



# HC70A, PLSS530, & SAS70A Winter 2016 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!!*

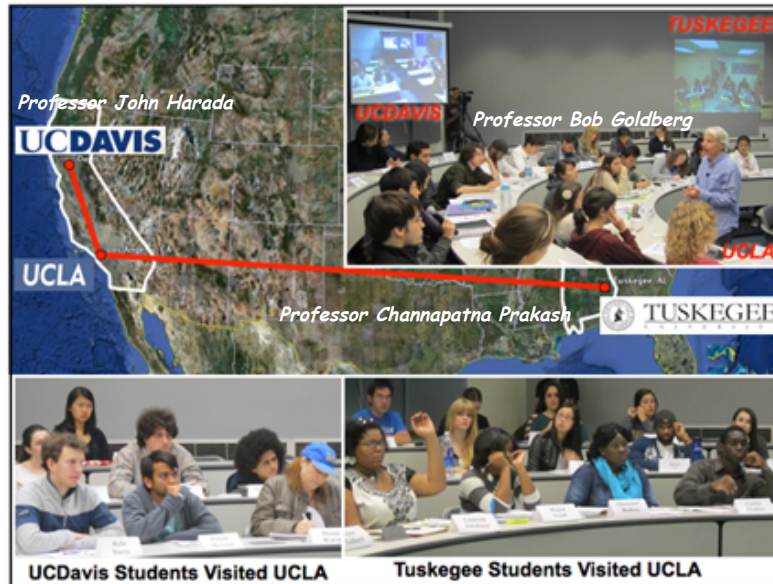


## THEMES

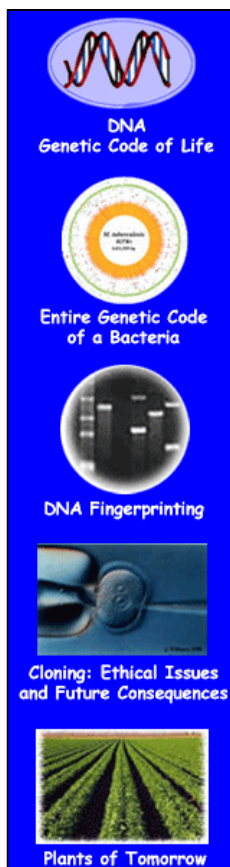
1. The Age of DNA, Genomics, Genetic Engineering & Synthetic Organisms
2. What Do Genes Look Like - DNA Demonstration
3. How Was Modern Genetic Engineering Invented & What Is the Genetic Engineering Process?
4. Why Use Genetic Engineering?
5. How Has Genetic Engineering Affected Our Lives?
6. How Has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



## The Long Distance Connection! HC70A, SAS70A, & PLSS530 Winter 2016



*A Model For Cross-Campus  
Interactive Learning*



## *Genetic Engineering in the News.. Medicine*

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

**British Lawmakers Approve 'Three-Parent' In-Vitro Fertilization**

**Gene therapy trial 'cures children'**

**Chinese scientists genetically modify human embryos** 

**UCLA researcher pioneers gene therapy cure for 'Bubble Baby' disease**

**UK scientists apply for licence to edit genes in human embryos**





## Genetic Engineering in the News.. *Agriculture*

### Super-muscly pigs created by small genetic tweak

Genetically Modified Salmon Is Safe To Eat,  
FDA Says

Gene-Altered Apples and Potatoes Are Safe, F.D.A.  
Says

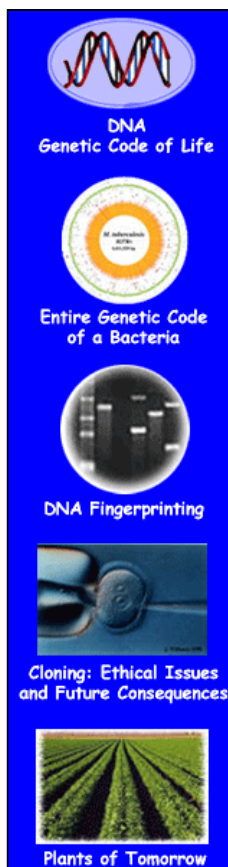
NOVEMBER 7, 2012, 9:21 AM



California Votes No on 37: Flawed Proposition on Food Labeling

G.M.O. Labels for Food Proliferate Even as a Battle  
Over Them Rages

SCIENTISTS DEVELOP GM CITRUS WITH ENHANCED  
RESISTANCE TO GREENING



## Genetic Engineering in the News.. *The Law*

DNA Test Frees Man After 34 Years In Prison

Supreme Court OKs DNA swab of people under arrest

Supreme Court Supports Monsanto in Seed-Replication  
Case

NOVEMBER 7, 2012, 9:21 AM



California Votes No on 37: Flawed Proposition on Food Labeling

Federal judge rules against Big Island GMO  
law

Supreme Court Free-Speech Decision  
Clobbers GMO Food-Labeling  
Activists

Justices, 9-0, Bar Patenting Human Genes



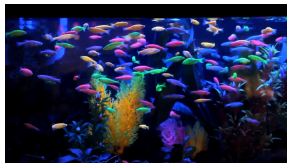
## Genetic Engineering in the News.....



## So....What's a GMO?



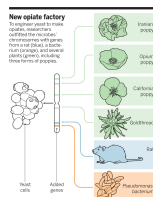
*A Genetically Engineered Bacteria  
Synthesizing  
Human Insulin Used as a Drug to  
Treat Diabetics?*



*A Genetically Engineered Glowing Fish Used as a Pet?*



*A Genetically Engineered Pig  
With Double Muscles For Leaner  
& More Meat*



*A Genetically Engineered Yeast  
That Synthesizes Opiates?*

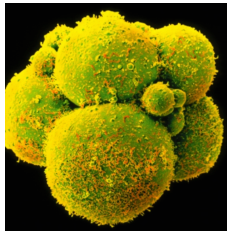
## What's a GMO?



*A Genetically Engineered Person  
With a Gene That They Weren't  
Born With That "Cures" a Lethal  
Genetic Disease?*



*A Genetically Engineered Baby  
With a Gene That They Weren't  
Born With That "Cures" a Lethal  
Genetic Disease?*



*A Human Embryo With a  
Defective Blood Disease Gene  
That Was "Edited" and  
Engineered to Be Normal?*

## What's a GMO?



*Crops That Are Grown  
For For  
Human & Animal  
Consumption?*





DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



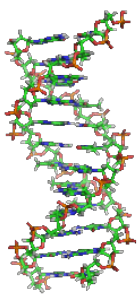
Plants of Tomorrow




# What is a GMO?

## What is Genetic Engineering?





*An Essential HC70A Theme!*

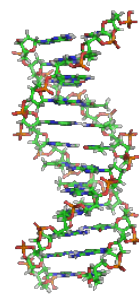
## We Live in The Age of Genetic Engineering & DNA!

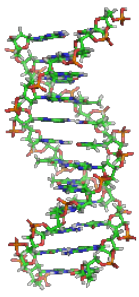
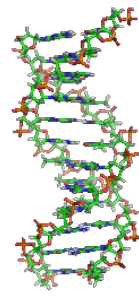
Genetic Engineering Is  
Manipulating DNA! ALL GMOs  
Have Engineered Genes



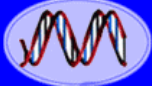
*By Classical Breeding  
or in a Test Tube  
It's All the Same!*






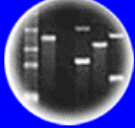





DNA  
Genetic Code of Life




Entire Genetic Code  
of a Bacteria



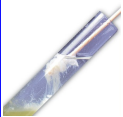
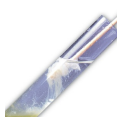
DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences

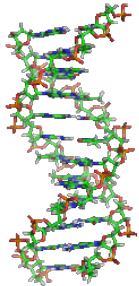
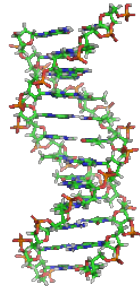
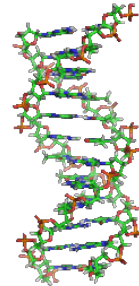


Plants of Tomorrow

# 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



Plants of Tomorrow

## We Live in the Era of....

1. Genomics & Whole Genome Sequencing
2. Genetic Engineering of Microbes, Plants Animals, & Humans!
3. Synthetic Microbes Made by "Man" Using Chemicals & Genetic Engineering
4. Personalized Genomes and Ability to Identify Any Individual or Disease Using DNA
5. Using Ancient DNA to See Into the Past
6. Being Able to Edit, or Change, Any Gene in Any Organism
7. Being Able To Release a Mosquito With One Altered Gene and Enable it To Change the Same Gene in Every Mosquito it Mates With (Think - Eliminate Malaria)!
8. A \$200B Medical and Agricultural Biotechnology Industry Using Genetic Engineering Technology and Proprietary Gene Patents, and Processes (Think - Drugs and Disease Treatments)
9. Stem Cells, Mammalian Reproduction, & Cloning
10. And the INTEGRATION of These Technologies!!



## We Live in the Era of....

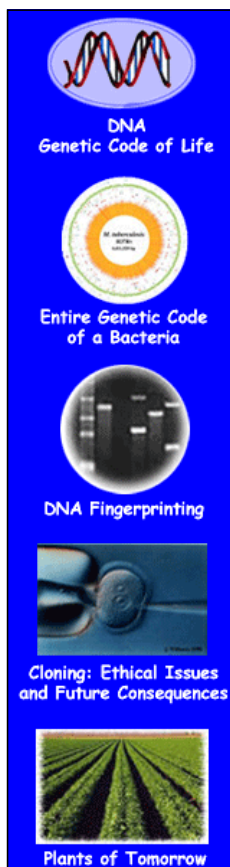
Being Able to Edit, or Change, Any Gene In a Human Egg Cell That Will Last Forever in Human Populations

1. Think - Eliminating "Disease" Genes Forever

2. Think - Eugenics, or "Enhancing" Human Traits"

3. Think - New Genetic Engineering Technologies Are Becoming Easier and More Precise at Warp Speed

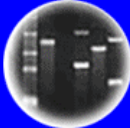
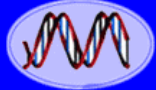
4. Think - What are the Benefits and the Risks of Using New Genetic Technologies?



Are You Uncomfortable With Genetic Engineering and These Rapidly Evolving Genetic Technologies?

a. Yes

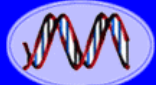
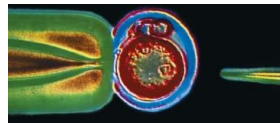
b. No



## A Few Examples of 21<sup>st</sup> Century DNA Applications That Have Affected Society and Knowledge About Ourselves

**Essential HC70A Concept: They Could Not Have Been Developed Without the Invention of Genetic Engineering!!!**

# Which You Will Learn the Basis of in HC70A!



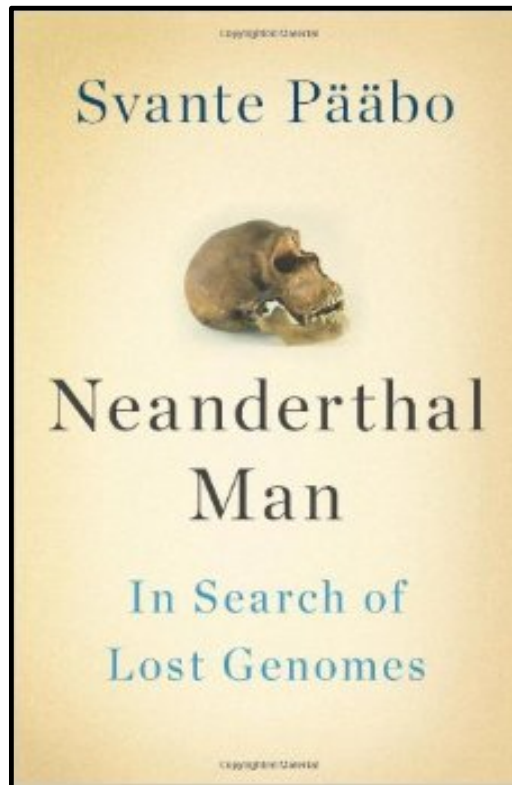
# DNA Can Be Used To Look Into The Past and Bring Back the Dead!!

# Ancient DNA & Technology Based On Genetic Engineering



## An Exciting Field Called *Ancient DNA*

An Excellent  
Book About  
"Inventing"  
the Field of  
Ancient DNA  
& the  
Evolution of  
Humans



## RESEARCH ARTICLE

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

### A Draft Sequence of the Neanderthal Genome From a 45,000 Year-Old Bone!

**Wilma**  
Female  
Red Hair  
Pale Skin  
Freckles

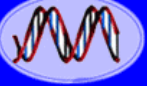


How Know What Wilma Looked Like?


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.

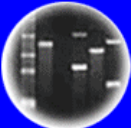





DNA  
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Entire Genetic Code  
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DNA Fingerprinting




Cloning: Ethical Issues  
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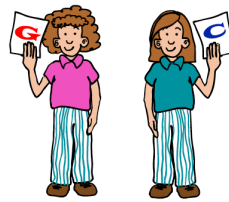


Plants of Tomorrow

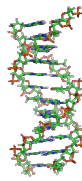
## DNA Sequences Can Be Used To Specify Eye Color....

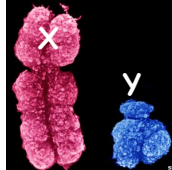


A A T G T



...As Well As Gender &  
Several Physical Features





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.

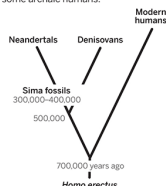
**New DNA Analysis Shows Ancient Humans Interbred with  
Denisovans**      Can Demonstrate Interbreeding of Ancient Humans!

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

# Using Ancient DNA to Unravel Human History

## Deeper branches

Putting the Sima fossils on the Neanderthal lineage implies an earlier split between modern and some archaic humans.



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

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

www.sciencemag.org SCIENCE VOL 334 7 OCTOBER 2011



**We Have  
Neanderthal &  
Denisovan  
Genes in Our  
Chromosomes**

**It's All in the DNA!**

Nature Reviews | Genetics  
September, 2011



**I Have ~3% Neanderthal DNA in My Genome -  
A Relic of Ancient Migration and Mating Tens of  
Thousand of Years Ago!**



## How Did I Learn That?

This lab estimates your genome-wide percentage of Neanderthal ancestry

**Got Neanderthal DNA?**

An estimated 2.6% of your DNA is from Neanderthals.

Bob Goldberg (you)



2.6%

33rd percentile

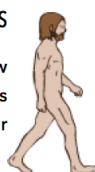
Average European user



2.7%

MODERN HUMANS

Higher brow  
Narrower shoulders  
Slightly taller



NEANDERTHALS

Heavy eyebrow ridge  
Long, low, bigger skull  
Prominent nose with developed nasal chambers for cold-air protection



**Without Genetic Engineering and DNA Sequencing Technologies  
This Could Not Have Been Done**

## Using Ancient DNA To Identify Richard III From a 550 Year-Old Skeleton



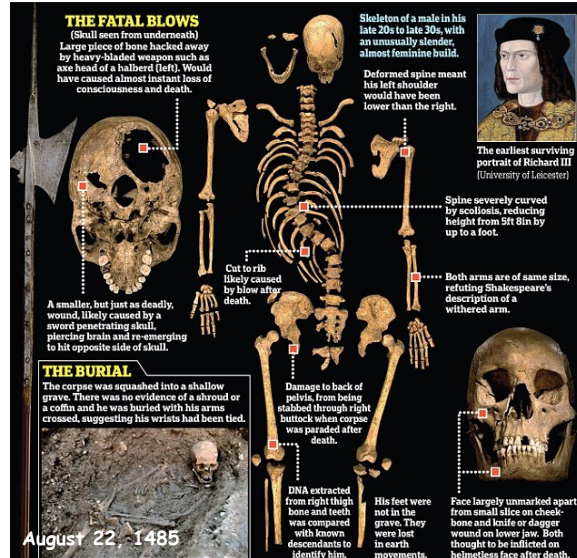
William  
Shakespeare

*"little of stature, ill-feature of limes, croke-backed, his left shoulder much higher then his right, hard-favoured of visage and suche as is in states called warley and in other menne otherwise."*



King Richard III of England Is Reburied in Leicester Cathedral

By JOHN F. BURNS MARCH 26, 2015



Nature, October 27, 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

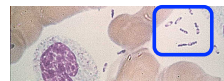
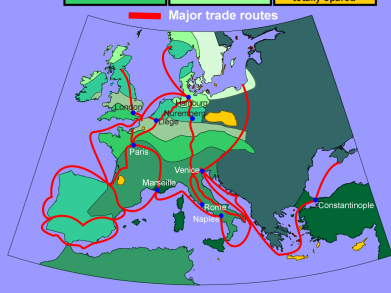
*The Power of DNA and Genetic Engineering!*

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>

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



Rat Blood



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





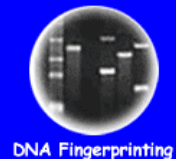
Nature, November 2008

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>



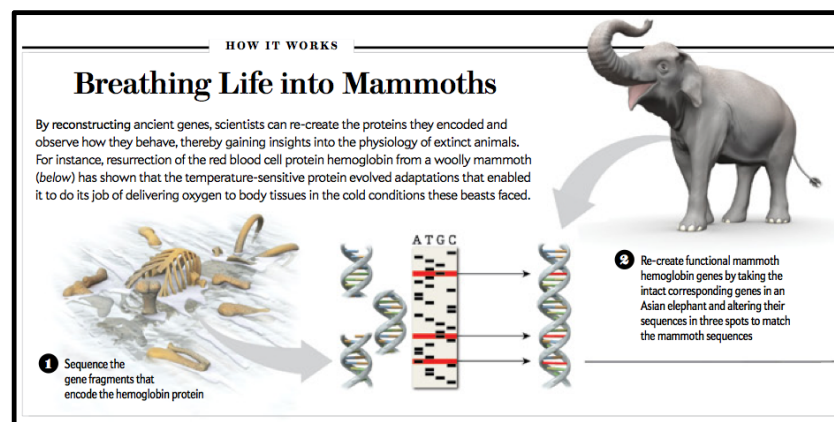
Scientific American, August, 2012

EVOLUTIONARY BIOLOGY

# New Life for Ancient DNA

Biotechnology reveals how the woolly mammoth survived the cold and other mysteries of extinct creatures  
By Kevin L. Campbell and Michael Hofreiter

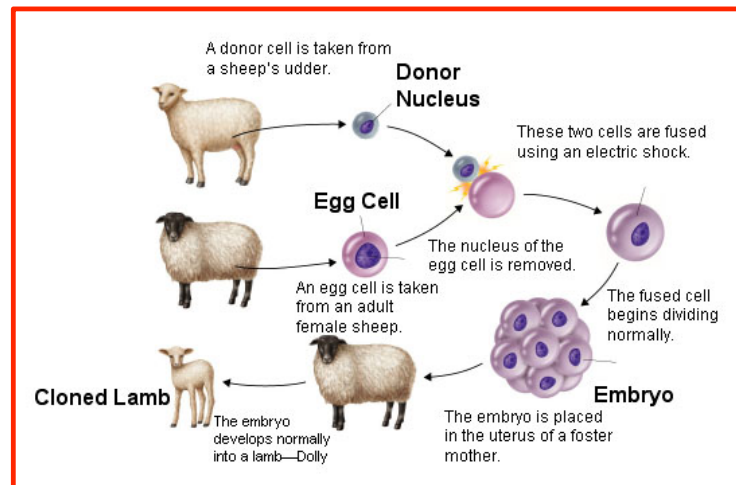
**Bring a Mammoth Back to Life? It Could Be Possible Using Genetic Engineering & Cloning**







# The Age of Cloning is Here "Replicating" Animals!



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

*Bring Back the Dead?*

PNAS

November 11, 2008

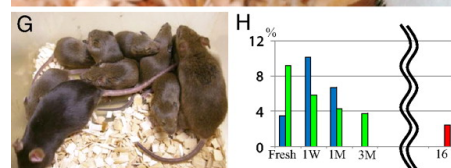
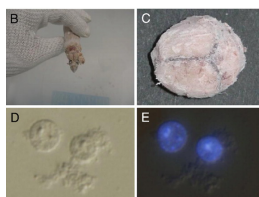
**Production of healthy cloned mice from bodies frozen at  $-20^{\circ}\text{C}$  for 16 years**

*Think of the possibilities!*

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

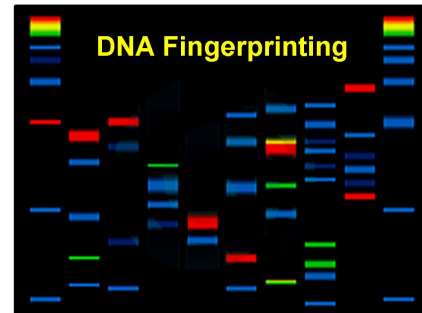
<sup>a</sup>RIKEN, Center for Developmental Biology, 2-2-3 Minatojima-minamimachi, Kobe, 650-0047, Japan; <sup>b</sup>Jikei University School of Medicine, Tokyo 105-8461, Japan; and <sup>c</sup>RIKEN, Research Center for Allergy and Immunology, 1-7-22, Sushiro-cho, Tsurumi-ku, Yokohama, 230-0045, Japan

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





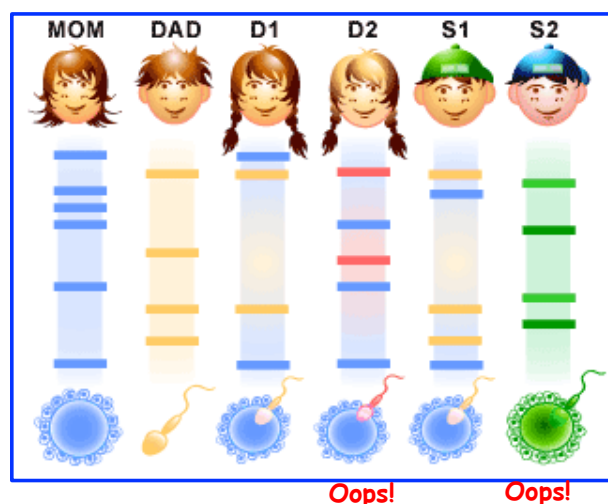
# DNA Can Be Used To Identify Individuals For Genetic Diseases, **Paternity**, Ancestry, **Forensics**, Crimes, and Much More



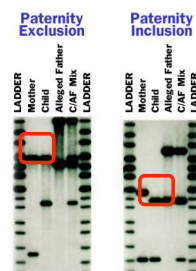
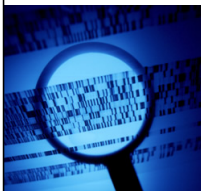
## Using **DNA Fingerprints** to Identify Individuals & Genes They Don't "Lie"

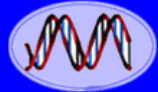
### DNA Fingerprints

*Sometimes They Reveal Unexpected Results!*



*What is YOUR DNA Fingerprint?*

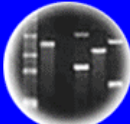




DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



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.



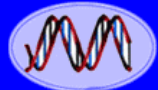
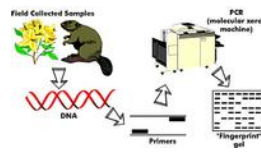
### \$11,250 IN FINES FOR ILLEGAL MOOSE HUNT AND COVER UP

NEWS

November 16, 2010

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

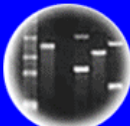
Anton Gerritsen Jr. and Anton Gerritsen Sr., both of Cayuga, Shank A. Vanderheide of Canfield and James E. Kruis of St. George, were each fined \$1,000 for obstructing a Ministry of Natural Resources conservation officer and Gerritsen Jr., Gerritsen Sr. and Vanderheide were each fined \$500 for illegally 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.



DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow

## DNA Can Also Be Used To Resolve Some Human and Animal "Mysteries"

### Dog-poop DNA tests nail non-scoopers



### 'Devious Defecator' Case Tests Genetics Law



DNA & The Law!



## Identifying Victims of 9/11 by DNA Fingerprinting

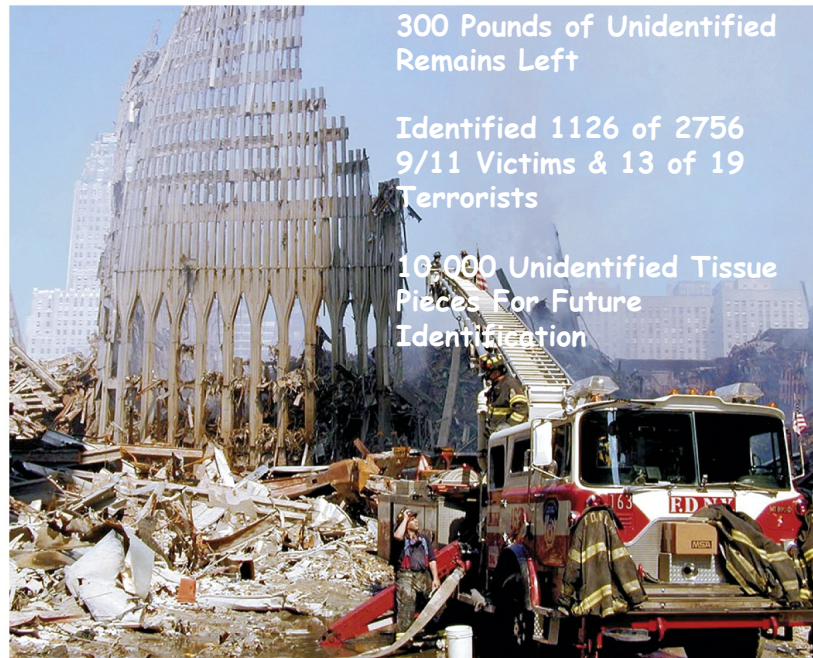


Figure 19-31  
Genetics: A Conceptual Approach, Third Edition  
© 2009 W.H. Freeman and Company

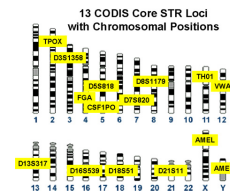
Newsweek, January 12, 2009

## 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



# NDIS Statistics

National DNA Index System

| [CODIS Home Page](#) | [FBI Home Page](#) |

**FEBRUARY, 2015**

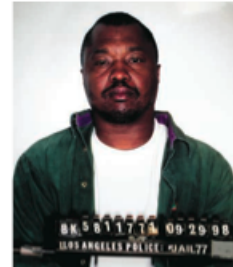
Offender Profiles	11,634,999	<a href="#">What Are State Laws?</a> <b>California Proposition 69</b>
Arrestee Profiles	1,911,810	
Forensic Profiles	612,477	
Database "Hits"	276,598 assisting 263,888 investigations	





## 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!!*

## Others 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



## Question

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

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

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



**And  
Before Birth!!!**

***Made Possible Because of Genetic Engineering!***

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



### *Prenatal Genetic Diagnosis (PGD)*

Fertility Clinics Scan for the Strongest Embryo



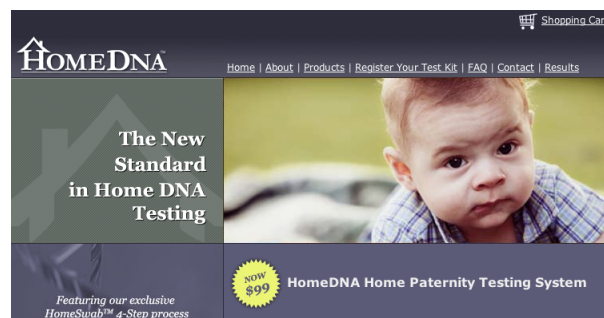
## DNA Testing Into the Home - Fast & Inexpensive DNA Testing Kits!

A banner for MedicalLegalTesting.com. It features a close-up of a baby's face on the left and three children on the right. The text reads: "MedicalLegalTesting.com", "Accurate DNA Identification Tests To Meet Requirements Of The Civil Court System", and "(800) 456-9913".

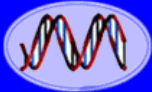
**Paternity**

A banner for DNA Tribes. It features a map of the world and a woman's face. The text reads: "DNA Tribes", "Genetic Ancestry Analysis", "What's Your Tribe?", and "Discover your connections to over 695 world populations in 4 easy steps."


**Ancestry**

A screenshot of the HomeDNA website. It features a navigation bar with links: Home, About, Products, Register Your Test Kit, FAQ, Contact, Results. The main content area has a large image of a baby's face and text: "The New Standard in Home DNA Testing", "Featuring our exclusive HomeSuab™ 4-Step process", and "HomeDNA Home Paternity Testing System". A yellow starburst graphic says "NOW \$99". A shopping cart icon is in the top right corner.

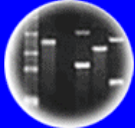
**Immigration**




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DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



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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
	48	Prostate cancer	Average	Average	Below average	Above average
		Hypertension	Average	Below average	Above average	Not tested

Source: GAO.

## Your Complete Genome Can Now Be Decoded and Sequenced Very Inexpensively (\$1,000)!!

**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

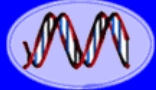


**Genome-Wide Detection of  
Single-Nucleotide and Copy-Number  
Variations of a Single Human Cell**

Science, December 20, 2012

*The Era of Personalized Genomes is Here!*

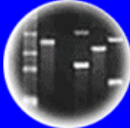




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DNA Fingerprinting



Cloning: Ethical Issues  
and Future Consequences



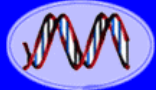
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## Question

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

- a. Yes
- b. No

Newborn screening varies from state to state. All states must screen for at least 21 disorders by law, and some states test for 30 or more. Parents can ask their doctor about expanded (supplemental) screening if they live in an area that screens for a limited number of disorders.



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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

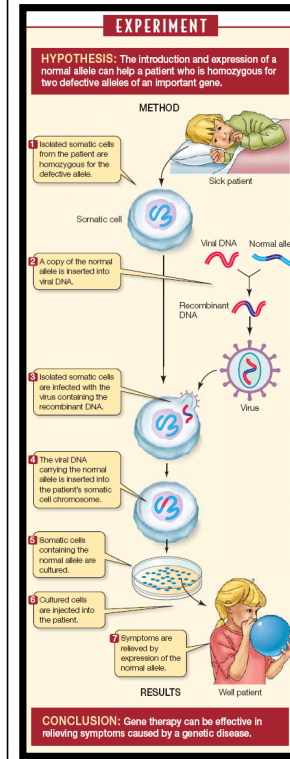
**Gene therapy trial 'cures children'**

**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) - Human GMOs!



## 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

The new england journal of medicine

established in 1812      january 29, 2009      vol. 360 no. 5

Gene Therapy for Immunodeficiency Due to Adenosine Deaminase Deficiency

Gene Therapy with the Adenosine Deaminase (ADA) Gene



The Era of Correcting, or Editing, Defective Genes in the Germline (e.g., Eggs) Has Arrived!!!!

This IS Human Genetic Engineering!





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and Future Consequences



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An early human embryo, the focus of controversy.

**BIOETHICS**

## Embryo engineering alarm

Researchers call for restraint in genome editing

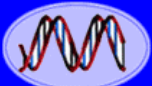
## Don't edit the human germ line

Heritable human genetic modifications pose serious risks, and the therapeutic benefits are tenuous, warn **Edward Lanphier**, **Fyodor Urnov** and colleagues.


## Scientists Seek Ban on Method of Editing the Human Genome

By **NICHOLAS WADE** MARCH 19, 2015

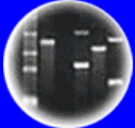
A group of leading biologists on Thursday called for a worldwide moratorium on use of a new genome-editing technique that would alter human DNA in a way that can be inherited.




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## Question

**Are You Comfortable With Changing Human Genes?**

- a. Yes
- b. No



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## 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

Genetic Engineering  
2.0  
40 Years After the  
Invention of Genetic  
Engineering




2 JULY 2010 VOL 329 SCIENCE [www.sciencemag.org](http://www.sciencemag.org)

## 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

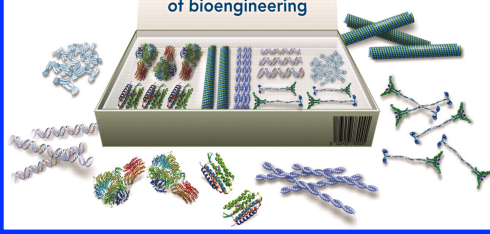
### Synthetic Generation of Influenza Vaccine Viruses for Rapid Response to Pandemics

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

Build your own cell with  
Synthetic Biology 2.0

The next generation  
of bioengineering


Genetic  
Engineering  
2.0



*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



## 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!!*

## *Genetic Engineering Enters the "Real World" - The "Debate" Begins*

### **Gene Transplants Seen Helping Farmers and Doctors**

Fertilizers Needed Genes From Sea Urchins A  
Stitching Platform Fast Multiplication  
Unrelated Species

### **Genetic Tests Renounced Over Possible Hazards**

POSSIBLE DANGER HALTS GENE TESTS  
Genes Are Multiplied Infectious Elements  
Other Experiments

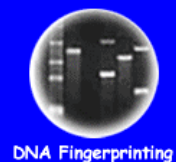
### **Work on Genetic Manipulation Must Continue, Scientists Insist**

### **Science Seeks 'Safe Bugs' For Genetic Engineering**

### **World Biologists Tighten Rules On 'Genetic Engineering' Work**

### **Synthesis of Working Gene Hailed as a Major Advance**

*New York Times - 1974 & 1975*



## **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



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

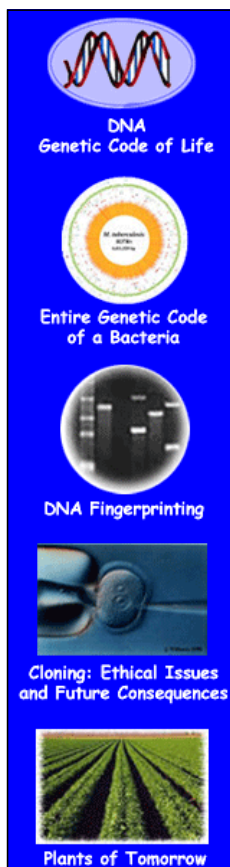
With An Unexpected “Eureka” Moment Dealing With Two Unrelated Areas of Study:

1. The Mechanism of Bacterial Antibiotic Resistance

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



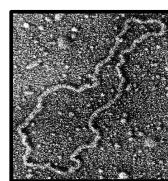
TIME, March, 1981



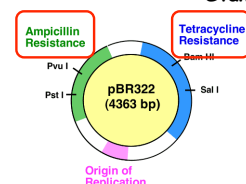
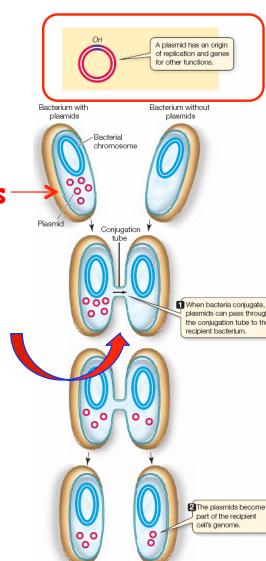
## Plasmids Are Circular Self-Replicating DNA Molecules in Bacterial Cells That Carry Antibiotic Resistance Genes



Stanley Cohen



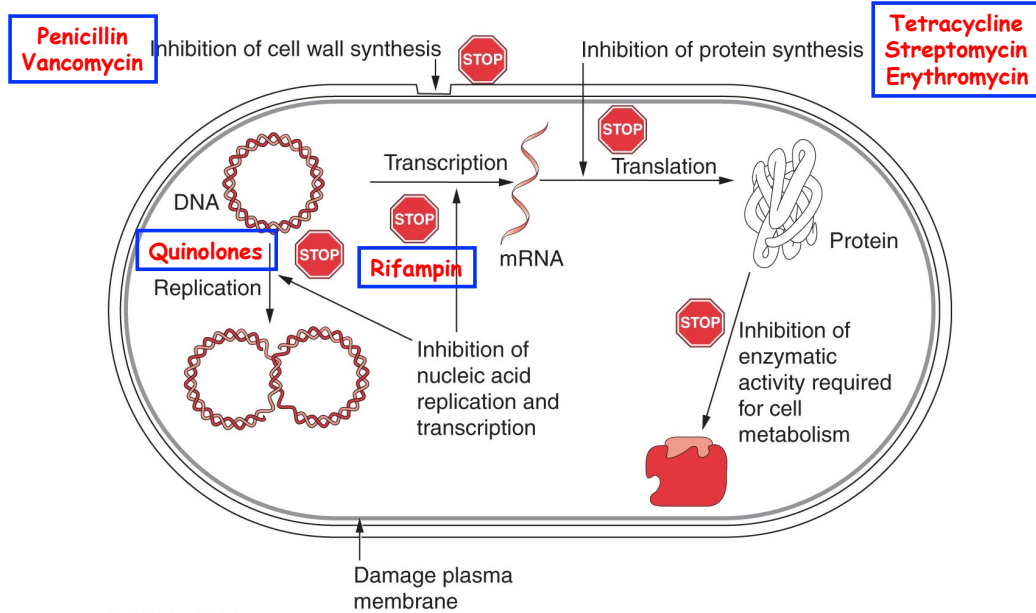
Plasmids



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

Plasmids Defend Bacteria Against Antibiotics!

## A Review.....How Do Antibiotics Kill Bacterial Cells?



**By Inhibiting Basic Microbial Cell Processes**

**DNA**  
Genetic Code of Life

**Entire Genetic Code**  
of a Bacteria

**DNA Fingerprinting**

**Cloning: Ethical Issues**  
and Future Consequences

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### Restriction Enzymes Are Proteins That "Cut" DNA Into Pieces

**"Killer" Virus**

**Enzymes?**

- 1 A restriction enzyme cleaves the incoming phage DNA at restriction sites.
- 2 Other enzymes degrade the phage DNA into smaller fragments.
- 3 Methyl groups at the restriction sites block the restriction enzyme and protect the bacterial DNA from being cleaved.

Bacterial host cell

Host DNA

**Restriction Enzymes Protect Bacteria From "Killer" Viruses!**

Herb Boyer



A circular gel electrophoresis image showing multiple lanes with horizontal DNA bands. The bands vary in intensity and position across the lanes, indicating different DNA profiles.



A circular gel electrophoresis image showing multiple lanes with DNA bands. The bands are arranged in a circular pattern, with some lanes showing more distinct bands than others. The bands are dark against a lighter background.



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**1** EcoRI cuts the two DNA strands at two different points in a palindromic recognition sequence.

*EcoRI* cuts at  
red arrows

DNA

CGATCCAGGAATTCATCCAGCC  
GCTAGGTCCTTAAGTAGGTCGG

AGGCTCTAGAATTCTTCTAGCT  
TCCGAGATCTTAAGAAGATCGA

CGATCCAGG  
GCTAGGTCC

AATTCATCCAGCC  
GTAGGTCGG

AGGCTCTAG  
TCCGAGATCT

AATTCTTCTAGCT  
GAAGATCGA

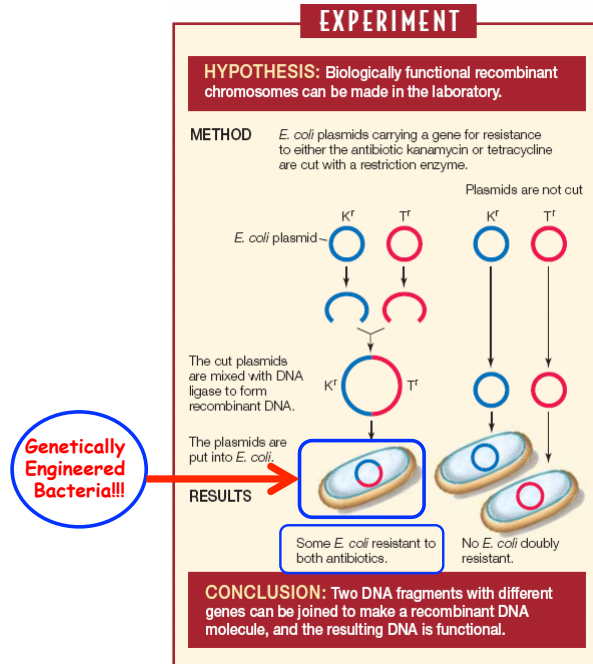
CGATCCAGGAATTCTTCTAGCT  
GCTAGGTCCTTAAGAAGATCGA

**3** The sticky ends can hydrogen-bond to complementary sticky ends from other DNAs, and the resulting recombinant DNA can be sealed with DNA ligase.

**2** The separated strands have "sticky ends" with unpaired bases.



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



**Cohen-Boyer Experiment**  
One of Your Discussion Articles For Tomorrow!

## “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!!**

  
DNA  
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DNA Fingerprinting

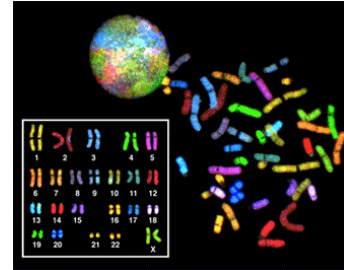
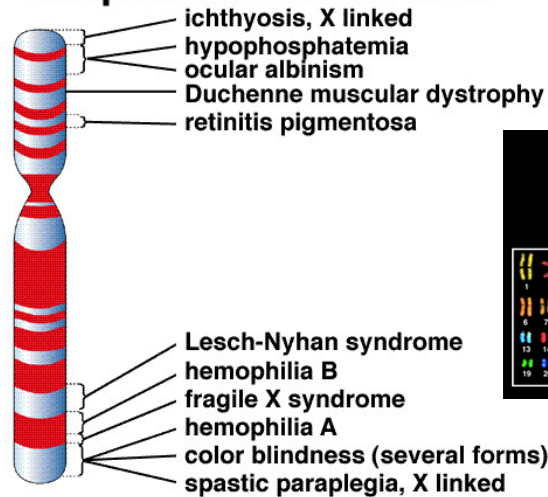
  
Cloning: Ethical Issues  
and Future Consequences

  
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## "Why" Clone Genes - Simply Put... Genomes & Chromosomes Contain Thousands of Genes

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

### Map of chromosome X



## How Can a Single Gene Be Studied?

  
DNA  
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Entire Genetic Code  
of a Bacteria

  
DNA Fingerprinting

  
Cloning: Ethical Issues  
and Future Consequences

  
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## Any Gene Can Be Isolated Using Genetic Engineering

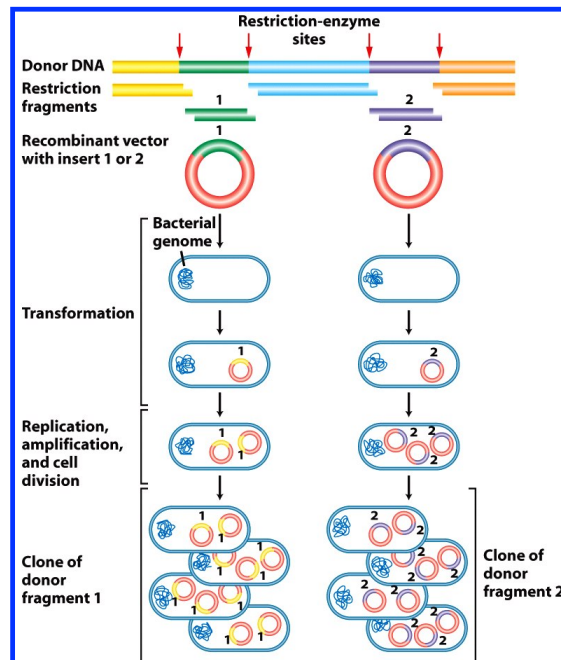
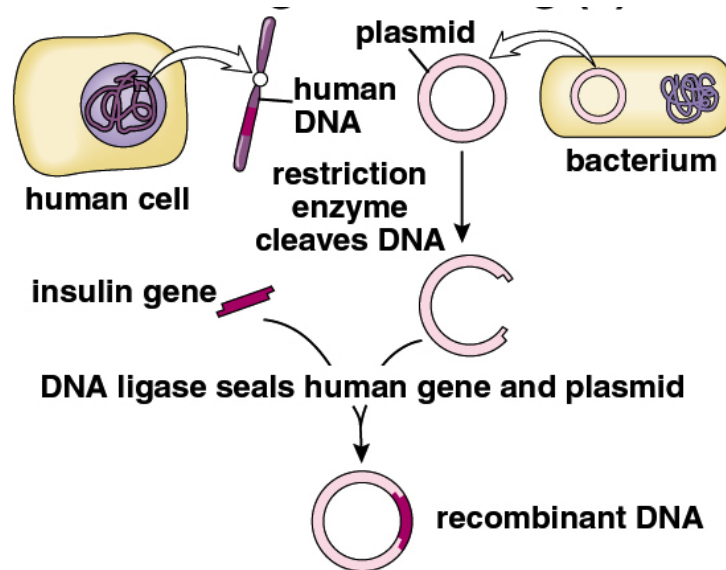


Figure 20-4  
Introduction to Genetic Analysis, Ninth Edition  
© 2008 W.H. Freeman and Company

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



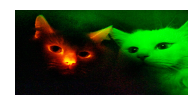
And Used to Treat Diabetes!



## Recombinant 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 (Genetic Engineering!!!!!!)**
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!!***







## Genetic Engineering.....

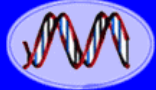
**Is the Most Revolutionary Technology in Biology to Have Been Invented in Human History!**

**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!**

## And .....Has Led to Many New Legal and Ethical Issues

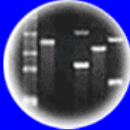
1. Patenting Genes, Cells, & Living Organisms?
2. Regulating Experimentation on DNA, Cells, Transgenic Organisms ("GMOs")?
3. Regulating the Release of Genetically Modified Organisms into the Environment?
4. Labeling of Genetically Modified Foods?
5. Genetic Testing: DNA Databases, Newborn Genetic Screening, 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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DNA Fingerprinting

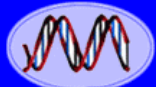


Cloning: Ethical Issues  
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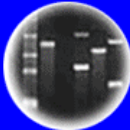
## Stop Part One!!



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## HC70A Winter 2016 Genetic Engineering in Medicine, Agriculture, and Law Professor Bob Goldberg

**Class Announcements**  
**1/5/16**



## HC70A Winter 2016 (UCLA) Genetic Engineering in Medicine, Agriculture, and Law

### Discussion Coordinator

**Dr. Kelli Henry**

### Undergraduate Assistants

**Allen Chung**  
**Dominic Lucido**  
**Dominic Saadi**

### Course Administrator

**Lauren Bowman**

**UCLA**



## SAS70A Winter 2016 (UC Davis) Genetic Engineering in Medicine, Agriculture, and Law

### UC Davis

**Professor John Harada**

### Teaching Assistant

**Leonardo Jo**

### Undergraduate Assistant

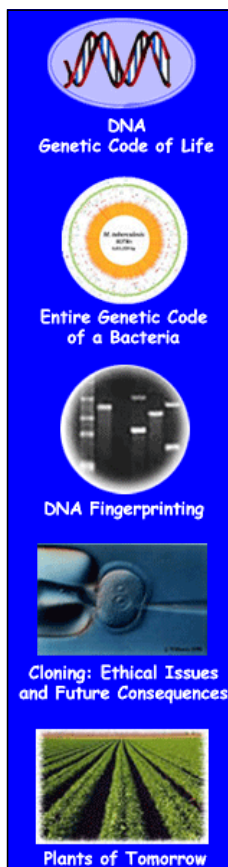
**Hala Addassi**

**UC DAVIS**  
UNIVERSITY OF CALIFORNIA



## Discussion Tomorrow

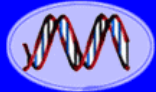
- **Genetic Engineering-The Origins**
- **Read Emailed Articles & Handed Out Again Today & Textbook Chapters 1 & 3 (pgs. 58-69)**
  - **Be Prepared for a Lively Discussion of the Technology of Genetic Engineering Providing the Foundation**



## 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?!**

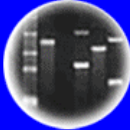




DNA  
Genetic Code of Life



Entire Genetic Code  
of a Bacteria



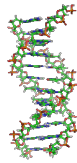
DNA Fingerprinting



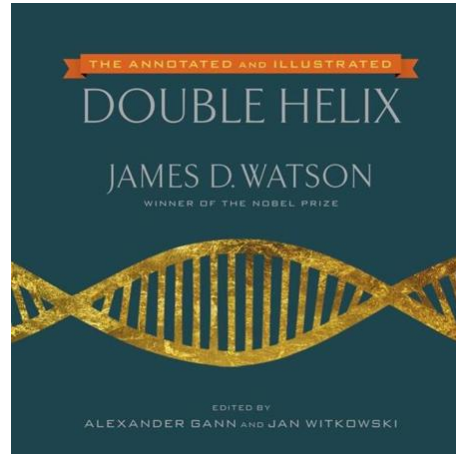
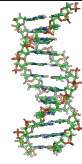
Cloning: Ethical Issues  
and Future Consequences



Plants of Tomorrow



# Start Reading: **The Double Helix** By J.D. Watson



*The Most Important Discovery in the History of Biology:  
The Structure of DNA*