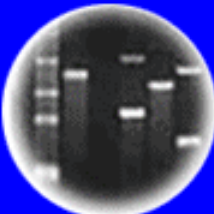
# Restriction Enzymes Are Proteins That “Cut” DNA Into Pieces At Specific Sequences



DNA  
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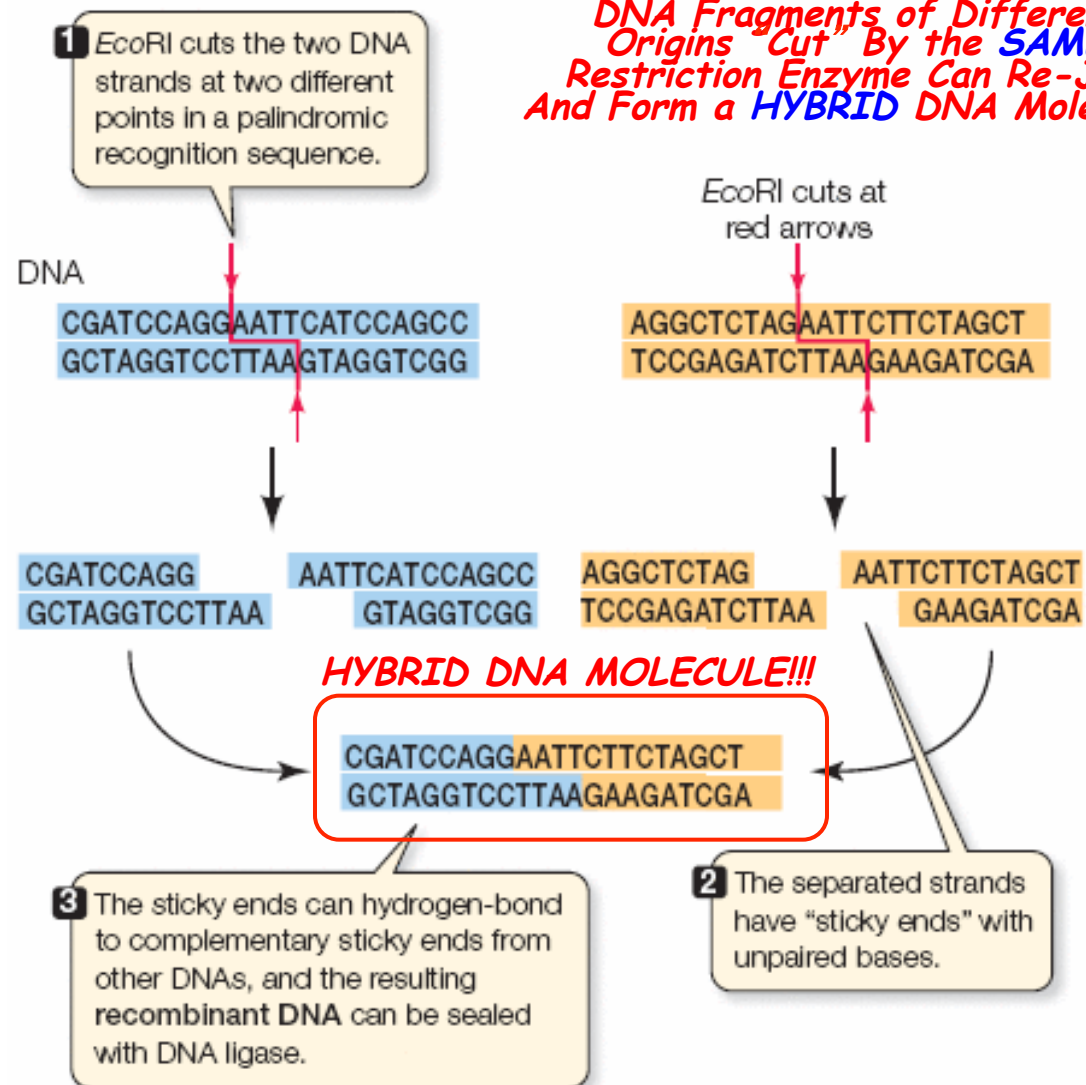
DNA Fingerprinting



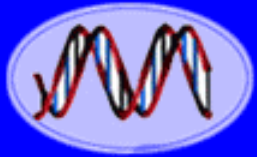
Cloning: Ethical Issues  
and Future Consequences



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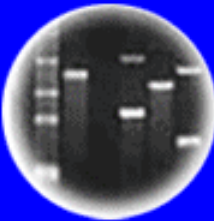
*DNA Fragments of Different  
Origins “Cut” By the SAME  
Restriction Enzyme Can Re-Join  
And Form a HYBRID DNA Molecule!!!*



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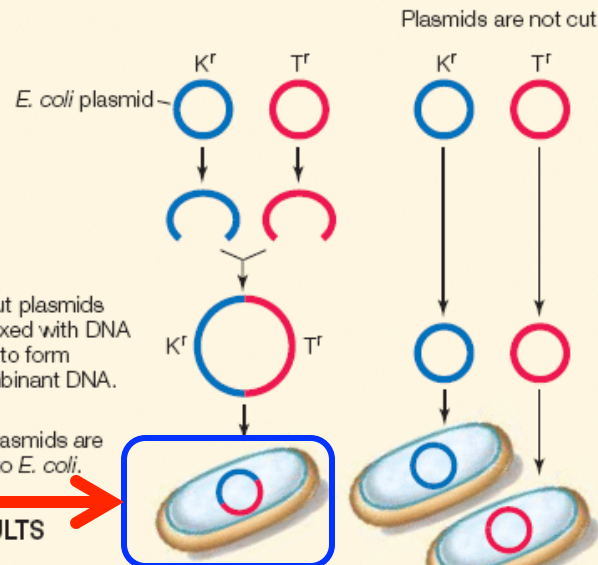
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# Genetic Engineering Technology Can Combine DNA (Genes) From Different Sources Leading to New Gene Combinations!!

## EXPERIMENT

**HYPOTHESIS:** Biologically functional recombinant chromosomes can be made in the laboratory.

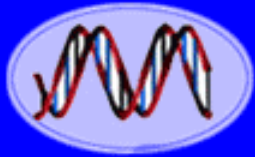
**METHOD** *E. coli* plasmids carrying a gene for resistance to either the antibiotic kanamycin or tetracycline are cut with a restriction enzyme.



Genetically Engineered Bacteria!!!

Cohen-Boyer Experiment

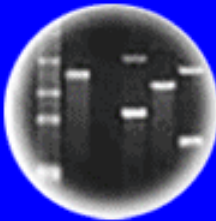
**CONCLUSION:** Two DNA fragments with different genes can be joined to make a recombinant DNA molecule, and the resulting DNA is functional.



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Leading to a **REVOLUTION** in  
Technology and Making it Possible  
For the First Time to Isolate,  
Manipulate, and Study Genes

# “Why” Clone Genes From An Organism’s Genome?

1. PURIFY Individual Genes From the Genome ( e.g., One of 25,000 Human Genes)
2. AMPLIFY The Gene to Obtain Enough DNA For Study
3. Use the Cloned Gene To:
  - a) Study Gene Structure & Function ( THE Major Use!)
  - b) Use to Convert Cells Into Factories To Make Drugs and Pharmaceuticals
  - c) Use to Diagnose Genetic Diseases
  - d) Use to Identify Individuals (e.g., paternity, forensics)
  - e) Use to Correct Genetic Disease
  - f) Use to Engineer New Crops and Farm Animals
  - g) Synthesize New Genomes and Many Other Uses

*Genetic Engineering Has Lead to New Knowledge About How Cells and Genes Function and Has Lead to Applications That Have Improved Our Lives!!*

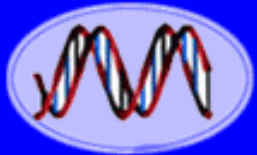


## The Era Of DNA Manipulation Means.....

1. Specific DNA/Genes Can Be Isolated From Any Organism
2. DNA Segments of Any Kind From Any Organism Can Be Combined
3. Isolated Genes Can Be Re-Inserted Into the Chromosomes of Any Organism and Made to Work
4. Genes and Genomes Can Be Synthesized and Made To Work in Any Organism

*There Are No Genetic Limits. All Biological Organisms Use the Same Genetic Rules. The Implications Are Enormous!!*

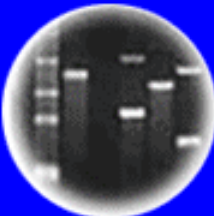
# Genomes & Chromosomes Contain Thousands of Genes



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Genetic Code of Life



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DNA Fingerprinting



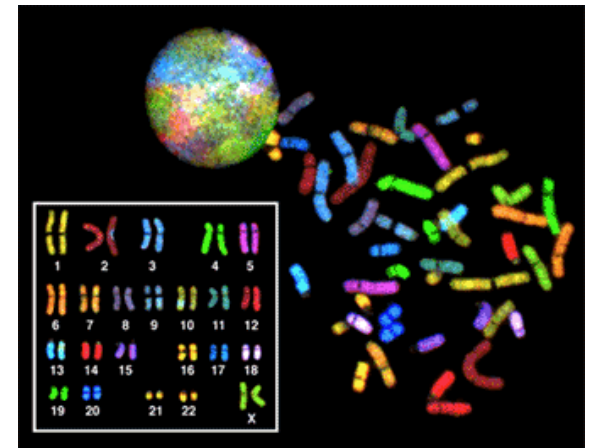
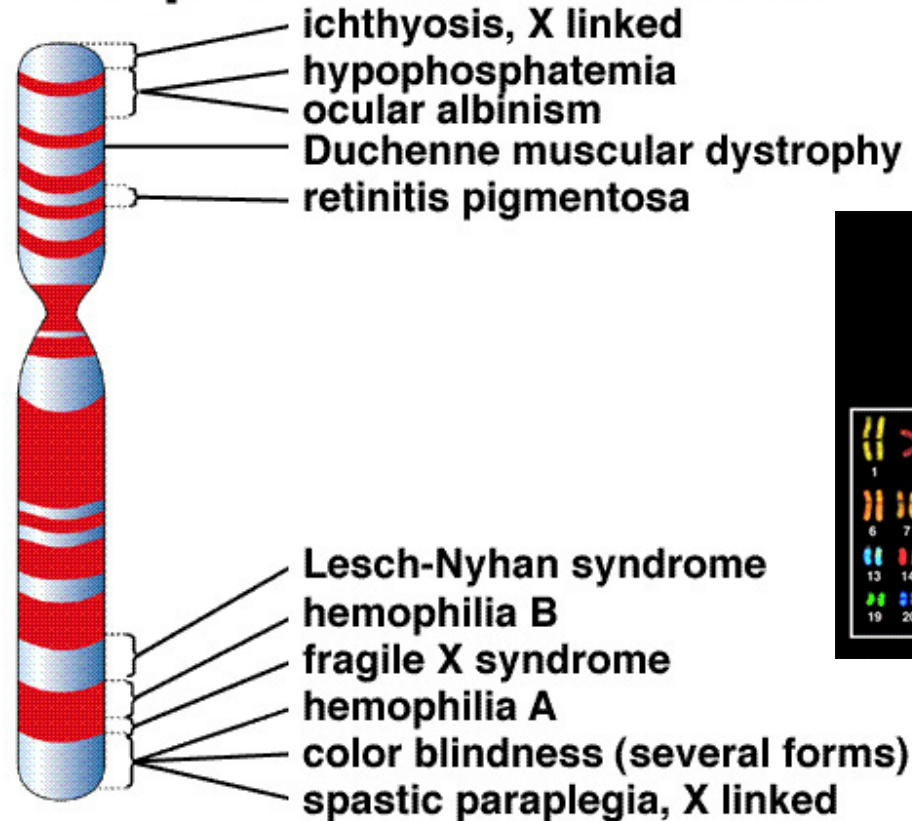
Cloning: Ethical Issues  
and Future Consequences



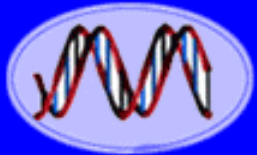
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## Map of chromosome X



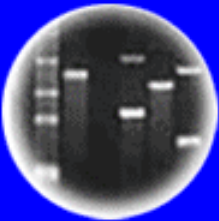
## How Can a Single Gene Be Studied?



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DNA Fingerprinting

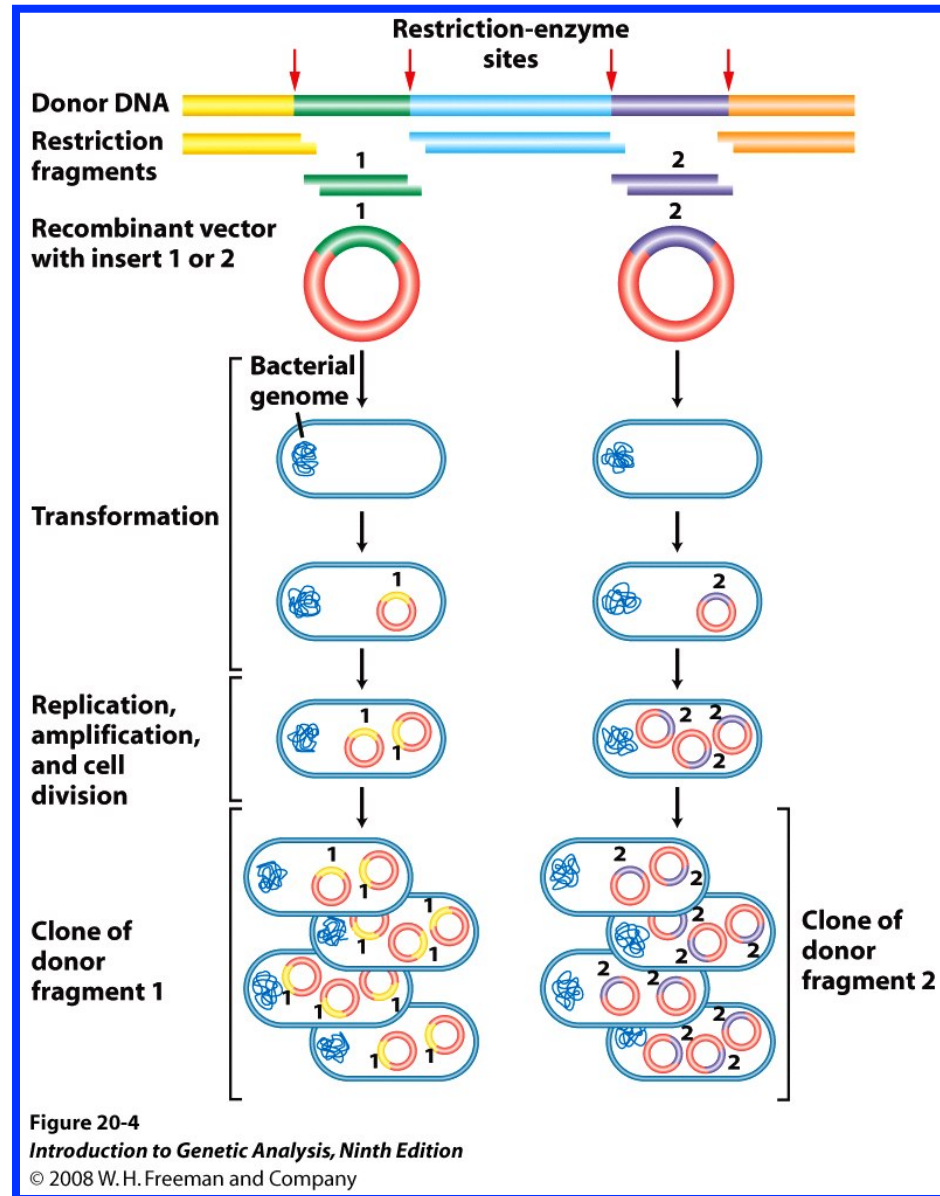


Cloning: Ethical Issues  
and Future Consequences

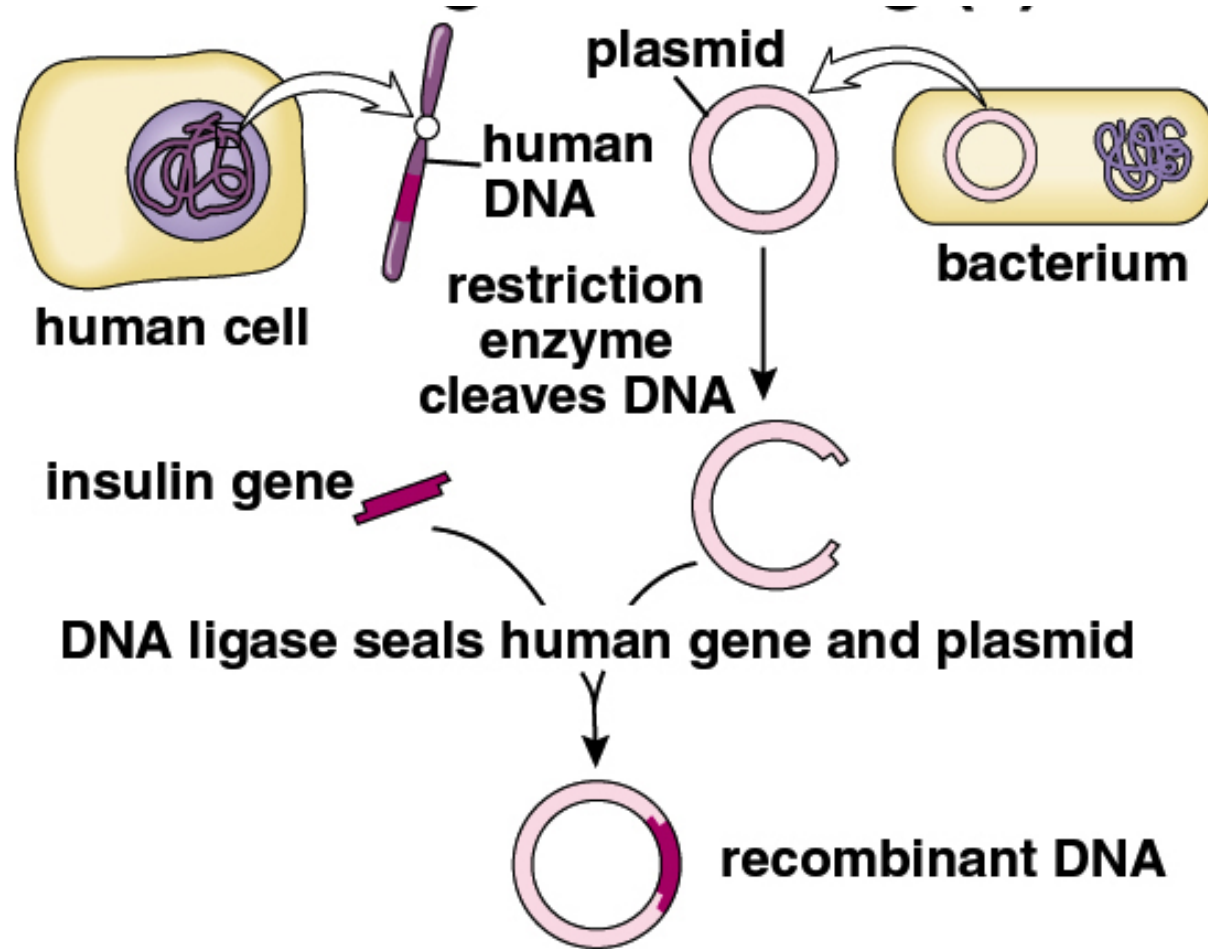


Plants of Tomorrow

# Any Gene Can Be Isolated Using Recombinant DNA



**For Example.....The Human Insulin Gene Can Be Separated From Other Human Genes and Cloned in Bacteria Using Recombinant DNA Methods!**



**And Used to Treat Diabetes!**

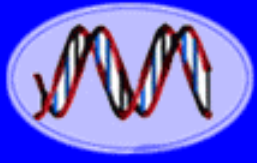




# There Are Now No Limits to What Can Be Done With Genetic Engineering!

*The Genes of Any Organism Can Be Isolated, Combined With Those of Another Organism, and Made to Function Normally in New Cellular Environments!*

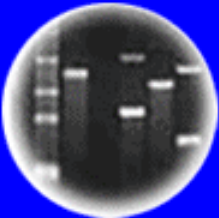
For Example: Jellyfish Genes in Monkeys, Bacterial Genes in Plants, Human Genes in Bacteria, etc., etc., etc., etc.



DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences





Plants of Tomorrow

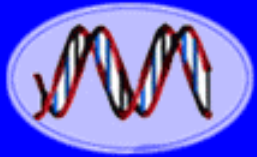


# The Age of DNA & Genetic Engineering Has Affected Our Lives in Many Ways

1. Basic Understanding of Living Processes and Ourselves
2. Basic Understanding of Genes and Their Functions
3. The Era of Genomics and the Sequence of the Human Genome and Those of Other Organisms
4. Basic Understanding of Human Diseases Such as Cancer and Novel New Treatments
5. A Multibillion Dollar Biotechnology Industry
6. New Legal Issues Such as Genetic Privacy, Forensics, and Patents on Genes and Genetically Engineered Organisms
7. A New Understanding of Human Origins and the Diversity of Human Populations (e.g., where we come from)
8. New Understanding of the Evolutionary Relationships Between Organisms (e.g., sequence of mammalian genomes, including mouse, human, dog, cat, chimpanzee)
9. Ability to Sequence the Genomes of Extinct Organisms
10. New Ethical Issues in "How Far" We Should Go in Using Genetic Engineering Technology

# Genetic Engineering Technology Has Led to Many New Legal and Ethical Issues

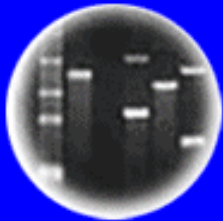
1. Patenting Genes, Cells, & Living Organisms?
2. Regulating Experimentation on DNA, Cells, Transgenic Organisms (“GMOs”)?
3. Regulating the Release of Genetically Modified Organisms into the Environment?
4. Labeling of Genetically Modified Foods?  
5. Genetic Testing: DNA Databases, Newborn Genetic Screening, Genetic Privacy, Involuntary or Voluntary Testing?
6. Genetic Discrimination?
7. Genetic Enhancement and Eugenics: Right to Enhance Your Child?
8. Gender Selection and Prenatal Diagnosis of Genetic Diseases?
9. Gene Therapy: Correcting Human Genetic Diseases?
10. Human Cloning and Genetic Improvement?
11. Gene Testing Companies (e.g., 23andMe): Liability?
12. Synthetic Genomes: Constructing New Organisms?



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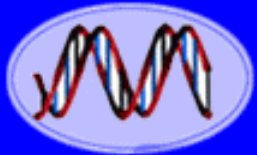
Plants of Tomorrow

## Question One

Are You Uncomfortable With Genetic Engineering?

- a. Yes
- b. No



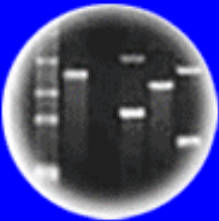


## DNA

### Genetic Code of Life



### Entire Genetic Code of a Bacteria



## DNA Fingerprinting



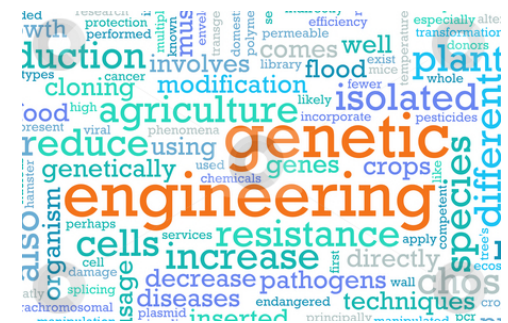
## Cloning: Ethical Issues and Future Consequences

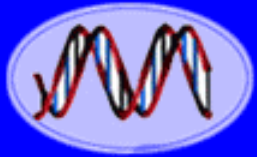


## Plants of Tomorrow

# Some 21<sup>st</sup> Century DNA Applications That Have Affected Society and Knowledge About Ourselves

*They Could Not Have Been  
Developed Without the Invention  
of Genetic Engineering!!!*

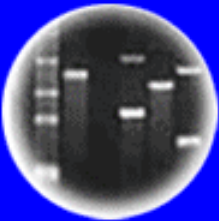




DNA  
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Entire Genetic Code  
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Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow

# DNA Can Be Used To Look Into The Past and “Bring Back the Dead!!



# RESEARCH ARTICLE

Science, May 7, 2010 (328, 710-722)

## A Draft Sequence of the Neandertal Genome

From a 45,000 Year-Old Bone

**Wilma**

Female

Red Hair

Pale Skin

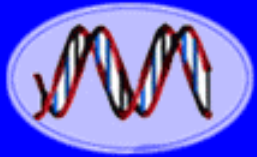
Freckles

**How Know What Wilma Looked Like?**

Reconstruction by Kennis & Kennis / Photograph by Joe McNally

For the first time, a Neanderthal female peers from the past in a reconstruction informed by both fossil anatomy and ancient DNA. At least some of her kind carried a gene for red hair and pale skin.

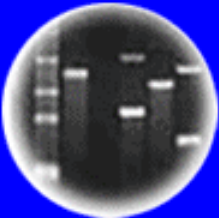




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DNA Fingerprinting

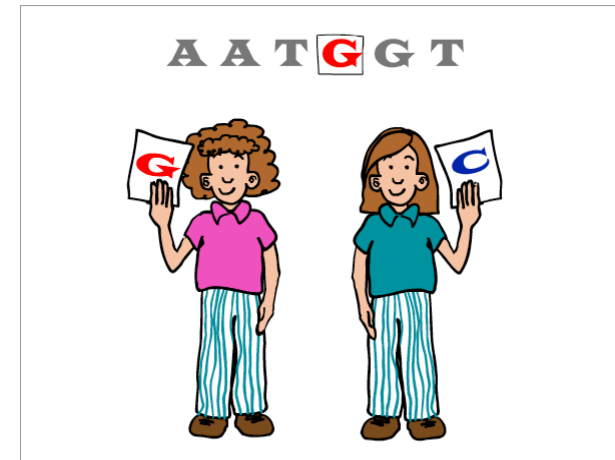


Cloning: Ethical Issues  
and Future Consequences

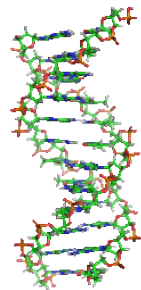
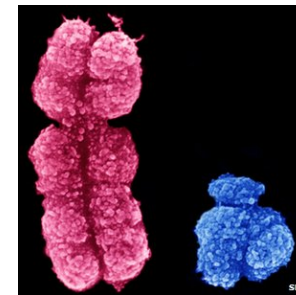


Plants of Tomorrow

# DNA Sequences Can Be Used To Specify Eye Color....



...As Well As Gender



*Yo.....It's In the DNA!*



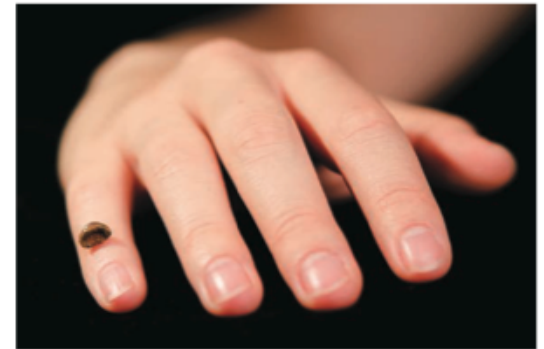
Science, October 12, 2012 (338,222-226)

ANCIENT DNA

# A Crystal-Clear View Of an Extinct Girl's Genome

**COMPLETE DNA  
Sequence From  
40,000 Year Old  
Fossil DNA With  
Accuracy of  
Sequencing Our Own  
Genome!!**

**Had 23 Chromosomes  
Like "Us" and Split  
From Human Line  
Between 150k and  
700k Years Ago**



**Slice of life.** This replica of a tiny finger bone from Denisova Cave (*right*) yielded an entire genome.

## **New DNA Analysis Shows Ancient Humans Interbred with Denisovans**

A new high-coverage DNA sequencing method reconstructs the full genome of Denisovans--relatives to both Neandertals and humans--from genetic fragments in a single finger bone

# The Shaping of Modern Human Immune Systems by Multiregional Admixture with Archaic Humans

www.sciencemag.org SCIENCE VOL 334 7 OCTOBER 2011

Comparing 40,000  
Year-Old  
Fossil Genomes to  
Our Genome  
Reveals Ancient  
“Matings”  
Between Different  
Human Ancestor  
Lineages!!



We Have  
Neanderthal &  
Denisovan Genes in  
Our Chromosomes

## It's All in the DNA!

Nature Reviews | **Genetics**  
September, 2011

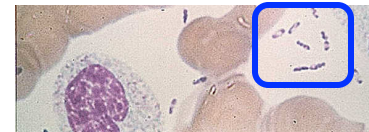
# LETTER

## Ancient DNA Can Be Studied to Find the Source of Major Epidemics From 100s of Years Ago!

doi:10.1038/nature10549

### A draft genome of *Yersinia pestis* from victims of the Black Death *The Power of DNA and Genetic Engineering!*

Kirsten I. Bos<sup>1\*</sup>, Verena J. Schuenemann<sup>2\*</sup>, G. Brian Golding<sup>3</sup>, Hernán A. Burbano<sup>4</sup>, Nicholas Waglechner<sup>5</sup>, Brian K. Coombes<sup>5</sup>, Joseph B. McPhee<sup>5</sup>, Sharon N. DeWitte<sup>6,7</sup>, Matthias Meyer<sup>4</sup>, Sarah Schmedes<sup>8</sup>, James Wood<sup>9</sup>, David J. D. Earn<sup>5,10</sup>, D. Ann Herring<sup>11</sup>, Peter Bauer<sup>12</sup>, Hendrik N. Poinar<sup>1,3,5</sup> & Johannes Krause<sup>2,12</sup>



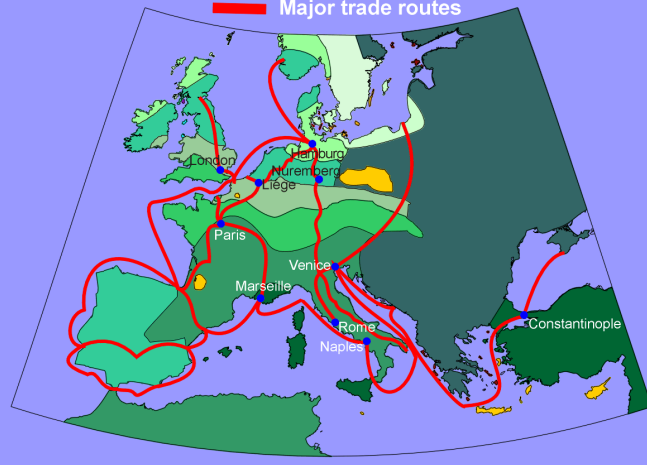
Rat Blood

1347-1351

#### The Spread of the Black Death

December 1347	June 1349	December 1350
June 1348	December 1349	After 1351
December 1348	June 1350	Areas partially or totally spared

Major trade routes



- Killed 30% of Europe's Population
- Killed 100M People in Four Years!
- Population of 450M to 350M
- Took 150 Years to Recover





Nature, November 2008

LETTERS

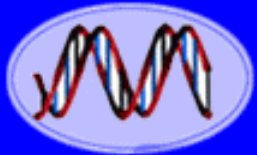
# Sequencing the nuclear genome of the extinct woolly mammoth

**Think About Bringing a Woolly Mammoth Back to Life!!**

Webb Miller<sup>1</sup>, Daniela I. Drautz<sup>1</sup>, Aakrosh Ratan<sup>1</sup>, Barbara Pusey<sup>1</sup>, Ji Qi<sup>1</sup>, Arthur M. Lesk<sup>1</sup>, Lynn P. Tomsho<sup>1</sup>, Michael D. Packard<sup>1</sup>, Fangqing Zhao<sup>1</sup>, Andrei Sher<sup>2,†</sup>, Alexei Tikhonov<sup>3</sup>, Brian Raney<sup>4</sup>, Nick Patterson<sup>5</sup>, Kerstin Lindblad-Toh<sup>5</sup>, Eric S. Lander<sup>5</sup>, James R. Knight<sup>6</sup>, Gerard P. Irzyk<sup>6</sup>, Karin M. Fredrikson<sup>7</sup>, Timothy T. Harkins<sup>7</sup>, Sharon Sheridan<sup>7</sup>, Tom Pringle<sup>8</sup> & Stephan C. Schuster<sup>1</sup>





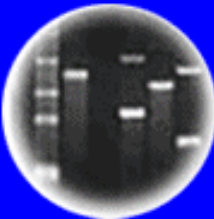


## DNA

### Genetic Code of Life



### Entire Genetic Code of a Bacteria



## DNA Fingerprinting

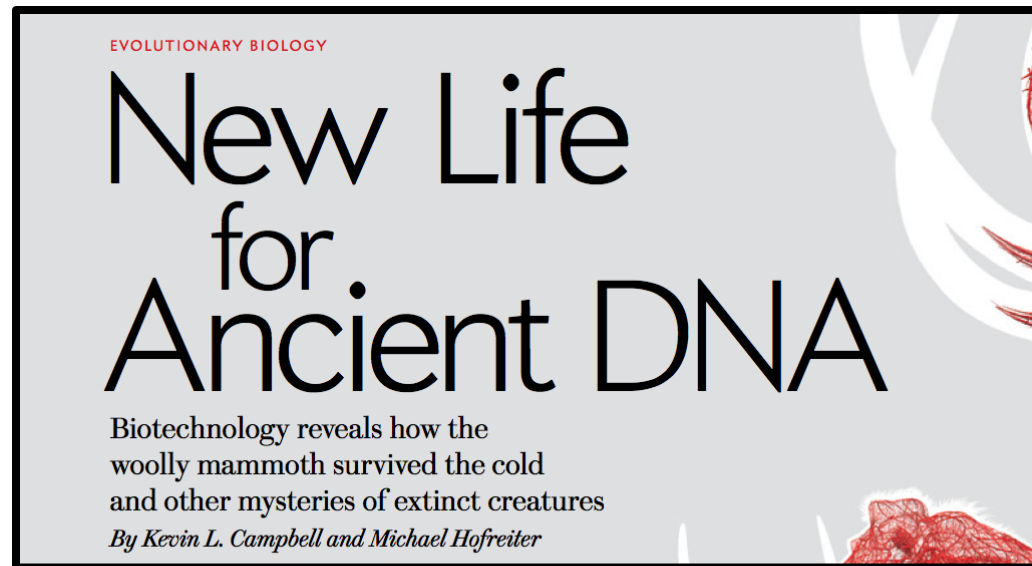


## Cloning: Ethical Issues and Future Consequences



## Plants of Tomorrow

**Scientific American, August, 2012**

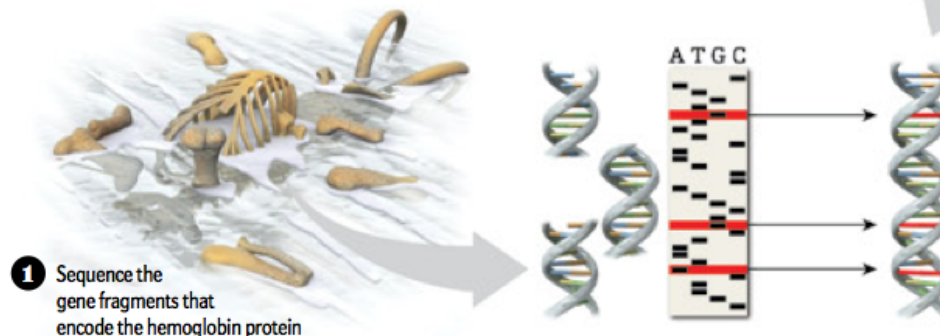


# Bring a Mammoth Back to Life?

## HOW IT WORKS

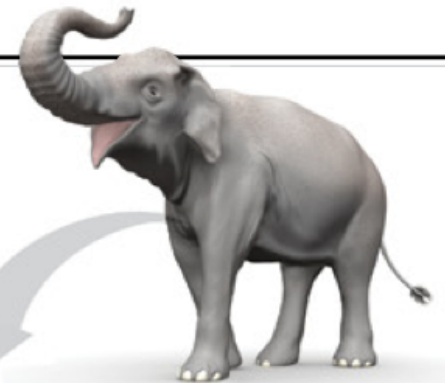
# Breathing Life into Mammoths

By reconstructing ancient genes, scientists can re-create the proteins they encoded and observe how they behave, thereby gaining insights into the physiology of extinct animals. For instance, resurrection of the red blood cell protein hemoglobin from a woolly mammoth (*below*) has shown that the temperature-sensitive protein evolved adaptations that enabled it to do its job of delivering oxygen to body tissues in the cold conditions these beasts faced.

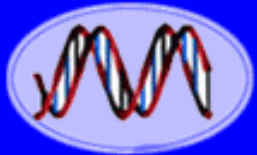


**1** Sequence the gene fragments that encode the hemoglobin protein

**2** Re-create functional mammoth hemoglobin genes by taking the intact corresponding genes in an Asian elephant and altering their sequences in three spots to match the mammoth sequences



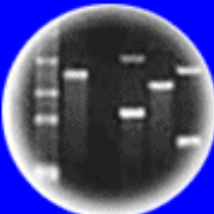
# Cloning an Animal – Now Routine!



DNA  
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Entire Genetic Code  
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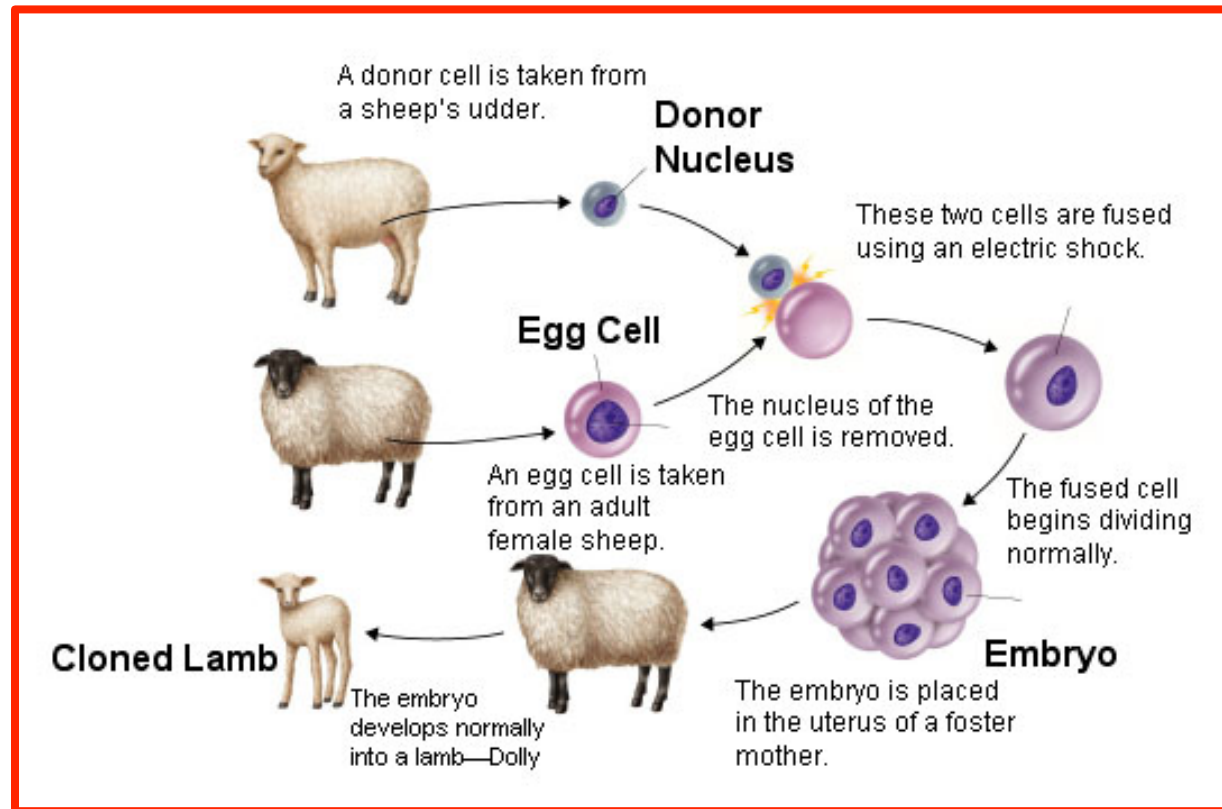
DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow



**Researchers successfully clone human embryonic stem cells** *Cell*, May 15, 2013

*Bring Back the Dead?*

November 11, 2008

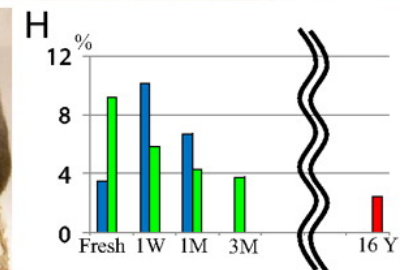
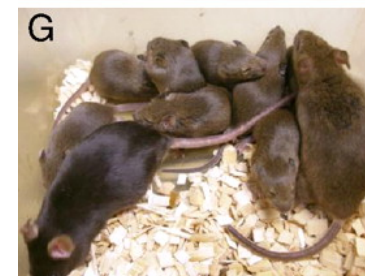
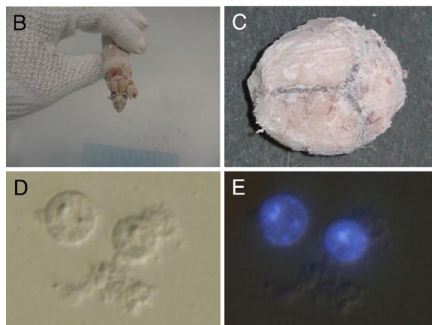
## Production of healthy cloned mice from bodies frozen at $-20^{\circ}\text{C}$ for 16 years

*Think of the possibilities!*

Sayaka Wakayama<sup>a</sup>, Hiroshi Ohta<sup>a</sup>, Takafusa Hikichi<sup>a</sup>, Elji Mizutani<sup>a</sup>, Takamasa Iwaki<sup>b</sup>, Osami Kanagawa<sup>c</sup>, and Teruhiko Wakayama<sup>a,1</sup>

<sup>a</sup>RIKEN, Center for Developmental Biology, 2-2-3 Minatojima-minamimachi, Kobe, 650-0047, Japan; <sup>b</sup>Jikei University School of medicine, Tokyo 105-8461, Japan; and <sup>c</sup>RIKEN, Research Center for Allergy and Immunology, 1-7-22, Sushiro-cho, Tsurumi-ku, Yokohama, 230-0045, Japan

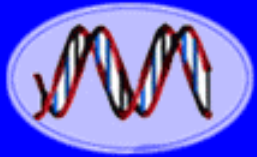
*How Know a Clone or Genetically Identical Individual - DNA!*



# Resurrecting the Extinct

60 Minutes, January, 2010

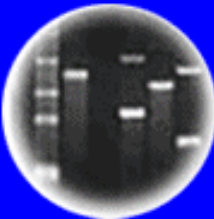




DNA  
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Entire Genetic Code  
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DNA Fingerprinting

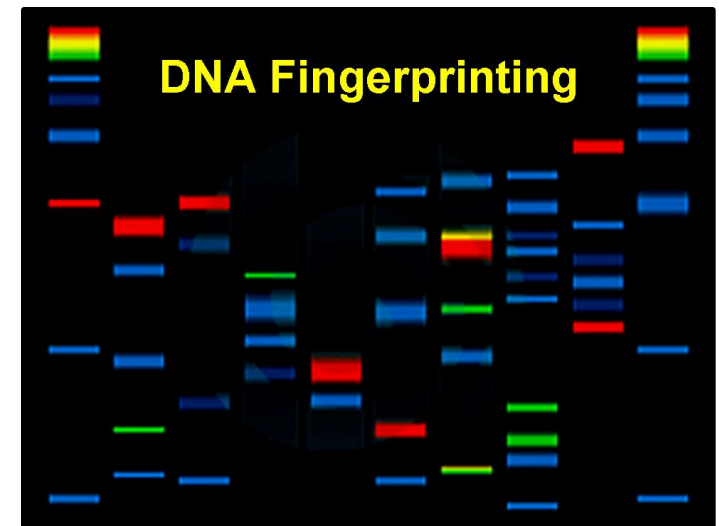


Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow

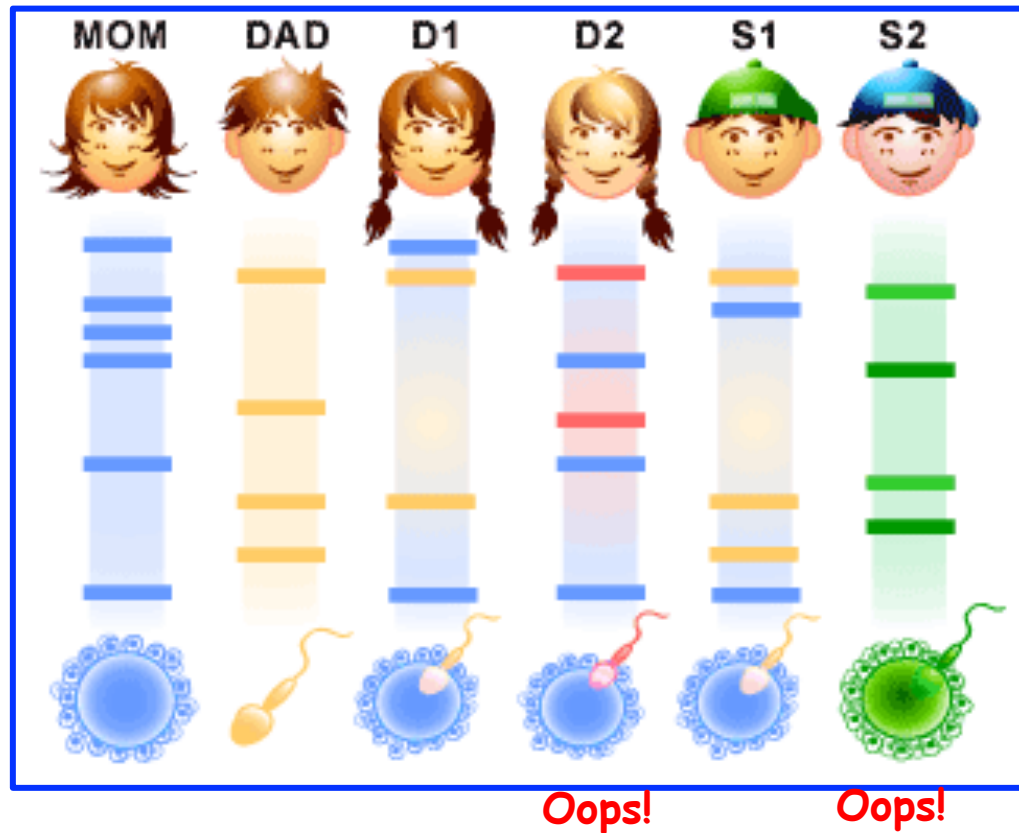
# DNA Can Be Used To Identify Individuals For Genetic Diseases, **Paternity**, **Ancestry**, **Forensics**, **Crimes**, and Much More



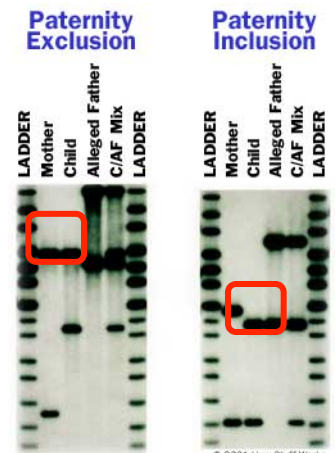
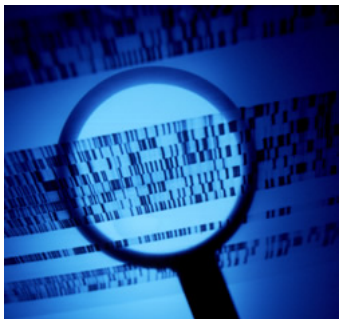
# Using DNA Fingerprints to Identify Individuals & Genes They Don't "Lie"

## DNA Fingerprints

*Sometimes  
They  
Reveal  
Unexpected  
Results!*



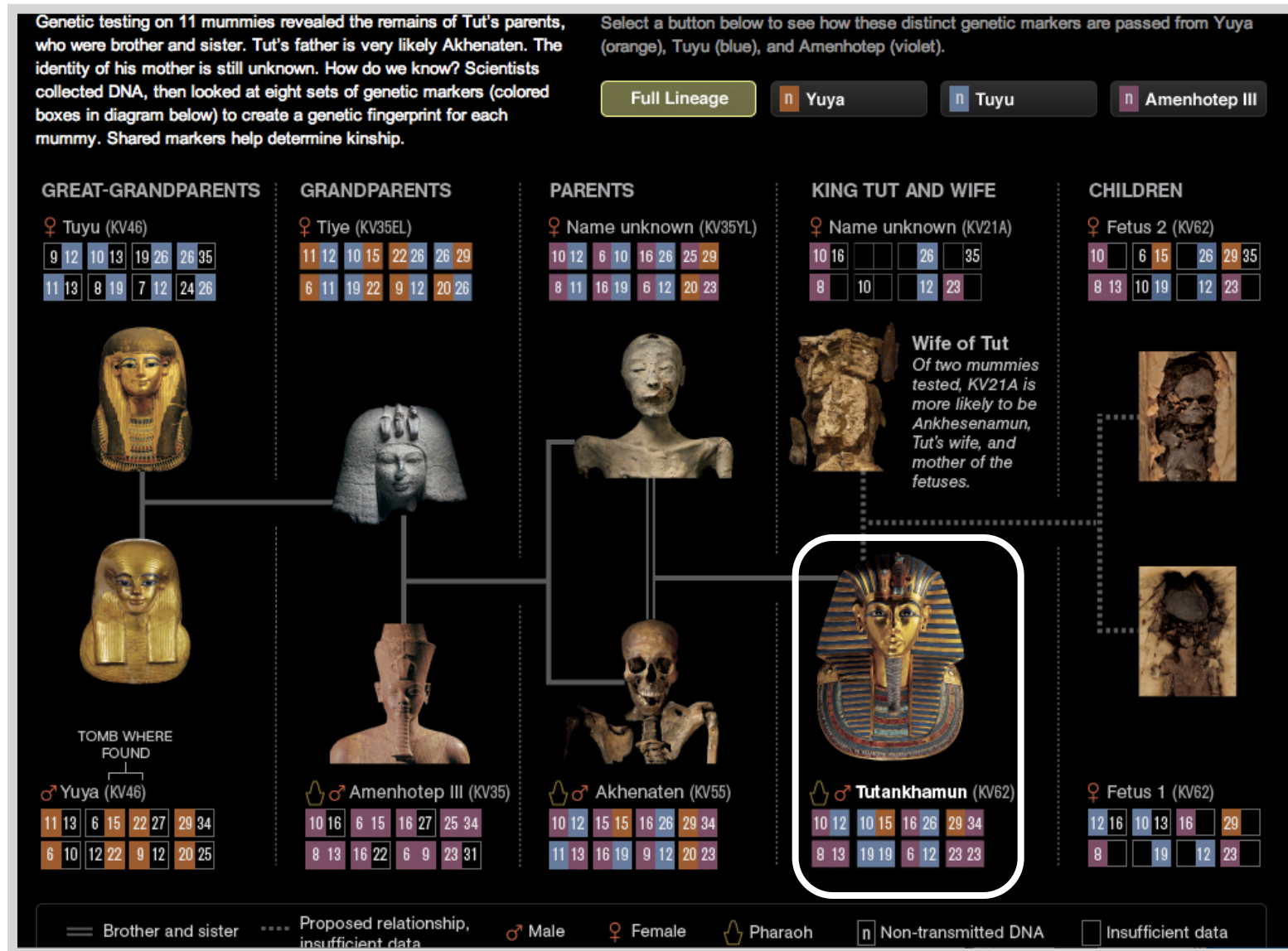
*What is YOUR  
DNA  
Fingerprint?*



# *What is YOUR DNA Fingerprint?*



# Lineages of Ancient Mummies Such As King Tut Can Be Determined Using DNA Fingerprinting!!



National Geographic, September 2010



King Tut Lived 3,500 years Ago!!

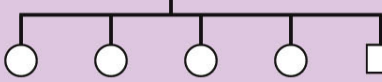


# DNA Fingerprints Used to Verify Remains of Russian Royal Family

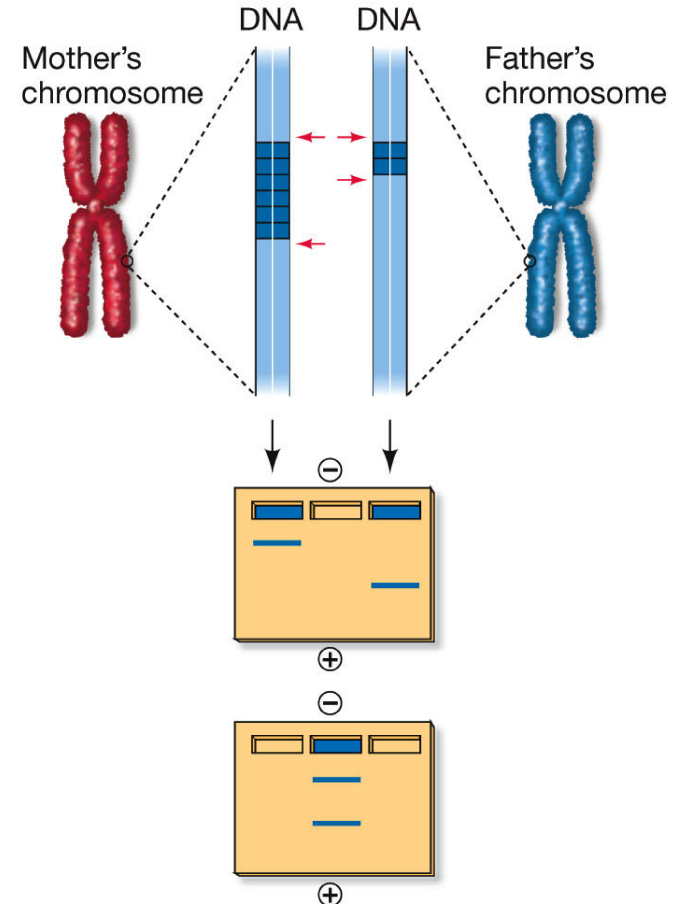


	Number of repeats			
STR-1	15,16	15,16		
STR-2	8,8	7,10		
STR-3	3,5	7,7		
STR-4	12,13	12,12		
STR-5	32,36	11,32		

Tsarina Alexandra  Tsar Nicholas II 



STR-1	15,16	15,16	15,16
STR-2	8,10	7,8	8,10
STR-3	5,7	5,7	3,7
STR-4	12,13	12,13	12,13
STR-5	11,32	11,36	32,36



## Genomic identification in the historical case of the Nicholas II royal family **PNAS, March, 2009**

Evgeny I. Rogayev<sup>1,2,3,4,5</sup>, Anastasia P. Grigorenko<sup>1,2</sup>, Yuri K. Mollaka<sup>1</sup>, Gulnaz Faskhutdinova<sup>1</sup>, Andrey Goltsov<sup>1</sup>, Arlene Lahti<sup>1</sup>, Curtis Hildebrandt<sup>1</sup>, Ellen L. W. Kittler<sup>1</sup>, and Irina Morozova<sup>1</sup>

<sup>1</sup>Department of Genomics and Laboratory of Evolutionary Genomics, Vavilov Institute of General Genetics, Russian Academy of Science, Gubkina Street, 3, Moscow, 119991, Russian Federation; <sup>2</sup>Brudnick Neuropsychiatric Research Institute, University of Massachusetts Medical School, 303 Belmont Street, Worcester, MA 01604; <sup>3</sup>Faculty of Bioinformatics and Bioengineering, Lomonosov Moscow State University, Moscow, 119991, Russian Federation; <sup>4</sup>Research Center of Mental Health, Russian Academy of Medical Science, Zagorodnaya Shosse 2/2, Moscow, 113152, Russia; <sup>5</sup>Molecular World, Inc., Thunder Bay, ON, Canada P7B 2T1; and <sup>6</sup>University of Massachusetts Medical School, Center for AIDS Research, Worcester, MA 01605

Communicated by James D. Watson, Cold Spring Harbor Laboratory, Cold Spring Harbor, NY, November 14, 2008 (received for review October 8, 2008)

## RESEARCH ARTICLE

## OPEN ACCESS

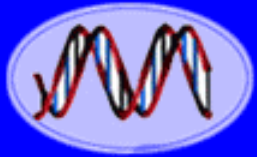
### Mystery Solved: The Identification of the Two Missing Romanov Children Using DNA Analysis

Michael D. Coble<sup>1,2,3,4,5</sup>, Odile M. Loreille<sup>1,2</sup>, Mark J. Wadhams<sup>1</sup>, Suni M. Edson<sup>1</sup>, Kerry Maynard<sup>1</sup>, Carina E. Meyer<sup>1</sup>, Harald Niederstätter<sup>2</sup>, Cordula Berger<sup>2</sup>, Burkhard Berger<sup>2</sup>, Anthony B. Falsetti<sup>3</sup>, Peter Gill<sup>4,5</sup>, Walther Parson<sup>2</sup>, Louis N. Finelli<sup>1</sup>

<sup>1</sup> Armed Forces DNA Identification Laboratory, Armed Forces Institute of Pathology, Rockville, Maryland, United States of America, <sup>2</sup> Institute of Legal Medicine, Innsbruck Medical University, Innsbruck, Austria, <sup>3</sup> University of Florida, Gainesville, Florida, United States of America, <sup>4</sup> Department of Pure and Applied Chemistry, University of Strathclyde, Glasgow, United Kingdom, <sup>5</sup> Institute of Forensic Medicine, University of Oslo, Oslo, Norway

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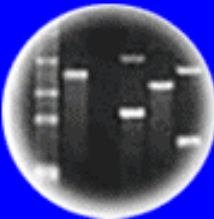
**PLOS,  
March,  
2009**



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Plants of Tomorrow

# DNA Can Also Be Used To Uncover Consumer Fraud and Identify Poached Wildlife

May 26, 2011

## Tests Reveal Mislabeling of Fish

By ELISABETH ROSENTHAL

Scientists aiming their gene sequencers at commercial seafood are discovering rampant labeling fraud in supermarket coolers and restaurant tables: cheap fish is often substituted for expensive fillets, and overfished species are passed off as fish whose numbers are plentiful.



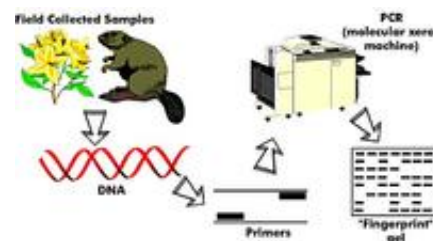
## \$11,250 IN FINES FOR ILLEGAL MOOSE HUNT AND COVER UP

### NEWS

November 16, 2010

Four southern Ontario men have been convicted of charges related to illegal moose hunting.

Anton Gerritsen Jr. and Anton Gerritsen Sr., both of Cayuga, Shank A. Vanderheide of Canfield and James E. Kruis of St. George, were each fined \$1,000 for obstructing a Ministry of Natural Resources conservation officer and Gerritsen Jr., Gerritsen Sr. and Vanderheide were each fined \$500 for illegally possessing a cow moose. Gerritsen Jr. was also fined \$250 for illegally possessing a calf moose, \$1,500 for hunting cow moose without a licence and \$500 for failing to immediately attach a game seal to a harvested animal. Gerritsen Sr. was fined \$500 for using a hunting licence that was issued to someone else.



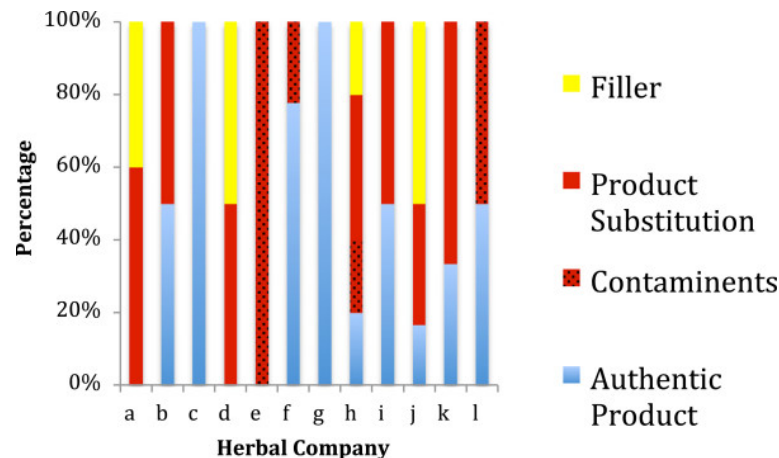
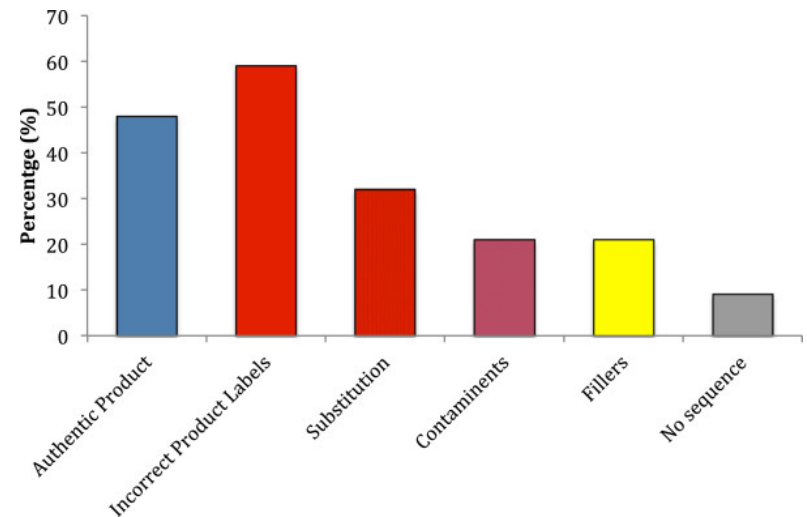
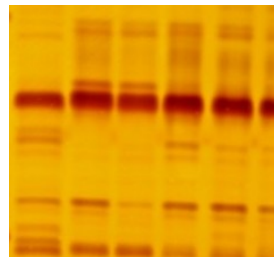


# And Consumer Fraud in the Natural Food Industry

DNA barcoding detects contamination and substitution in North American herbal products

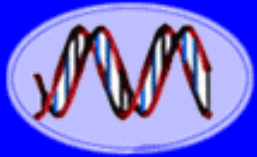
BMC Medicine, 11, 222, 2013

*Barcoding = DNA Fingerprinting!*





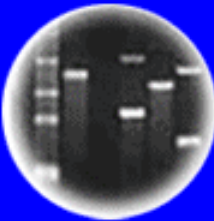
# DNA Fingerprints Can Also Be Used To Trace the Source of Illegal Drugs



DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



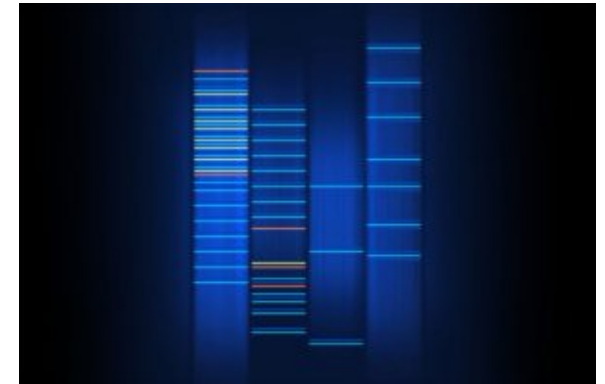
DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences

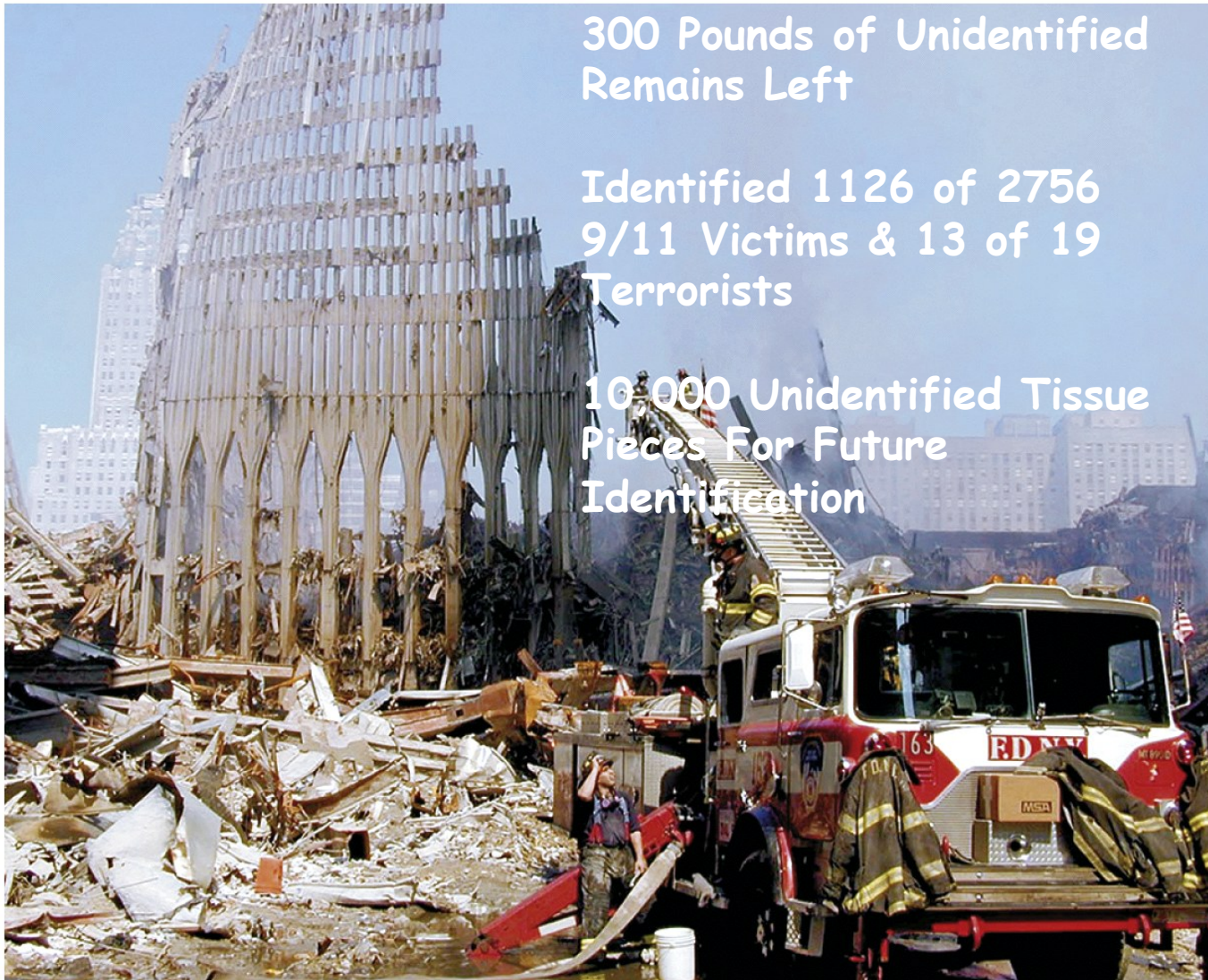


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# Identifying Victims of 9/11 by DNA Fingerprinting



300 Pounds of Unidentified Remains Left

Identified 1126 of 2756  
9/11 Victims & 13 of 19  
Terrorists

10,000 Unidentified Tissue  
Pieces For Future  
Identification

Figure 19-31  
*Genetics: A Conceptual Approach, Third Edition*  
© 2009 W. H. Freeman and Company

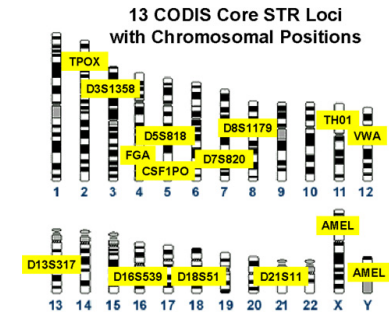
Newsweek, January 12, 2009

# DNA Has Impacted the Law in Dramatic Ways

## Combined DNA Index System (CODIS) of DNA Profiles



- Convicted Felons
- Suspects Arrested For Felonies
- DNA Samples From Crime Scenes
- Unidentified Human Remains
- Relatives of Missing Persons



November, 2013

Offender Profiles 10,692,400  
Arrestee Profiles 1,711,100  
Forensic Profiles 527,400  
Database "Hits" 228,500

What Are State Laws?  
**California Proposition 69**

assisting 219,300 investigations



## FORENSICS

# Familial DNA Testing Scores A Win in Serial Killer Case



Proud of their work. A familial DNA search by forensic scientists in California led to the arrest of Lonnie Franklin, the suspected Grim Sleeper killer.

*Grim Sleeper Caught By DNA!!*



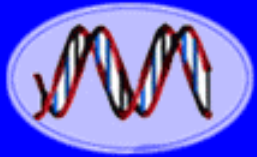
# *Set Free By DNA Evidence*



**15th Person Cleared by DNA in Dallas.** Charles Chatman was released from state custody Jan. 3 in Dallas, after serving nearly 27 years in prison for a rape he didn't commit. He is the 15th Dallas man to be cleared by DNA testing after being wrongfully convicted. After his hearing, he hugged Judge John Creuzot, who advocated for testing in the case. Innocence Project of Texas Attorney Jeff Blackburn (left) represents Chatman.

- 281 Post-Conviction DNA Exonerations Since 1989
- 17 of 281 People Exonerated Were on Death Row
- Average Time Served Was 13 Years
- Average Age at Time of Wrongful Conviction Was 27
- **75% of Wrongful Convictions Due to Eyewitness Misidentification**
- 50% of Wrongful Convictions Due to Improper Forensic Science, Such As Hair Sample, Shoe Print, & Bite Mark Comparisons

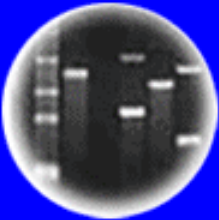




DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



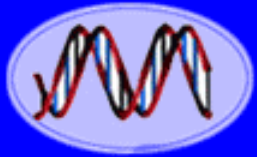
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## Question Two

Should every individual who is arrested for a crime be required to give a cheek swab for DNA testing without a search warrant?

- a. Yes
- b. No

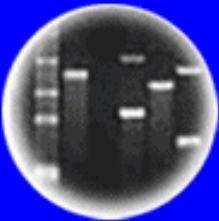
# DNA Is Leading to a New Era in Personalized Medicine



DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



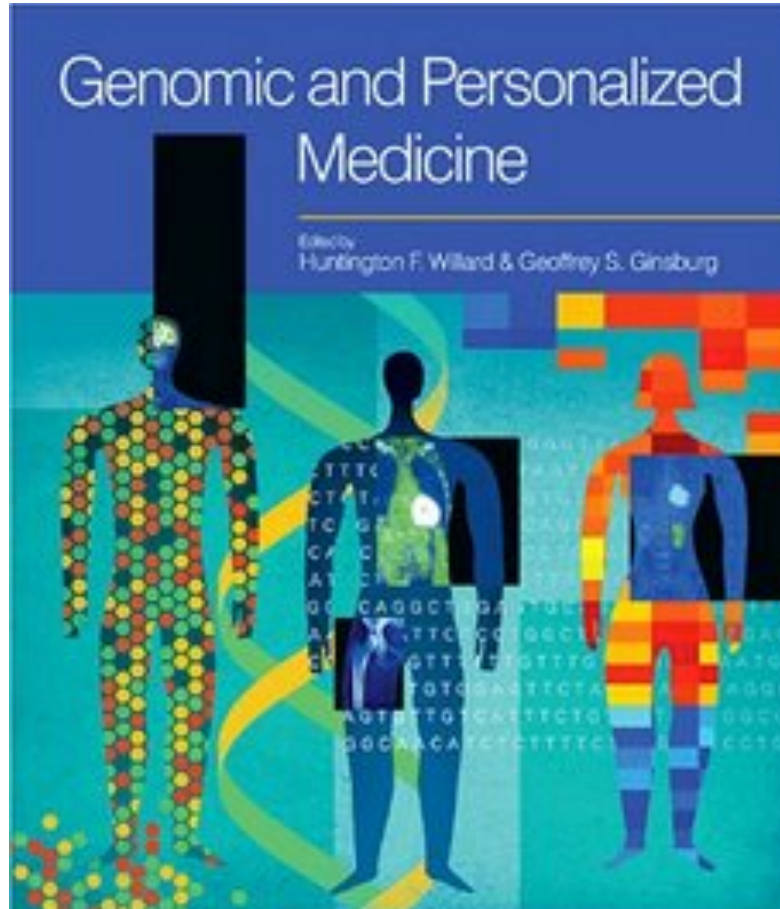
DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



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# DNA Testing Into the Home - Fast & Inexpensive DNA Testing Kits!



**MedicalLegalTesting.com**  
Accurate DNA Identification Tests To Meet  
Requirements Of The Civil Court System  
(800) 456-9913

The banner features a close-up of a baby's face on the left and three young children on the right.

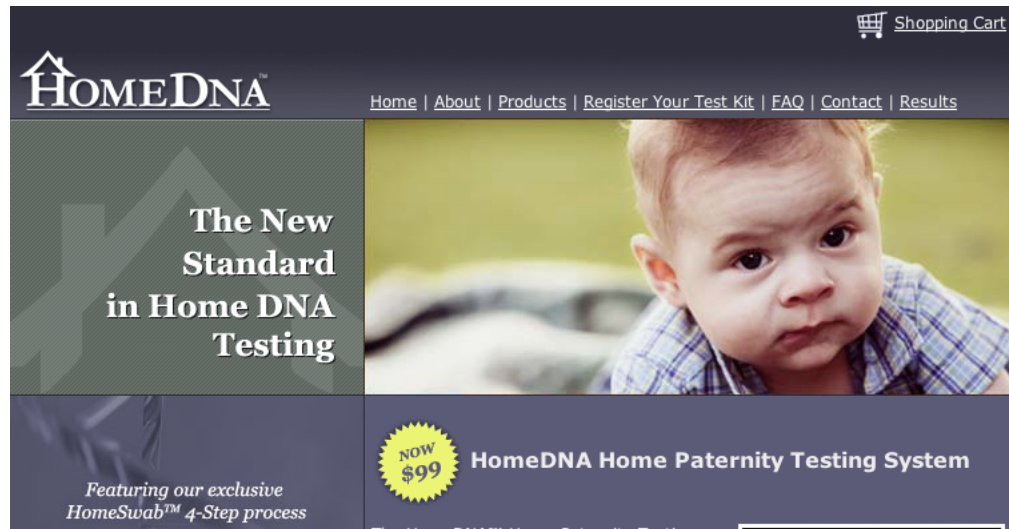
**Paternity**



**DNA Tribes**  
Genetic Ancestry Analysis  
What's Your Tribe?  
Discover your connections to over 695 world populations in 4 easy steps:

The banner includes a satellite map of the world and two circular portraits of people from different cultures.

**Ancestry**



**HomeDNA**  
Home | About | Products | Register Your Test Kit | FAQ | Contact | Results  
Shopping Cart

**The New Standard in Home DNA Testing**

Featuring our exclusive HomeSwab™ 4-Step process

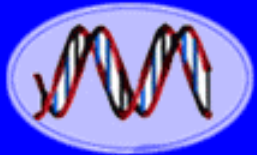
**HomeDNA Home Paternity Testing System**  
NOW \$99

The screenshot shows a website layout with a navigation bar, a main headline, and a featured product.

**Immigration**



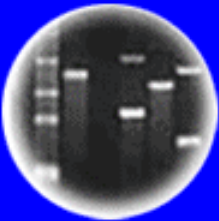
# Walmart Personalized DNA Test!



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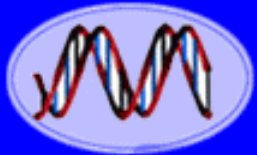
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Disease  
Genes



*What are the Scientific,  
Legal, Ethical, &  
Privacy Issues??*

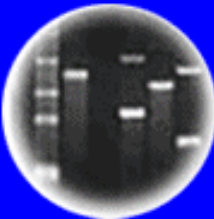




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## And Has Lead To a New Set of Ethical Issues & Controversies

**F.D.A. Orders Genetic Testing Firm to  
Stop Selling DNA Analysis Service**

**Poking Holes in Genetic Privacy**


**I Had My DNA Picture Taken, With  
Varying Results**

**Why You Shouldn't Trust  
Newfangled Gene Tests**

**DIRECT-TO-CONSUMER GENETIC TESTS**

**Misleading Test Results Are Further Complicated by  
Deceptive Marketing and Other Questionable  
Practices**

### Contradictory Risk Predictions for Prostate Cancer and Hypertension

	Gender	Age	Condition	Company 1	Company 2	Company 3	Company 4
	Male	48	Prostate cancer	Average	Average	Below average	Above average
			Hypertension	Average	Below average	Above average	Not tested

Source: GAO.



# DNA Can Be Used To Test For Hundreds of Disease Genes and Human Traits and Generate Personalized Gene Profiles

What Are  
the Problems  
& Laws That  
Govern  
Direct To  
Consumer  
DNA Tests?



And  
Before Birth!!!

# Decoding Disease

Genetic testing can detect more than 2,500 medical conditions so far, some 500 of which are treatable. Scientists have the ability to search all 21,000 or so genes at once for mutations that could increase the risk of disease. The price for this is \$7,500 and falling fast

## INDIVIDUAL GENES

Think of human DNA as an encyclopedia. Testing a **specific gene** involves pulling out the right volume (chromosome) and looking for spelling errors on a particular page



The human genome consists of 23 pairs of chromosomes, one copy inherited from each parent



## GENOME SEQUENCING

Scanning a person's **entire genetic code** can help diagnose a mysterious illness, but murky results can lead to a lot of anxiety

## CONNECTING THE DOTS

Some diseases are caused by a single mutation, while others involve a complex interplay among many genes and environmental factors

### Early-onset Alzheimer's disease

Chromosomes 1, 14 and 21

Someone who inherits one of several mutations on chromosomes 1, 14 or 21 is almost certain to develop a rare form of Alzheimer's (accounting for less than 5% of cases) between the ages of 30 and 60

### Colon cancer

Chromosome 5

Most cases of familial adenomatous polyposis, a rare form of colon cancer in which polyps have been detected in kids as young as 7, are caused by mutations in a tumor-suppressor gene on chromosome 5

### Diabetes

Chromosome 6

Mutations on chromosome 6 play a role in Type 1 diabetes, but so do other factors, including early diet. If an identical twin has the condition, formerly called juvenile diabetes, the other twin has at most a 50% chance of developing it

### Breast cancer

Chromosomes 13 and 17

A woman who inherits mutations in either of two genes (BRCA 1 on chromosome 17 or BRCA 2 on chromosome 13) is about five times as likely to develop breast cancer as a woman who does not have such a mutation

### Autism

Chromosomes 15 and 16

About 20% of autism cases can be traced to genetic abnormalities, including deletions or duplications on chromosomes 15 and 16. A new experimental blood test looking at 55 genes might help diagnose the condition earlier

### Obesity

Chromosome 16

It's a mistake to attribute the obesity epidemic to DNA alone, but dozens of genes, including the fat mass and obesity-associated (FTO) gene on chromosome 16, appear to play a role in weight variation in adults

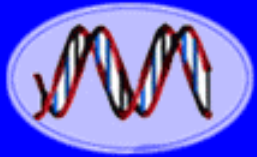
### Alzheimer's disease

Chromosome 19

A common variant of the ApoE gene on chromosome 19 increases a person's risk of getting late-onset Alzheimer's, which develops after age 60. Mutations in several other genes have also been linked to the disease

*Made Possible Because of Genetic Engineering....*

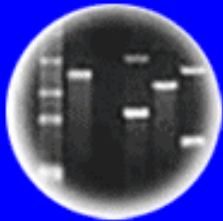




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## Question Three

Should Individuals Be Told That They Have a Genetic Disease Even Though There is No Treatment or Cure?

- a. Yes
- b. No



# Your Complete Genome Can Now Be Decoded and Sequenced Very Inexpensively (\$5,000)!!

## Genome of DNA Pioneer Is Deciphered

By NICHOLAS WADE  
Published: May 31, 2007

### DNA sequencer raises doctors' hopes for personalized medicine

The device could accelerate the use of genetic information in everyday medical care, physicians hope, improving diagnoses and treatments.

**PRENATAL DIAGNOSIS** *~10% of DNA in Maternal Plasma is From the Fetus*

### Maternal Plasma DNA Sequencing Reveals the Genome-Wide Genetic and Mutational Profile of the Fetus

Science Translational Medicine, December 8, 2010



knomeDISCOVERY

**\$4,998**  
/whole genome 30x

Sequencing & in-depth interpretation

### Genome-Wide Detection of Single-Nucleotide and Copy-Number Variations of a Single Human Cell

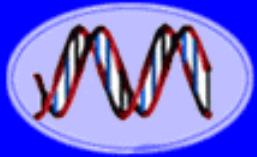
Science, December 20, 2012

*The Era of Personalized Genomes is Here!*

# Determining the Genetic Identity of a Human Embryo Before Implantation!



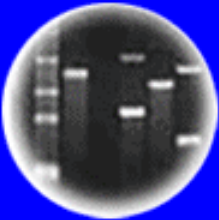
*Prenatal Genetic Diagnosis (PGD)*



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## Question Four

Should Parents Be Required to Have Their  
Newborn Children Genetically Tested?

- a. Yes
- b. No

# Your Complete Genome Can Now Be Decoded and Sequenced For \$1,000!

## Science Moves At Warp Speed

*"Scientists Always Overestimate What Can Be Done in a Short  
Time and Always Underestimate What Can Be Done Over  
Longer Periods of Time!"*

THE WALL STREET JOURNAL  
WSJ.com

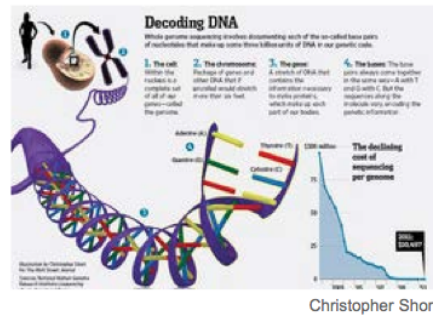
U.S. NEWS | JANUARY 10, 2012

## Soon, \$1,000 Will Map Your Genes

By RON WINSLOW And SHIRLEY S. WANG

SAN FRANCISCO—The quest to harness the power of DNA to develop personalized medicine is on the threshold of a major milestone: the \$1,000 genome sequencing.

[Life Technologies](#) Corp., a Carlsbad, Calif., genomics company, plans to introduce Tuesday a machine it says will be able to map an individual's entire genetic makeup for \$1,000 by the end of this year. Moreover, the machine and accompanying microchip technology, both developed by the company's Ion Torrent unit, will deliver the information in a day, the company says.



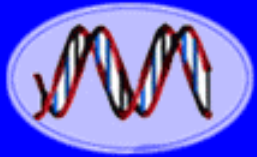
If Life Technologies delivers on the claim, it would likely make the company the first among a group of rivals racing to produce a \$1,000 gene map. The current cheapest sequencing costs about \$3,000 and takes a week.

The goal, triggered in part by an initiative launched by the U.S. government's National Human Genome Research Institute in 2004, already has resulted in a dramatic cost reduction in sequencing all three billion units of DNA, known as base-pairs, that make up the human genetic code.

Scientists say that breaking the \$1,000 barrier—roughly the price of an MRI test—will accelerate an already fast-moving transformation in genetic discovery and drug development.



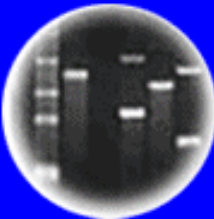




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# We Are Also in the Era of Human Gene Engineering - Using Gene Therapy to Cure Lethal Genetic Diseases

**In Girl's Last Hope, Altered Immune Cells Beat Leukemia**

DNA-swap technology almost ready for fertility clinic

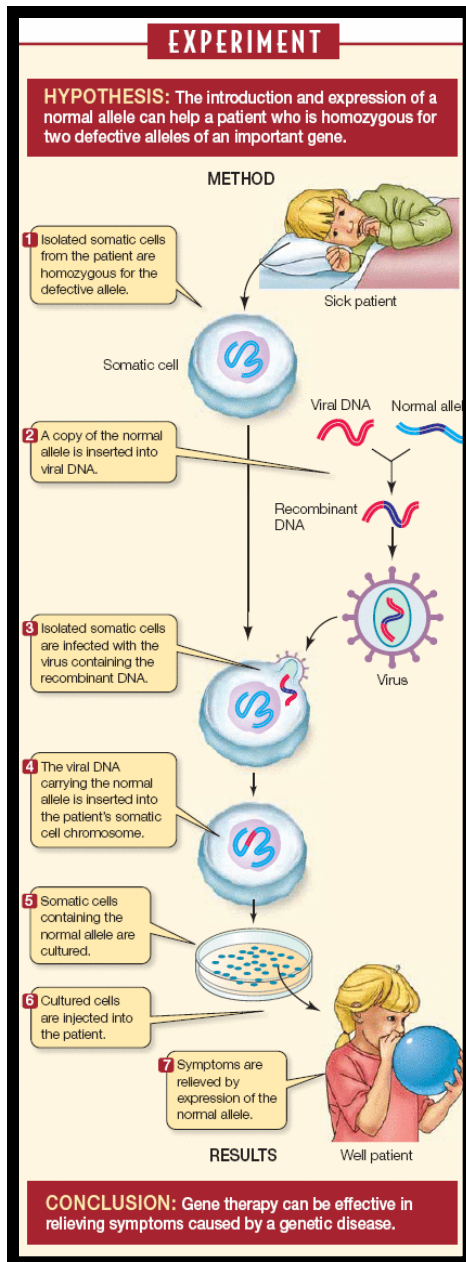
**Gene therapy trial 'cures children'**

**Treatment for Blood Disease Is Gene Therapy Landmark**

**In A First, An Experimental Drug May Help Boys With Muscular Dystrophy**

**Immune systems of 'bubble babies' restored by gene therapy, UCLA researchers find**

# Humans Have Been Genetically Engineered To Cure a Lethal Genetic Disease (SCID)



## Gene therapy cures 'bubble boy disease'

31 Jan 2009, 1128 hrs IST, AP

The Age of Human Genetic Engineering Began More Than Twenty Years Ago - SCID Treated With Normal ADA Gene!!!

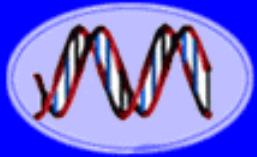
Several People are Alive Because They Have Been Engineered With an ADA Gene



Gene Therapy for Immunodeficiency Due to Adenosine Deaminase Deficiency

Gene Therapy with the Adenosine Deaminase (ADA) Gene

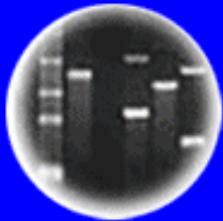




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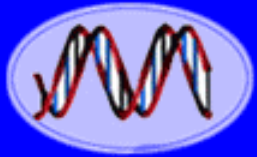
## Question Five

Are You Comfortable With Human *GMOs*?

- a. Yes
- b. No

# Finally....We Have Entered a New Era of Genetic Engineering -The Era of Synthetic Biology - Genetic Engineering 2.0

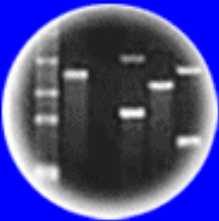
**Genetic Engineering Can Be Used To Synthesize and Engineer Entire Chromosomes From Chemicals and Create Synthetic Microbes in a Test Tube**



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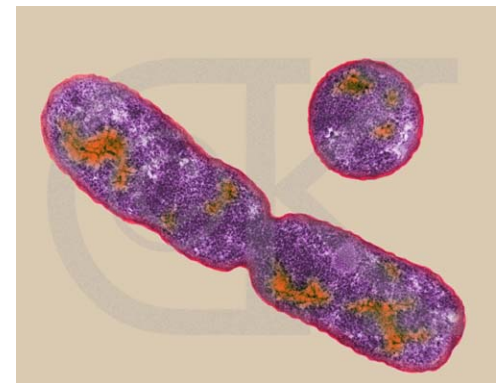


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Genetic Engineering  
2.0

40 Years After the  
Invention of Genetic  
Engineering





# Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome

May 20, 2010

## Researchers Say They Created a 'Synthetic Cell'

By NICHOLAS WADE

The genome pioneer J. Craig Venter has taken another step in his quest to create synthetic life, by synthesizing an

July 14, 2011

## Genetic Code of E. Coli Is Hijacked by Biologists

By NICHOLAS WADE

Science, July 15, 2011

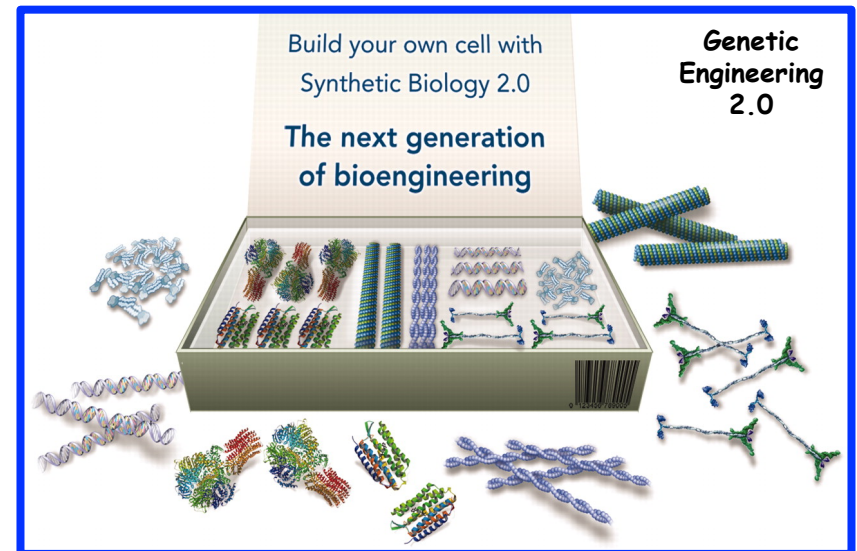
## Synthetic Generation of Influenza Vaccine Viruses for Rapid Response to Pandemics

Sci. Transl. Med., May 15, 2013,

*Think of the Possibilities.....*

## George Church: De-Extinction Is a Good Idea

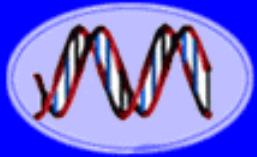
Reviving mammoths and other extinct creatures is a good idea



# Creating Life: Synthetic Microbes

## J. Craig Venter

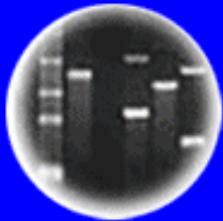
60 Minutes-December 2010



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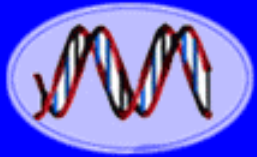


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## Question Six

Should Limits Be Placed on the Use of  
Synthetic Biology?

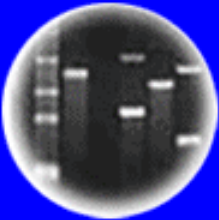
- a. Yes
- b. No



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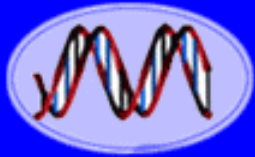
Cloning: Ethical Issues  
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# Stop Part One!!

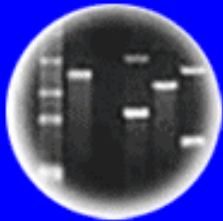




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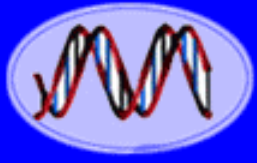
# HC70A Winter 2014

## Genetic Engineering in Medicine, Agriculture, and Law

### Professor Bob Goldberg

## Class Announcements

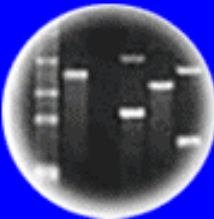
### 1/7/14



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# HC70A Winter 2014 (UCLA) Genetic Engineering in Medicine, Agriculture, and Law

## Teaching Fellows

William Barshop

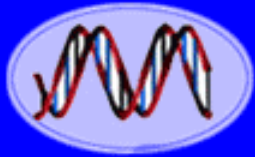
Reece Fenning

Mike Lyons

## Course Administrators

Lauren Bowman

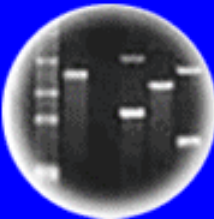
Ann Amores



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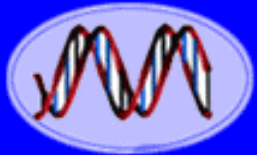
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# SAS70A Winter 2014 (UC Davis) Genetic Engineering in Medicine, Agriculture, and Law

UC Davis

Professor John Harada  
TA - Alex Olson

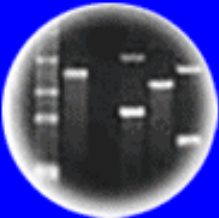
**UCDAVIS**  
UNIVERSITY OF CALIFORNIA



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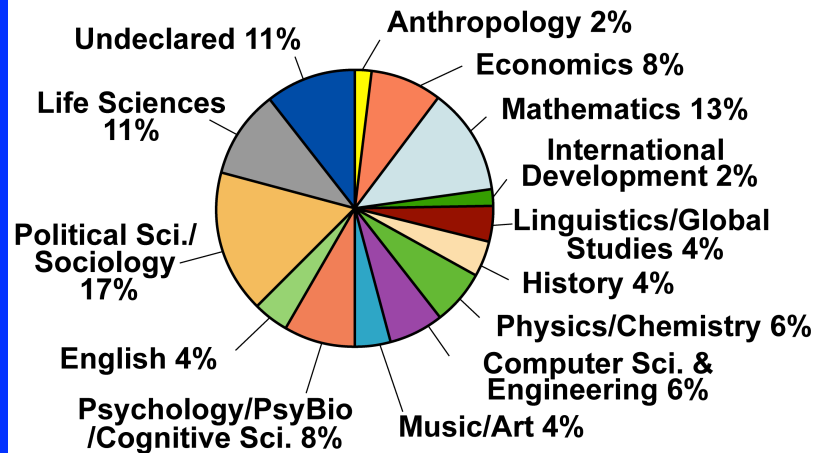


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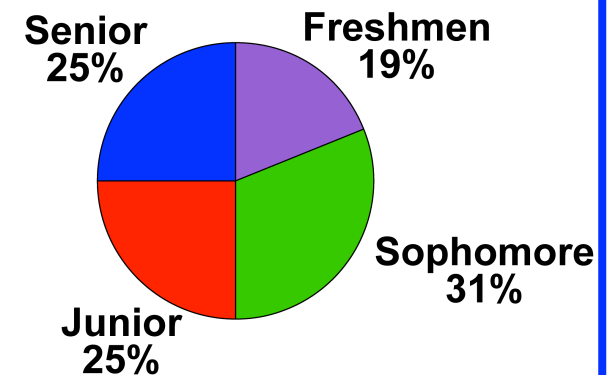
# HC70A - A Unique Class!

## *A Unique Way To Teach & Learn Science*

### MAJOR



### YEAR IN SCHOOL

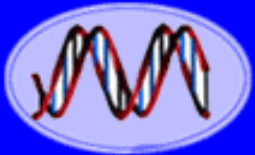


*Long-Distance Learning & Much, Much More..... We'll Discuss on Thursday When Syllabus Handed Out*



# Discussion Tomorrow

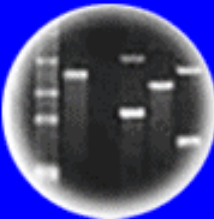
- Genetic Engineering-The Origins
  - Read Articles Handed Out Today & Textbook Chapters 1 & 3.1 (pgs. 64-72)
  - Be Prepared for a Lively Discussion of the Technology of Genetic Engineering Providing the Foundation



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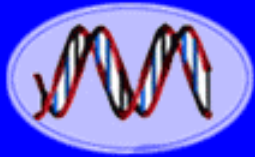
DNA Fingerprinting



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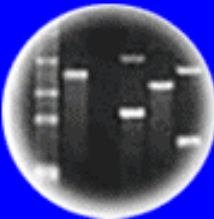
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# Discussion Instructions

- Come **PREPARED!!!!!!**
- Read Articles Carefully Prior to Discussion
- What's the Question, the Approach, the Results, the Conclusions?
- Study Each Figure/Experiment/Legend-Ask The Same Questions!
- Read Relevant Parts of Text That Relate to Concepts Covered in Articles
- Read Articles **ACTIVELY** - Look Up Unknown Words/Concepts - Ask Yourself Questions Along the Way - What Does This Mean?!