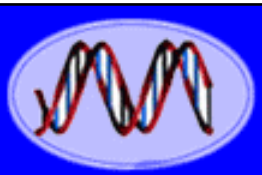

DNA
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Entire Genetic Code
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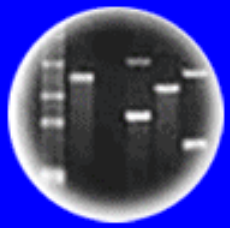


DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

HC70A, SAS70A, & PLSS059
Winter 2019
Genetic Engineering in Medicine, Agriculture, and Law

Professors Bob Goldberg, John Harada, & Channapatna Prakash

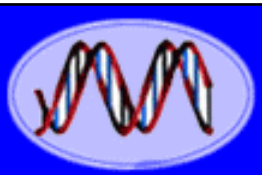
Lecture 1
The Age of DNA: What Is Genetic Engineering-Part One

Please Turn Off Your Cell Phones!!

UCLA

TUSKEGEE UNIVERSITY

UCDAVIS UNIVERSITY OF CALIFORNIA



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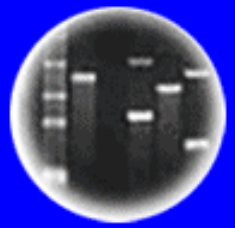

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LECTURE THEMES

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

The Politics of....

GMOs

US rethinks crop regulation

Committee begins study to guide oversight of gene-edited organisms.

Congress Passes GMO Food Labeling Bill

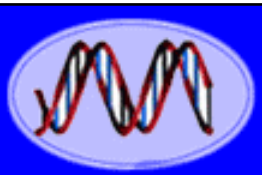
The world's first GMO apple will not turn brown, but is it safe?

FDA, EPA approve 3 types of genetically engineered potatoes

Genetic Details of Controversial "3-Parent Baby" Revealed

Justices Back Monsanto on Biotech Seed Planting

Human Gene Editing Receives Science Panel's Support



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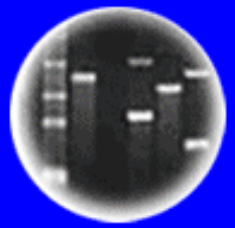

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Genetic Engineering in the News..

Law

Congress Passes Bill to Bar Bias Based on Genes

Scientists want relaxation of laws to allow gene editing of human embryos

Justices, 9-0, Bar Patenting Human Genes

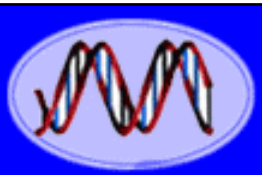
Harvard and M.I.T. Scientists Win Gene-Editing Patent Fight

Supreme Court OKs DNA swab of people under arrest

DNA Test Frees Man After 34 Years In Prison

Supreme Court Supports Monsanto in Seed-Replication Case

Congress Passes GMO Food Labeling Bill



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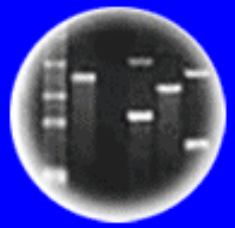

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Genetic Engineering in the News..

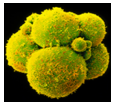
Medicine

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

Gene therapy trial 'cures children'

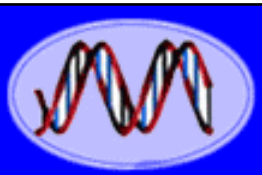
British Lawmakers Approve 'Three-Parent' In-Vitro Fertilization

Chinese scientists genetically modify human embryos



Genome-edited baby claim provokes international outcry

Scientists Talk Privately About Creating a Synthetic Human Genome



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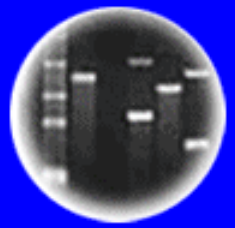

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Genetic Engineering in the News..

Agriculture

Genetically Modified Salmon Is Safe To Eat, FDA Says

Super-muscly pigs created by small genetic tweak

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

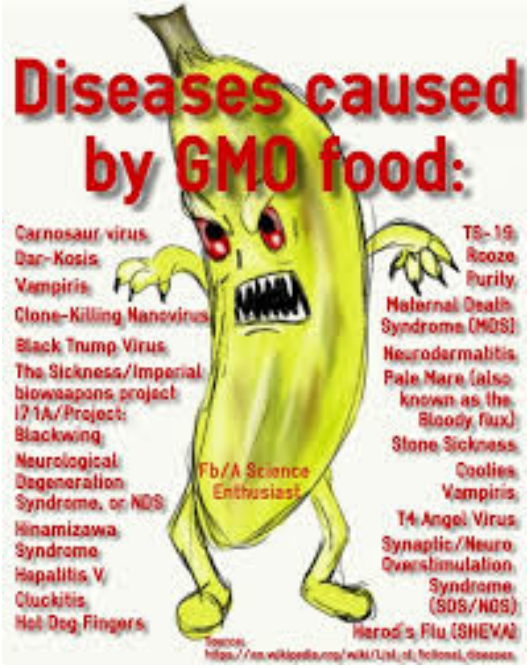
GM Wheat Used to Make Bread with Less Gluten

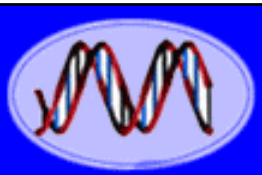
GM banana shows promise against deadly fungus strain

Scientists hack plant photosynthesis to boost crop yields by 40%

January 3, 2019

And All the GMO Misconceptions!!!!!!





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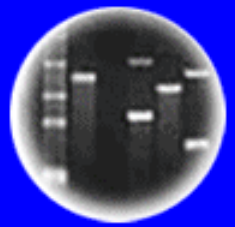

DNA Fingerprinting

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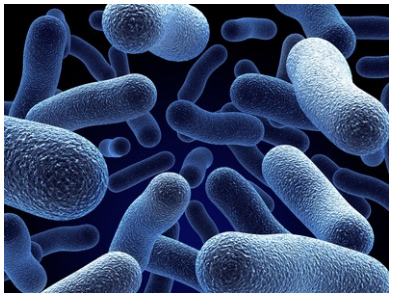
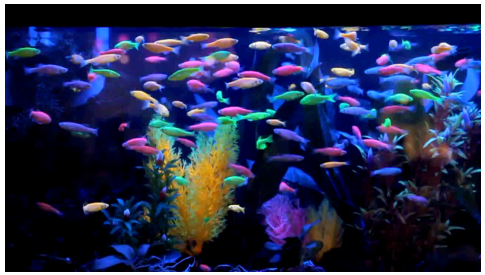
What's a GMO???

So……..What is a GMO?

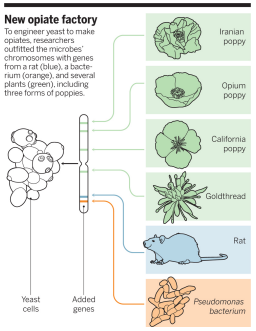


A Genetically Engineered Bacteria Synthesizing Human Insulin Used as a Drug to Treat Diabetics?



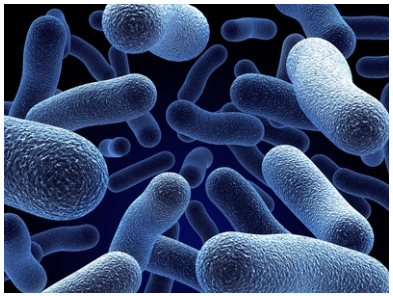
A Genetically Engineered GloFish Used as a Pet?

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



A Genetically Engineered Yeast That Synthesizes Opiates For Medicine?

So……..What is a GMO?



A Bacteria With a Genome Synthesized in a Laboratory?

A Yeast With Chromosomes Synthesized in a Laboratory?

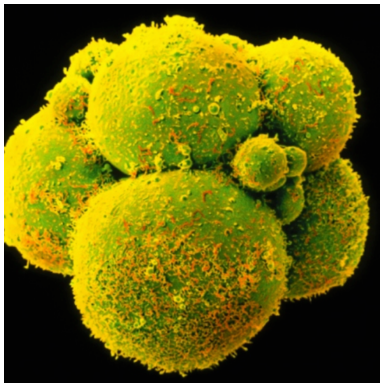
A Genetically Engineered Bacteria Making Blue Dye For Jeans?

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

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 "Cures" a Lethal Genetic Disease?



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



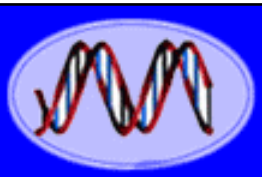








So……What is a GMO?



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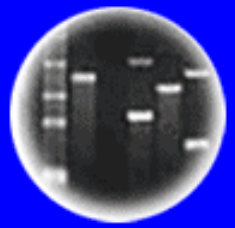

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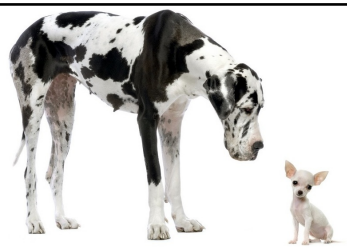
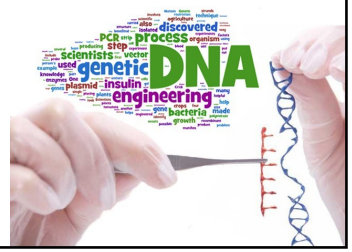
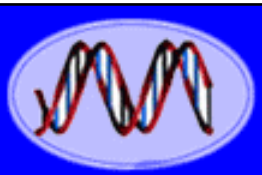


What is Genetic Engineering and a Genetically Modified Organism?

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

ge·net·ic en·gi·neer·ing
jəˈnedik ˌenjəˈni(ə)riNG/
noun
noun: genetic engineering
the deliberate modification of the characteristics of an organism by manipulating its genetic material.





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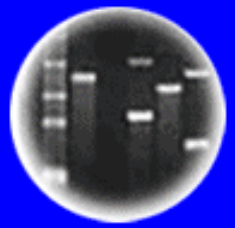

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Plants of Tomorrow

Genetic Engineering is the TECHNIQUE! That Generates GMOs

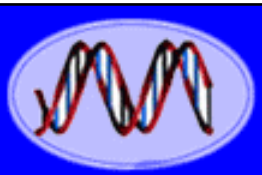
1. Classical Breeding By Selective Mating (Thousands of Years)
2. Insertion of New Genes Into An Organism's Chromosomes (50 Years) – Transgenic Organism
3. Editing Existing Genes Like A "Word Program" (1-2 Years) – CRISPR Gene Editing

Breeding or DNA Manipulation – They Are the SAME

&

Called *Gene Manipulation*

So…….WHAT IS A GMO???



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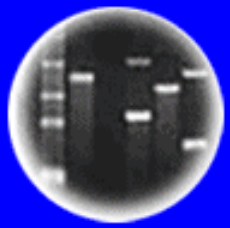

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Three Genetic Engineering Techniques That Generate GMOs!!!

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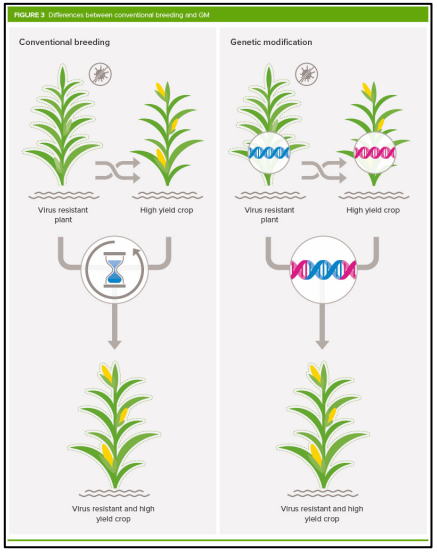
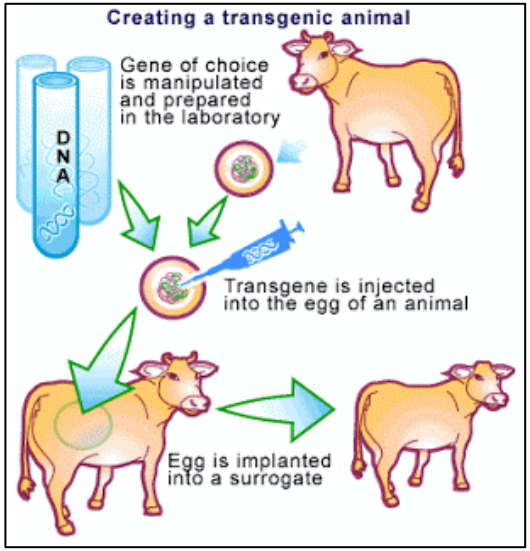
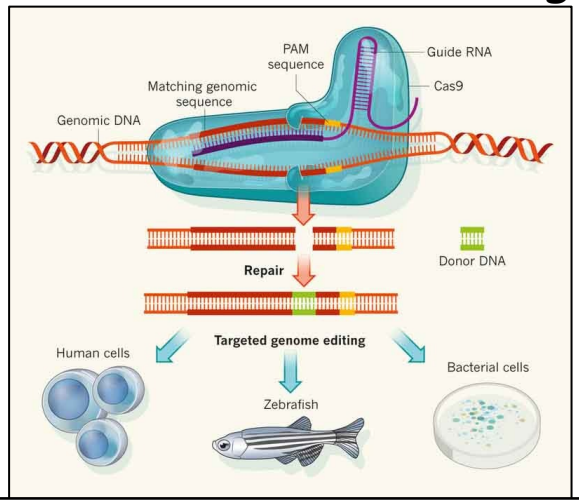


2. Transgenic Organism



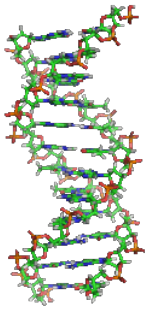
3. CRISPR Gene Editing

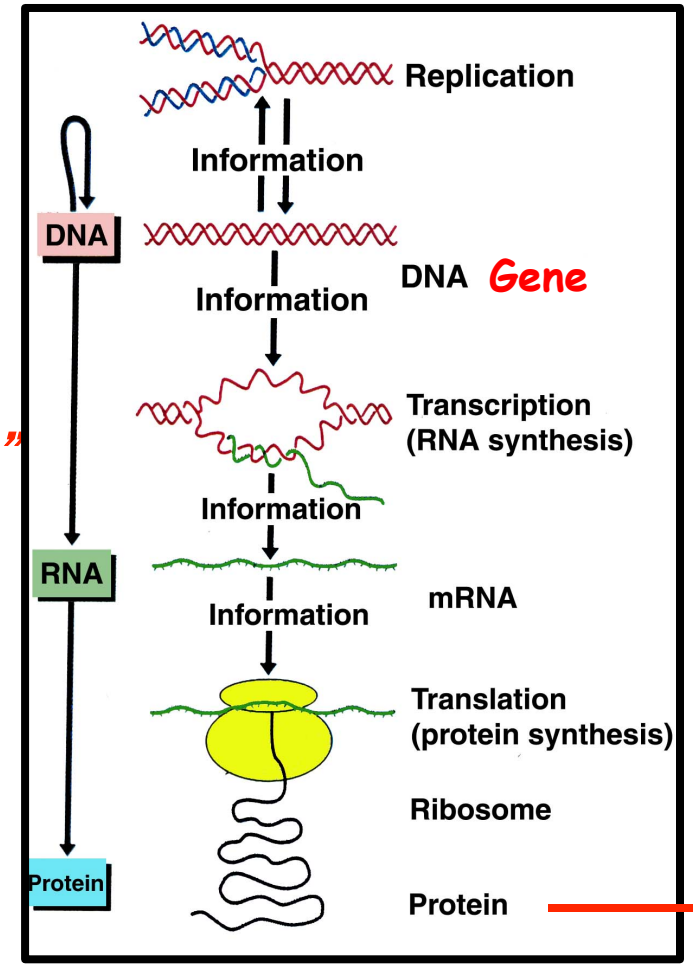


Genes & DNA Obey the Same Rules Using Either Classical or Modern DNA Engineering Approaches!! BOTH Produce GMOs!!!!!!!

Can Intervene in This Process in Cells

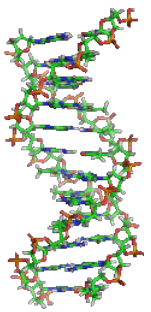
Genetic Engineering Is not "Hocus Pocus." It Uses "Natural" Cell Processes!!!!

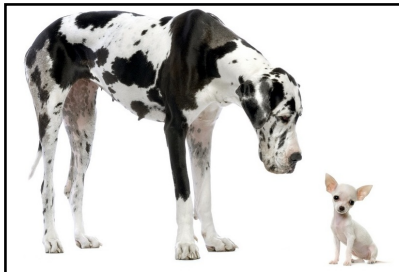




All Organisms Use The SAME Processes And "RULES" to Generate Traits!! And The SAME Molecules & Chemistry!!

Coat Color Trait



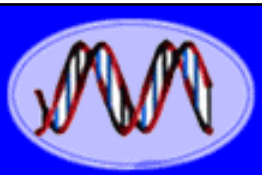


Important HC70A Theme!

We Live in The Age of Genetic Engineering!

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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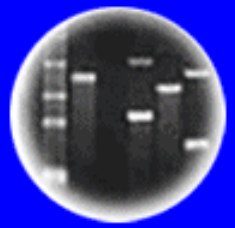

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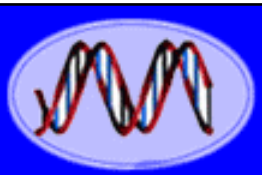
What Does Your DNA Look Like?

Have You Ever Seen or Touched Your Genes?



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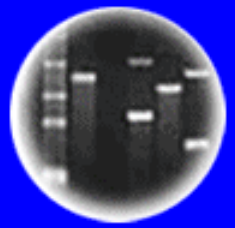

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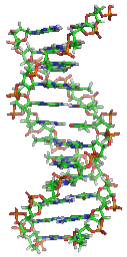
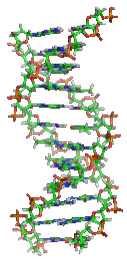
How Was Genetic Engineering Using DNA Invented?

&

How Did It Lead To Remarkable Advances In Medicine, Agriculture, & Law?





DNA Genetic Engineering Has Been in the News For 45 Years!!! It's Old Technology!!!!!!

Gene Transplants Seen Helping Farmers and Doctors

By VICTOR K. MCELHENY MAY 20, 1974

1974

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

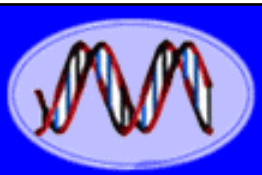
By HAROLD M. SCHMECK Jr. Special to The New York Times (); May 24, 1977.

1977

Substance Usually Made in Brain Grown in Bacteria

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

1976



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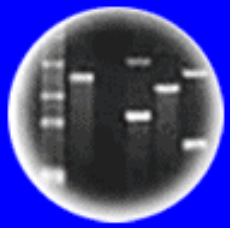

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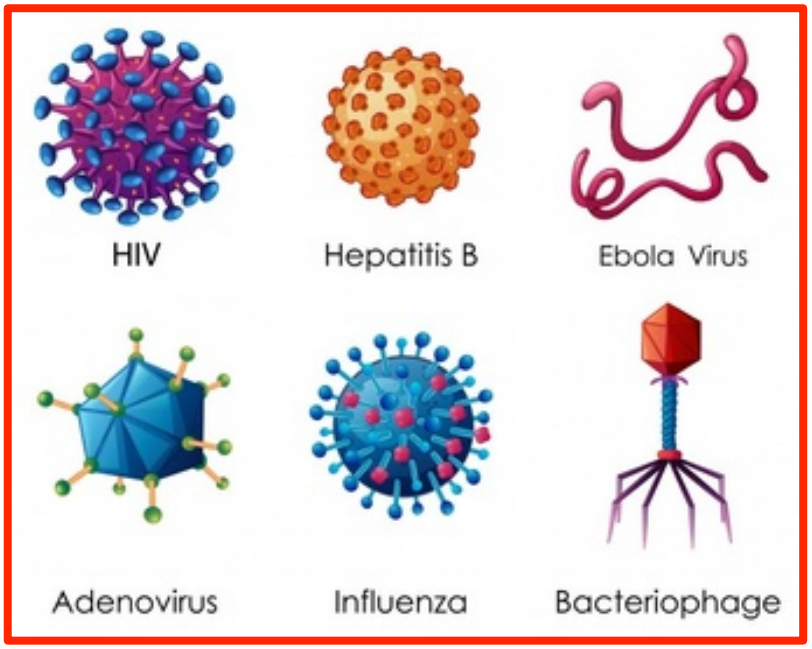
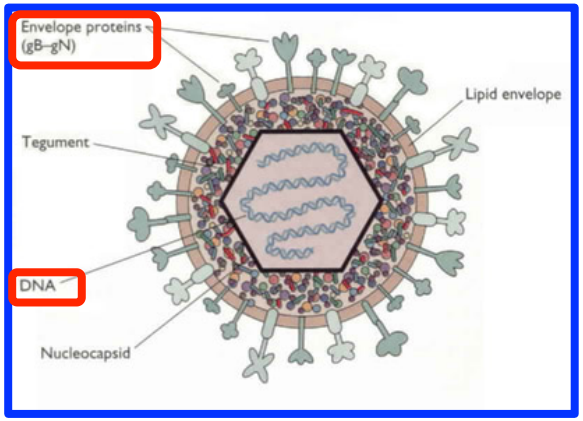
The Idea That DNA From Different Species Could Be Recombined Started With Viruses 46 Years Ago!

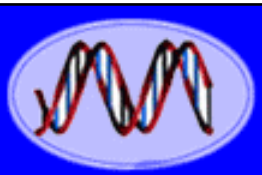
There is a Variety of Viruses That Engage in "Warfare" With Living Cells of Diverse Organisms



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



They Exist to Exist!!!



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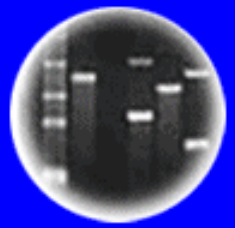

DNA Fingerprinting

Cloning: Ethical Issues
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Plants of Tomorrow

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

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 stepwise 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.

Paul Berg

The prospect of recombinant DNA emerged from a series of advances in biochemistry—most especially, from discoveries 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 much-studied SV40 monkey virus and a bacterial virus known as the l (or lambda) bacteriophage. The SV40 virus has few genes, lacks a protein coat, and is is convenient to work with. The l 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 cells, as in nature, 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 (another enzyme) 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 anneal naturally. Addition of DNA ligase would seal the plasmid. In succeeding with a series of enzymatic reactions, Berg wrote that his methods "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 in humans, the prospect of an altered form of the virus spreading through such a common bacterial agent as *E. coli* caused Berg to defer part of his 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 "his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant DNA."

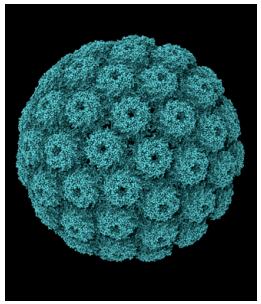
Proc. Nat. Acad. Sci. USA
Vol. 69, No. 10, pp. 2904–2909, October 1972

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

(molecular hybrids/DNA joining/viral transformation/genetic transfer)

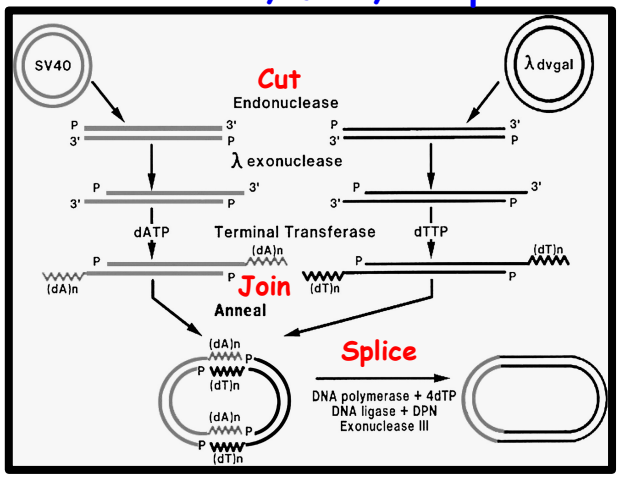
DAVID A. JACKSON*, ROBERT H. SYMONS†, AND PAUL BERG

Simian Virus 40



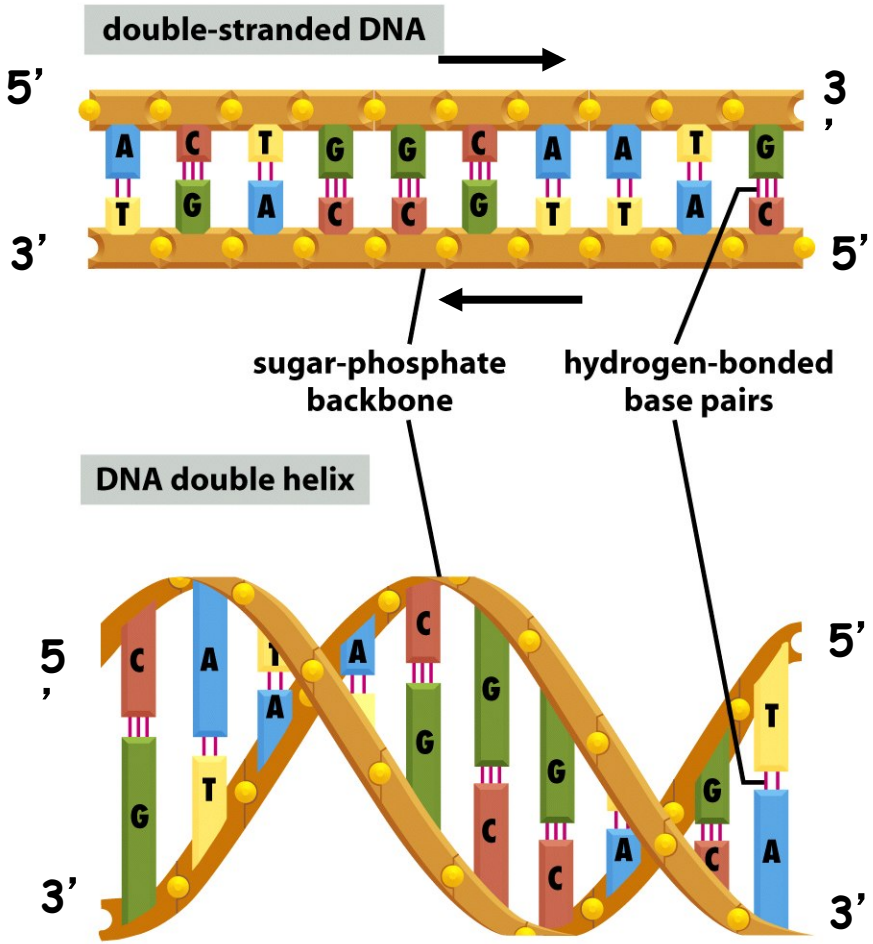
λ Bacteriophage

"Cut, Join, & Splice"

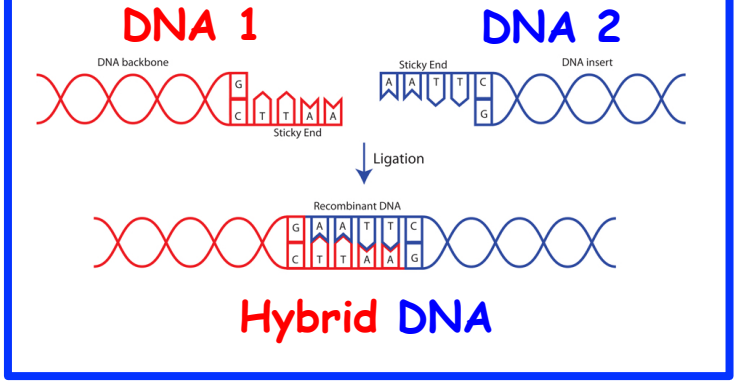


In Test Tube Only!

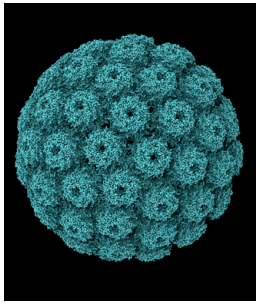
Major HC70A Concept - Complementary Bases of the DNA Double Helix Allows Two DNAs to be Spliced (Joined) Together & Form a Hybrid



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

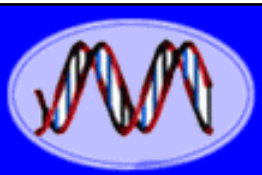


Simian Virus 40



λ Bacteriophage

Major Genetic Engineering Concept!!



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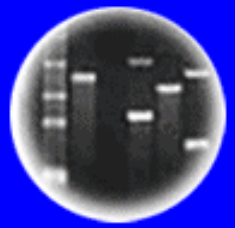

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Modern Genetic Engineering of Living Cells Was Invented a Year Later & Caused a Revolution in Biology – 45 Years Ago!

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

This is the 45th Anniversary of Genetic Engineering's Origins

Construction of Biologically Functional Bacterial Plasmids *In Vitro*

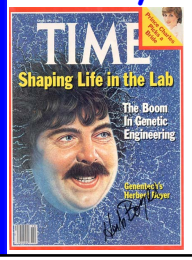
(R factor/restriction enzyme/transformation/endonuclease/antibiotic resistance)

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

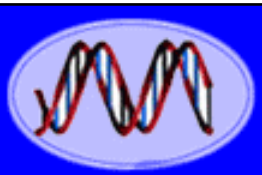
Communicated by Norman Davidson, July 18, 1973

Herb Boyer



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

Stanley Cohen



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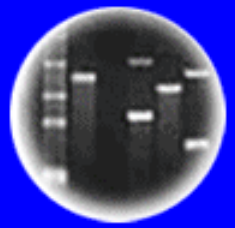

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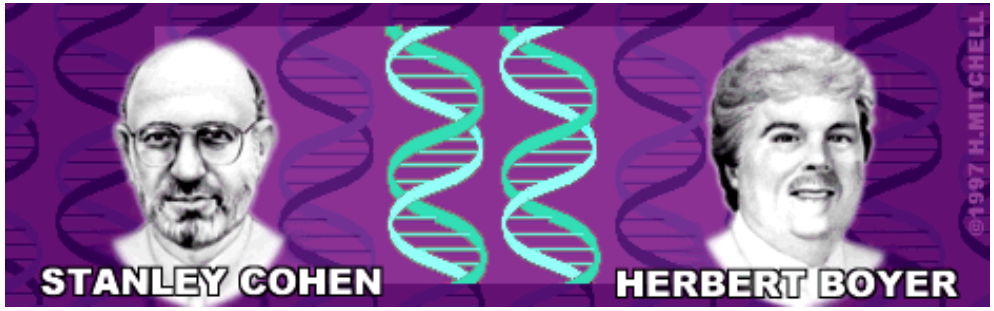
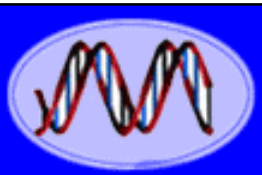
Modern Genetic Engineering Was Invented in 1973 With An Unexpected "Eureka" Moment Dealing With Two Unrelated Areas of Study Related To Bacterial Defense Systems:

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





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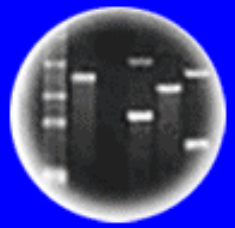

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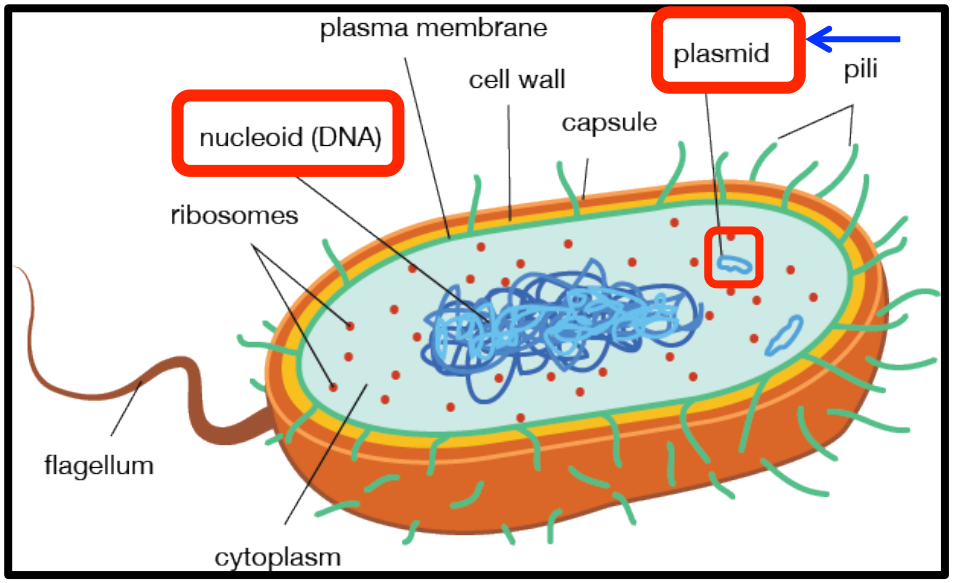
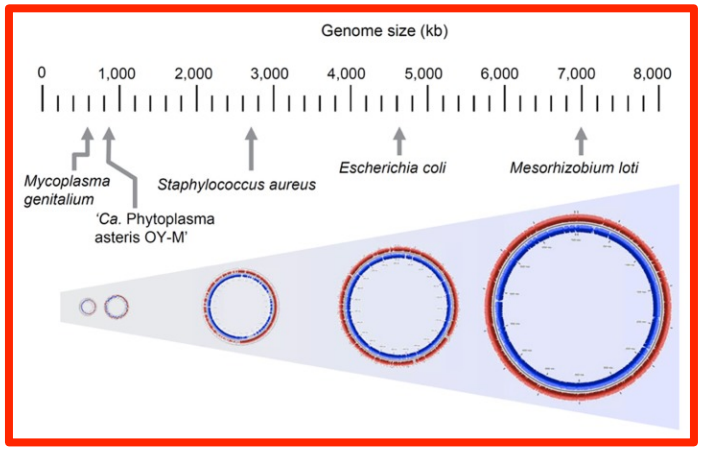
A Typical Bacterial Cell

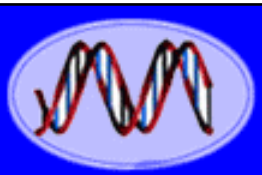


1. Replicates/Divides
2. Produces Energy
3. Responds to Stimuli
4. Communicates

Bacterial Chromosomes Are Circular & Contain 500 to 7500 Genes



Humans Have
Linear Chromosomes
With 25,000 Genes



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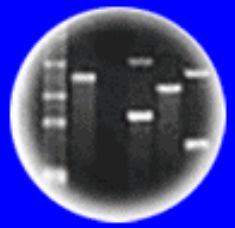

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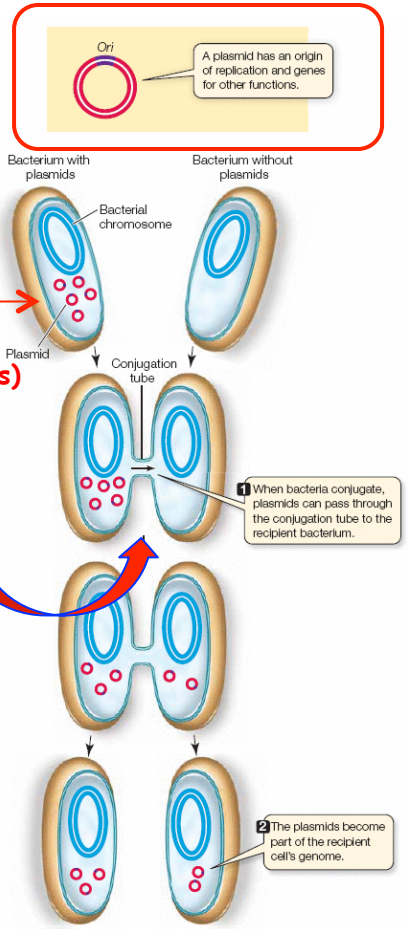
Bacteria Also Contain Plasmids - Circular Self-Replicating DNA Molecules - That Carry Antibiotic Resistance Genes

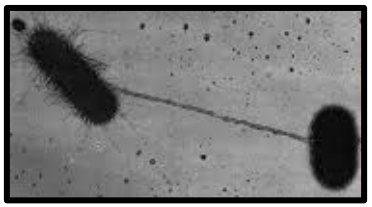
Stanley Cohen

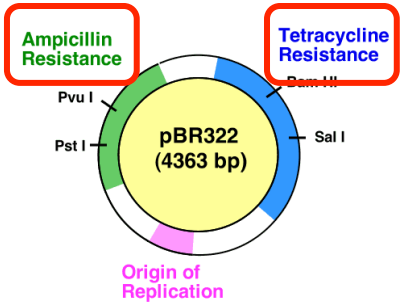
Electron Micrograph

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



Bacteria Mating



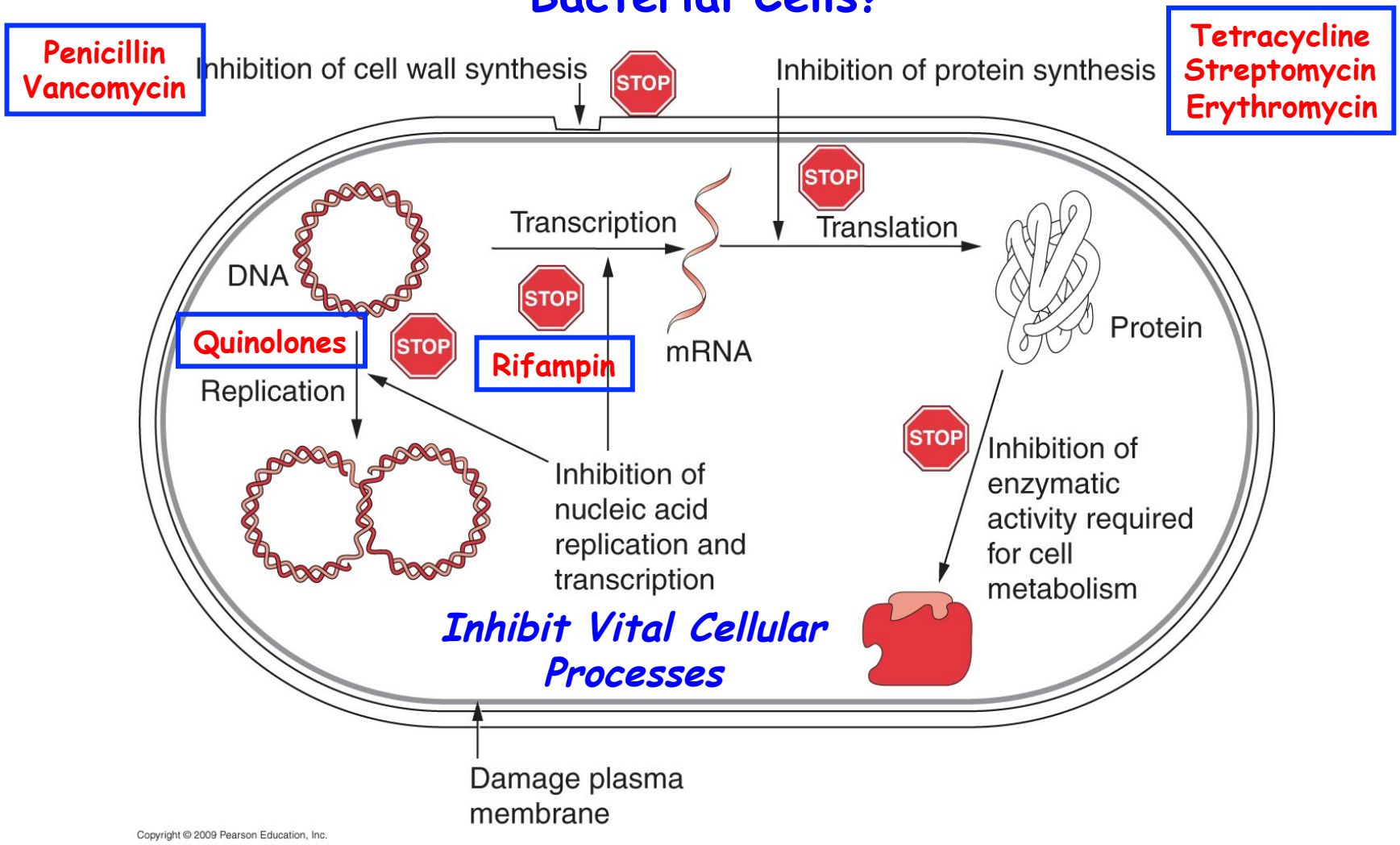


Small Plasmids Move From Cell to Cell Spreading Antibiotic Resistance Genes in Bacterial Populations!

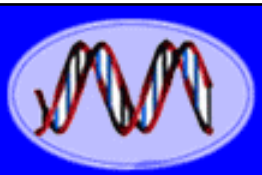
Plasmids Defend Bacteria Against Antibiotics!

(The "Workhorses" or Vectors for Genetic Engineering)

Microorganisms Produce Antibiotics To Protect Themselves Against Predators (Cellular "Warfare") - How Do Antibiotics Kill Bacterial Cells?



Plasmid Antibiotic Resistance Genes Allow Bacteria to "Fight Off" the Effects of Antibiotics & Select For Genetically Engineered Organisms!



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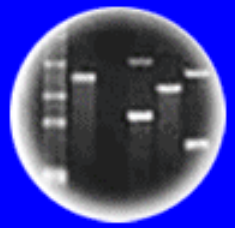

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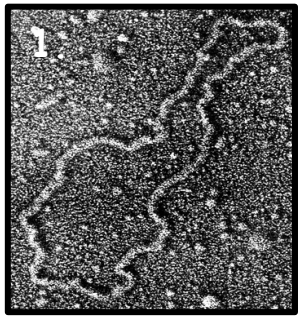
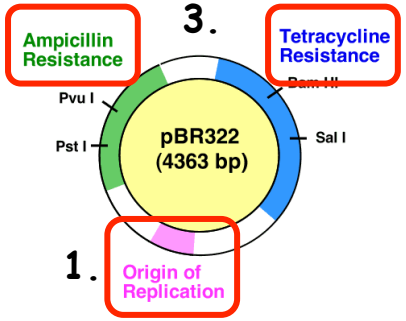
Plasmid Properties Making Them Ideal For Genetic Engineering





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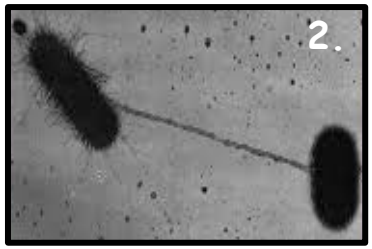
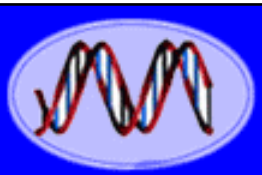


1. Small DNA Molecule That Can Self Replicate (Copy Itself)
2. Can Move Between Bacterial Cells – Easy to Isolate & Put Back In Cells
3. Have Antibiotic Resistance Genes – Can Select Bacteria With a Plasmid
4. Easy To Manipulate & Modify With Foreign Genes

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



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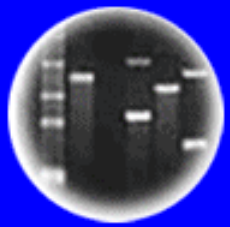

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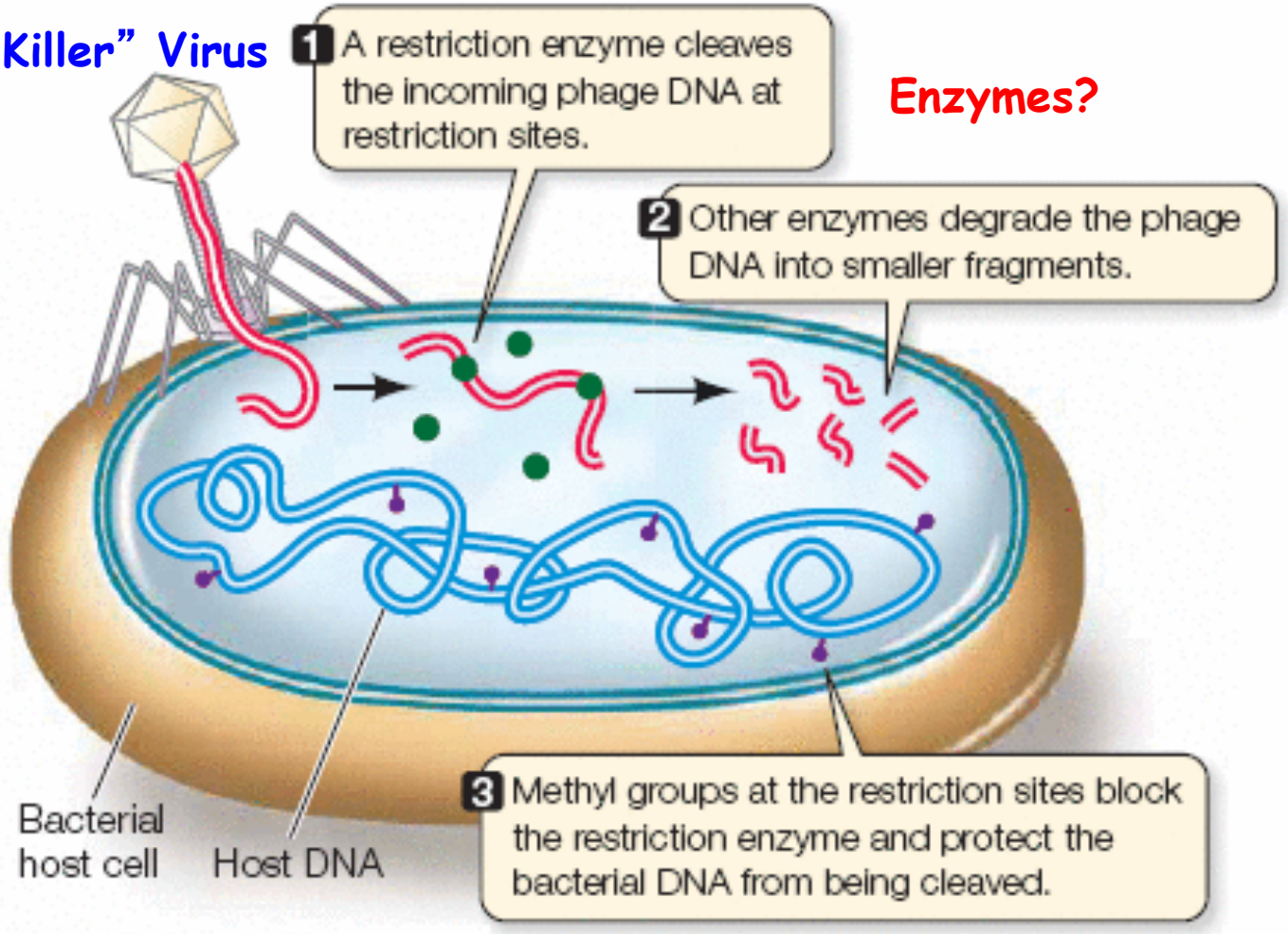
Restriction Enzymes Are Proteins in Bacteria That "Cut" DNA Into Pieces

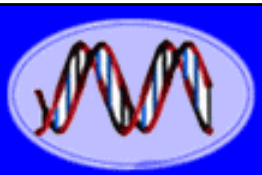
Herb Boyer

"Killer" Virus



Enzymes?

Restriction Enzymes Protect Bacteria From "Killer" Viruses!



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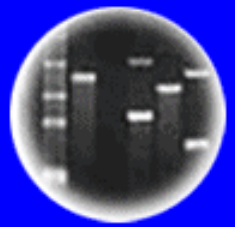

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Properties of Restriction Enzymes

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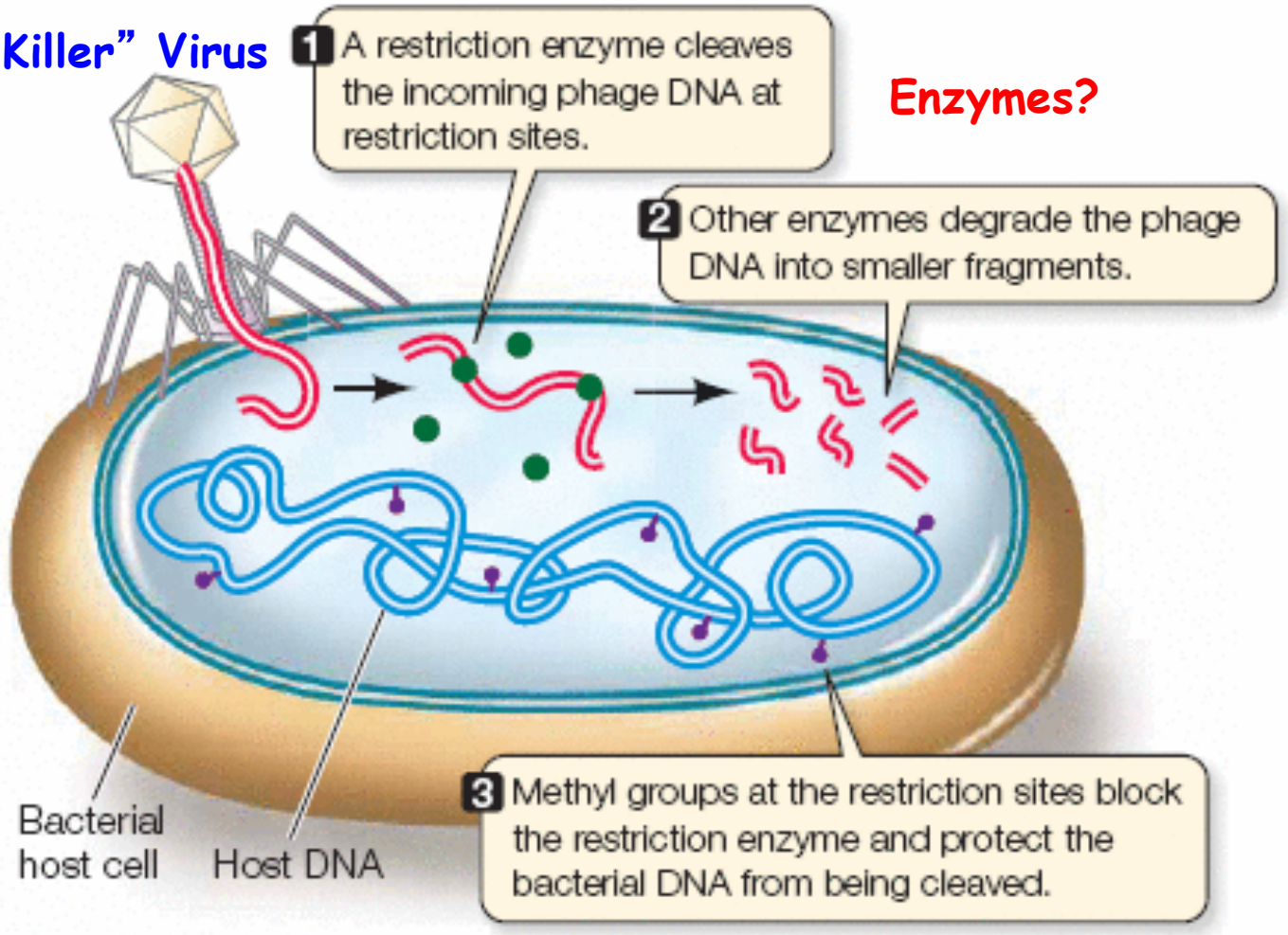

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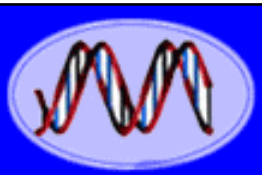

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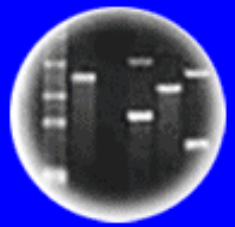

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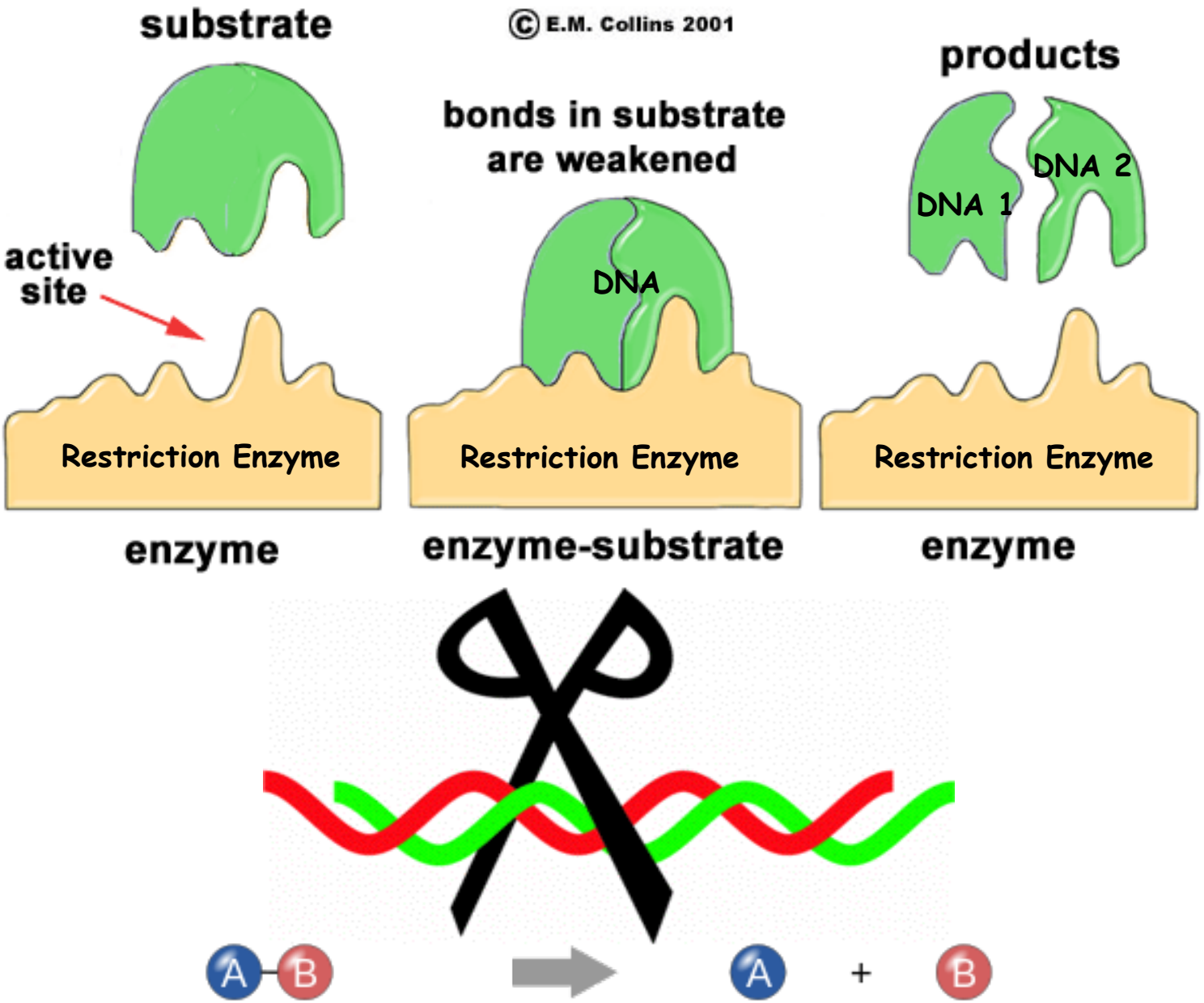
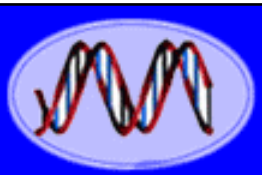
Enzymes Are Proteins That Catalyze or Facilitate Chemical Reactions





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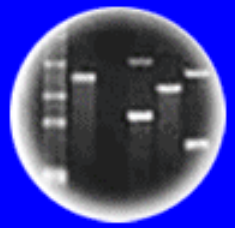

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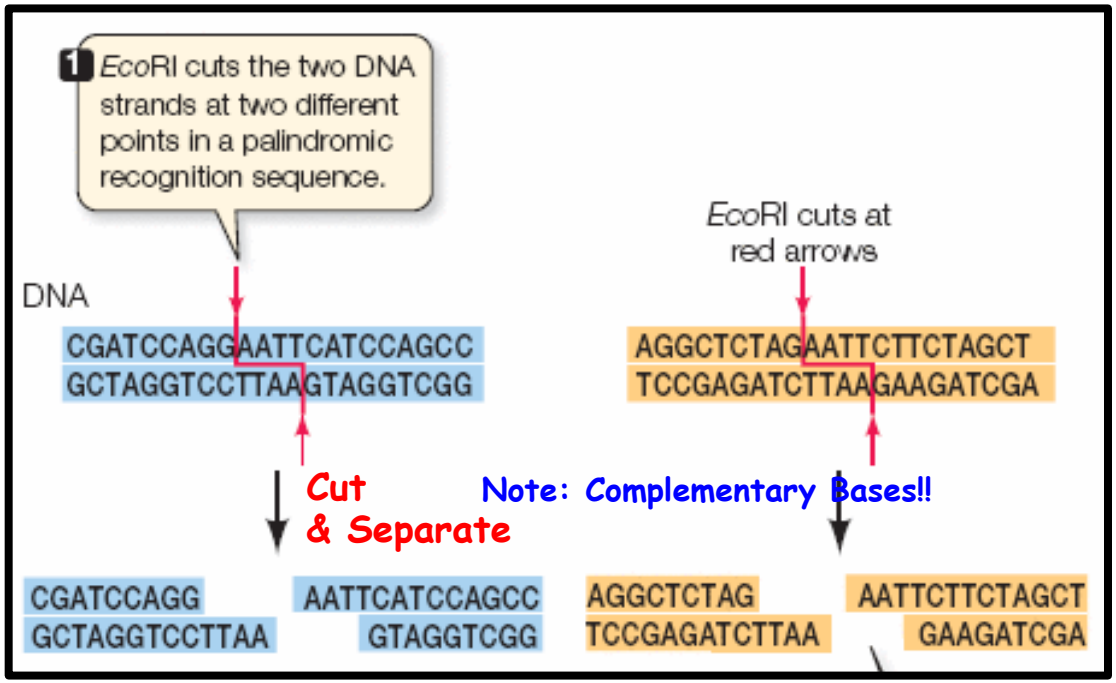
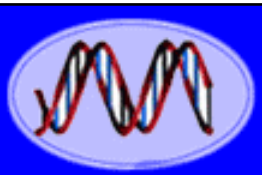


The "Scissors" For Genetic Engineering



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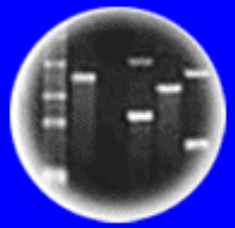

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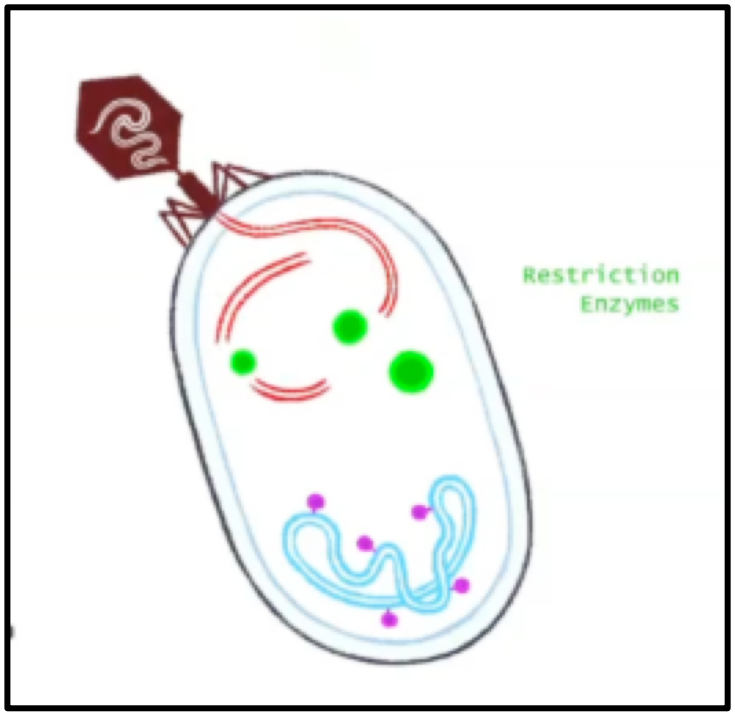
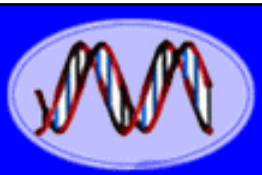
Herb Boyer's Restriction Enzymes Digesting DNA



Restriction Enzymes Protect Bacteria From "Killer" Viruses!



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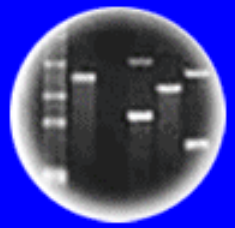

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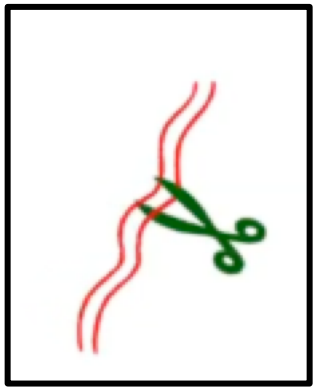
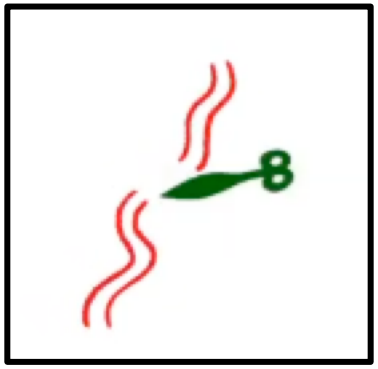
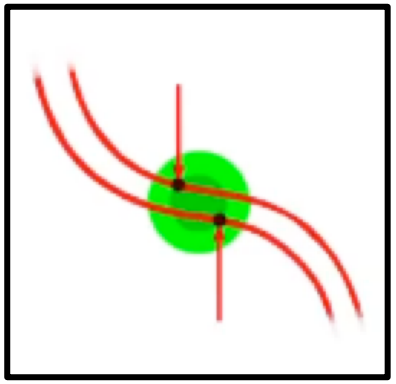
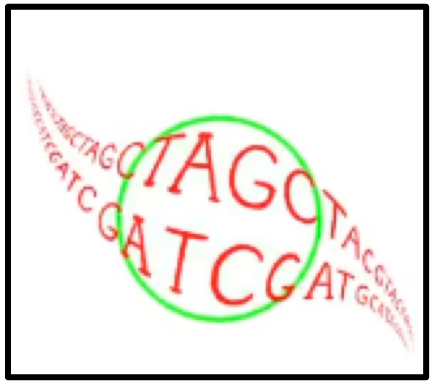
Plants of Tomorrow

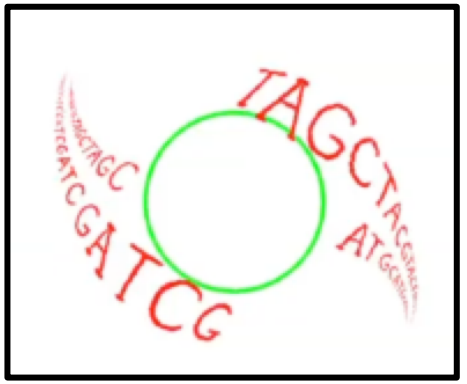
Restriction Enzymes Digest DNA At Specific DNA Sequences That Produce "Sticky Ends" That Can Be Used to Join ANY Two DNA Molecules

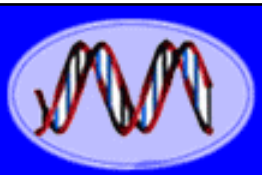






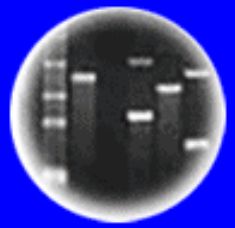






DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

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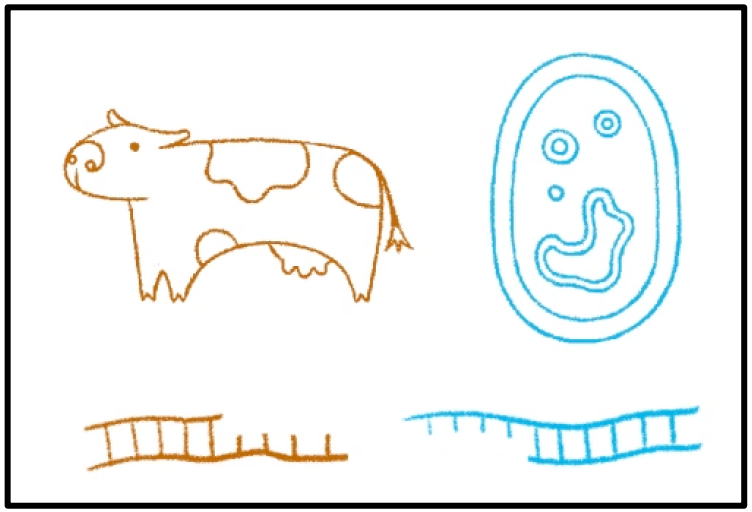

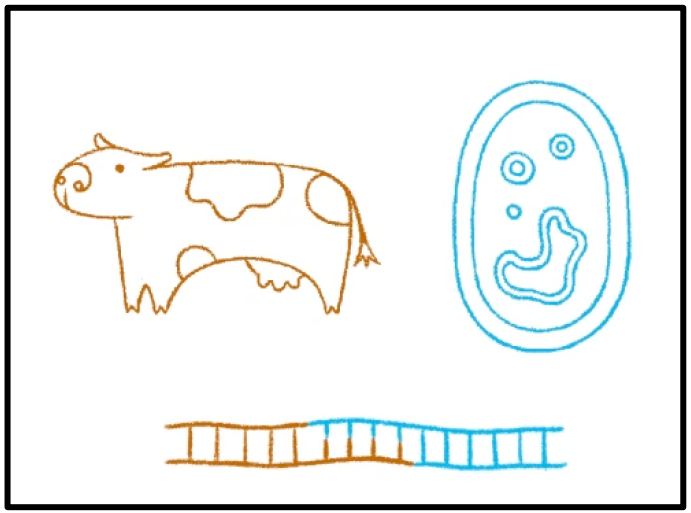

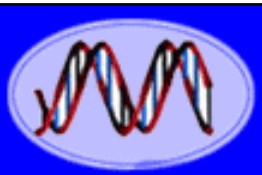

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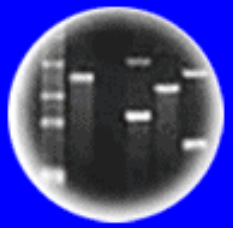

DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

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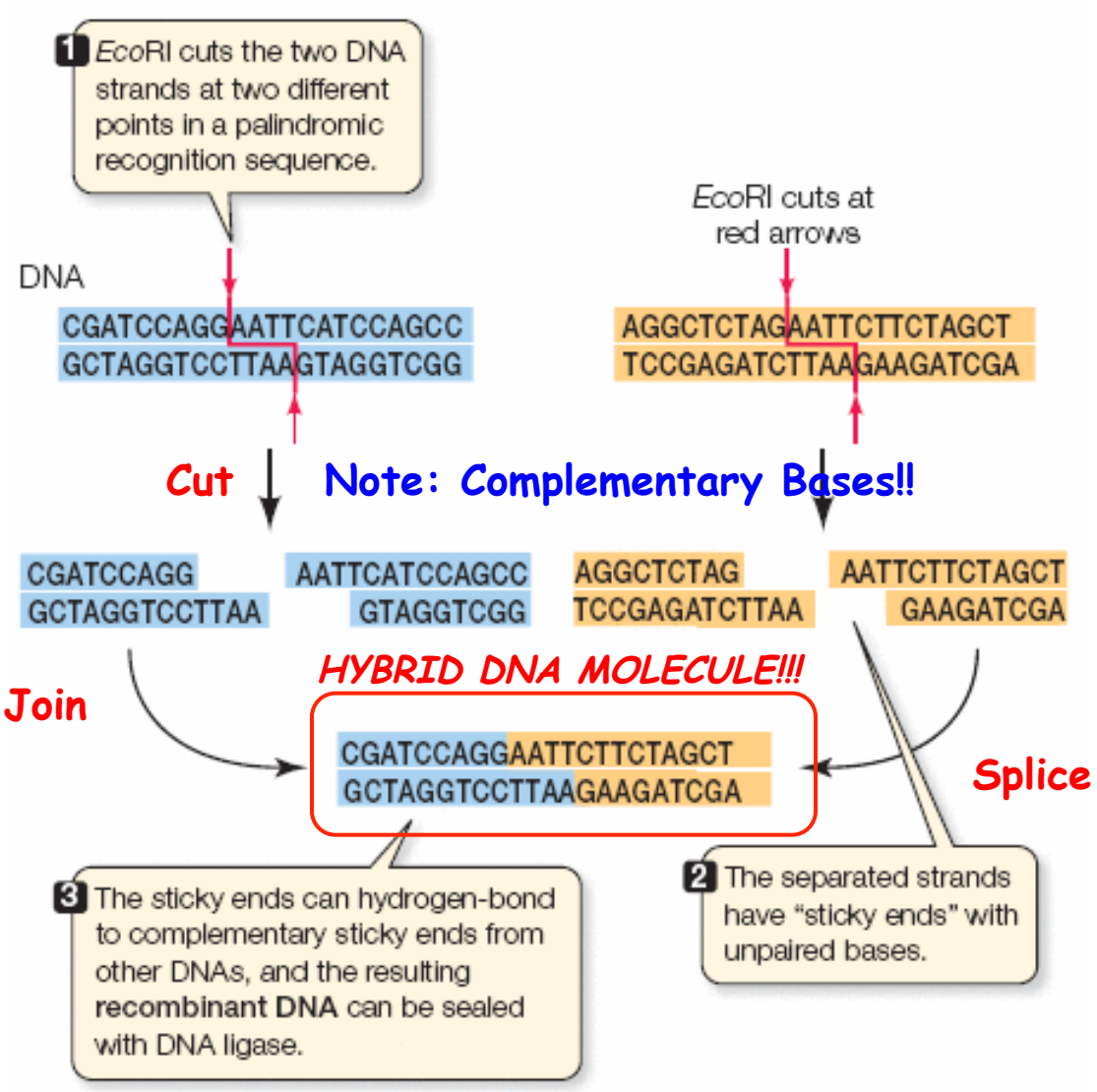
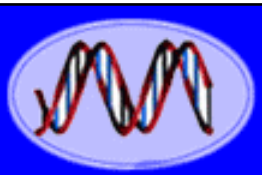
DNA Fragments of Different Origins "Cut" By the SAME Restriction Enzyme Can Re-Join and Form a HYBRID DNA Molecule!!!



The "Scissors" For Genetic Engineering



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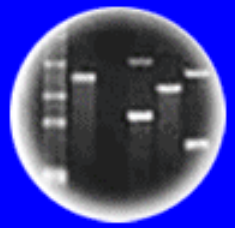


DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

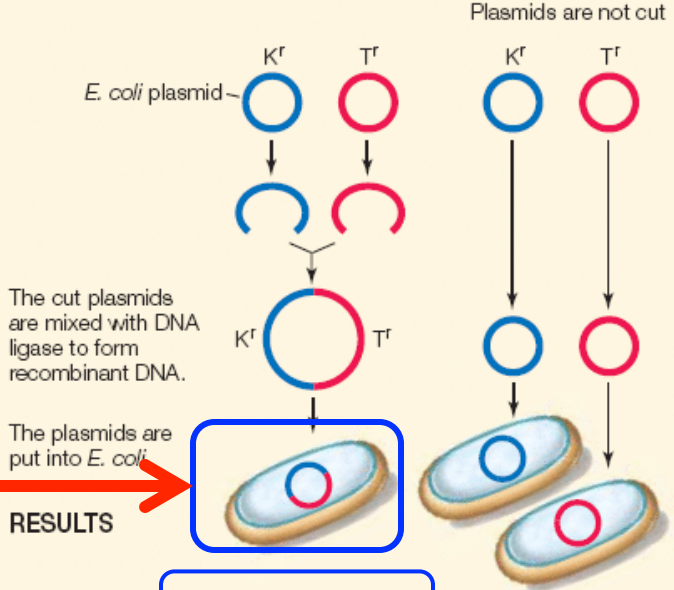
The Cohen-Boyer Experiment That Started the Gene Engineering Revolution

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

EXPERIMENT

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

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



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

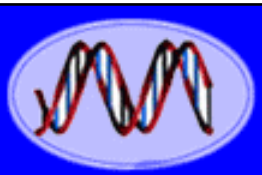
Cut
↓
Join
↓
Splice

Genetically Engineered Bacteria!!!

Insert Back Into Bacterial Cell
Transform

Hypothesis?
Predictions?

This Was the FIRST GMO!!!



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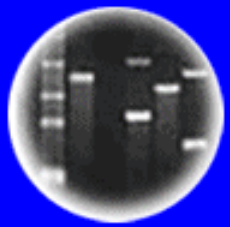

DNA Fingerprinting

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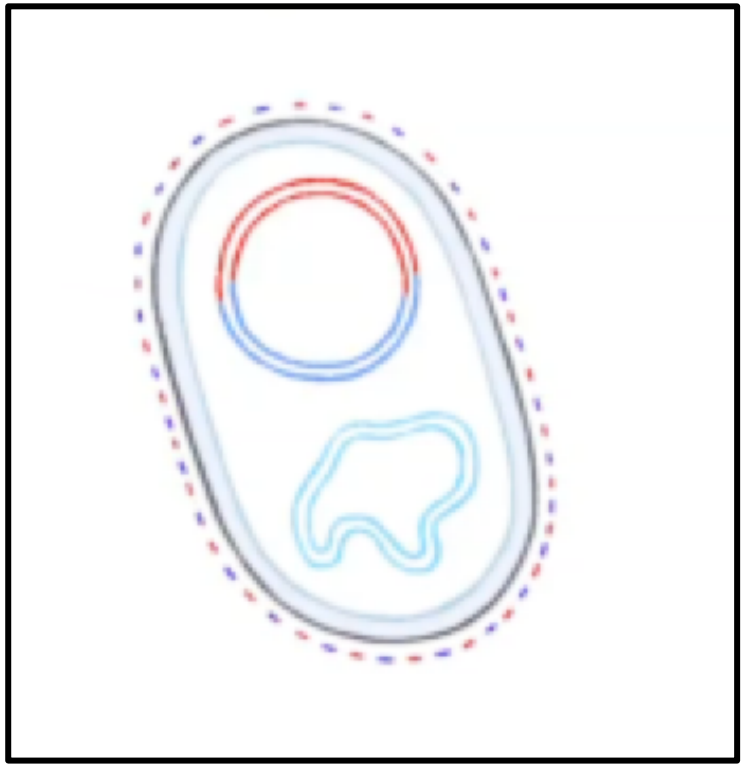
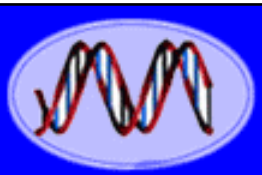
Genetic Engineering Technology Can Combine DNA (Genes) From Different Sources Leading to New Gene Combinations!!

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





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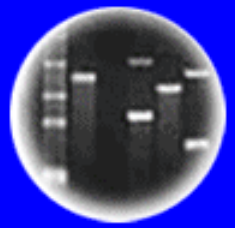
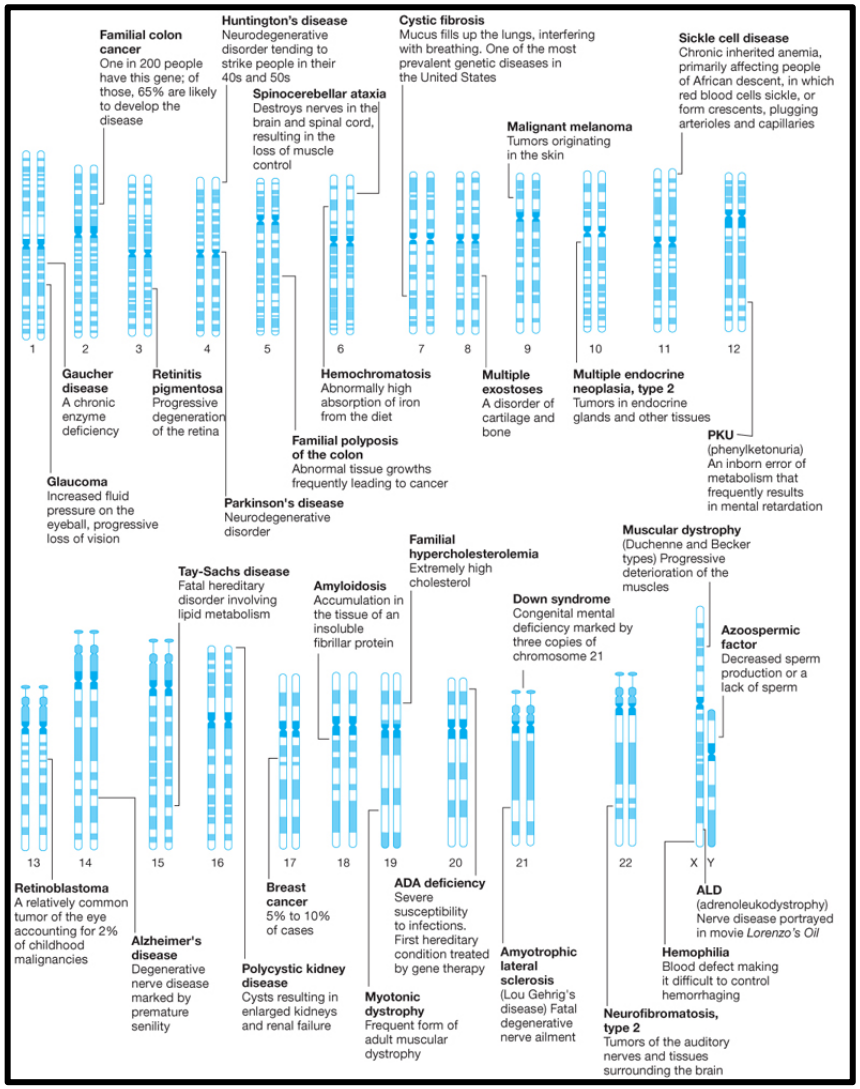


DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

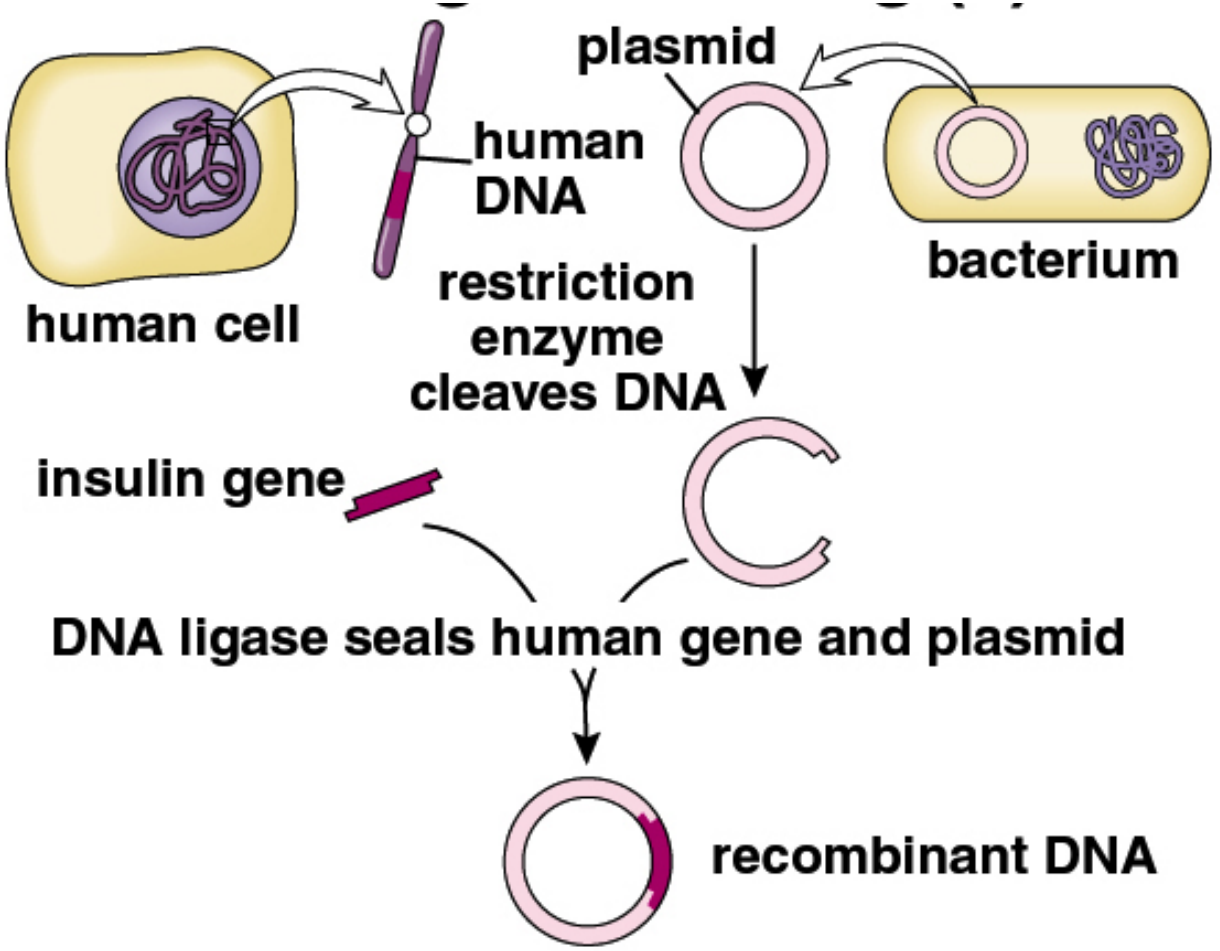
"Why" Clone Genes – *Simply Put….Genomes & Chromosomes Contain Thousands of Genes*



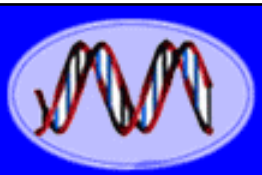
The Human Genome Has 25,000 Genes

How Can a Single Gene Be Studied?

For Example…..The Human Insulin Gene Can Be Separated From Other Human Genes and Transferred to a Bacterial Cell Using Recombinant DNA Methods!



And Used to Treat Diabetes!



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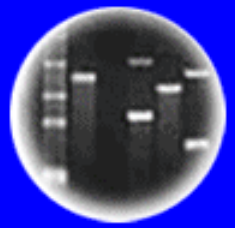

DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

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Any Gene Can Be Isolated & Transferred to Any Organism Using Genetic Engineering!!

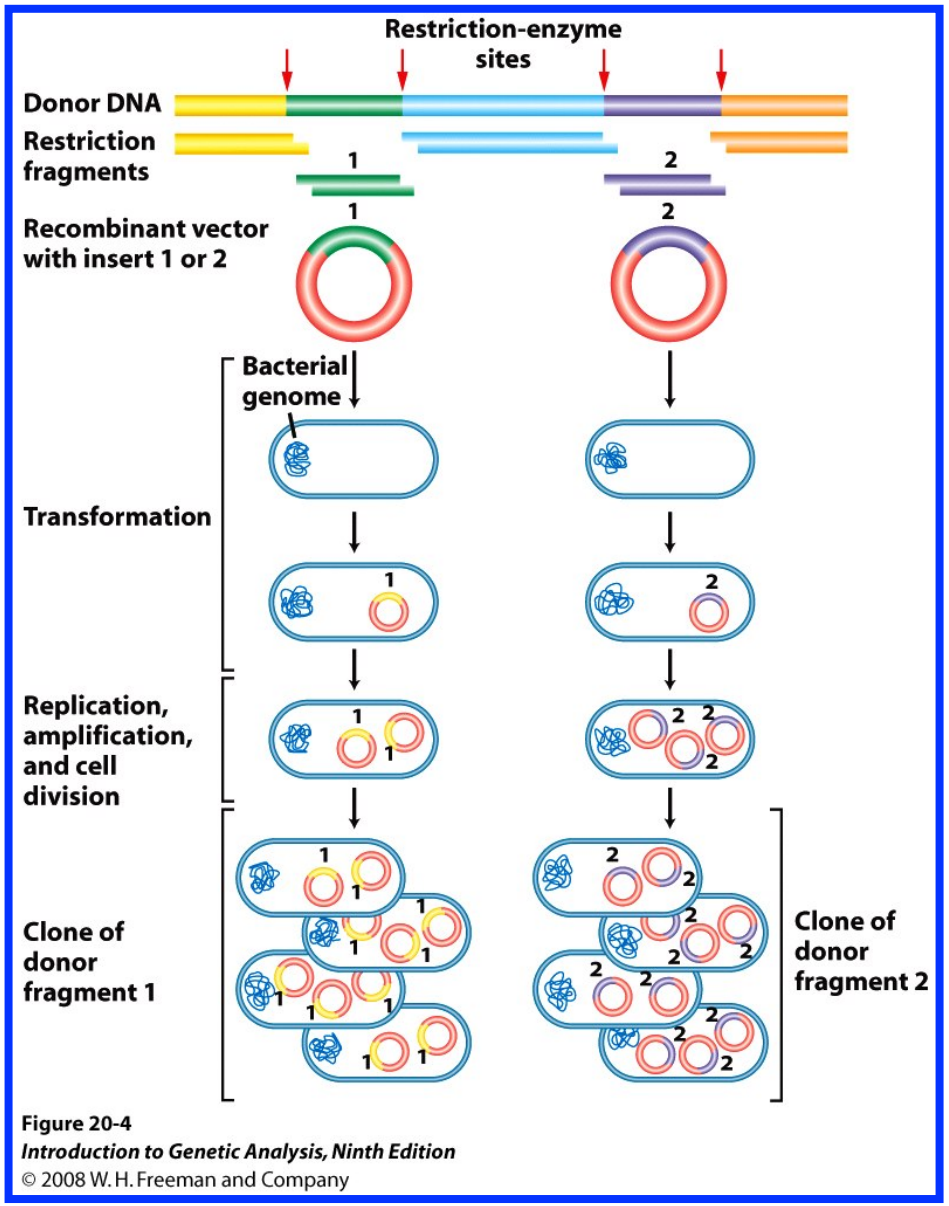
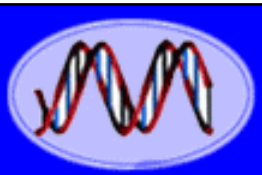


Figure 20-4
Introduction to Genetic Analysis, Ninth Edition



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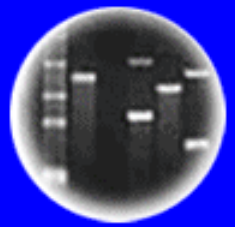
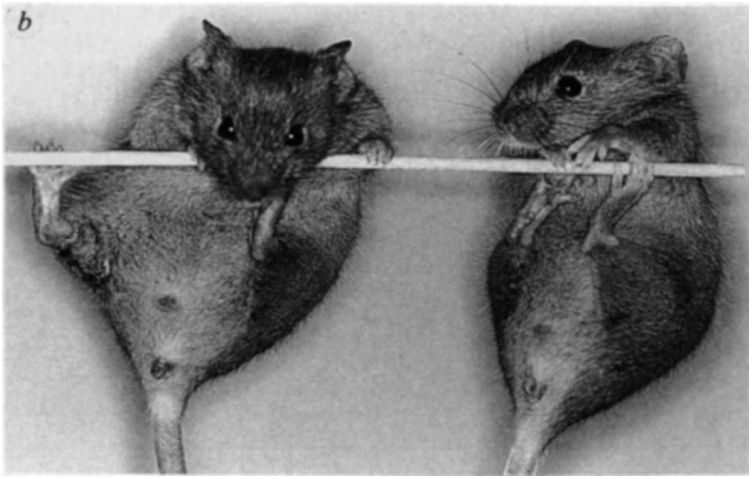


DNA Fingerprinting

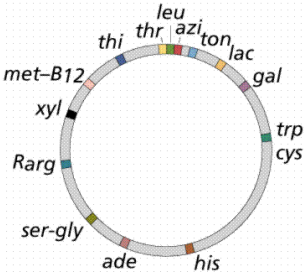
Cloning: Ethical Issues
and Future Consequences

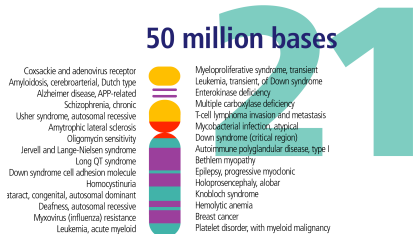
Plants of Tomorrow

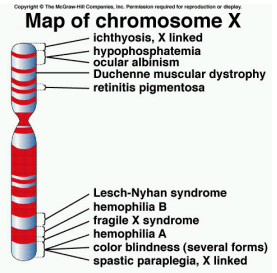
And Made to Perform Any Function That We Want Using Normal Cellular Processes!!



"Why" Clone Genes From An Organism's Genome?
An Essential HC70A Concept!







1. PURIFY Individual Genes From the Genome (e.g.,One of 25,000 Human Genes)
2. AMPLIFY The Gene 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
   - g) Synthesize New Genomes and Many Other Uses

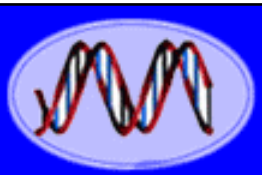
Genetic Engineering Has Lead to New Knowledge About How Cells and Genes Function and Has Lead to Applications That Have Improved Our Lives!!

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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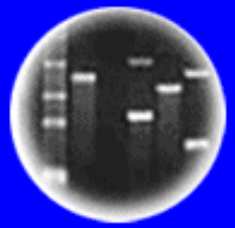

DNA Fingerprinting

Cloning: Ethical Issues
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Plants of Tomorrow

Genetic Engineering……..

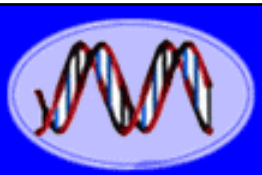
Is the Most Revolutionary Technology in Biology to Have Been Invented in Human History!

Has Generated the Vast Majority of New Biological Knowledge Over the Past 45 Years From Experiments in Biology Laboratories Around the Globe

Has Changed Our Lives Dramatically!

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

1. 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. Gene Testing Companies (e.g., 23andMe): Liability?
8. Patenting Genes, Cells, & Living Organisms?
9. Regulating Experimentation on DNA, Cells, Transgenic Organisms ("GMOs")?
10. Regulating the Release of Genetically Modified Organisms into the Environment?
11. Labeling of Genetically Modified Foods?
12. Synthetic Genomes: Constructing New Organisms?



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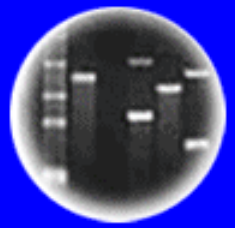

DNA Fingerprinting

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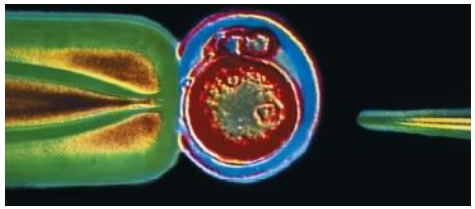
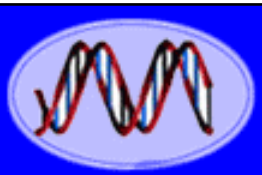
A Few Examples of 21st Century DNA Applications That Have Affected Society and Knowledge About Ourselves

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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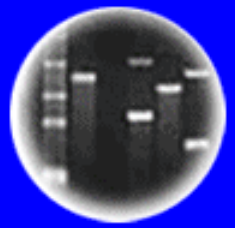

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Cloning: Ethical Issues and Future Consequences

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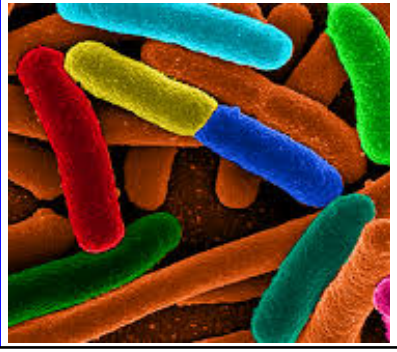
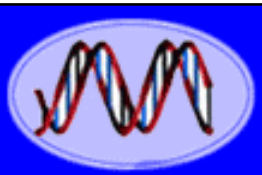
Genetic Engineering Has Been A Major Source of Drugs To Treat Human and Animal Diseases Over the Past 30 Years!

Bacteria



Crops

Livestock



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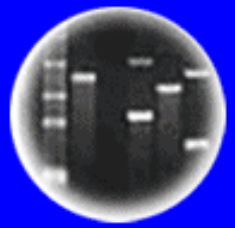

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Drugs Manufactured Using Genetic Engineering

TABLE 1.2 Examples of Recombinant Proteins Manufactured from Cloned Genes

Product	Application
Blood Factor VIII (clotting factor)	Treat hemophilia
Epidermal growth factor	Stimulate antibody production in patients with immune system disorders
Growth hormone	Correct pituitary deficiencies and short stature in humans; other forms are used in cows to increase milk production
Insulin	Treat diabetes
Interferons	Treat cancer and viral infections
Interleukins	Treat cancer and stimulate antibody production
Monoclonal antibodies	Diagnose and treat a variety of diseases including arthritis and cancer
Tissue plasminogen activator	Treat heart attacks and stroke

TABLE 1.1 *2016—Top 10 Biotechnology Drugs (Each with Worldwide Sales over $5 Billion)

Drug Name	Developer	Drug Type	Function (Treatment of Human Disease Conditions)
Humira	AbbVie	Antibody (monoclonal)	Rheumatoid arthritis, Crohn's disease, Ulcerative colitis
Harvoni	Gilead Sciences	Small molecule	Hepatitis C
Rituxan	Roche	Antibody (monoclonal)	Non-Hodgkin's lymphoma
Revlimid	Celgene	Small molecule	Multiple myeloma
Avastin	Roche	Antibody (monoclonal)	Colorectal cancer; breast cancer; non–small cell lung cancer; ovarian, brain, and cervical cancer
Herceptin	Roche	Antibody (monoclonal)	Breast cancer, gastric cancer
Enbrel	Amgen	Recombinant protein	Rheumatoid arthritis, psoriasis
Prevnar 13	Pfizer	Vaccine	Pneumococcal (*Streptococcus Pneumoniae*) antibacterial vaccine
Lantus	Sanofi	Peptide	Diabetes mellitus types I and II
Neulasta	Amgen	Recombinant protein	Anemia (neutropenia/leukopenia)

*Data based on the most recent source available at the time of publication: Morrison C, Lähteenmäki R. Public biotech in 2016—the numbers. *Nat Biotechnol.* 2017;35:623–629.

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.

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

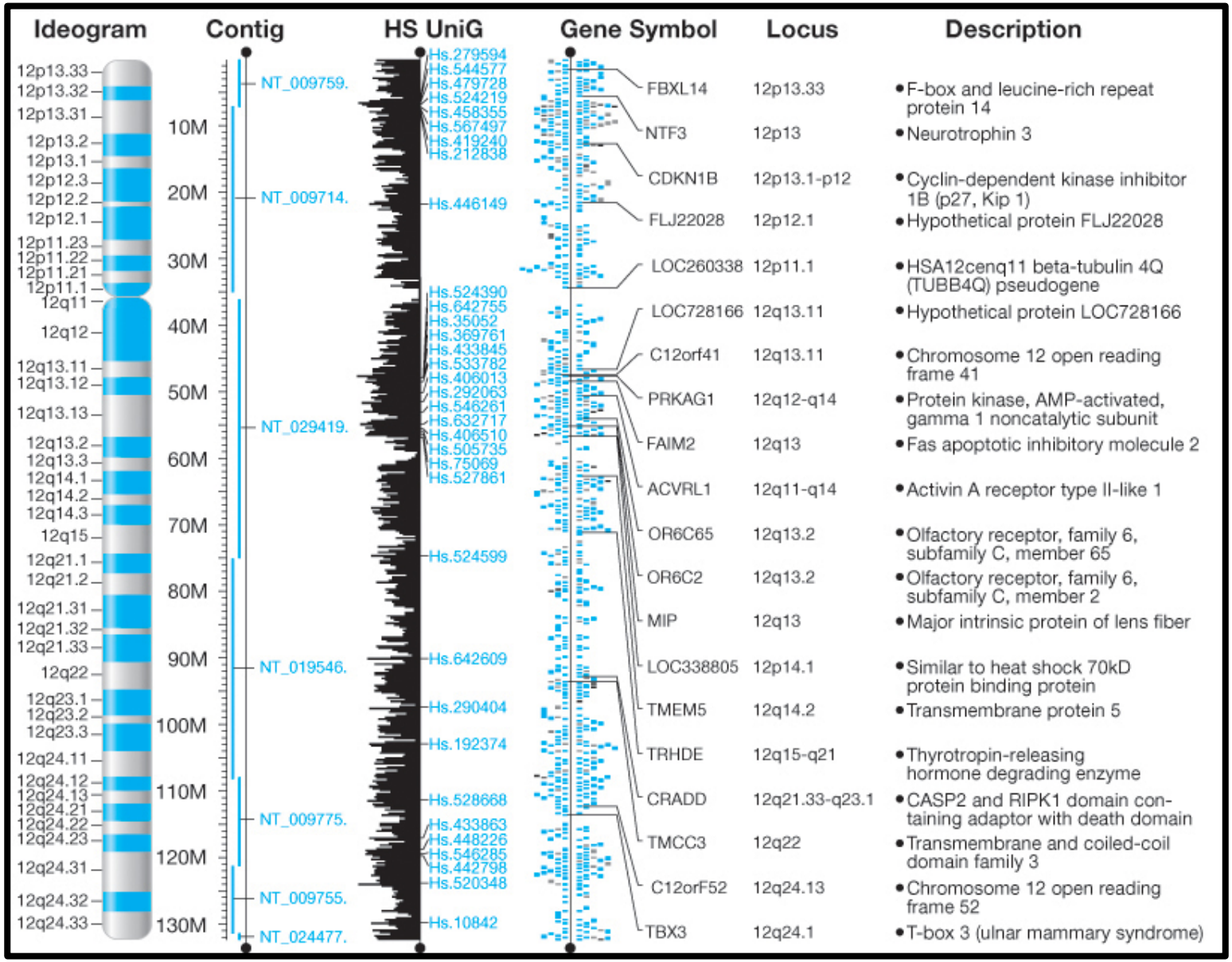
MinIon DNA Sequencer

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

Science, December 20, 2012

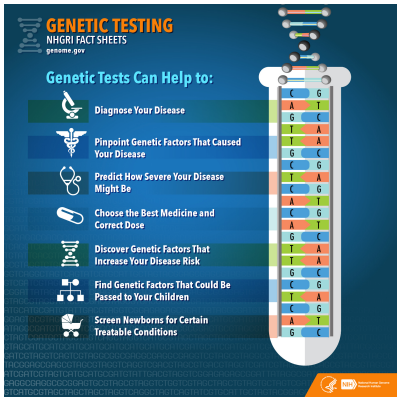
The Era of Personalized Genomes is Here!

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



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

23andMe



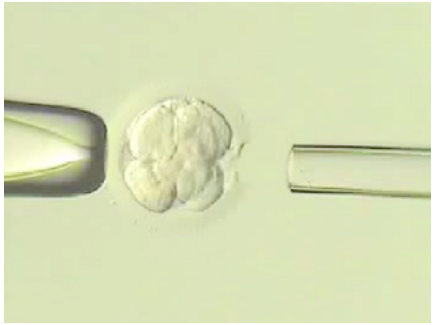
And Before Birth!!!

Made Possible Because of Genetic Engineering!

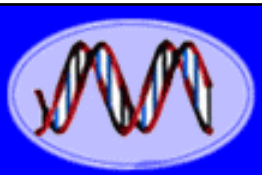
Determining the Genetic Identity of a Human Embryo Before Implantation!

Prenatal Genetic Diagnosis (PGD)

Fertility Clinics Scan for the Strongest Embryo



DNA Testing Has Led To Inexpensive Home DNA Testing Kits!



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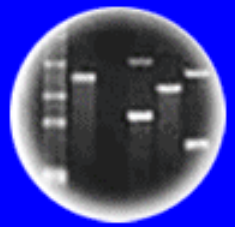


DNA Fingerprinting

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

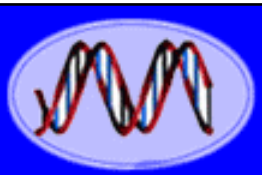
Misleading Test Results Are Further Complicated by Deceptive Marketing and Other Questionable Practices

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.

23andMe · DNA TRIBES · Navigenics · IDENTIGENE · HOMEDNA



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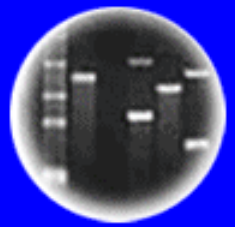

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Genetic Engineering Has Led to the Era of Human Gene Engineering – Using Gene Therapy to Cure Lethal Genetic Diseases

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

DNA-swap technology almost ready for fertility clinic

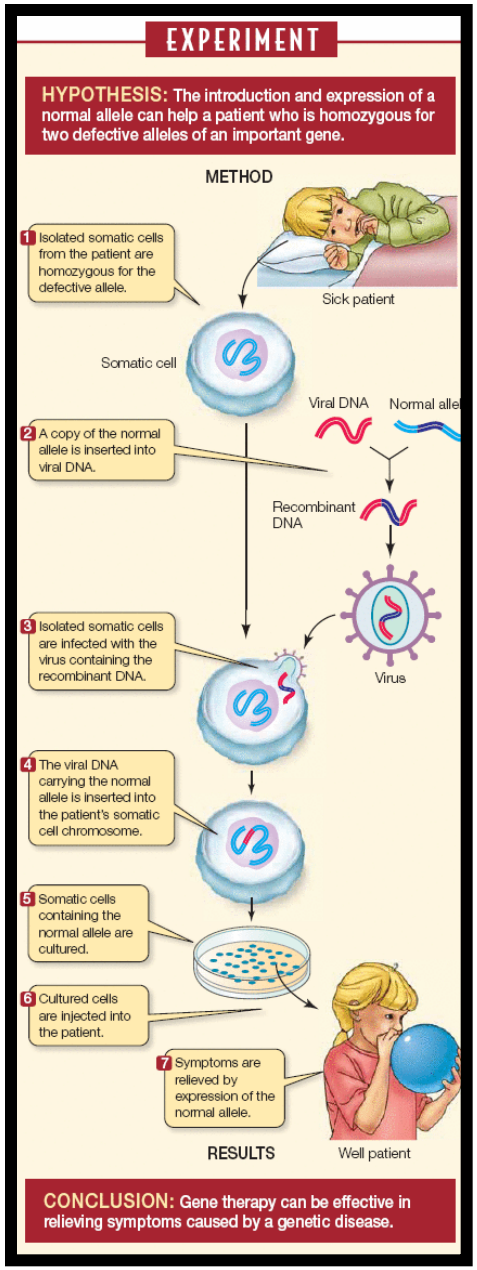
Gene therapy trial 'cures children'

Treatment for Blood Disease Is Gene Therapy Landmark

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

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

Humans Have Been Genetically Engineered To Cure a Lethal Genetic Disease (SCID) – Human GMOs!



Gene therapy cures 'bubble boy disease'

31 Jan 2009, 1128 hrs IST, AP

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

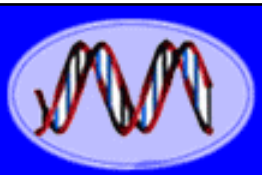
Several People are Alive Because They Have Been Engineered With an ADA Gene

The new england journal of medicine

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

Gene Therapy for Immunodeficiency Due to Adenosine Deaminase Deficiency

Gene Therapy with the Adenosine Deaminase (ADA) Gene



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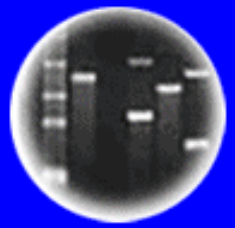

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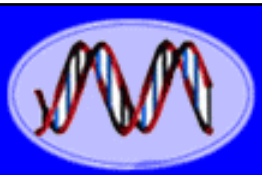
And More Recently The Era of Correcting, or Editing, Defective Genes in the Germline (e.g., Eggs) Has Arrived!!!!!



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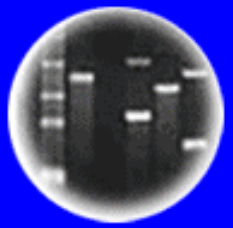

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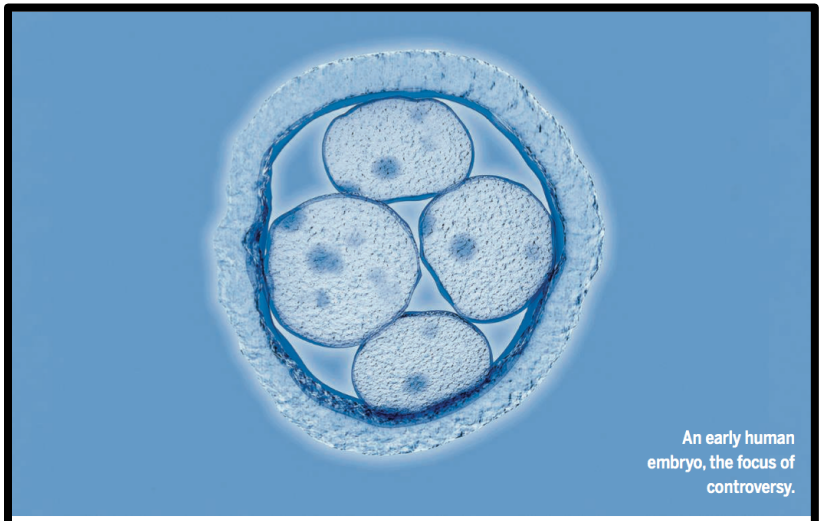


An early human embryo, the focus of controversy.

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

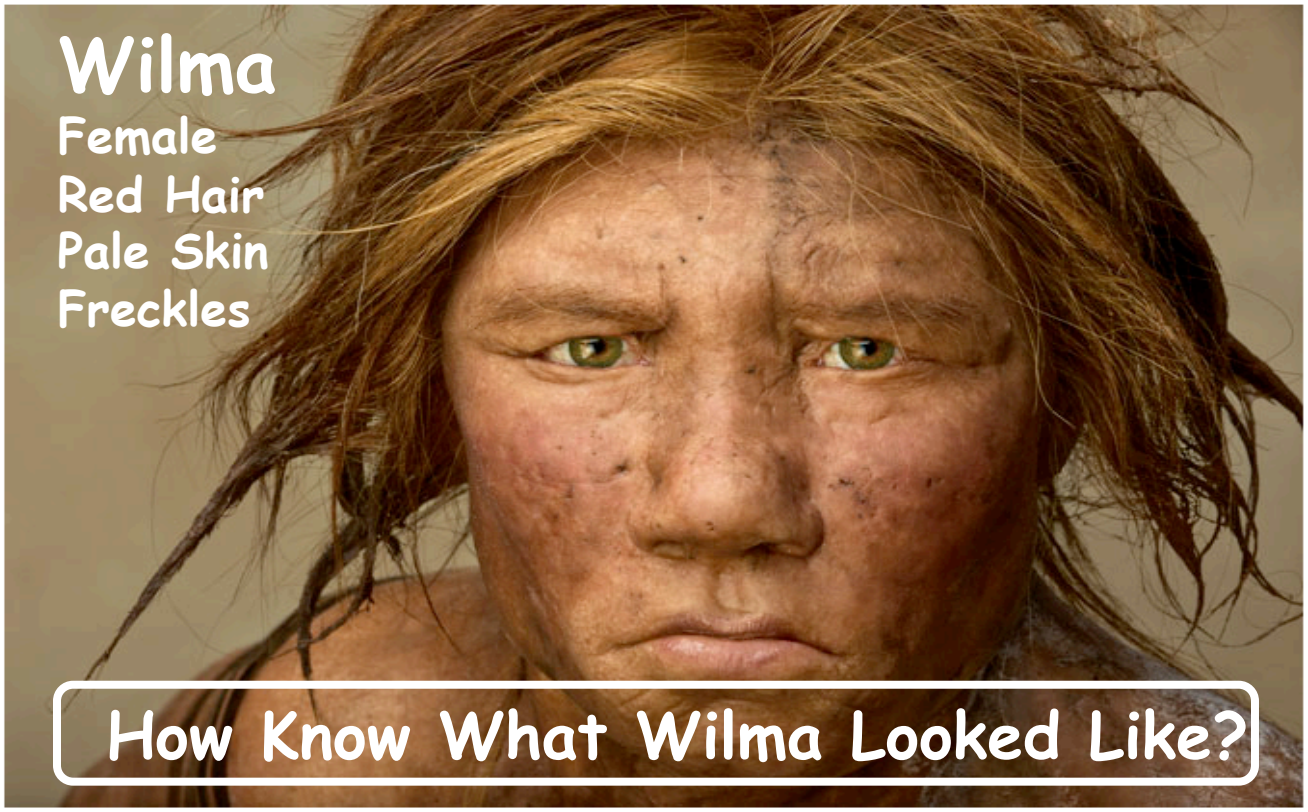
A group of leading biologists on Thursday called for a worldwide moratorium on use of a new genome-editing technique that would alter human DNA in a way that can be inherited.

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

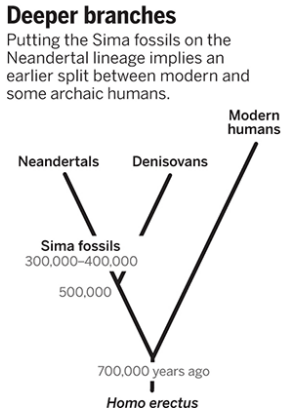
From a 45,000 Year-Old Bone!



Reconstruction by Kennis & Kennis / Photograph by Joe McNally

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

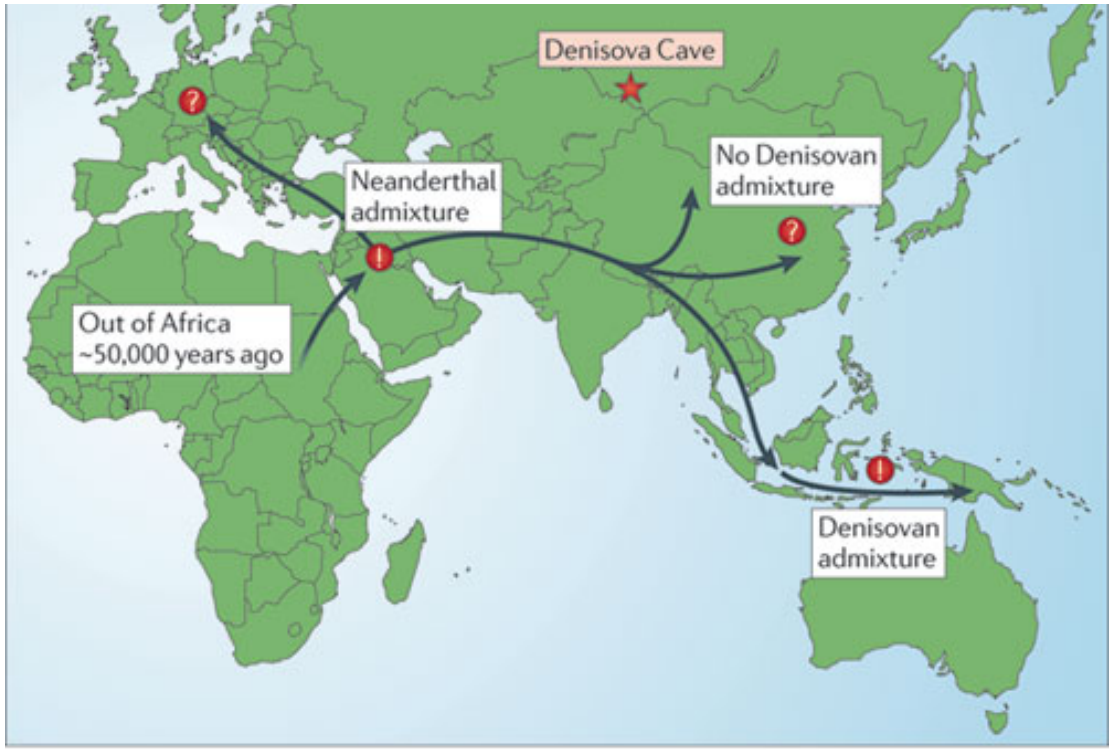
Genetic Engineering Has Led to Remarkable New Insights into Human Origins and Ancestry



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

www.sciencemag.org **SCIENCE** VOL 334 7 OCTOBER 2011

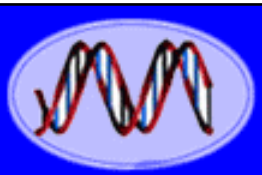
Comparing 40,000 Year-Old Fossil Genomes to Our Genome Reveals Ancient "Matings" Between Diffferent Human Ancestor Lineages!!



We Have Neanderthal Genes in Our Chromosomes

It's All in the DNA!

Nature Reviews | Genetics
September, 2011



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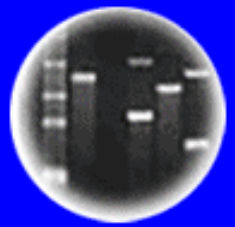

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Inexpensive Home DNA Testing Kits Can Determine a Person's Ancestry!

ancestryDNA™

And New Ethical Issues

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

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?

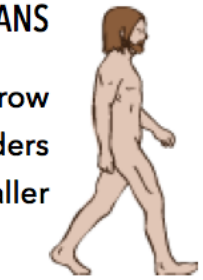
This lab estimates your genome-wide percentage of Neanderthal ancestry

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

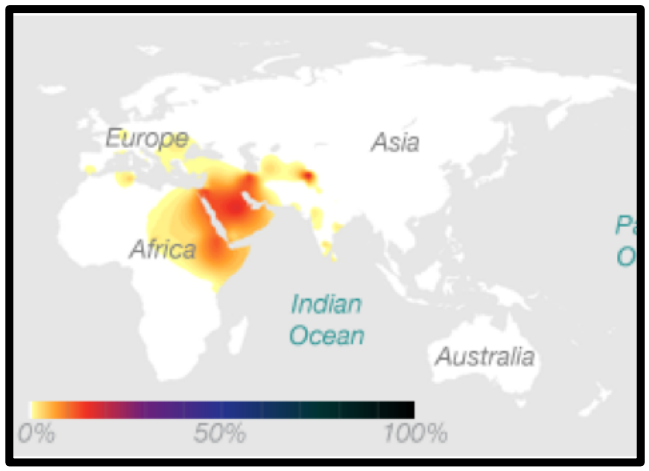
NEANDERTHALS

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

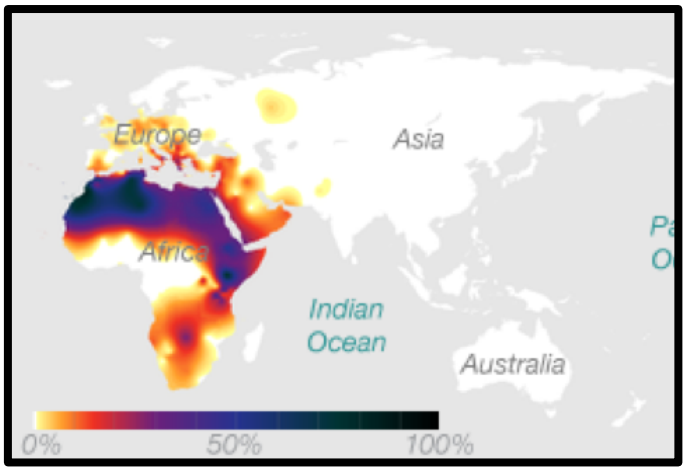
Without Genetic Engineering and DNA Sequencing Technologies This Could Not Have Been Done

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

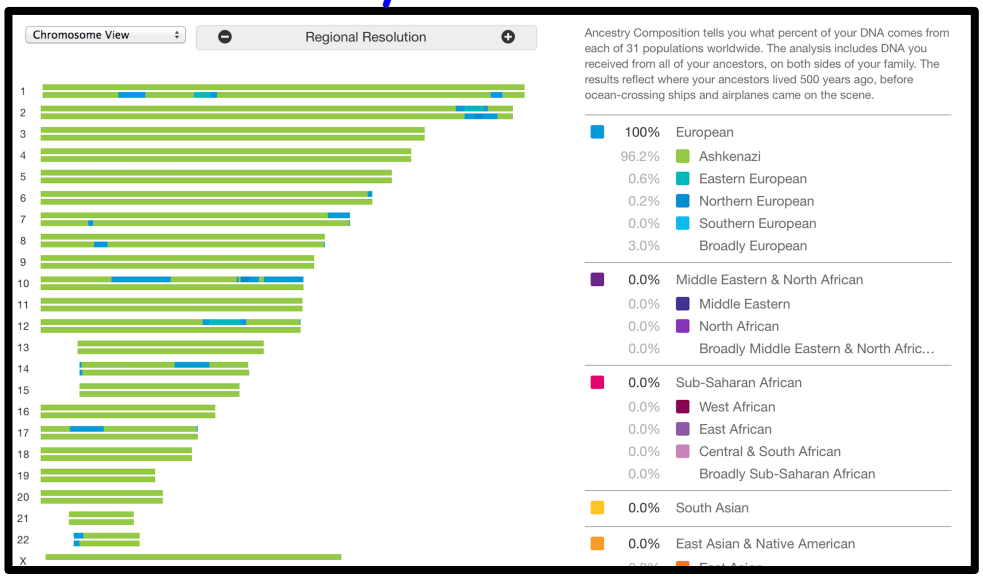
Mom



Dad



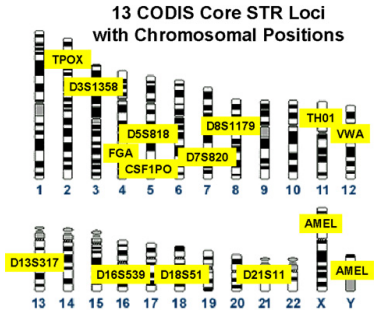
My Chromosomes



DNA Has Impacted the Law & Forensics in Dramatic Ways!!!

Combined DNA Index System (CODIS) of DNA Profiles

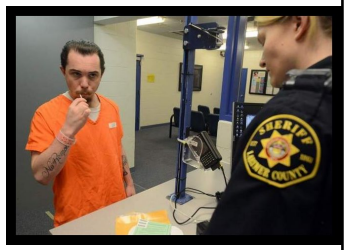
- Convicted Felons
- Suspects Arrested For Felonies
- DNA Samples From Crime Scenes
- Unidentified Human Remains
- Relatives of Missing Persons



October 2018

Offender Profiles	13,566,716
Arrestee Profiles	3,323,611
Forensic Profiles	752,508
Database "Hits"	440,346 assisting 428,808 investigations

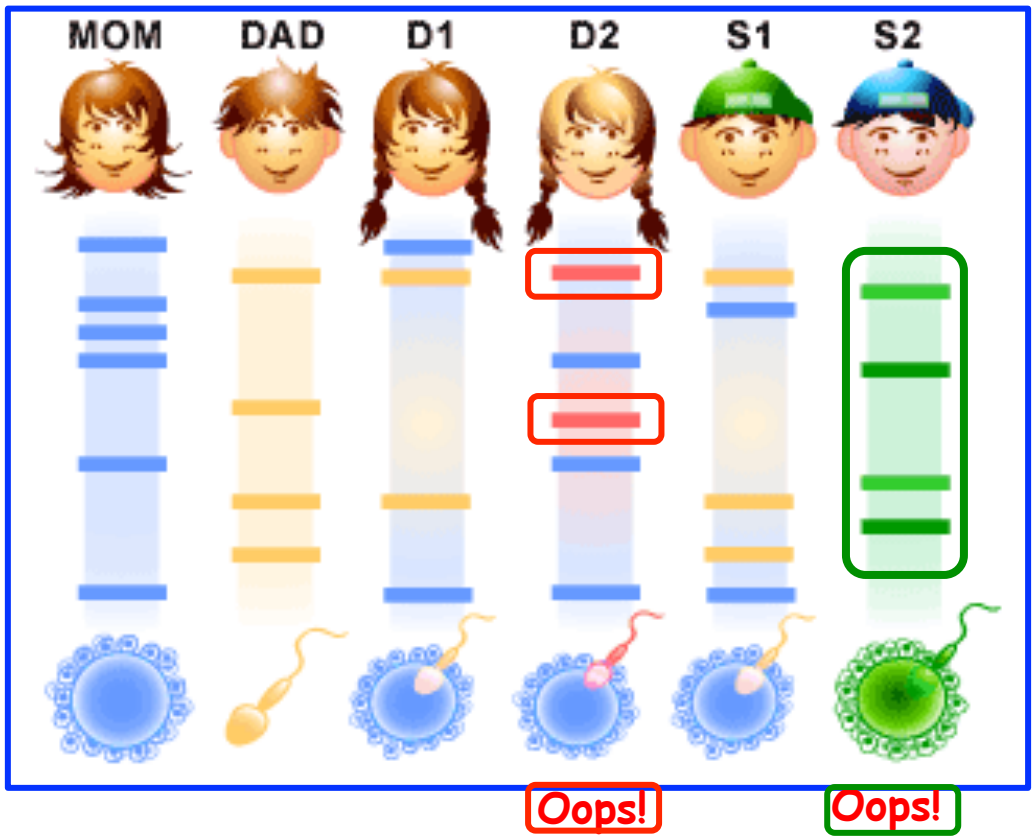
King vs. Maryland SCOTUS
4th Amendment Case



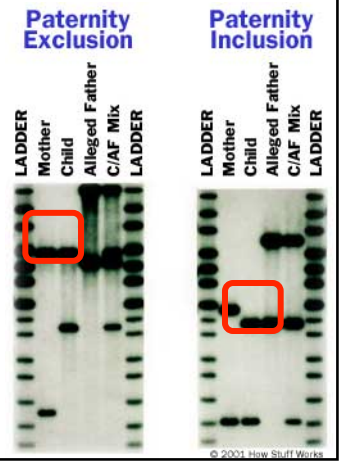
DNA Fingerprints Can Identify Individuals They Don't "Lie"

Sometimes They Reveal Unexpected Results!

DNA Fingerprints



What is YOUR DNA Fingerprint?



FORENSICS

Familial DNA Testing Scores A Win in Serial Killer Case

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

Grim Sleeper Caught By DNA!!

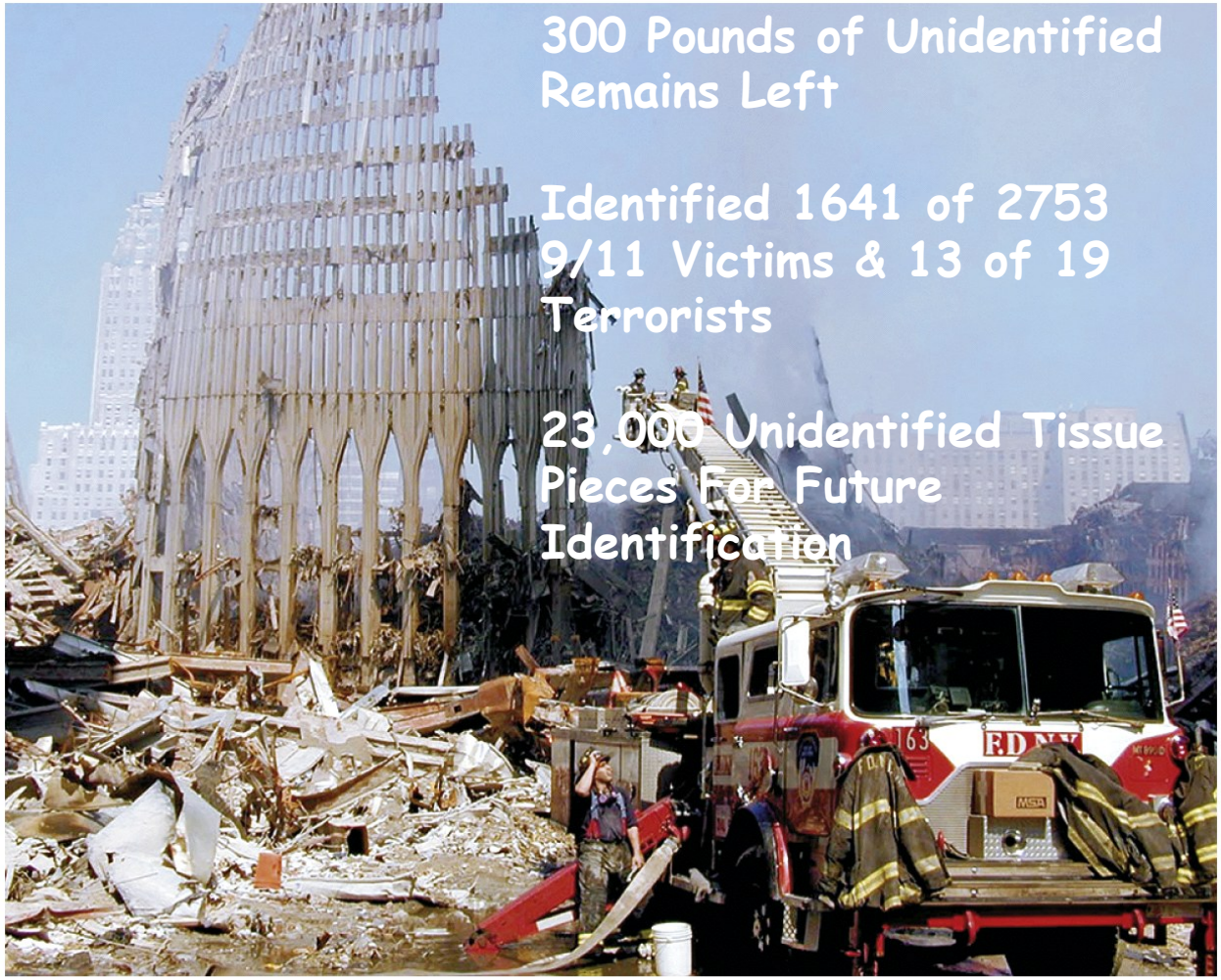
Others Set Free By DNA Evidence

INNOCENCE PROJECT

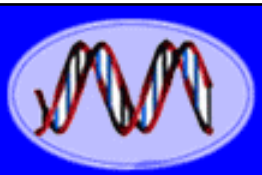
15th Person Cleared by DNA in Dallas. Charles Chatman was released from state custody Jan. 3 in Dallas, after serving nearly 27 years in prison for a rape he didn't commit. He is the 15th Dallas man to be cleared by DNA testing after being wrongfully convicted. After his hearing, he hugged Judge John 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

And Identifying Victims of 9/11 And Other Tragedies by DNA Fingerprinting (and Perpetrators)



Sept. 11 Victim Identified, Nearly 17 Years Later



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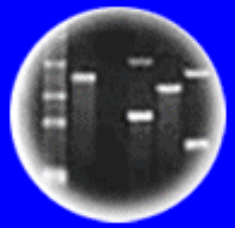

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Plants of Tomorrow

DNA Fingerprints Can Also Be Used To Uncover Fraud

May 26, 2011

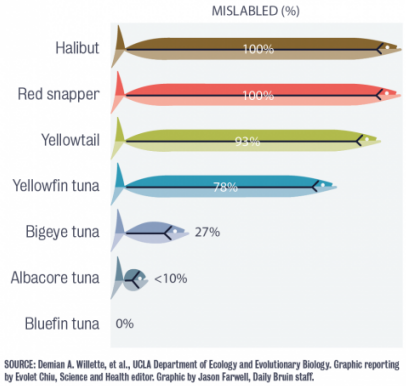
Tests Reveal Mislabeling of Fish

By ELISABETH ROSENTHAL

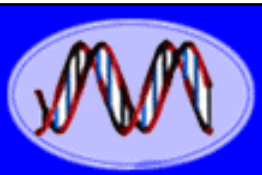
Scientists aiming their gene sequencers at commercial seafood are discovering rampant labeling fraud in supermarket coolers and restaurant tables: cheap fish is often substituted for expensive fillets, and overfished species are passed off as fish whose numbers are plentiful.

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



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



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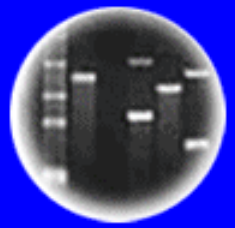

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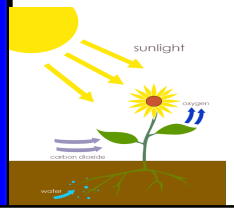
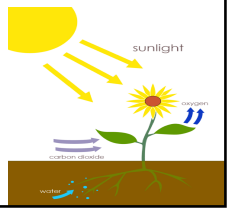
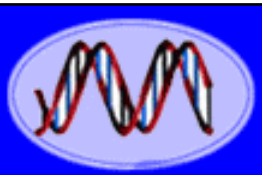
Genetic Engineering of Photosynthesis Increases Plant Size!

1/3/19







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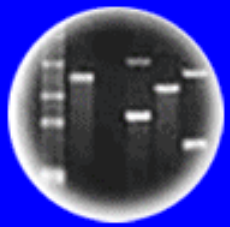

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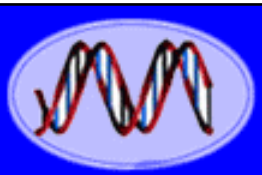
Genetic Engineering Faster Growing Salmon For More Productive Aquafarms!

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



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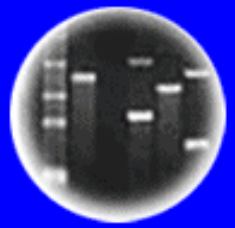

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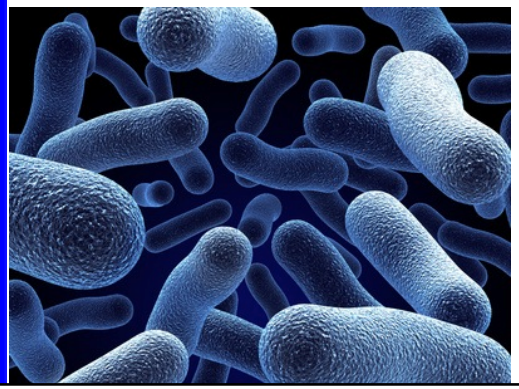
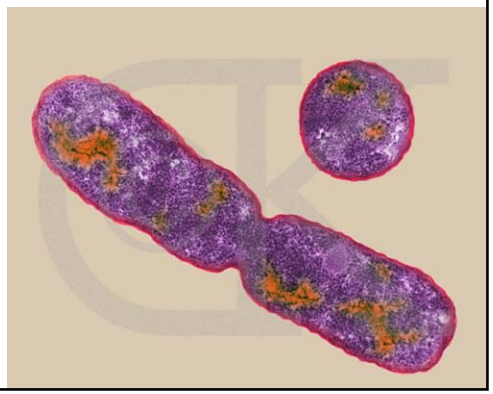
Finally….We Have Entered a New Era of Genetic Engineering
The Era of Synthetic Biology

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



Synthetic Genomes & Chromosomes 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

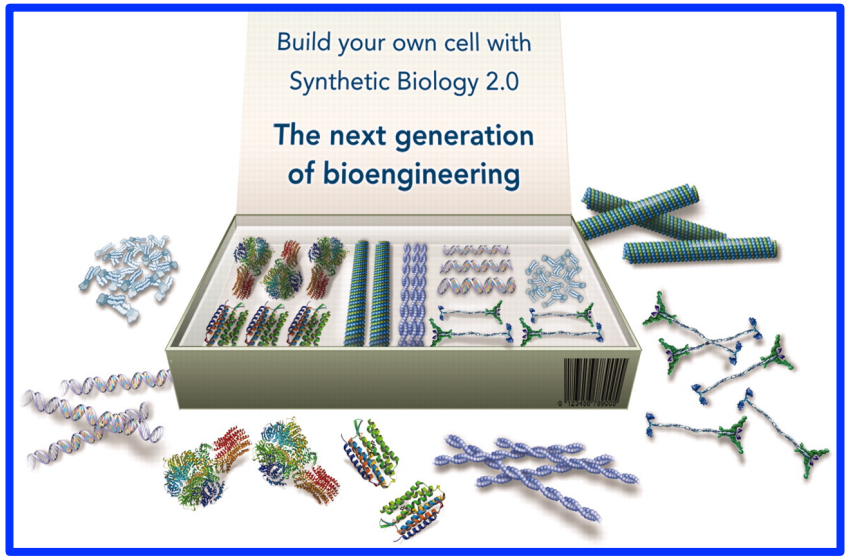
Genetic Code of E. Coli Is Hijacked by Biologists

By NICHOLAS WADE

Science, July 15, 2011

Synthetic Generation of Influenza Vaccine Viruses for Rapid Response to Pandemics

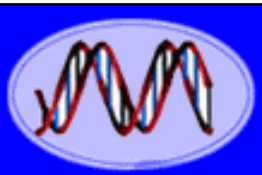
Sci. Transl. Med., May 15, 2013,



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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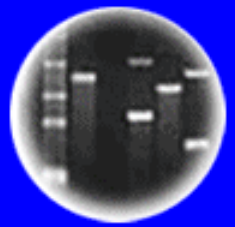

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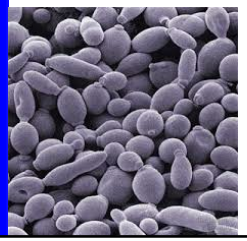
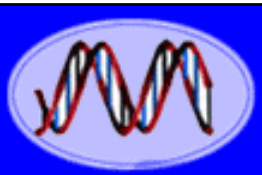
A Yeast Cell With Chromosomes Synthesized in the Laboratory From A, G, C, & T DNA Bases !!!!



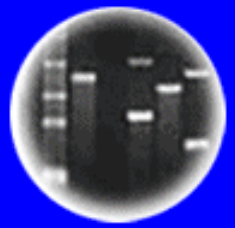
Creating Life: Synthetic Microbes
J. Craig Venter

60 Minutes-December 2010



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria

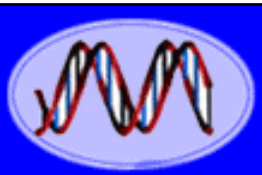


DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

Stop Part One!!



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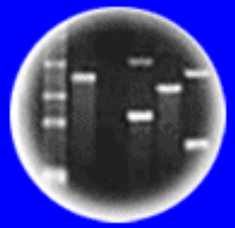

DNA Fingerprinting

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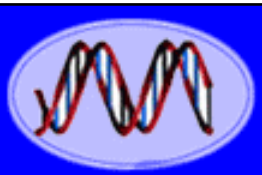
HC70A Winter 2019
Genetic Engineering in Medicine, Agriculture, and Law
Professor Bob Goldberg

Class Announcements
1/8/19



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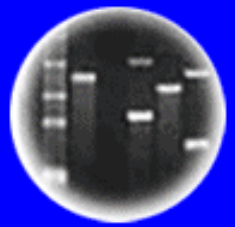

DNA Fingerprinting

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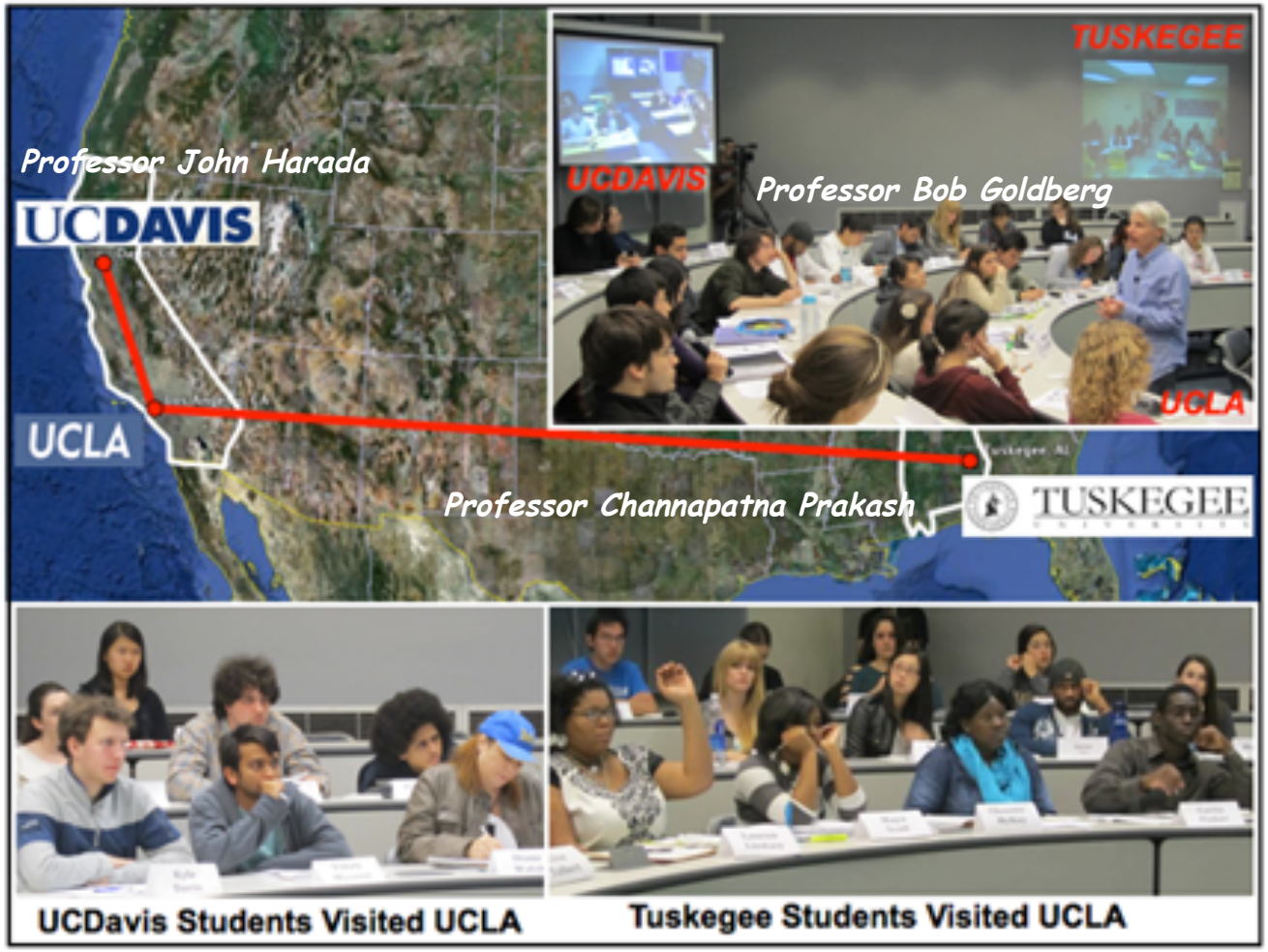
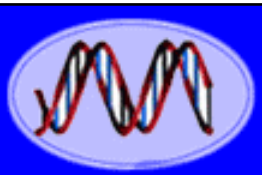
The Long Distance Connection!
HC70A, SAS70A, & PLSS530
Winter 2019



A Model For Cross-Campus Interactive Learning



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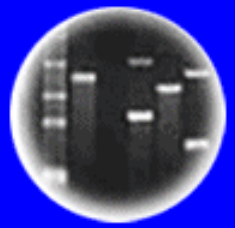

DNA Fingerprinting

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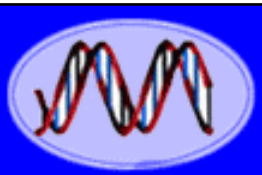
HC70A Winter 2019 (UCLA)
Genetic Engineering in Medicine, Agriculture, and Law

Discussion Coordinator
Dr. Kelli Henry

Undergraduate Assistants
Pierce Ford
Madelyn Gehrich
Emily Teng

Course Administrator
Dr. Lauren Bowman

UCLA



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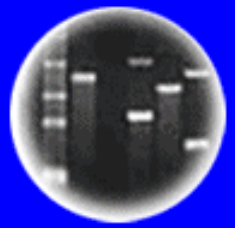

DNA Fingerprinting

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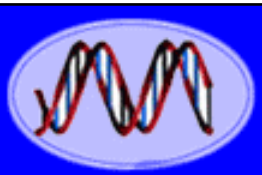
SAS70A Winter 2019 (UC Davis)
Genetic Engineering in Medicine, Agriculture, and Law

Professor John Harada

Graduate Teaching Assistant
Leonardo Jo

UCDAVIS
UNIVERSITY OF CALIFORNIA



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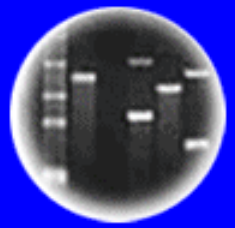

DNA Fingerprinting

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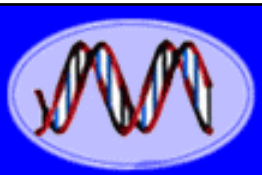
PLSO559 Winter 2019 (Tuskegee)
Genetic Engineering in Medicine, Agriculture, and Law

Professor Channapatna Prakash

TUSKEGEE
UNIVERSITY



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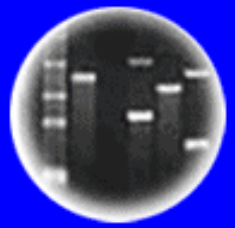

DNA Fingerprinting

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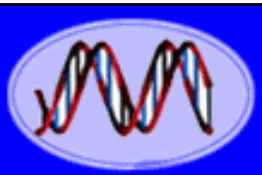
Discussion Tomorrow

- Your Perceptions of Genetic Engineering & Its Applications
- Fill Out Survey Handed Out at the End of Class & Hand In Tomorrow in Discussion
- Be Prepared For a Lively Discussion



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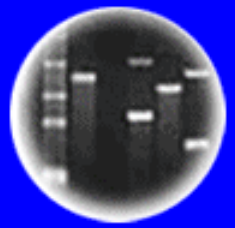

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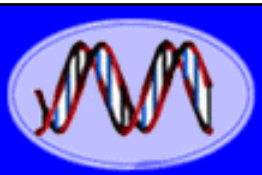
What Can You Do?

- Study the Lecture Slides
- Read Articles For Discussion
- Read Text to Reinforce Lecture Concepts
- Ask Questions
- Work Together
- Come to My Office Hours

Friday 1:30-2:30 –Terasaki 4121



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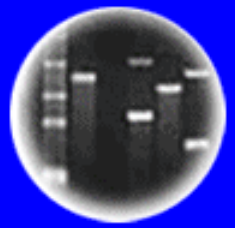

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Pick Up After Class

1. Survey
2. Syllabus
3. Your Genes-Your Choices