

DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria

DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

HC70A
Spring 2021
**Genetic Engineering in Medicine,
Agriculture, and Law**

Professor Bob Goldberg

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

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LECTURE THEMES

1. Genetic Engineering and DNA in the News!
2. What is a *GMO*?
3. What is Genetic Engineering?
4. What Do Genes Look Like - DNA Demonstration
5. How Was Modern Genetic Engineering Invented & What Is the Genetic Engineering Process?
6. Why Use Genetic Engineering?
7. How Has Genetic Engineering Affected Our Lives?
8. How Has Genetic Engineering Created New Ethical and Legal Issues?
9. Genetic Engineering in Medicine, Agriculture, Law, & Society - Some Examples

2

Just Say No To GMO

NON GMO VERIFIED

GMO FREE NJ

NO FRANKENFISH! BAN GMO SALMON!

GMO FREE FLORIDA

YES Right to Know

The Politics of ... GMOs

NO ON 37 STOP THE DECEPTIVE FOOD LABELING SCHEME

PRO GMO

MIDDLE GROUND

NO GMO

GMO CARROT

GMO SOYBEAN POD

GMO are safe for God sake

IT'S UP TO YOU TO MAKE THE CHOICE!

To bolster the nation's blood supply, the Red Cross genetically engineers giant nucleotides that instinctively deposit their loads in a blood bank.

3

Genetic Engineering in the News..

Law

Justices, 9-0, Bar Patenting Human Genes

Harvard and M.I.T. Scientists Win Gene-Editing Patent Fight

Chinese Scientist Who Genetically Edited Babies Gets 3 Years in Prison

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

Congress Passes Bill to Bar Bias Based on Genes

F.D.A. Authorizes Moderna Vaccine, Adding Millions of Doses to U.S. Supply

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Genetic Engineering in the News..
Medicine

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

New gene therapy appears safe, feasible for sickle cell disease

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

Genome-edited baby claim provokes international outcry

Scientists Talk Privately About Creating a Synthetic Human Genome

→ **COVID-19 brings a new dawn for messenger RNA vaccines**

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Genetic Engineering in the News..
Agriculture

Genetically Modified Salmon Is Safe To Eat, FDA Says

Super-muscly pigs created by small genetic tweak

→ *By 'Editing' Plant Genes, Companies Avoid Regulation*

GM Wheat Used to Make Bread with Less Gluten

GM banana shows promise against deadly fungus strain

Scientists hack plant photosynthesis to boost crop yields by 40% January 3, 2019

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And All the GMO Misconceptions!!!!

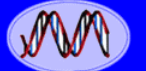


Don't label GMOs



7

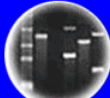
What's a GMO???



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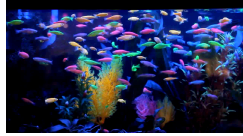


8

So.....What is 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 Pig With Double Muscles For Leaner & More Meat?



A Genetically Engineered Yeast That Synthesizes a Plant Protein Giving the Impossible Burger Its Red Color?

9

So.....What is a GMO?



A Bacteria With a Genome Synthesized in a Laboratory?



A Yeast With Chromosomes Synthesized in a Laboratory?



A Genetically Engineered Bacteria Making Blue Dye For Jeans?



A Genetically Engineered Goat Making a Human Anti-Clotting Drug?

10

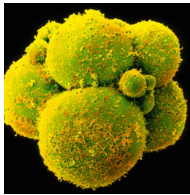
So.....What is a GMO?



A Genetically Engineered Salmon That Grows Faster Than Non-Engineered Salmon & Has Been Approved by the FDA For Human Consumption?



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



Babies Whose Genomes Were "Edited" to Make Them "Resistant" to the HIV Virus?

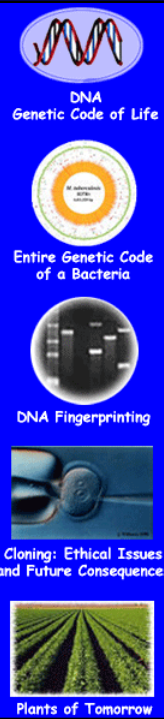


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And.....Crops That Are Grown For For Human & Animal Consumption?

So.....What is a GMO?


12

What is Genetic Engineering and a Genetically Modified Organism?

Directed Change of an Organism's Genetic Blueprint or DNA = GMO!!!!!!!

genetic engineering
 jəˈnetɪk enʒɪˈnɪ(ə)rɪŋɪŋ/
 noun
 noun: genetic engineering
 the deliberate modification of the characteristics of an organism by manipulating its genetic material.



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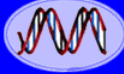
Genetic Engineering is the TECHNIQUE! That Generates GMOs

1. Classical Breeding By Selective Mating (Thousands of Years)
2. Insertion of a New Gene Into An Organism's Chromosomes (50 Years) - Transgenic Organism
3. Editing Existing Genes Like A "Word Program" (5 Years) - CRISPR Gene Editing


Breeding or DNA Manipulation - They Are the SAME & Called *Gene Engineering* So..... WHAT IS A GMO??





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DNA Fingerprinting



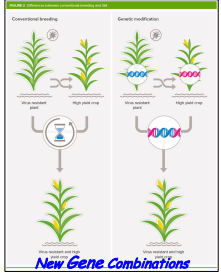
Cloning: Ethical Issues
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Plants of Tomorrow

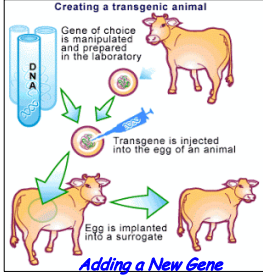
Three Genetic Engineering Techniques That Generate GMOs!!!

1. Classical Breeding



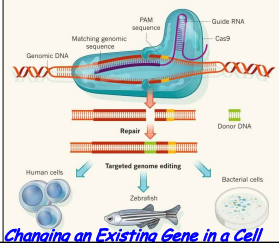
New Gene Combinations

2. Transgenic Organism



Adding a New Gene

3. CRISPR Gene Editing



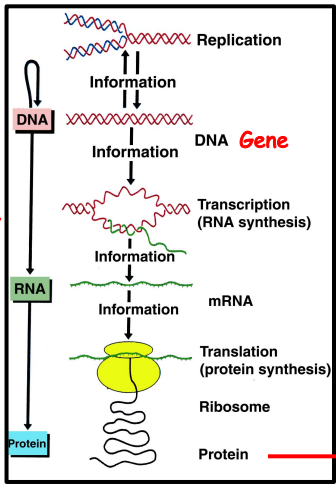
Changing an Existing Gene in a Cell

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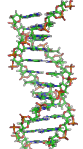
*Genes & DNA Obey the Same Rules Using Either
Classical or Modern DNA Engineering Approaches!!
BOTH Produce GMOs!!!!!!*

*Can Intervene
in This Process in
Cells*


*Genetic Engineering
Is not "Hocus Pocus."
It Uses "Natural"
Cell Processes!!!!*

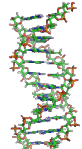


*All Organisms Use
The SAME Processes
And "RULES" to
Generate Traits!! And
The SAME Molecules
& Chemistry!!*



Coat Color Trait





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Essential HC70A Theme!





**We Live in
The Age of Genetic
Engineering and DNA!**

**Genetic Engineering Is
Manipulating DNA! ALL GMOs
Have Engineered Genes**

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

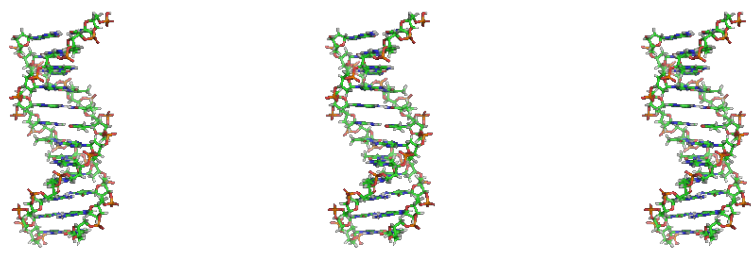


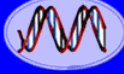

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**What Does Your DNA Look
Like?**

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

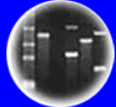





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DNA Fingerprinting



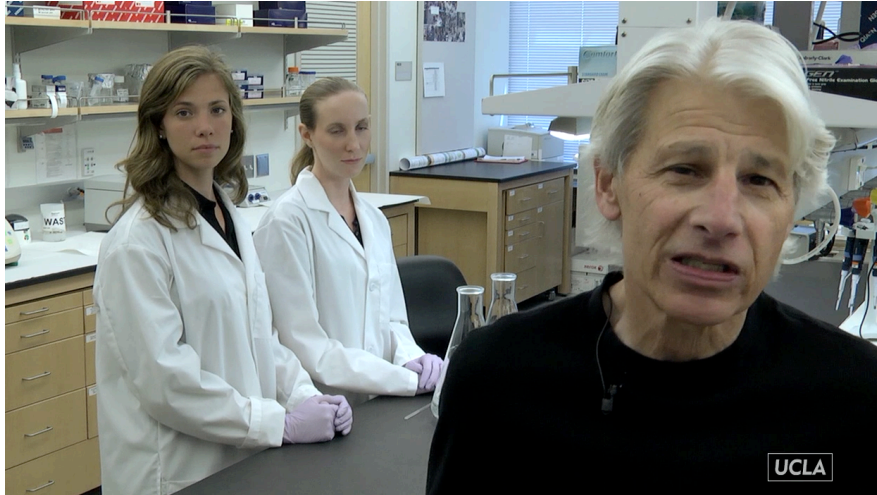
Cloning: Ethical Issues
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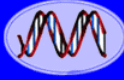
Plants of Tomorrow


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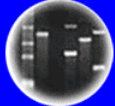
What Does Your DNA Look Like?





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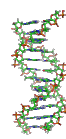
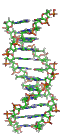

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How Was Genetic Engineering Using DNA Invented? & How Did It Lead To Remarkable Advances In Medicine, Agriculture, & Law?



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DNA Genetic Engineering Has Been in the News For Almost 50 Years!!! It's Old Technology!!!!!!

Gene Transplants Seen Helping Farmers and Doctors

By VICTOR K. MCELHENY MAY 20, 1974 1974 (20 Years After Structure of DNA Discovered)

Debate on Shifting Genes Nearing a Critical Phase

By BOYCE RENSBERGER MAY 16, 1976 1976

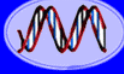
Scientists Report Using Bacteria To Produce the Gene for Insulin; Bacteria Used to Make Insulin Gene

By HAROLD M. SCHMECK Jr. Special to The New York Times (); May 24, 1977 1977


Substance Usually Made in Brain Grown in Bacteria

By HAROLD M. SCHMECK JR. NOV. 3, 1977 1976

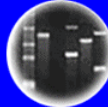
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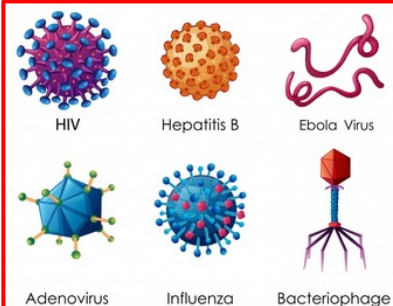


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The Idea That DNA From Different Species Could Be Recombined Started With Viruses ~50 Years Ago!

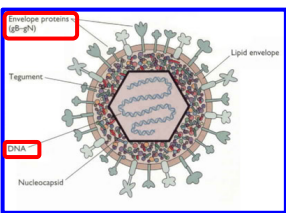
There is a Variety of Viruses That Engage in "Warfare" With Living Cells of Diverse Organisms

A Virus Consists of a Protein Protective Coat and a Nucleic Acid (DNA or RNA) Genome That Contains Its Genes



HIV Hepatitis B Ebola Virus

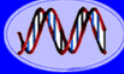
Adenovirus Influenza Bacteriophage




Envelope proteins (S, M, N)
Lipid envelope
Tegument
DNA
Nucleocapsid

They Exist to Exist!!!

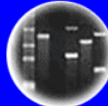
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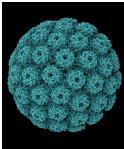
Cloning: Ethical Issues
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A Hybrid DNA Molecule Was Produced By Combining the DNAs of a Monkey Virus With a Bacteria Virus

Simian Virus 40



λ Bacteriophage



1972

Paul Berg (1926-) creates first recombinant DNA molecules

Paul Berg assembled the first DNA molecules that combined genes from different organisms. Results of his experiments, published in 1972, represented crucial steps in the subsequent development of recombinant genetic engineering. By various methods such as he devised, individual genes could be isolated and inserted into mammalian cells or into such rapidly growing organisms as bacteria. The genes themselves could then be studied, and their protein products expressed and even manufactured in quantity.

The prospect of recombinant DNA emerged from a series of advances in biochemistry—most especially, from discovery of new enzymes. Particularly important were the restriction enzymes that act as “scissors” to cut molecules of DNA at specific points. Similarly, ligases are enzymes that forge covalent bonds. The discovery of DNA ligase provided a kind of chemical soldering that could restore DNA after a foreign gene was spliced into it. These and other enzymes, captured from nature, could be used as tools in genetic engineering.

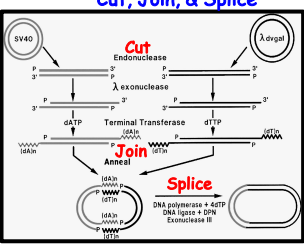
In creating hybrid DNA molecules, Berg employed the multi-stated SV40 monkey virus and a bacterial virus known as the (or lambda) bacteriophage. The SV40 virus has few genes, lacks a protein coat, and is convenient to work with. The bacteriophage normally invades a type of *E. coli*, where it replicates according to the nutritional environment. The DNA of both viruses takes the form of closed loops. Berg's original idea was to open the SV40 DNA, and splice into it genes snipped out of the bacteriophage. The virus could then replicate in *E. coli*, and the products of the bacteriophage genes could also be expressed.

In Berg's cut-and-splice method he created, in the DNA of both viruses, what came to be known as “sticky ends.” Restriction enzymes were first used to open the circular units of DNA of phage and virus. In separate operations, types of terminal transferase (and/or polymerase) were used to add complementary DNA bases (adenine and thymine) to the ends of the molecules. When both kinds of DNA were incubated together, the ends would attach naturally. Addition of DNA ligase would seal the plasmid. In succeeding with a series of accurate reactions, Berg wrote that his method “are general and offer an approach for covalently joining any two DNA molecules together.”

Potential dangers of recombinant genetic engineering emerged even before Berg published his landmark paper. Although the SV40 virus was thought to be innocuous to humans, the prospect of an altered form of the virus spreading through such a common bacterial agent as *E. coli* did not escape Berg's delicate part of the research program. He did not insert the recombinant virus into bacterial cells as he originally planned. (With bacterial and animal genes, Herbert Boyer and Stanley Cohen took this step shortly.) A professor at Stanford University, in 1974, Berg published a widely discussed letter on the potential dangers of recombinant DNA research. Subsequently, a moratorium on research in 1975 provided time for regulations to be devised and put into effect in 1976.

In 1980 Paul Berg shared the Nobel Prize in Chemistry with Walter Gilbert and Frederick Sanger, for “the fundamental studies of the biochemistry of nucleic acids, with particular emphasis on recombinant DNA.”

“Cut, Join, & Splice”



In Test Tube Only!

SV40

λ

Join


Anneal

Splice

DNA polymerase + dATP
DNA ligase + dNTP
Exonuclease III

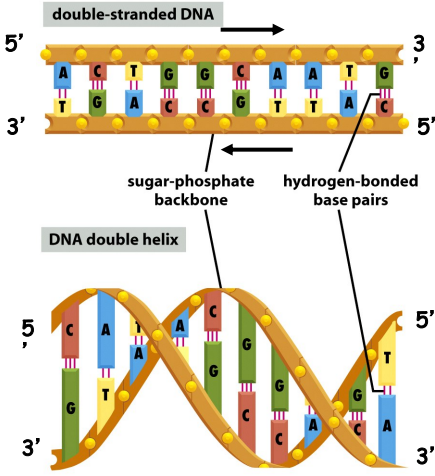
Biotechnical Method for Inserting New Genetic Information into DNA of Simian Virus 40 Cloning SV40 DNA Molecules Containing Lambda Phage Genes and the Galactose Operon of *Escherichia coli*

DAVID A. JACKSON, ROBERT B. FRYNOLD, AND PAUL BERG



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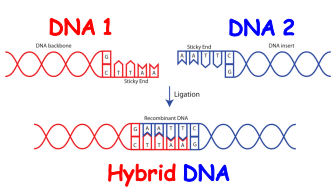
Major HC70A Concept - Complementary Bases of the DNA Double Helix Allows Two DNAs to be Spliced (Joined) Together & Form a Hybrid



Major Genetic Engineering Concept!!

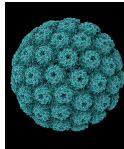
Complementary Strands
A=T and G=C (Four Bases)

DNA 1 DNA 2




Hybrid DNA

Simian Virus 40

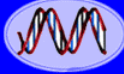


λ Bacteriophage




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Plants of Tomorrow

Modern Genetic Engineering of Living Cells Was Invented a Year Later & Caused a Revolution in Biology A Half a Century Ago!

Proc. Nat. Acad. Sci. USA
Vol. 70, No. 11, pp. 3240-3244 November 1973 November 1973 *This is the 47th 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..... To Those of Us Who Have Done This Our Entire Careers, It is an OLD technology!!

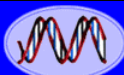


Herb Boyer




Stanley Cohen

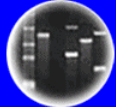
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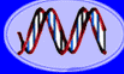
Modern Genetic Engineering Was Invented in 1973 With An Unexpected "Eureka" Moment Dealing With Two Unrelated Areas of Study Related To Bacterial Defense Systems:

1. The Mechanism of Bacterial Antibiotic Resistance To Fight Off "Predators"
2. How Novel Enzymes Protect Bacteria From Destruction By Viruses "Cut" DNA Into Pieces




STANLEY COHEN
HERBERT BOYER


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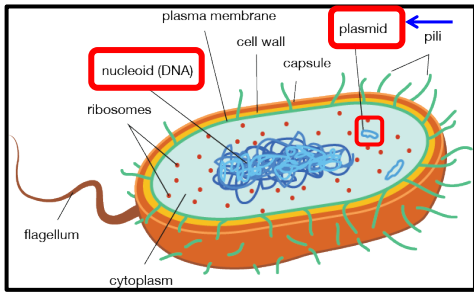


Cloning: Ethical Issues and Future Consequences



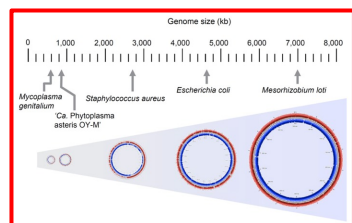
Plants of Tomorrow


A Typical Bacterial Cell



1. Replicates/Divides
2. Produces Energy
3. Responds to Stimuli
4. Communicates

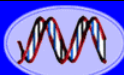
Bacterial Chromosomes Are Circular & Contain 500 to 7500 Genes






Humans Have
Linear Chromosomes
With 25,000 Genes


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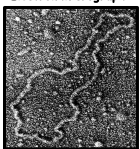
Cloning: Ethical Issues and Future Consequences



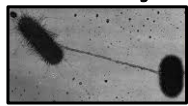
Plants of Tomorrow

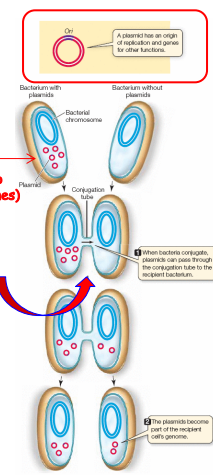
Bacteria Also Contain Plasmids - Circular Self-Replicating DNA Molecules - That Carry Antibiotic Resistance Genes

Electron Micrograph



Bacteria Mating






Plasmids
2,000 to 150,000 bp
(One to Several Genes)

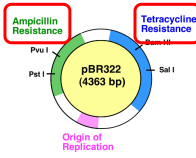
Bacteria Mating

When bacteria conjugate, plasmids can pass through the conjugation tube to the recipient bacterium.

The plasmids become part of the recipient cell's genome.



Stanley Cohen



Small Plasmids Move From Cell to Cell Spreading Antibiotic Resistance Genes in Bacterial Populations! A Major Public Health Crisis!

Plasmids Defend Bacteria Against Antibiotics! (The "Workhorses" or Vectors for Genetic Engineering)

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Antibiotic Resistance - Use in Genetic Engineering



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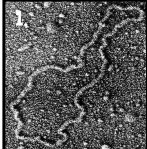


Cloning: Ethical Issues and Future Consequences



Plants of Tomorrow

Plasmid Properties Making Them Ideal For Genetic Engineering





pBR322 (4363 bp)

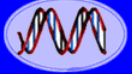
Bacteria Mating




1. Small DNA Molecule That Can Replicate Into Many Copies
2. Easy to Isolate & Put Back In Cells
3. Have Antibiotic Resistance Genes - Can Select Bacteria With a Plasmid
4. Easy To Manipulate & Modify With Foreign Genes

Ideal Vehicles For Isolating, Replicating, & Engineering "Foreign" Genes

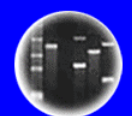
30




DNA Genetic Code of Life




Entire Genetic Code of a Bacteria



DNA Fingerprinting




Cloning: Ethical Issues and Future Consequences



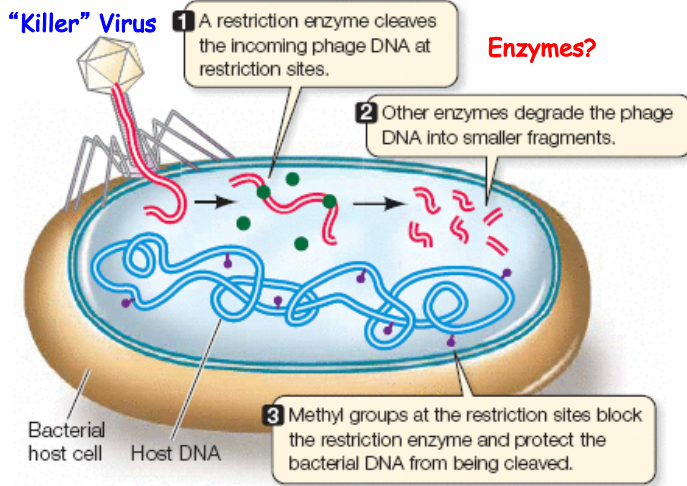
Plants of Tomorrow

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



Herb Boyer

"Killer" Virus

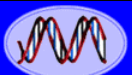


Enzymes?


- 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.

Restriction Enzymes Protect Bacteria From "Killer" Viruses!

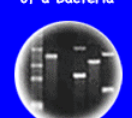
31




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Entire Genetic Code of a Bacteria



DNA Fingerprinting



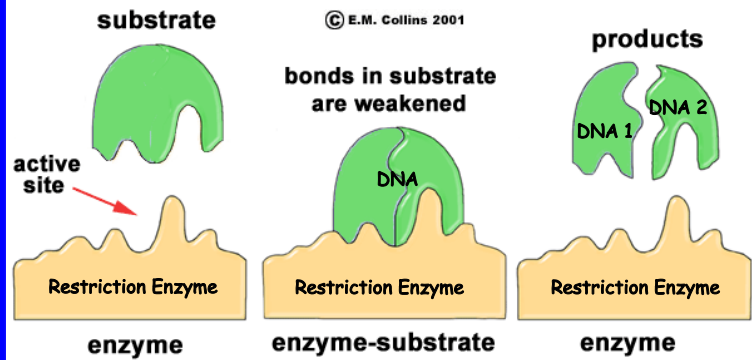
Cloning: Ethical Issues and Future Consequences



Plants of Tomorrow

Enzymes Are Proteins That Catalyze or Facilitate Chemical Reactions

© E.M. Collins 2001




substrate products

bonds in substrate are weakened

active site DNA DNA 1 DNA 2

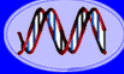
Restriction Enzyme Restriction Enzyme Restriction Enzyme

enzyme enzyme-substrate enzyme




A-B → A + B

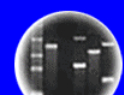
32




DNA
Genetic Code of Life




Entire Genetic Code
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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

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

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

EcoRI cuts at red arrows

DNA

CGATCCAGG	AATTCATCCAGCC	AGGCTCTAG	AATCTTCTAGCT
GCTAGGTCCTTAA	GTAGGTCGG	TCCGAGATCTTAA	GAAGATCGA

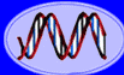
Cut & Separate

Note: Complementary Bases!!


CGATCCAGG	AATTCATCCAGCC	AGGCTCTAG	AATCTTCTAGCT
GCTAGGTCCTTAA	GTAGGTCGG	TCCGAGATCTTAA	GAAGATCGA

The "Scissors" For Genetic Engineering


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DNA
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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

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

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

EcoRI cuts at red arrows

DNA

CGATCCAGG	AATTCATCCAGCC	AGGCTCTAG	AATCTTCTAGCT
GCTAGGTCCTTAA	GTAGGTCGG	TCCGAGATCTTAA	GAAGATCGA

Cut

Note: Complementary Bases!!

CGATCCAGG	AATTCATCCAGCC	AGGCTCTAG	AATCTTCTAGCT
GCTAGGTCCTTAA	GTAGGTCGG	TCCGAGATCTTAA	GAAGATCGA

HYBRID DNA MOLECULE!!!

Join

CGATCCAGGAATCTTCTAGCT

GCTAGGTCCTTAAAGAATCGA

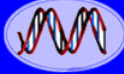
Splice

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.

The "Scissors" For Genetic Engineering


34




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DNA Fingerprinting

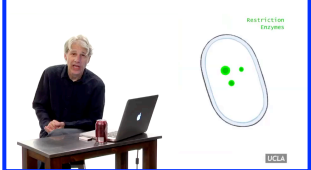




Cloning: Ethical Issues
and Future Consequences

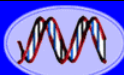


Plants of Tomorrow


Restriction Enzymes Animated!

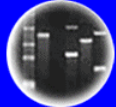
35




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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

The Cohen-Boyer Experiment That Started the Gene Engineering Revolution

Genetic Engineering Technology Can Combine DNA (Genes) From Different Sources Leading to New Gene Combinations in Living Organisms (i.e., GMOs)!!

EXPERIMENT

Cut
↓
Join
↓
Splice

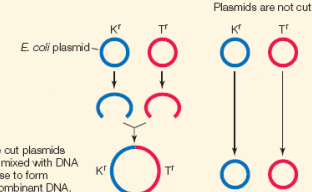
Genetically Engineered Bacteria!!!

Insert Back Into Bacterial Cell
Transform

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

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

Plasmids are not cut



The cut plasmids are mixed with DNA ligase to form recombinant DNA.

The plasmids are put into *E. coli*.

RESULTS:

Some *E. coli* resistant to both antibiotics.

No *E. coli* doubly resistant.

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

Hypothesis? Predictions?

This Was the FIRST GMO!!!

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DNA
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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

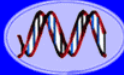
Genetic Engineering Technology Can Combine DNA (Genes) From Different Sources Leading to New Gene Combinations!!

Cohen & Boyer Created a Revolutionary New Technology That Changed in Biology Forever Recombinant DNA!!!!




UCLA

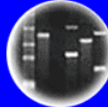
37




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DNA Fingerprinting

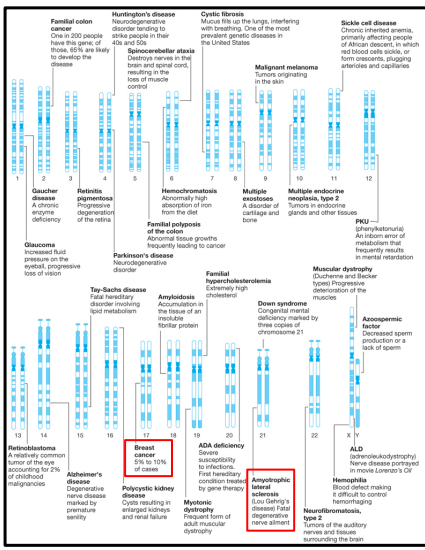


Cloning: Ethical Issues
and Future Consequences

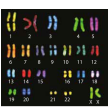


Plants of Tomorrow

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



Retinoblastoma A relatively common tumor of the eye, accounting for 2% of childhood malignancies.
Alzheimer's disease Degenerative nerve disease marked by premature senility.
Polycystic kidney disease Cysts resulting in enlarged kidneys and renal failure.
Breast cancer 2% to 3% of cases.
ADA deficiency Severe susceptibility to infections. First hereditary condition treated by gene therapy.
Myotonic dystrophy Cyst resulting in enlarged heart and adult muscular dystrophy.
Amyotrophic lateral sclerosis Slowly fatal disease. First hereditary condition treated by gene therapy.
Neurofibromatosis, type 2 Frequent form of tumor of the auditory nerve and tumor of the brain.

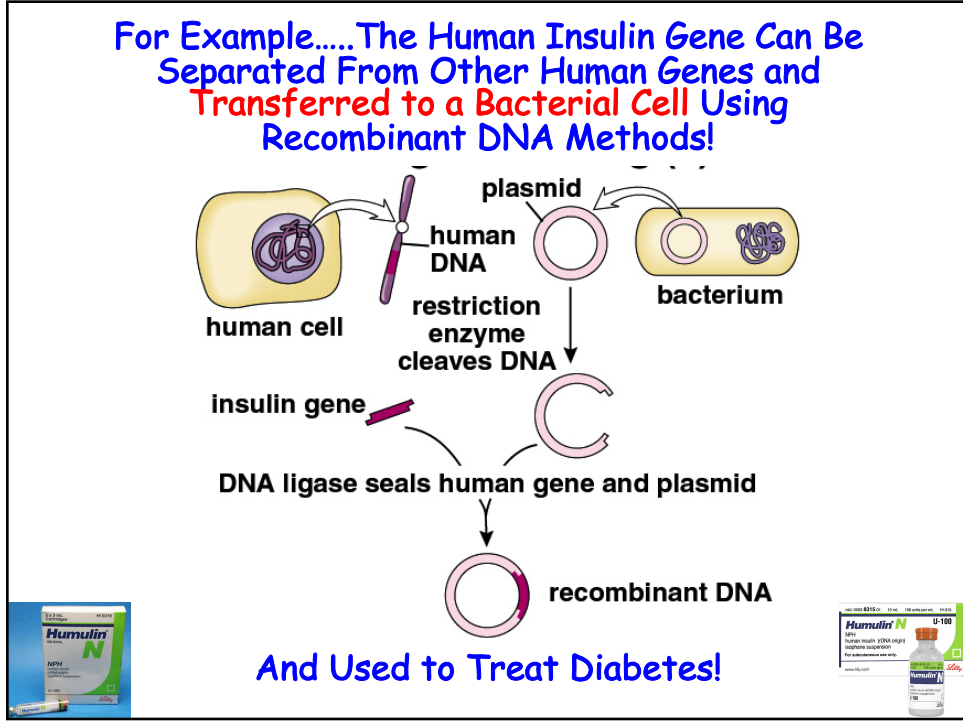


The Human Genome Has 25,000 Genes

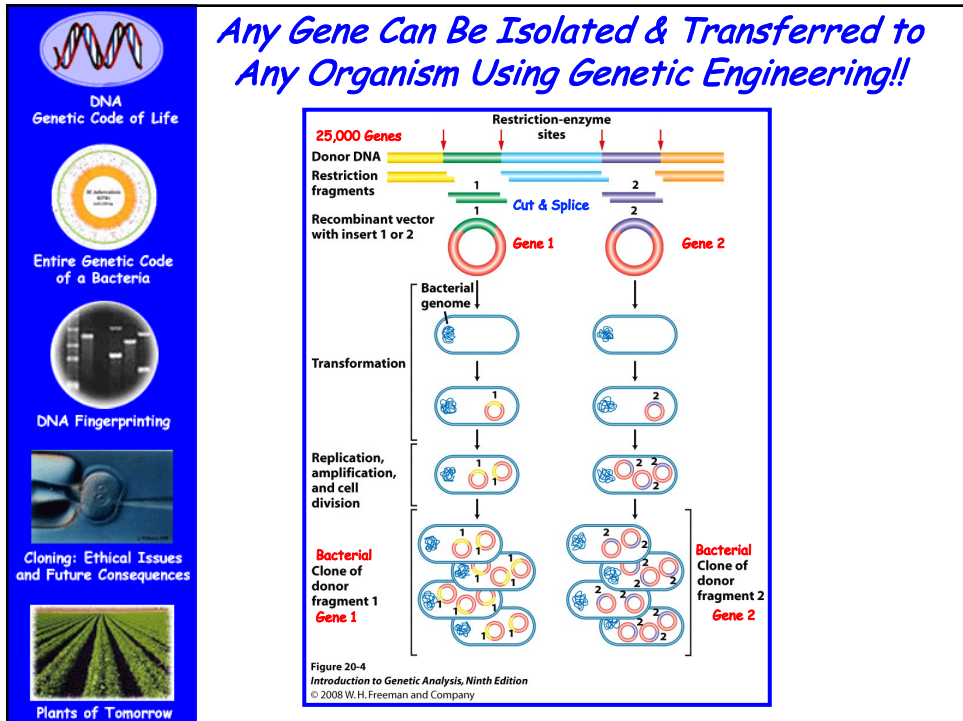
How Can a Single Gene Be Studied?

38

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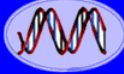


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And Made to Perform Any Function That We Want Using Normal Cellular Processes!!




DNA
Genetic Code of Life




Entire Genetic Code of a Bacteria




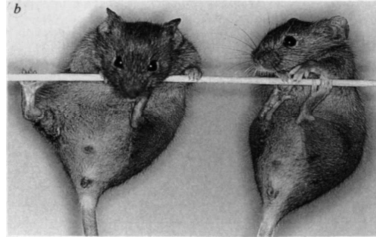


DNA Fingerprinting



Cloning: Ethical Issues and Future Consequences

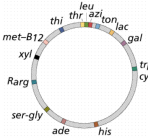


Plants of Tomorrow

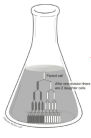





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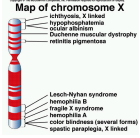
**“Why” Clone Genes From An Organism’s Genome?
An Essential HC70A Concept!**



Cut & Splice →



← Cut & Splice



1. **PURIFY** Individual Genes From the Genome (e.g., One of 25,000 Human Genes) Using Restriction Enzymes & Plasmids (*Cut & Slice*)
2. **AMPLIFY** The Gene Within Plasmids in Bacterial Cells 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



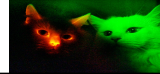
Genetic Engineering Has Lead to New Knowledge About How Cells and Genes Function and Has Lead to Applications That Have Improved Our Lives!!

42

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!!

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DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

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 50 Years From Experiments in Biology Laboratories Around the Globe

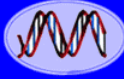
Has Changed Our Lives Dramatically!

44


AndHas Led to Many New Legal and Ethical Issues

1. **Genetic Enhancement and Eugenics: Right to Enhance Your Child?**
2. **Gender Selection and Prenatal Diagnosis of Genetic Diseases?**
3. **Gene Therapy: Correcting Human Genetic Diseases?**
4. **Genetic Testing: DNA Databases, Newborn Genetic Screening, Genetic Privacy, Involuntary or Voluntary Testing?**
5. **Genetic Discrimination?**
6. **Human Cloning and Genetic Improvement?**
7. **Patenting Genes, Cells, & Living Organisms?**
8. **Regulating the Release of Genetically Modified Organisms into the Environment?**
9. **Labeling of Genetically Modified Foods?**
10. **Synthetic Genomes: Constructing New Organisms?**

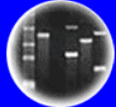
45




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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences


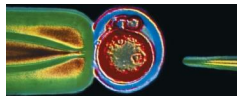



Plants of Tomorrow

A Few Examples of 21st 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 Because They Require Specific Genes or DNA Sequences!!!

Which You Will Learn the Basis of in HC70A!

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Genetic Engineering Has Been A Major Source of **Drugs To Treat Human and Animal Diseases Over the Past 30 Years!**



DNA
Genetic Code of Life



Entire Genetic Code of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues and Future Consequences



Plants of Tomorrow





Bacteria



Crops



Livestock




47

Genetic Engineering Gave Birth to **DNA Sequencing and Now Your Genome Can Be Decoded Very Quickly and Inexpensively (\$1,000)!!**

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.



MinIon DNA Sequencer

\$1,000

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

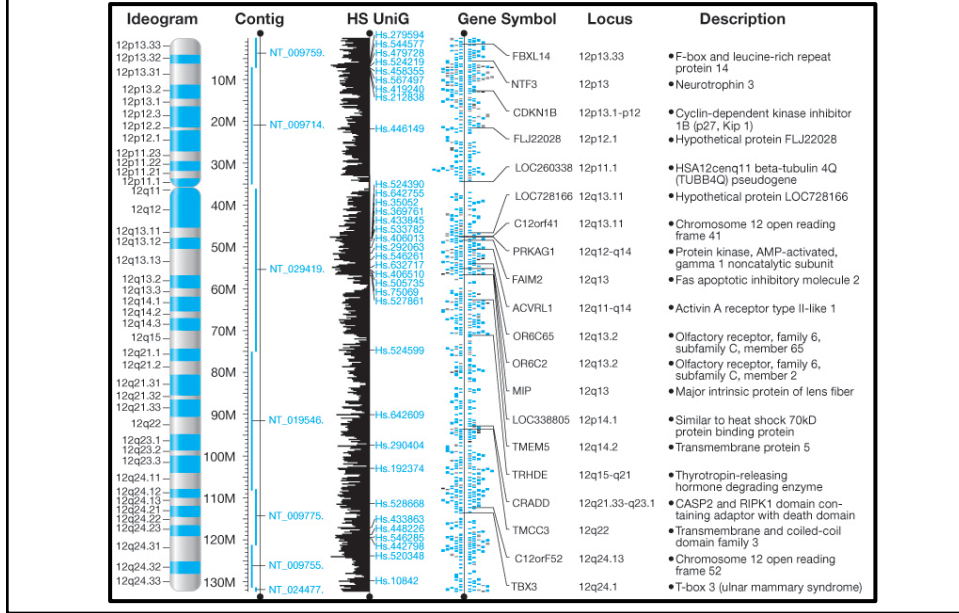
Genome-Wide Detection of Single-Nucleotide and Copy-Number Variations of a Single Human Cell

Science, December 20, 2012

The Era of Personalized Genomes is Here!

48

Knowledge of Human Gene Sequences Can Lead to Tests For Specific Genetic Disorders and Much More!



49

Genetic Engineering Has Enabled DNA Tests For Hundreds of Disease Genes and Human Traits - Generating Personalized Gene Profiles

And Before Birth!!!

Made Possible Because of Genetic Engineering!

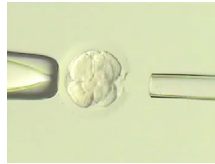
50

Determining the Genetic Identity of a Human Embryo Before Implantation!



Prenatal Genetic Diagnosis (PGD)

Fertility Clinics Scan for the Strongest Embryo

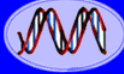


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DNA Testing Has Led To Inexpensive Home DNA Testing Kits!



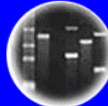
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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

.....Leading 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

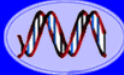
Contradictory Risk Predictions for Prostate Cancer and Hypertension

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.

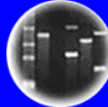
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DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

Genetic Engineering Has Led to the Era of
Human Gene Engineering - Using Gene Therapy
to Cure Lethal Genetic Diseases

Alabama Man Free of Sickle Cell After Gene Therapy

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

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

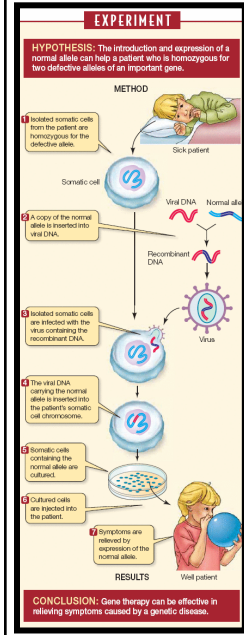
Gene therapy trial 'cures children'

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

DNA-swap technology almost ready for fertility clinic

54

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



Gene Therapy for Immunodeficiency Due to Adenosine Deaminase Deficiency

Gene Therapy with the Adenosine Deaminase (ADA) Gene



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DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

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And More Recently 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



Plants of Tomorrow



An early human embryo, the focus of controversy.

BIOETHICS
Embryo engineering alarm
Researchers call for restraint in genome editing

Genome-edited baby claim provokes international outcry

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.

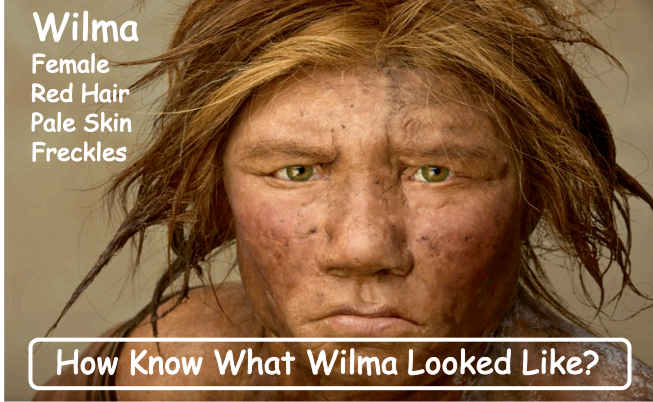
57

Genetic Engineering Has Made the Field of Ancient DNA Possible - Going Back in Time to Understand Human Origins

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.

58

Genetic Engineering Has Led to Remarkable New Insights into Human Origins and Ancestry

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

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 Genes in Our Chromosomes

It's All in the DNA! Nature Reviews | Genetics September, 2011

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DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

Inexpensive Home DNA Testing Kits Can Determine a Person's Ancestry!

And New Ethical Issues

- Surprise Ethnic Identity
- Identity of Biological Parents & Relatives
 - Genetic Privacy
- Unauthorized Use in Identifying Criminals

60



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? Your Neanderthal DNA might actually be doing you some good

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

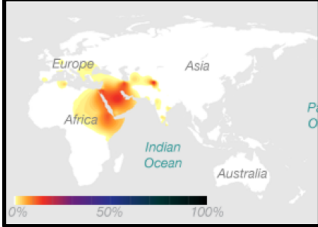


Without Genetic Engineering and DNA Sequencing Technologies This Could Not Have Been Done

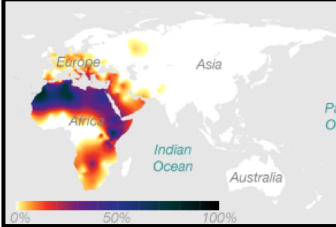
61

Home DNA Testing Has Revealed My Ancestry (No Surprises!)

Mom



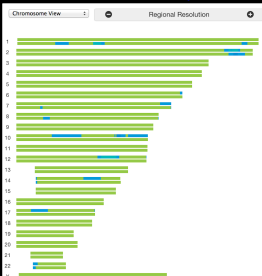
Dad



My Chromosomes

Chromosome View: Regional Resolution



Ancestry Composition tells you what percent of your DNA comes from each of 31 populations worldwide. The analysis includes DNA you received from all of your ancestors, on both sides of your family. The results reflect where your ancestors lived 500 years ago, before recombining their own genomes on the same.

	<table border="0"> <tr><td>100%</td><td>European</td></tr> <tr><td>95.2%</td><td>Ashkenazi</td></tr> <tr><td>0.6%</td><td>Eastern European</td></tr> <tr><td>0.2%</td><td>Northern European</td></tr> <tr><td>0.0%</td><td>Southern European</td></tr> <tr><td>3.0%</td><td>Broadly European</td></tr> <tr><td>0.0%</td><td>Middle Eastern & North African</td></tr> <tr><td>0.0%</td><td>Middle Eastern</td></tr> <tr><td>0.0%</td><td>North African</td></tr> <tr><td>0.0%</td><td>Broadly Middle Eastern & North African</td></tr> <tr><td>0.0%</td><td>Sub-Saharan African</td></tr> <tr><td>0.0%</td><td>West African</td></tr> <tr><td>0.0%</td><td>East African</td></tr> <tr><td>0.0%</td><td>Central & South African</td></tr> <tr><td>0.0%</td><td>Broadly Sub-Saharan African</td></tr> <tr><td>0.0%</td><td>South Asian</td></tr> <tr><td>0.0%</td><td>East Asian & Native American</td></tr> </table>	100%	European	95.2%	Ashkenazi	0.6%	Eastern European	0.2%	Northern European	0.0%	Southern European	3.0%	Broadly European	0.0%	Middle Eastern & North African	0.0%	Middle Eastern	0.0%	North African	0.0%	Broadly Middle Eastern & North African	0.0%	Sub-Saharan African	0.0%	West African	0.0%	East African	0.0%	Central & South African	0.0%	Broadly Sub-Saharan African	0.0%	South Asian	0.0%	East Asian & Native American
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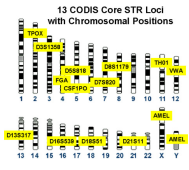
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DNA Has Impacted the Law & Forensics in Dramatic Ways!!!

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

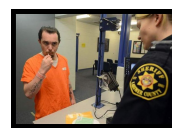




| CODIS Home Page | FBI Home Page |

October 2018

Offender Profiles	13,566,716	King vs. Maryland SCOTUS 4th Amendment Case
Arrestee Profiles	3,323,611	
Forensic Profiles	752,508	
Database "Hits"	440,346 assisting 428,808 investigations	

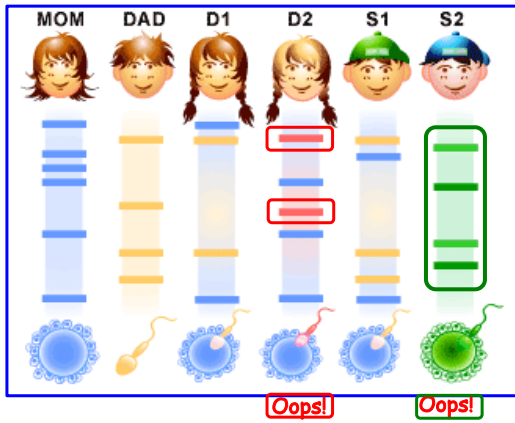


63

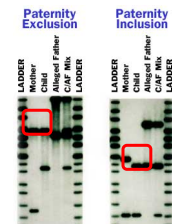
DNA Fingerprints Can Identify Individuals They Don't "Lie"

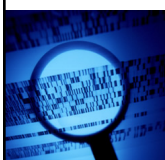
DNA Fingerprints

Sometimes They Reveal Unexpected Results!



What is YOUR DNA Fingerprint?





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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

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DNA Fingerprints Can Also Be Used To Uncover Fraud

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 filets, and overfished species are passed off as fish whose numbers are plentiful.



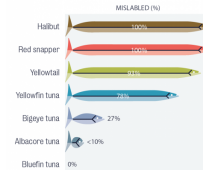
Herbal supplements fail DNA test in New York investigation of store brands

Just 21% of test results verified that DNA from plants listed on labels were what was inside, with only 4% of Walmart products passing test



HIGH RATES OF MISLABELING IN LA SUSHI RESTAURANTS

UCLA researchers used DNA barcoding to assess seafood served in Los Angeles restaurants from 2010 to 2010. They found 41 percent of fish had been mislabeled overall. However, mislabeling was inconsistent across different fish species, as shown below.



66

- DNA Genetic Code of Life
- Entire Genetic Code of a Bacteria
- DNA Fingerprinting
- Cloning: Ethical Issues and Future Consequences
- Plants of Tomorrow

Genetic Engineering Has Led to Crops Grown For Human And Animal Consumption

Crops That Are Grown For For Human & Animal Consumption

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Genetic Engineering Faster Growing Salmon For More Productive Aquafarms!

HOW THEY COMPARE

Species	Length	Weight
GM salmon	24ins	6.6lb
Farm salmon	13ins	2.8lb

*Both fish are 18 months

GMO salmon caught in U.S. regulatory net, but Canadians have eaten 5 tons

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

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



DNA Genetic Code of Life



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Plants of Tomorrow



Synthetic Genomes & Chromosomes 40 Years After the Invention of Genetic Engineering



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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

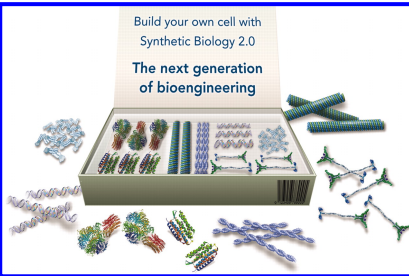
July 14, 2011

Genetic Code of E. Coli Is Hijacked by Biologists

By NICHOLAS WADE Science, July 15, 2011

Build your own cell with Synthetic Biology 2.0

The next generation of bioengineering




Synthetic Generation of Influenza Vaccine Viruses for Rapid Response to Pandemics Sci. Transl. Med., May 15, 2013

Think of the Possibilities.....


George Church: De-Extinction Is a Good Idea

Reviving mammoths and other extinct creatures is a good idea



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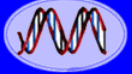
**A Yeast Cell With Chromosomes
Synthesized in the Laboratory From
A, G, C, & T DNA Bases !!!!**




Science
SYNTHETIC CHROMOSOMES
Remodeling the yeast genome piece by piece (p. 20)

\$15
10 MARCH 2017
sciencemag.org


AAAS




DNA
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Entire Genetic Code
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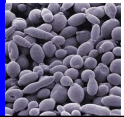
DNA Fingerprinting




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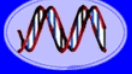





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**COVID Vaccines Synthesized in the
Laboratory From A, G, C, & U RNA
Bases !!!!**

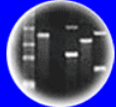
mRNA Vaccines




DNA
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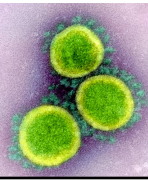
DNA Fingerprinting

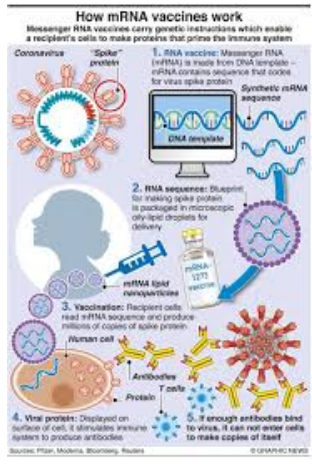


Cloning: Ethical Issues
and Future Consequences



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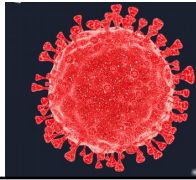





How mRNA vaccines work
Messenger RNA vaccines carry genetic instructions which enable a recipient's cells to make proteins that prime the immune system

- 1. mRNA vaccine:** Messenger RNA (mRNA) is made from DNA template — mRNA contains sequence that codes for virus spike protein
- 2. RNA sequence:** Blueprint for making spike protein. It's packaged in microscopic oily-lipid droplets for delivery.
- 3. Vaccination:** Recipient cells read mRNA sequence and produce millions of copies of spike protein
- 4. Virus proteins:** Displayed on surface of cell. It stimulates immune system to produce antibodies
- 5. If enough antibodies bind to virus, it can not enter cells to make copies of itself**

Source: Pfizer, Moderna, Bloomberg, Reuters © GRAPHIC NEWS

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**These Are These Issues
That Will Be Covered in
HC70A & the Science
Driving the Genetic
Engineering Technology
Revolution**

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**HC70A Spring 2021
Genetic Engineering in Medicine,
Agriculture, and Law
Professor Bob Goldberg**

**Class Announcements
3/30/21**

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HC70A Winter 2021
**Genetic Engineering in Medicine,
Agriculture, and Law**

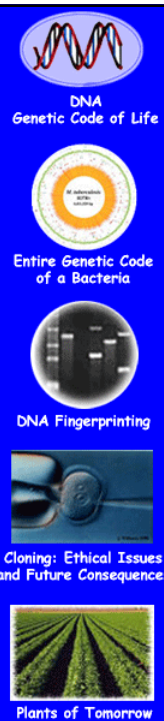
Course Administrator
Dr. Lauren Bowman

Discussion Coordinator
Dr. Kelli Henry

Learning Assistants
Pierce Ford
Ava Gordon

UCLA

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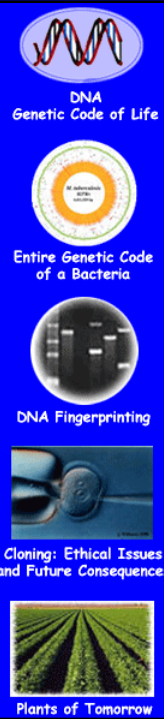
Cloning: Ethical Issues
and Future Consequences

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Discussion Tomorrow

- Your Perceptions of Genetic Engineering & Its Applications
- Fill Out Survey Downloaded From CCLE Website and Upload It Before Tomorrow's Discussion
- Be Prepared For a Lively Discussion
- I Will Discuss Unique Aspects of HC70A and Grading

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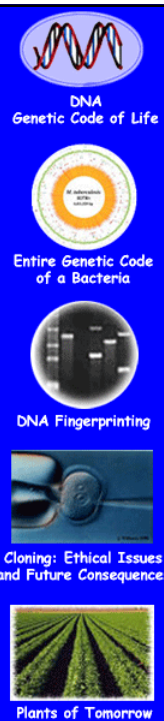
Cloning: Ethical Issues and Future Consequences

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What Can You Do This Quarter?

- **Study the Lecture Slides**
- **Read Articles For Discussion**
- **Read Text to Reinforce Lecture Concepts**
 - **Ask Questions**
- **Work Together!!!!!!!!!!!!**
- **Come to My Office Hours**
 - **Friday 2:00 - 4:00 pm**

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Syllabus & Survey Can Be Downloaded From CCLE Website After Class

I Will Answer Your Questions About HC70A At the Beginning of Discussion Tomorrow

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