



HC70A, PLSS530, & SAS70A
Spring 2015

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!!

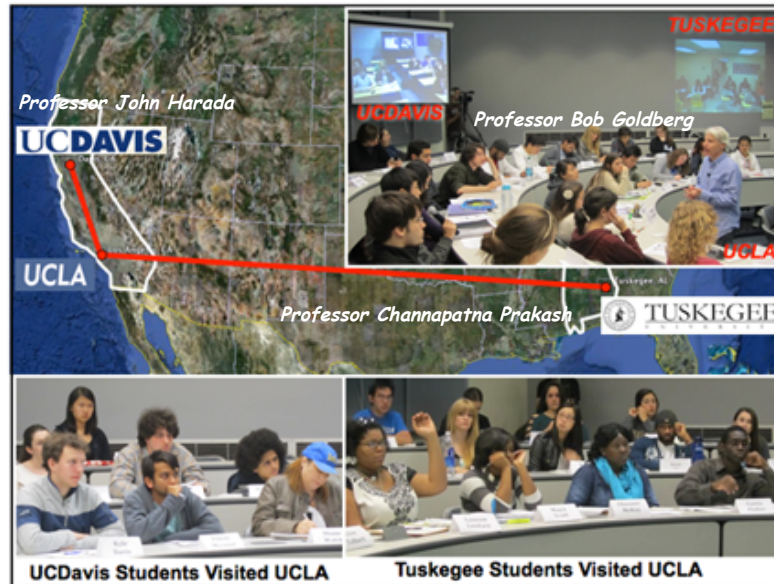


THEMES

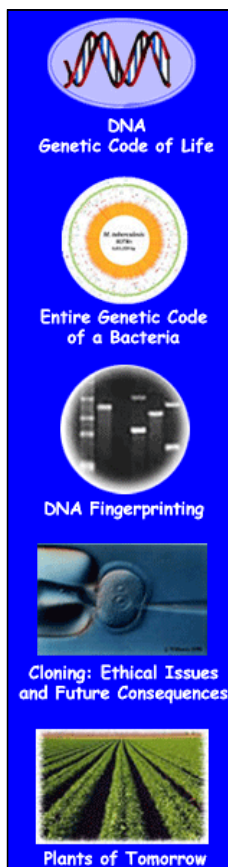
1. The Age of DNA, Genomics, Genetic Engineering & Synthetic Organisms
2. What Do Genes Look Like - DNA Demonstration
3. How Was Modern Genetic Engineering Invented & What Is the Genetic Engineering Process?
4. Why Use Genetic Engineering?
5. How Has Genetic Engineering Affected Our Lives?
6. How Has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



The Long Distance Connection! HC70A, SAS70A, & PLSS530 Spring 2015



*A Model For Cross-Campus
Interactive Learning*



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

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

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

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

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

NOVEMBER 7, 2012, 9:21 AM



NO.37
STOP THE DECEPTIVE
FOOD LABELING CAMPAIGN

California Votes No on 37: Flawed Proposition on Food Labeling

.....and Politics



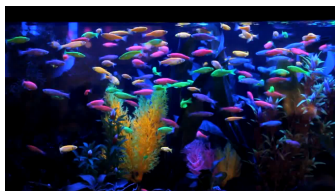
Genetic Engineering and DNA in the News.....



What's a *GMO*?



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



*A Genetically Engineered GloFish
Used as a Pet?*



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

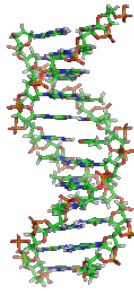
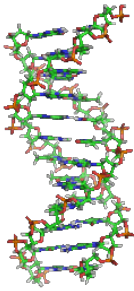
What's a *GMO*?



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



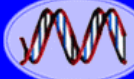
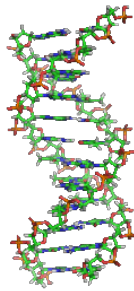
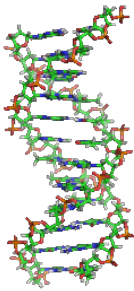
"It's In Our DNA!"




**Not Surprising Because
We Live in
The Age of DNA!**

**Genetic Engineering Is
Manipulating DNA!**

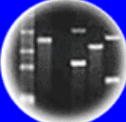
*By Classical Breeding
or in a Test Tube
It's All the Same!*




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting



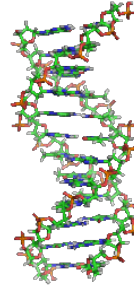
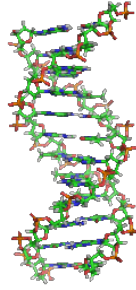
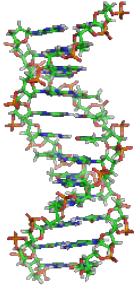
Cloning: Ethical Issues
and Future Consequences

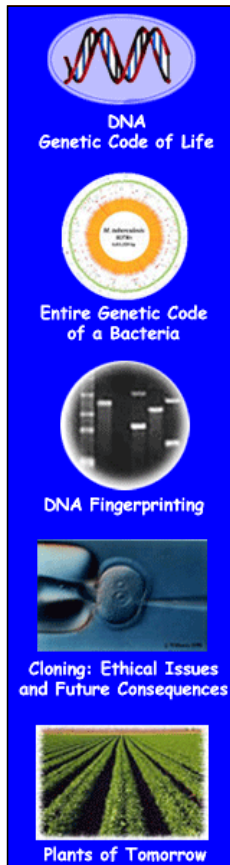


Plants of Tomorrow

**What Does Your DNA
Look Like?**

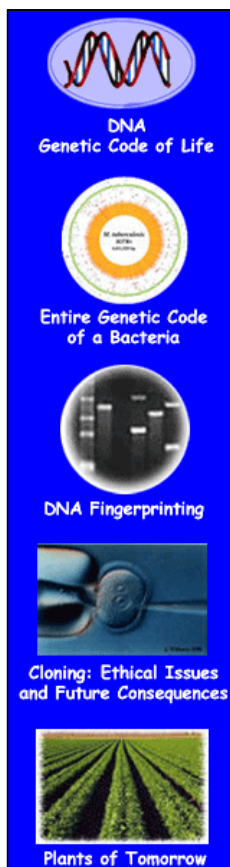
**Have You Ever Seen or
Touched Your Genes???**





We Live in the Era of....

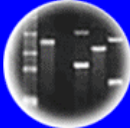
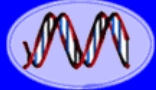
- Genes & DNA
- Genomics & Whole Genome Sequencing
- Genetic Engineering of Microbes, Plants Animals, & Humans!
- A \$200B Medical and Agricultural Biotechnology Industry Using Genetic Engineering Technology and Proprietary Gene Patents, and Processes
- Synthetic Microbes Made Using Genetic Engineering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



Question One

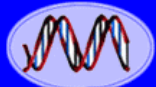
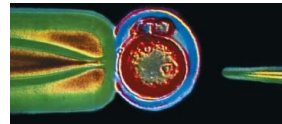
Are You Uncomfortable With Genetic Engineering?

- a. Yes
- b. No



Some 21st Century DNA Applications That Have Affected Society and Knowledge About Ourselves

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



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

Ancient DNA & More



An Exciting Field Called *Ancient DNA*

RESEARCH ARTICLE

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

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

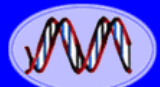
Wilma
Female
Red Hair
Pale Skin
Freckles



How Know What Wilma Looked Like?

Reconstruction by Kennis & Kennis / Photograph by Joe McNally

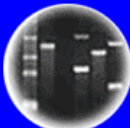
For the first time, a Neandertal female peers from the past in a reconstruction informed by both fossil anatomy and ancient DNA. At least some of her kind carried a gene for red hair and pale skin.



DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting

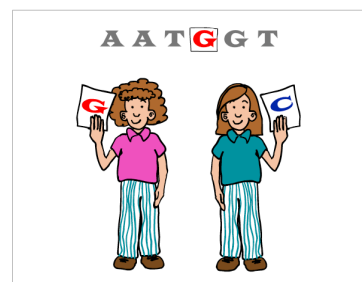


Cloning: Ethical Issues
and Future Consequences

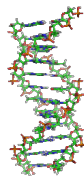
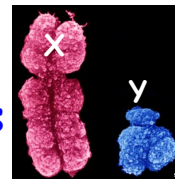


Plants of Tomorrow

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



...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 Neanderthals and humans--from genetic fragments in a single finger bone

Using Ancient DNA to Unravel Human History

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!!**

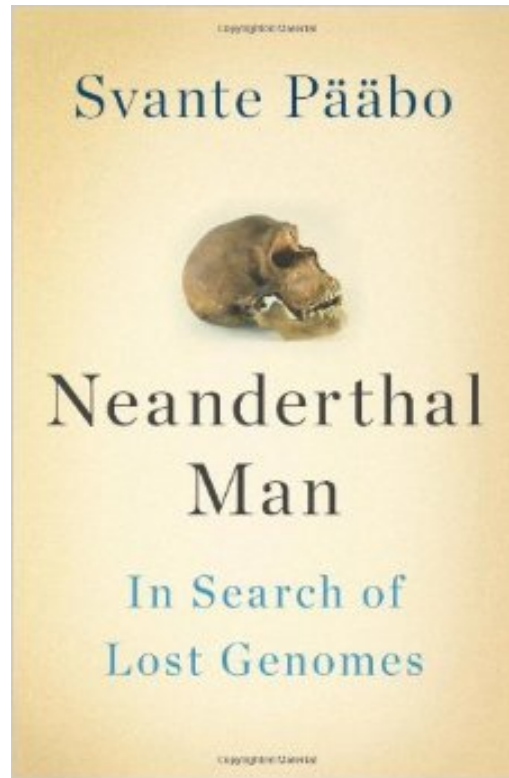


**We Have
Neanderthal &
Denisovan
Genes in Our
Chromosomes**

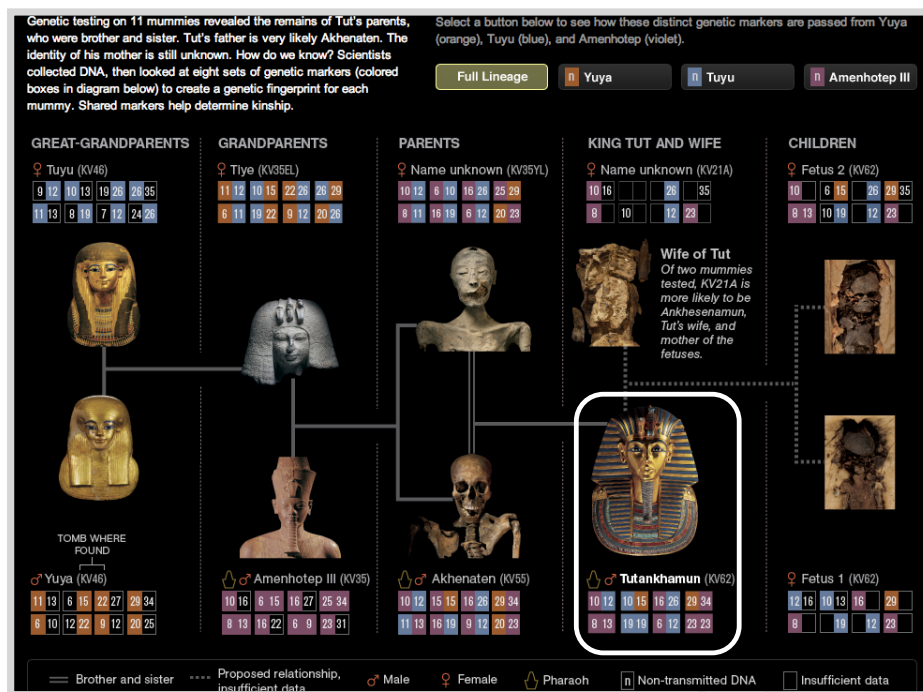
It's All in the DNA!

Nature Reviews | **Genetics**
September, 2011

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



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!!

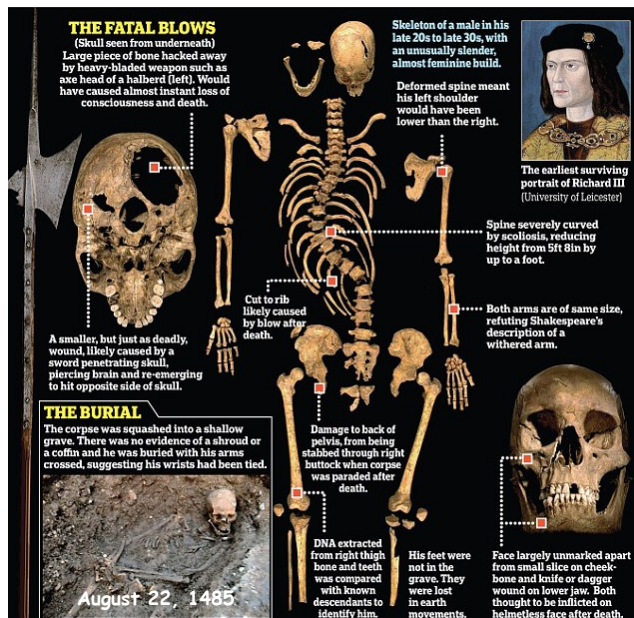
Using Ancient DNA to "Recent" History



King Richard III of England Is Reburied in Leicester Cathedral

By JOHN F. BURNS MARCH 26, 2015

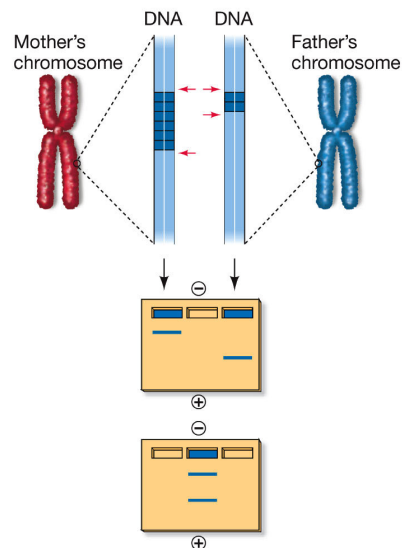
...little of stature, ill-fetured of limmes, croke-backed, his left shoulder much higher then his right, hard-favoured of visage and suche as is in states called warlye and in other menne otherwise.



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



Genomic identification in the historical case of the Nicholas II royal family

PNAS, March, 2009

Evgeny I. Rogayev^{1,2,3,4,5}, Anastasia P. Grigorenko^{4,6}, Yuri K. Molodtsov^{1,2,3,4,5}, Grigoriy V. Fokhtikov^{1,2,3,4,5}, Andrey Goltsov^{1,2,3,4,5}, Arlene Lahti^{1,2,3,4,5}, Curtis Hildebrandt^{1,2,3,4,5}, Ellen L. W. Kittler^{1,2,3,4,5}, and Irina Morozova^{1,2,3,4,5}

¹Department of Genetics and Laboratory of Evolutionary Genetics, Vavilov Institute of General Genetics, Russian Academy of Sciences, Gubkina Street, 3, Moscow, 119991, Russian Federation; ²Neurobiological Research Institute, University of Massachusetts Medical School, 300 Belmont Street, Worcester, MA 01604; ³Faculty of Bioinformatics and Biophysics, Lomonosov Moscow State University, Moscow, 119899, Russian Federation; ⁴Research Center of Medical Health, Russian Academy of Medical Science, Zagorodnaya Street 25, Moscow, 119152, Russia; ⁵Molecular World, Inc., Thunder Bay, ON, Canada P7R 2T1; and ⁶University 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

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

Michael D. Coble^{1,2,3,4,5}, Odile M. Loreille^{1,2,3,4,5}, Mark J. Wadham^{1,2,3,4,5}, Suniti M. Edson^{1,2,3,4,5}, Jerry Maynard^{1,2,3,4,5}, Carin E. Meyer^{1,2,3,4,5}, Harald Niederstätter^{1,2,3,4,5}, Cornelia Berger^{1,2,3,4,5}, Burkhard Berger^{1,2,3,4,5}, Anthony B. Falchetti^{1,2,3,4,5}, Peter Gill^{1,2,3,4,5}, Walter Pearson^{1,2,3,4,5}, Louis N. Finelli^{1,2,3,4,5}

¹Armed Forces DNA Identification Laboratory, Armed Forces Institute of Pathology, Rockville, Maryland, United States of America; ²Institute of Legal Medicine, Innsbruck Medical University, Innsbruck, Austria; ³University of Florida, Gainesville, Florida, United States of America; ⁴Department of Forensic and Applied Chemistry, University of Southampton, Southampton, United Kingdom; ⁵Institute of Forensic Medicine, University of Oslo, Oslo, Norway

PLOS, March, 2009

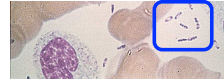
Ancient DNA Can Be Studied to Find the Source of Major Epidemics From 100s of Years Ago!

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^{1*}, Verena J. Schuenemann^{2*}, G. Brian Golding³, Hernán A. Burbano⁴, Nicholas Waglechner⁵, Brian K. Coombes⁵, Joseph B. McPhee⁵, Sharon N. DeWitte^{6,7}, Matthias Meyer⁴, Sarah Schmedes⁸, James Wood⁹, David J. D. Earn^{5,10}, D. Ann Herring¹¹, Peter Bauer¹², Hendrik N. Poinar^{1,3,5} & Johannes Krause^{2,12}

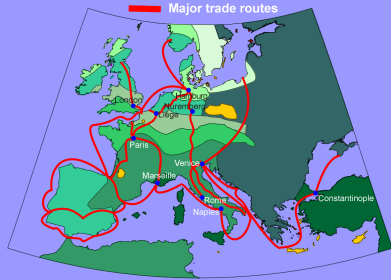
1347–1351



Rat Blood

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



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



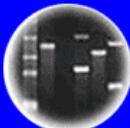
Scientific American, August, 2012



DNA Genetic Code of Life



Entire Genetic Code of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues and Future Consequences



Plants of Tomorrow

EVOLUTIONARY BIOLOGY

New Life for Ancient DNA

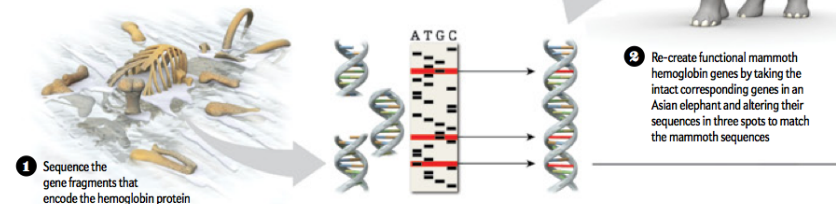
Biotechnology reveals how the woolly mammoth survived the cold and other mysteries of extinct creatures
By Kevin L. Campbell and Michael Hofreiter

Bring a Mammoth Back to Life?

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.



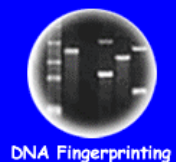
Nature, November 2008

LETTERS

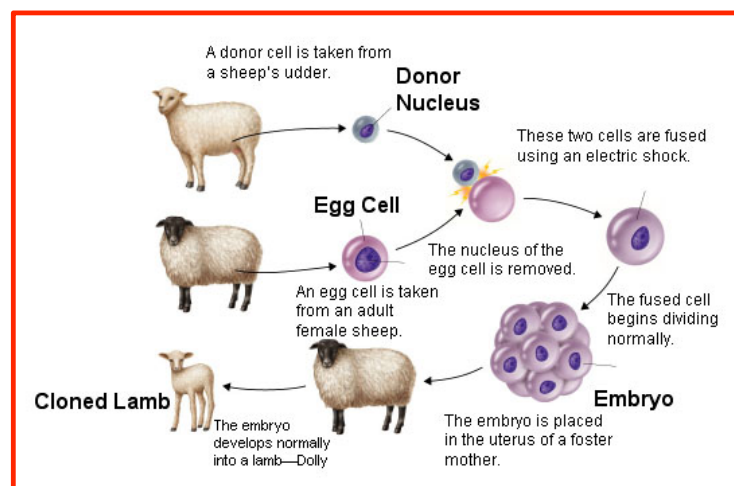
Sequencing the nuclear genome of the extinct woolly mammoth

Think About Bringing a Woolly Mammoth Back to Life!!

Webb Miller¹, Daniela I. Drautz¹, Aakrosh Ratan¹, Barbara Pusey¹, Ji Qi¹, Arthur M. Lesk¹, Lynn P. Tomsho¹, Michael D. Packard¹, Fangqing Zhao¹, Andrei Sher^{2,†}, Alexei Tikhonov³, Brian Raney⁴, Nick Patterson⁵, Kerstin Lindblad-Toh⁵, Eric S. Lander⁵, James R. Knight⁶, Gerard P. Irzyk⁶, Karin M. Fredrikson⁷, Timothy T. Harkins⁷, Sharon Sheridan⁷, Tom Pringle⁸ & Stephan C. Schuster¹



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

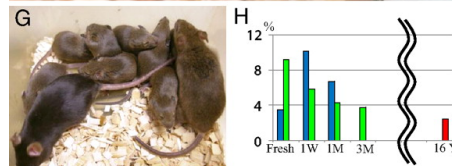
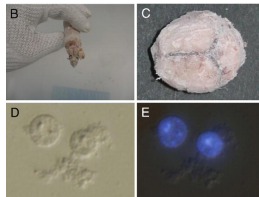
Production of healthy cloned mice from bodies frozen at -20°C for 16 years

Think of the possibilities!

Sayaka Wakayama^a, Hiroshi Ohta^a, Takafusa Hikichi^a, Eiji Mizutan^a, Takamasa Iwaki^b, Osami Kanagawa^c, and Teruhiko Wakayama^{a,1}

^aRIKEN, Center for Developmental Biology, 2-2-3 Minatojima-minamimachi, Kobe, 650-0047, Japan; ^bJikei University School of Medicine, Tokyo 105-8461, Japan; and ^cRIKEN, 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!

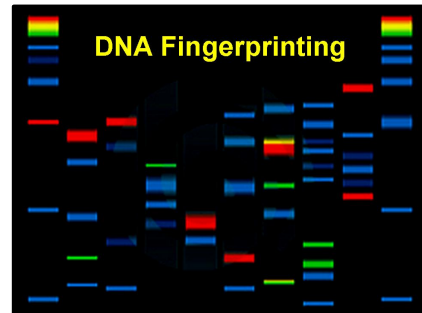


Resurrecting the Extinct

60 Minutes, January, 2010



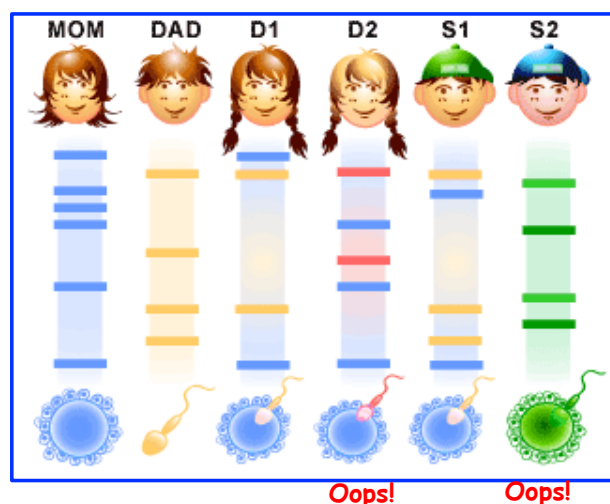
DNA Can Be Used To Identify Individuals For Genetic Diseases, **Paternity**, Ancestry, **Forensics**, Crimes, and Much More



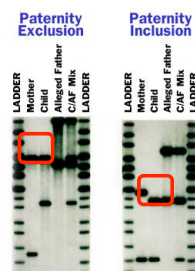
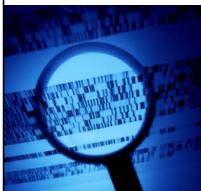
Using **DNA Fingerprints** to Identify Individuals & Genes They Don't "Lie"

DNA Fingerprints

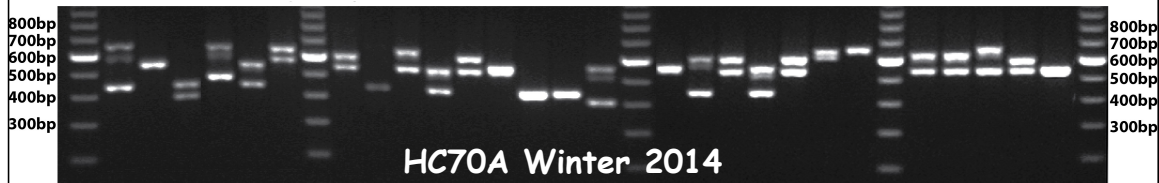
Sometimes They Reveal Unexpected Results!



What is YOUR DNA Fingerprint?



What is YOUR DNA Fingerprint?





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.




FISH YOU PURCHASE FISH YOU GET




Flounder Dover Sole

FISH OF INFERIOR QUALITY ARE
OFTEN SUBSTITUTED FOR HIGHER
VALUE VARIETIES

\$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.

How technology helps investigation of wildlife crimes

DNA analysis helps link suspect to crime animal and crime scene

Blood, skin or tissue can be used for analysis

Can help identify species, determine sex and establish parent-offspring relationship

Creation of genetic database of threatened species

Project to begin with DNA fingerprinting of tiger and leopard

Field Collected Samples



PCR (molecular science machines)

Primers

Fingerprint gel




DNA
Genetic Code of Life


Entire Genetic Code
of a Bacteria


DNA Fingerprinting


Cloning: Ethical Issues
and Future Consequences

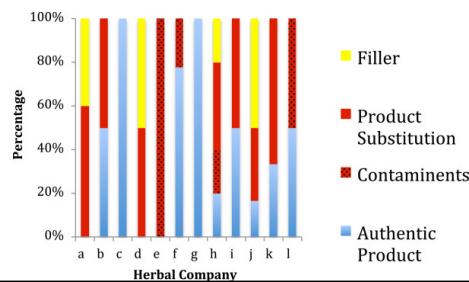
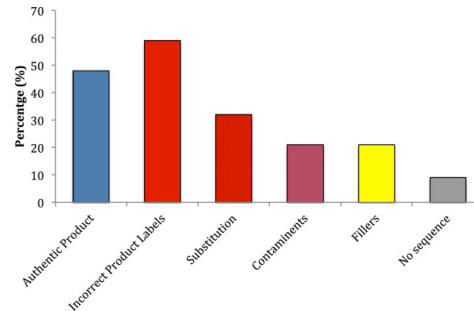
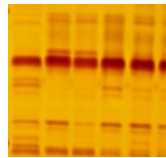

Plants of Tomorrow

And Consumer Fraud in the Natural Food Industry

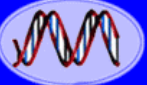
DNA barcoding detects contamination and substitution in North American herbal products


BMC Medicine, 11, 222, 2013

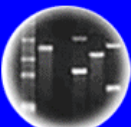
Barcoding = DNA Fingerprinting!




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

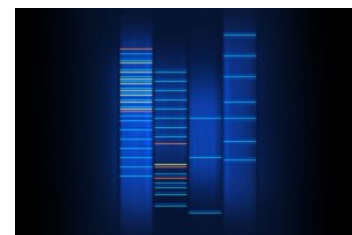

DNA
Genetic Code of Life


Entire Genetic Code
of a Bacteria


DNA Fingerprinting


Cloning: Ethical Issues
and Future Consequences


Plants of Tomorrow



Identifying Victims of 9/11 by DNA Fingerprinting

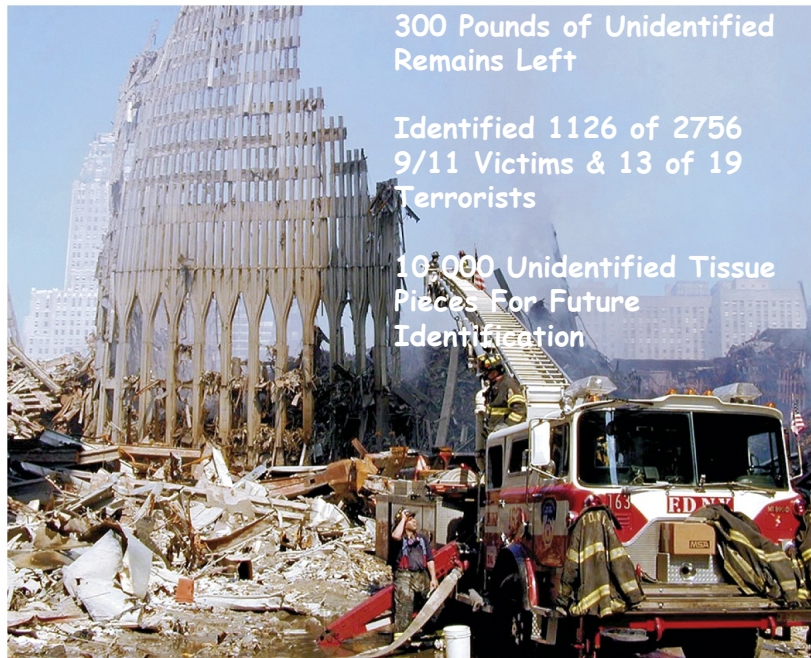


Figure 19-31
Genetics: A Conceptual Approach, Third Edition
© 2009 W.H. Freeman and Company

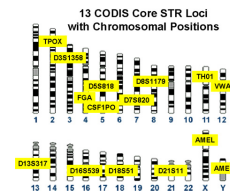
Newsweek, January 12, 2009

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](#) |

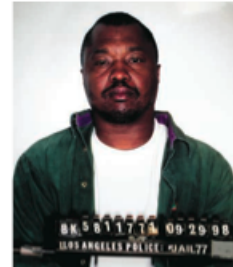
FEBRUARY, 2105

Offender Profiles	11,634,999	What Are State Laws? California Proposition 69
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.

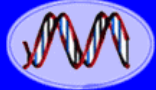
Grim Sleeper Caught By DNA!!

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.

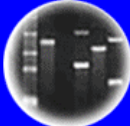
- 281 Post-Conviction DNA Exonerations Since 1989
- 17 of 281 People Exonerated Were on Death Row
- Average Time Served Was 13 Years
- Average Age at Time of Wrongful Conviction Was 27
- **75% of Wrongful Convictions Due to Eyewitness Misidentification**
- 50% of Wrongful Convictions Due to Improper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



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and Future Consequences

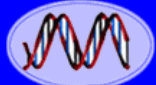


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Question Two

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

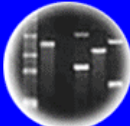
- a. Yes
- b. No



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DNA Is Leading to a New Era in Understanding Our Ancestry

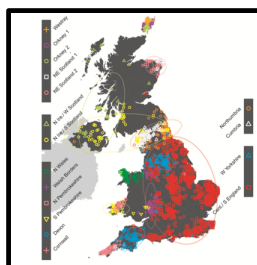
Study of Britain produces first fine-scale genetic map of a nation

By **MONTE MORIN**

MARCH 18, 2015, 8:54 PM

Britain may be famous for preserving its royal DNA, but a genetic analysis of the nation is providing new insights into the "story of the masses," according to scientists.

Researchers announced Wednesday that they had created the world's first fine-scale genetic map of any country, an achievement that allowed them to settle a few long-running debates about the history and bloodlines of England, Scotland, Wales and Northern Ireland.





Walmart Personalized DNA Test!

Disease
Genes



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

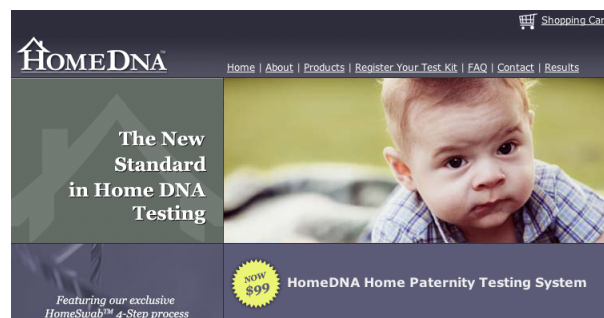
DNA Testing Into the Home - Fast & Inexpensive DNA Testing Kits!



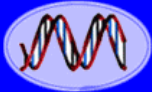
Paternity




Ancestry



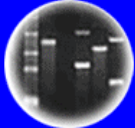
Immigration




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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 Genetic Privacy?



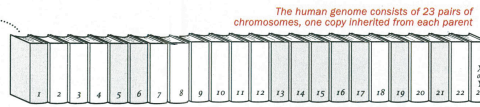
And Before Birth!!!

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



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...

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

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!

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

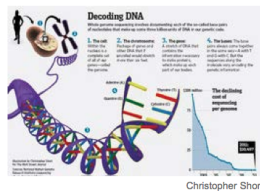
U.S. NEWS | JANUARY 10, 2012

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.

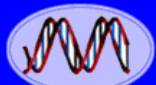
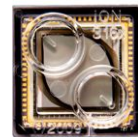


Christopher Short

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.

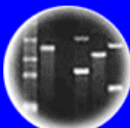
Scientists say that breaking the \$1,000 barrier—roughly the price of an MRI test—will accelerate an already fast-moving transformation in genetic discovery and drug development.



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DNA Fingerprinting



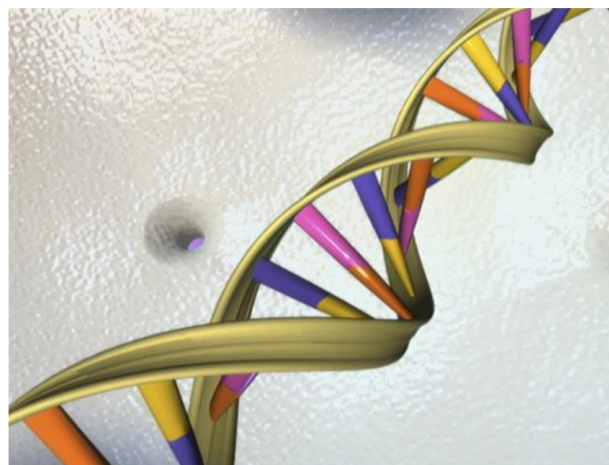
Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

Iceland Completes DNA Records for Entire Nation

BY HAYLEY RICHARDSON 3/26/15 AT 2:35 PM



A DNA double helix is seen in an undated artist's illustration released by the National Human Genome Research Institute to Reuters on May 15, 2012. NATIONAL HUMAN GENOME RESEARCH INSTITUTE/REUTERS



FILED UNDER: World, DNA, Iceland

Researchers in Iceland have recorded the human genetic code of the "entire nation" in the largest ever study of its kind.



Question Three

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

- a. Yes
- b. No

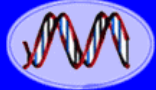
Determining the Genetic Identity of a Human Embryo Before Implantation!



Prenatal Genetic Diagnosis (PGD)

Fertility Clinics Scan for the Strongest Embryo

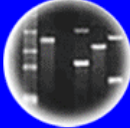




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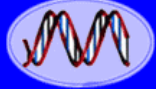


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Question Four

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

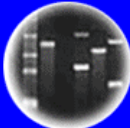
- a. Yes
- b. No



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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

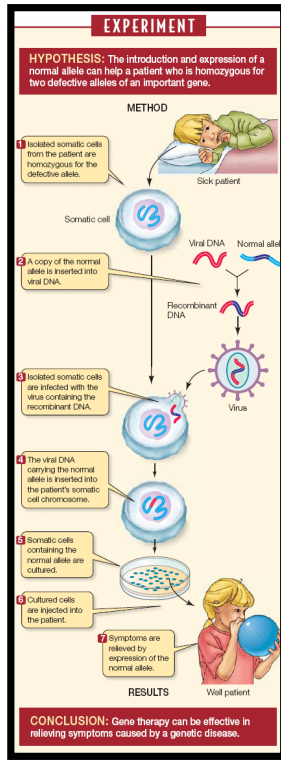
Gene therapy trial 'cures children'

**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!!!

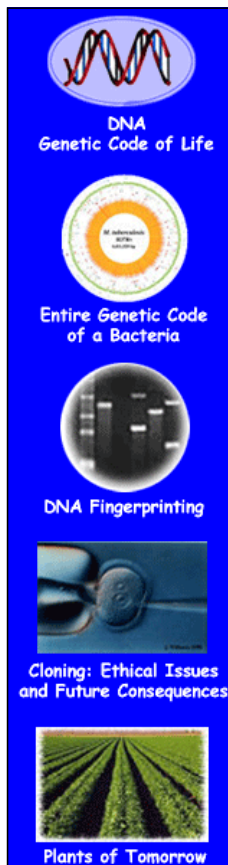
Several People are Alive Because They Have Been Engineered With an ADA Gene

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!!!!





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DNA Fingerprinting



Cloning: Ethical Issues
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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Plants of Tomorrow

Question Five

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

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

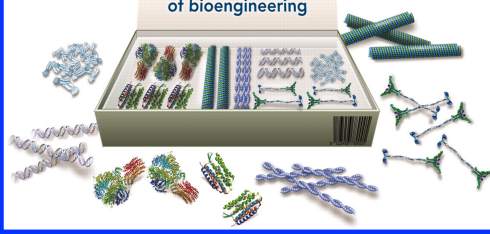
By **NICHOLAS WADE** Science, July 15, 2011

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





Total Synthesis of a Functional Designer Eukaryotic Chromosome

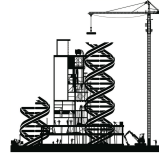
First synthetic yeast chromosome revealed

US-based project recruited dozens of undergraduates to stitch DNA fragments together.

Ewen Callaway

27 March 2014

 [Rights & Permissions](#)



It took geneticist Craig Venter 15 years and US\$40 million to synthesize the genome of a bacterial parasite. Today, an academic team made up mostly of undergraduate students reports the next leap in synthetic life: the redesign and production of a fully functional chromosome from the baker's yeast *Saccharomyces cerevisiae*.

As a eukaryote, a category that includes humans and other animals, *S. cerevisiae* has a more complex genome than Venter's parasite. The synthetic yeast chromosome — which has been stripped of some DNA sequences and other elements — is 272,871 base pairs long, representing about 2.5% of the 12-million-base-pair *S. cerevisiae* genome. The researchers, who report their accomplishment in *Science*¹, have formed an international consortium to create a synthetic version of the full *S. cerevisiae* genome within 5 years.

Creating Life: Synthetic Microbes J. Craig Venter

60 Minutes-December 2010



Discover Magazine, March, 2015

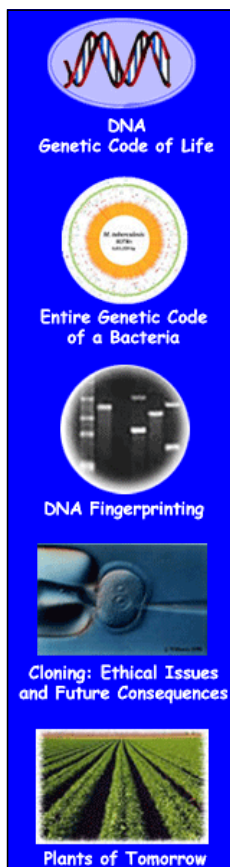
FROM THE MARCH 2015 ISSUE

The Quest to Resurrect Extinct Species

A father-son duo of biologists has set the stage for so-called de-extinction. But should we be doing this at all?

By Virginia Gewin | Thursday, January 22, 2015

RELATED TAGS: [GENETICS](#), [ANIMALS](#), [BIOTECHNOLOGY](#)



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 40th 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!!



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)

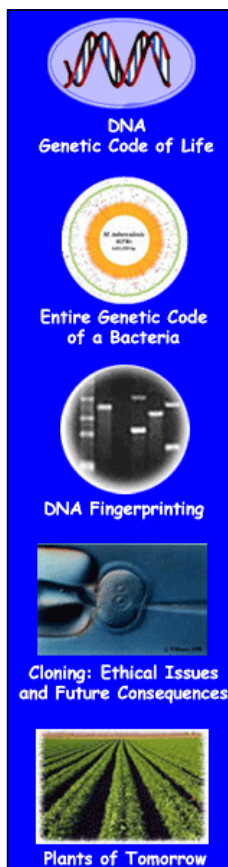
STANLEY N. COHEN*, ANNIE C. Y. CHANG*, HERBERT W. BOYER†, AND ROBERT B. HELLING†

*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. Cohen¹ 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



DNA
Genetic Code of Life

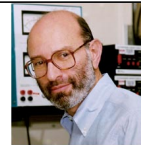
Entire Genetic Code of a Bacteria

DNA Fingerprinting

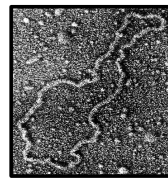
Cloning: Ethical Issues and Future Consequences

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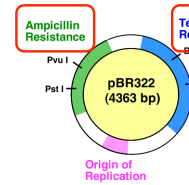
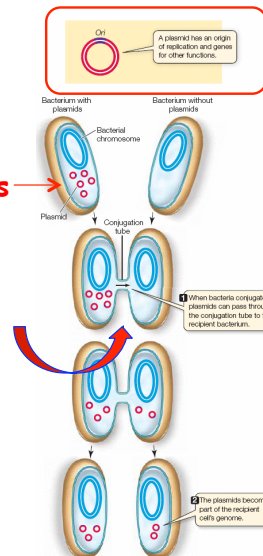
Plasmids Are Circular Self-Replicating DNA Molecules in Bacterial Cells That Carry Antibiotic Resistance Genes



Stanley Cohen



Plasmids



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

Plasmids Defend Bacteria Against Antibiotics!

DNA
Genetic Code of Life

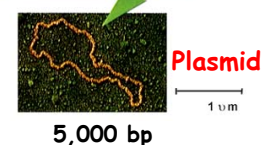
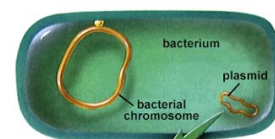
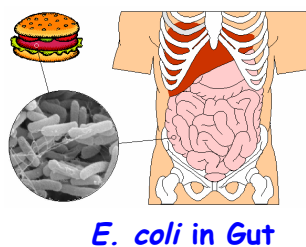
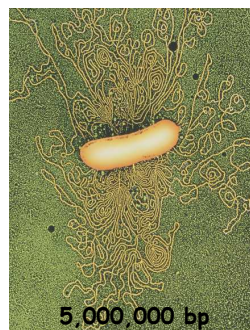
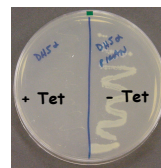
Entire Genetic Code of a Bacteria

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



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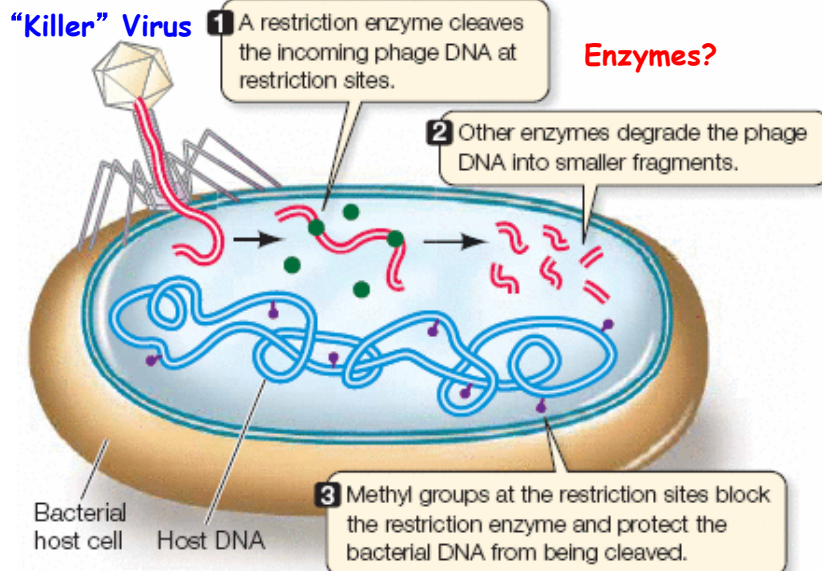
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Restriction Enzymes Are Proteins That "Cut" DNA Into Pieces



Restriction Enzymes Protect Bacteria From "Killer" Viruses!

DNA
Genetic Code of Life

Entire Genetic Code of a Bacteria

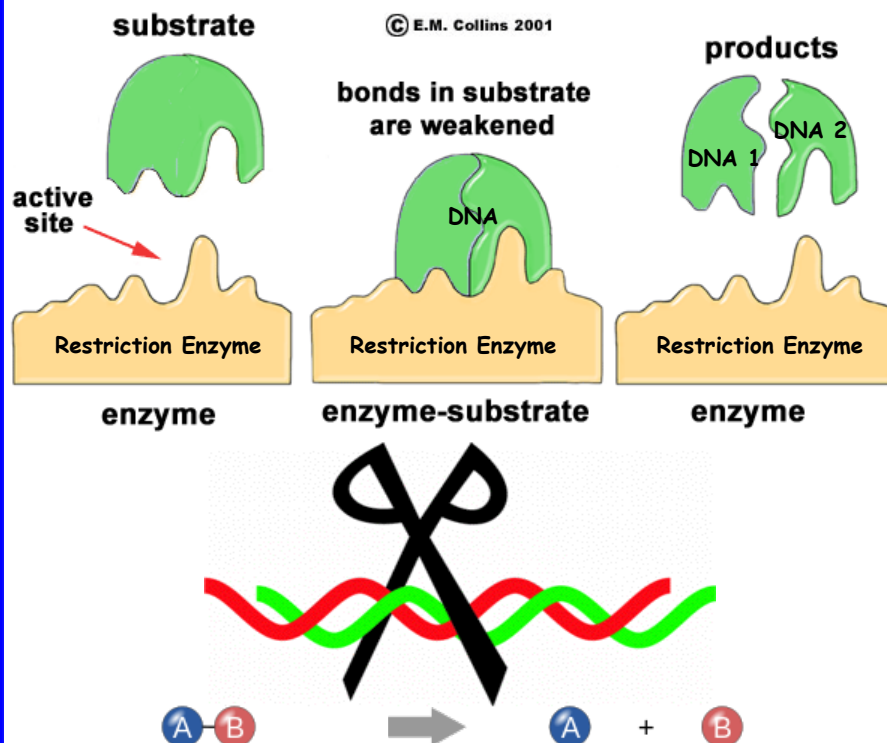
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Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

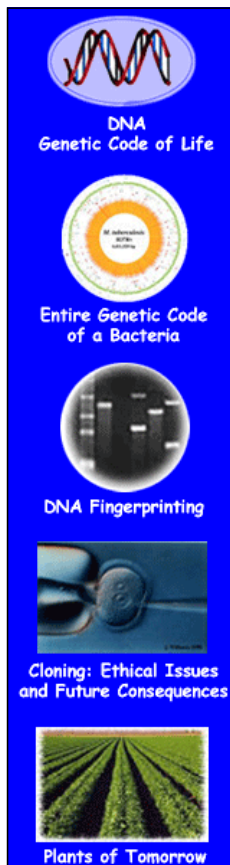
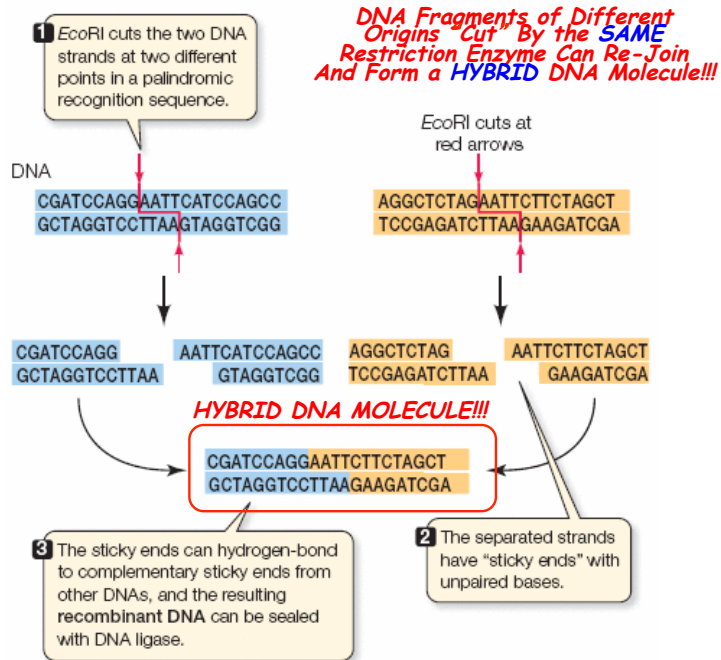
Enzymes Are Proteins That Catalyze or Facilitate Chemical Reactions

© E.M. Collins 2001

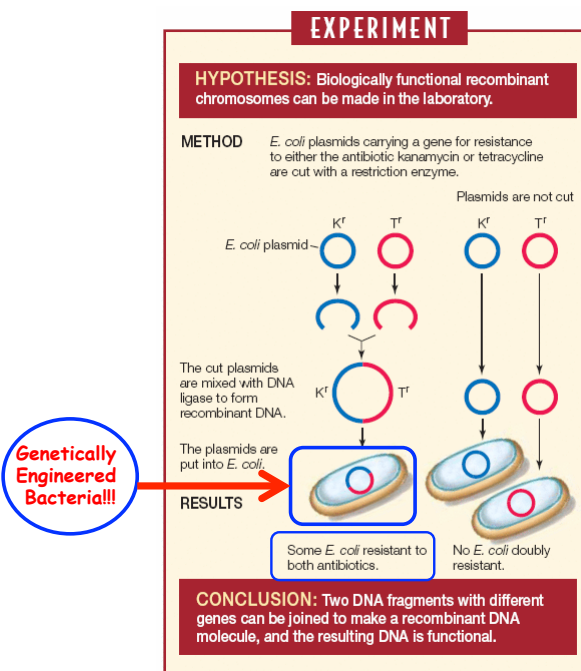




Restriction Enzymes Are Proteins That “Cut” DNA Into Pieces At Specific Sequences



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

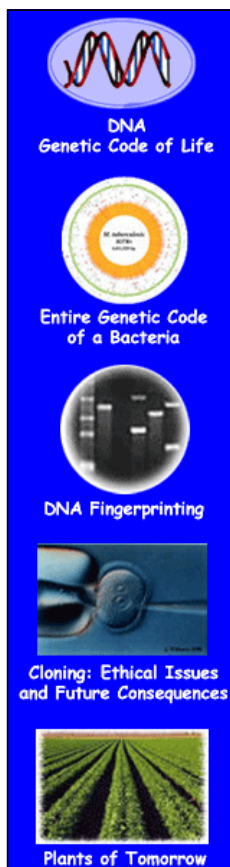


Cohen-Boyer Experiment

“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

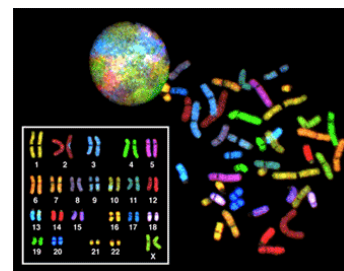
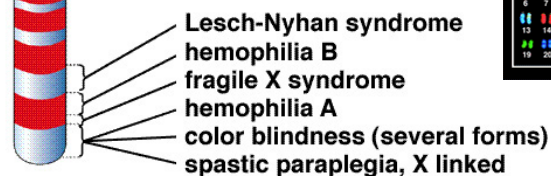
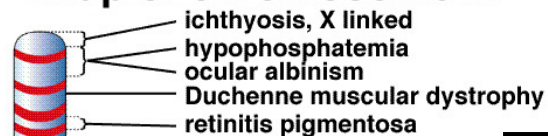
Genetic Engineering Has Lead to New Knowledge About How Cells and Genes Function and Has Lead to Applications That Have Improved Our Lives!!



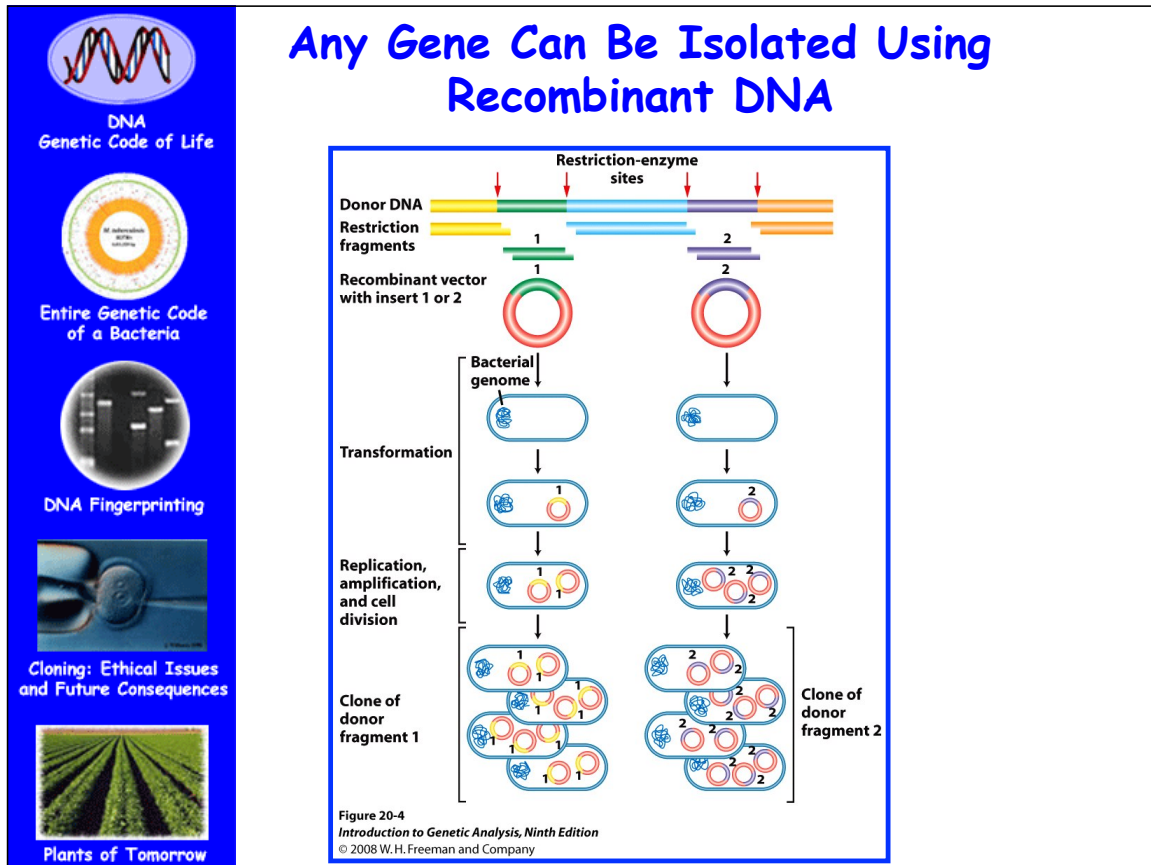
Genomes & Chromosomes Contain Thousands of Genes

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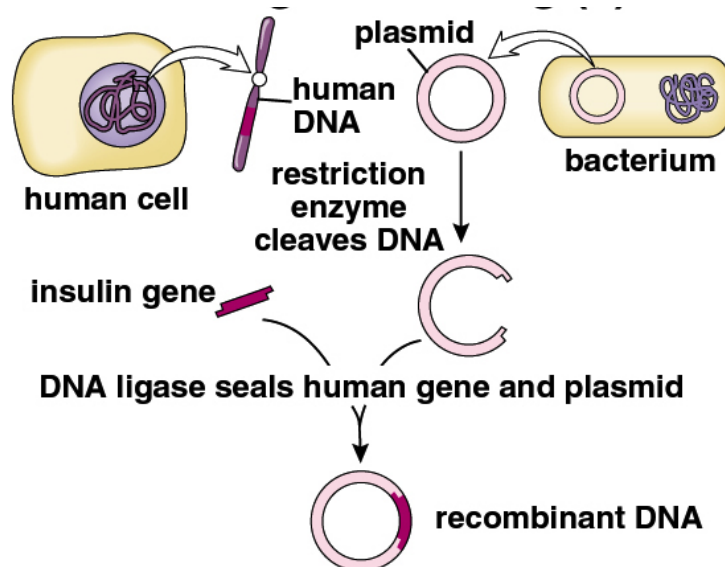
Map of chromosome X



How Can a Single Gene Be Studied?



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**
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!!

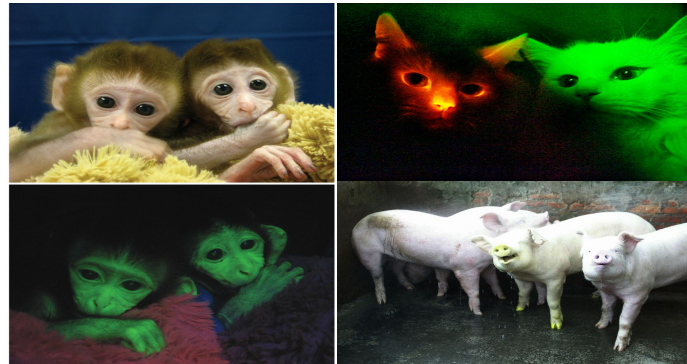
 <p>DNA Genetic Code of Life</p>  <p>Entire Genetic Code of a Bacteria</p>  <p>DNA Fingerprinting</p>  <p>Cloning: Ethical Issues and Future Consequences</p>  <p>Plants of Tomorrow</p>	<h2>Genetic Engineering.....</h2> <div>Is the Most Revolutionary Technology in Biology to Have Been Invented in Human History!</div> <div>Has Generated the Vast Majority of New Biological Knowledge Over the Past 40 Years From Experiments in Biology Laboratories Around the Globe</div> <div>Has Changed Our Lives Dramatically!</div>
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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.

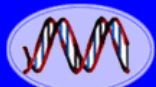


The Age of DNA & Genetic Engineering Has Affected Our Lives in Many Ways

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

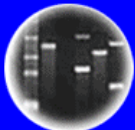
1. Patenting Genes, Cells, & Living Organisms?
2. Regulating Experimentation on DNA, Cells, Transgenic Organisms ("GMOs")?
3. Regulating the Release of Genetically Modified Organisms into the Environment?
4. Labeling of Genetically Modified Foods?  
5. Genetic Testing: DNA Databases, Newborn Genetic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



DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences

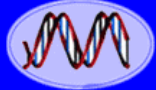


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Question Six

Should Limits Be Placed on the Use of Genetic Engineering?

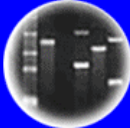
- a. Yes
- b. No



DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting

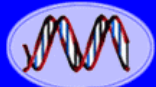


Cloning: Ethical Issues
and Future Consequences



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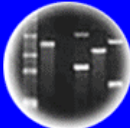
Stop Part One!!



DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

HC70A Winter 2015 Genetic Engineering in Medicine, Agriculture, and Law Professor Bob Goldberg

Class Announcements 3/31/15



HC70A Winter 2015 (UCLA) Genetic Engineering in Medicine, Agriculture, and Law

Teaching Fellows

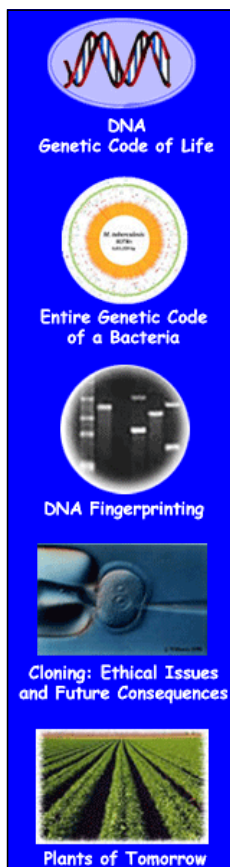
William Barshop

Dominic Lucido

Dominic Saadi

Course Administrators

Lauren Bowman



SAS70A Winter 2015 (UC Davis) Genetic Engineering in Medicine, Agriculture, and Law

UC Davis

Professor John Harada

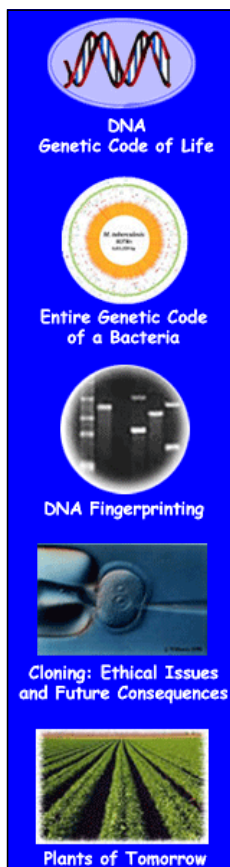
TA - Alec Olson

UC DAVIS
UNIVERSITY OF CALIFORNIA



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**



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?!**