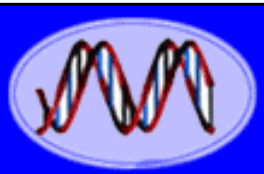
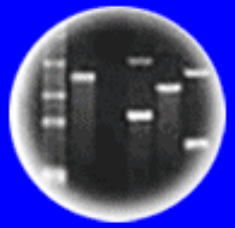


DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

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

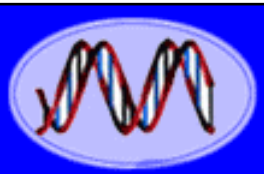
Professors Bob Goldberg, John Harada, & Channapatna Prakash

Lecture 4
What Are Genes & How Do They Work: Part Two

UCLA

TUSKEGEE UNIVERSITY

UCDAVIS UNIVERSITY OF CALIFORNIA



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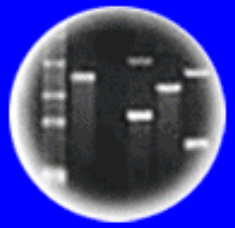

DNA Fingerprinting

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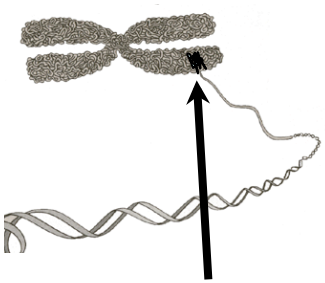
THEMES

1. What Are Genes & Their Properties
2. How Do Switches Regulate Genes in Space & Time?
3. How Does DNA Replication Occur?
4. What is the Polymerase Chain Reaction (PCR) and How is PCR Used in Society?
5. How Do Mutations Occur?
6. How Can Pedigrees Be Used To Follow the Inheritance of Mutant Genes With Phenotypes and RFLPs?
7. How Do Mutations Change Phenotypes?
8. What is the Colinearity Between Genes & Proteins (i.e. how does the DNA sequence specify a protein sequence)?
9. What is the Genetic Code?
10. Yo!-It's in the DNA Sequences- What Are the Implications For Genetic Engineering?

A Chromosome Contains Many Genes Operating Independently

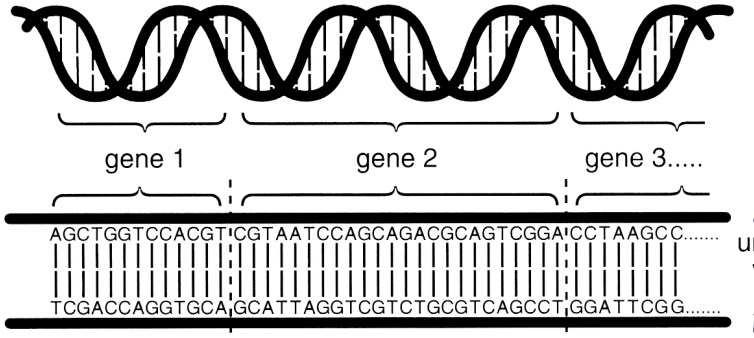
What is the Evidence?



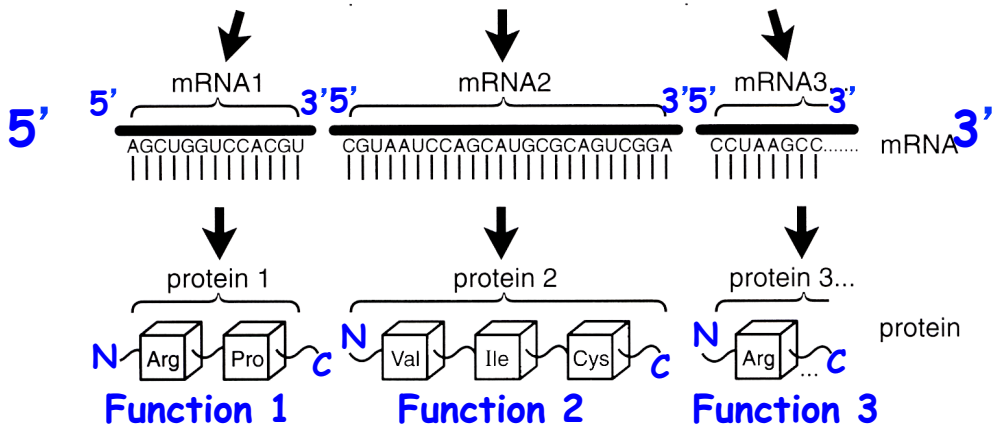
Position of Genes 1, 2, & 3 in chromosome

Discrete Units!

What delineates each gene?



Notice sequence of each gene



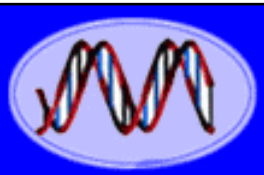
Note sequence of each protein

Notice- Each gene, mRNA, & protein has a <u>unique order/ sequence</u> of <u>monomeric units</u>

Central Dogma
∴Genes -> Functions in Cells via Proteins
Cells duplicate & stay the same -> DNA replication

IMPORTANT HC70A CONCEPT!

<u>COLINEARITY</u> BETWEEN GENE SEQUENCE AND PROTEIN SEQUENCE



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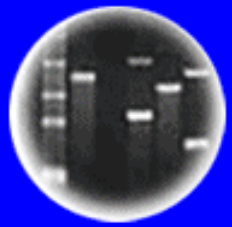

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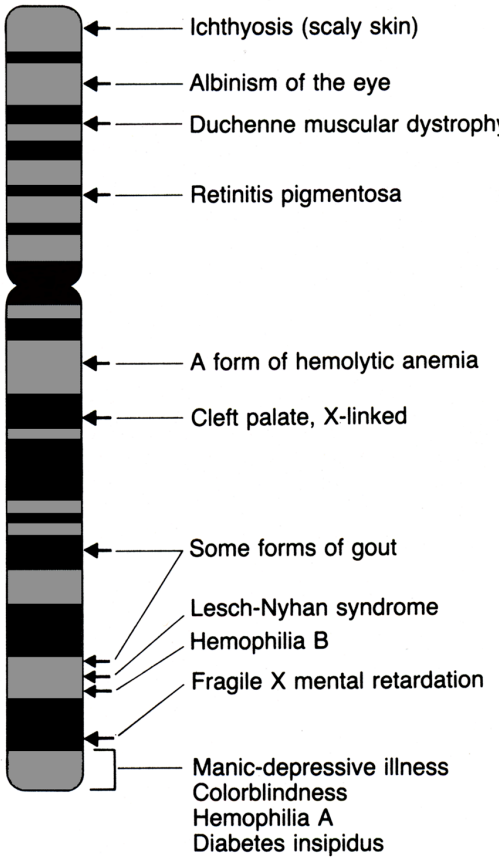
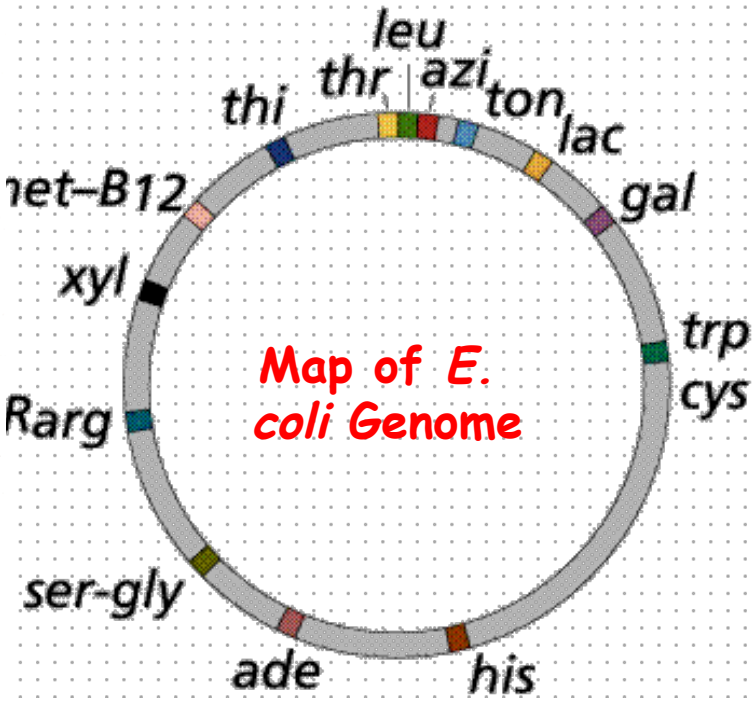
Genes Reside at Specific Locations (Loci) That Can Be Mapped

Human X Chromosome



Linear DNA
How Know?



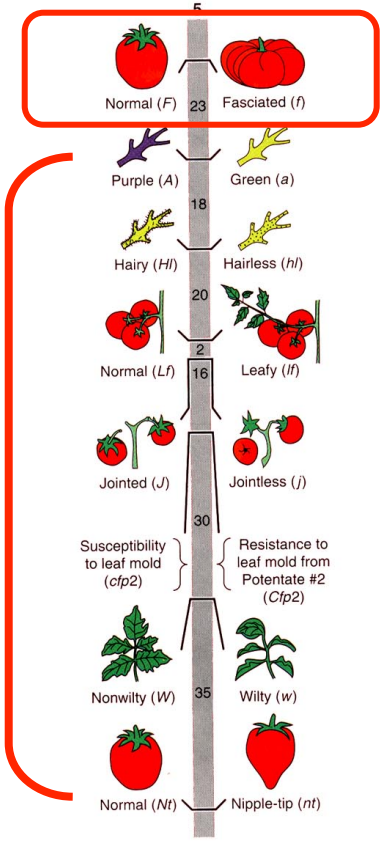
Circular DNA
How Know?

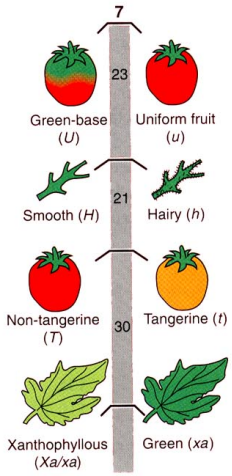
Alleles Reside at the Same Position on a Chromosome

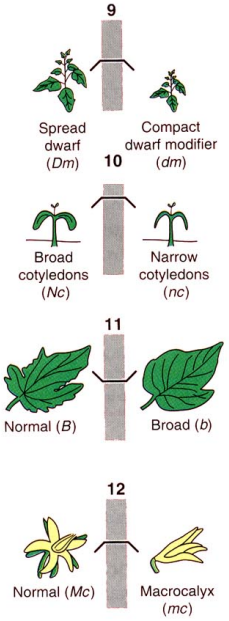
Allele Phenotypes Specify Markers For Each Gene Location!

Different Genes

Alleles





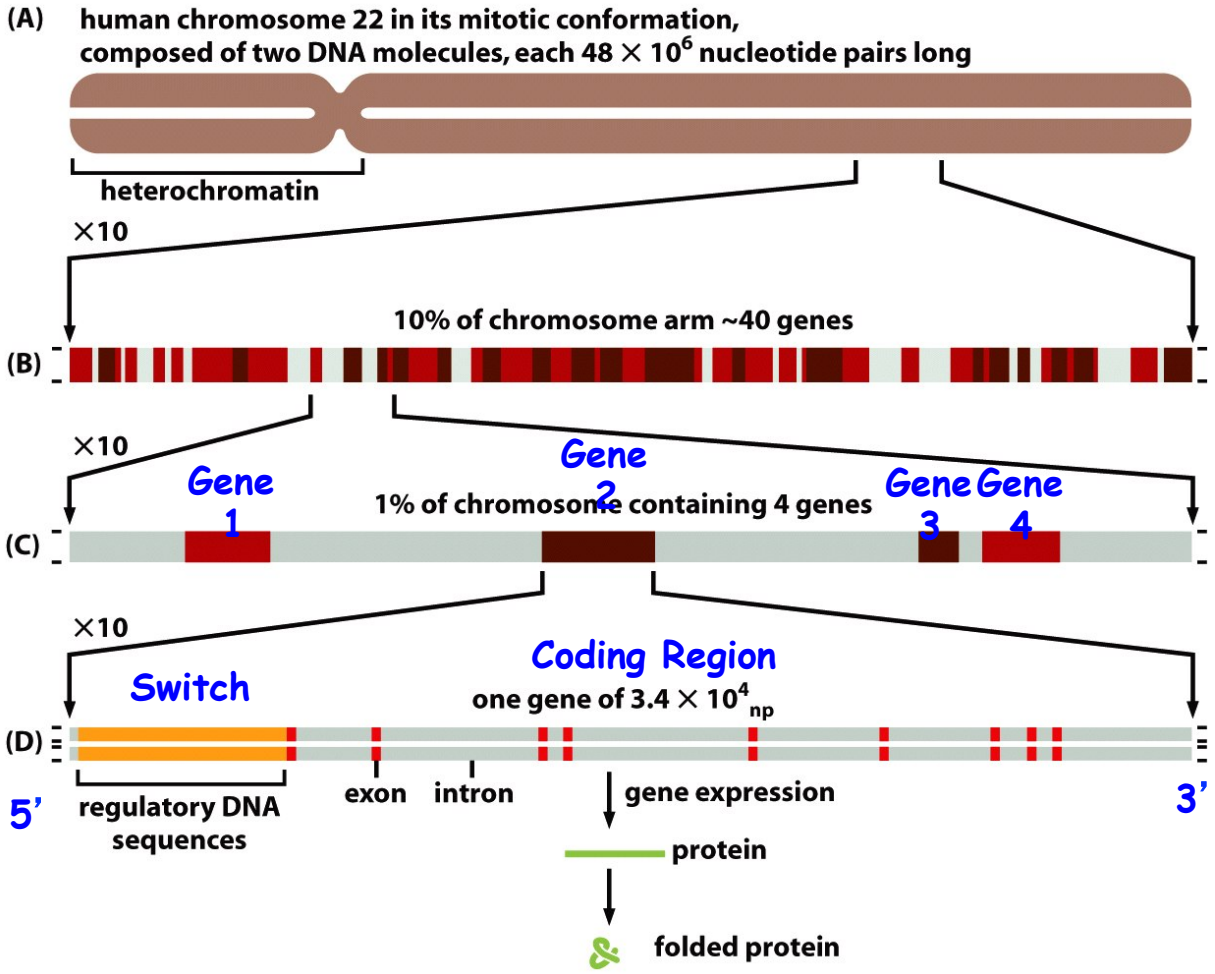


Gene Engineering Can Generate New Forms of Alleles of a Gene and, therefore, Results in More Genetic Diversity

mutations result in genetic diversity!!!

Alleles Are <u>Different Forms of the Same Gene</u>
That Arise By Mutation & Can be Made in a Laboratory By Modern Genetic Engineering!

Organization of Genes on Human Chromosome 22



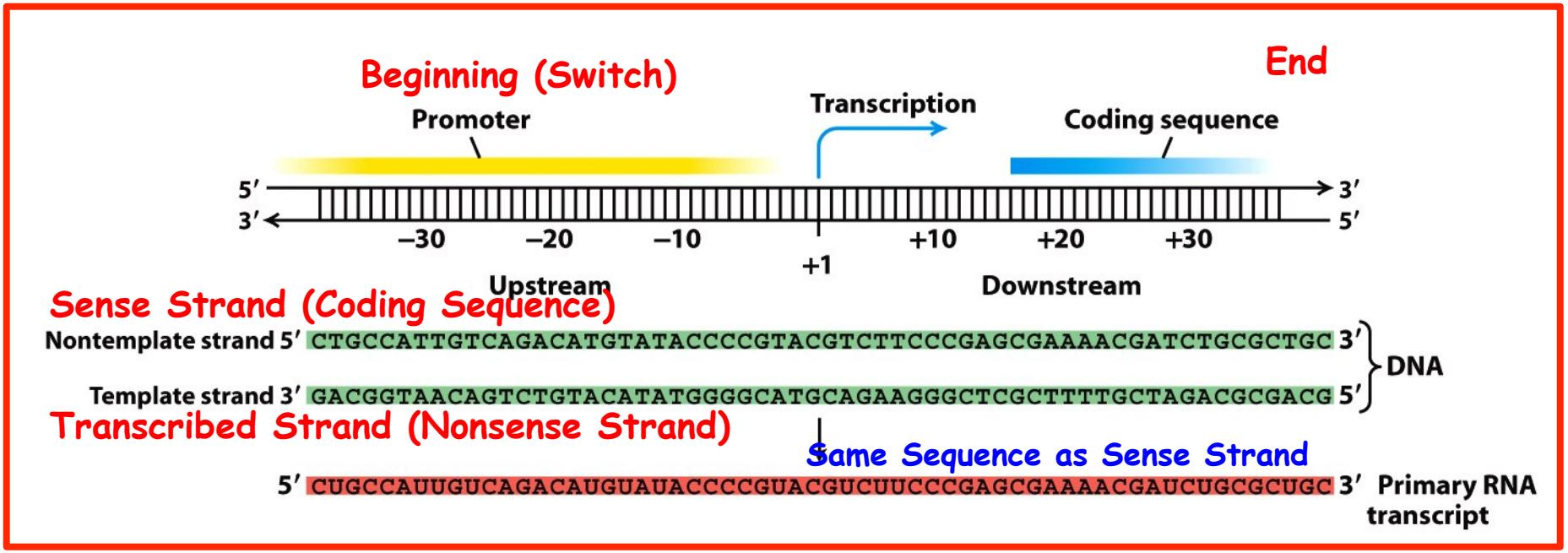
250 genes

Genes Are Defined/ Precise Regions of DNA

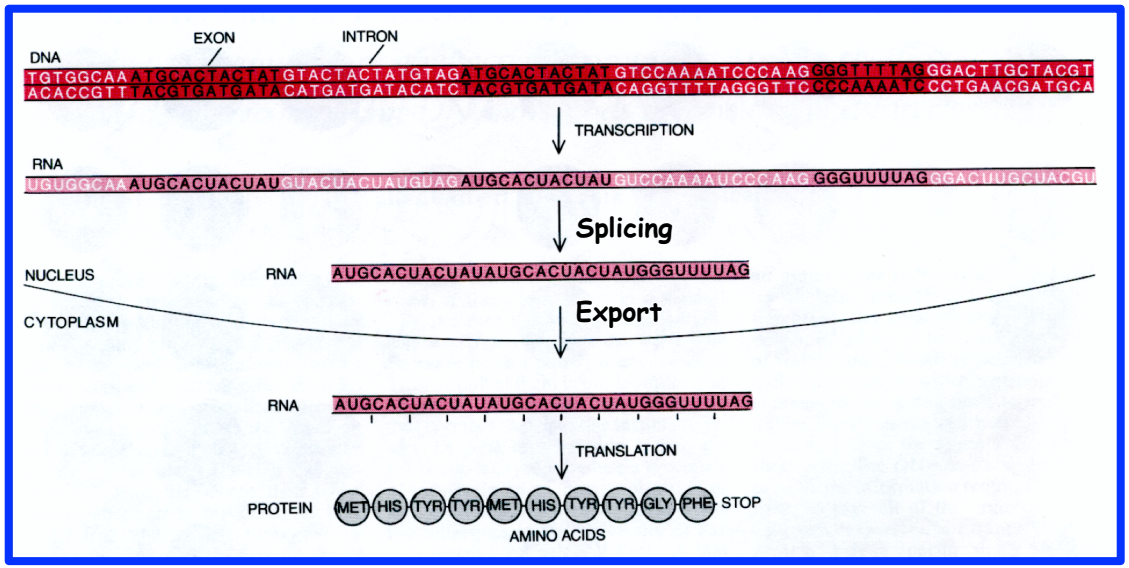
One Large Gene!
(Note Size of Introns & Exons)

Genes Act As Individual Units?
How Know? GloFish Experiment! Genetic Engineering Antibiotic^R

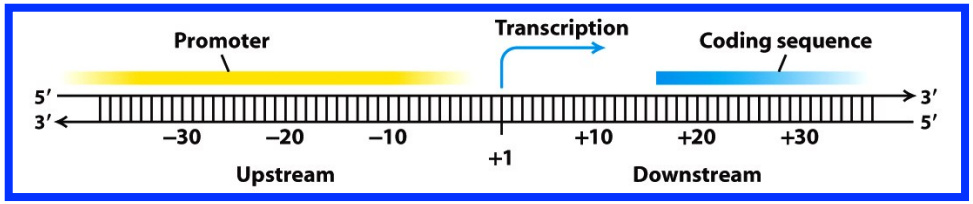
A Conceptualized Gene

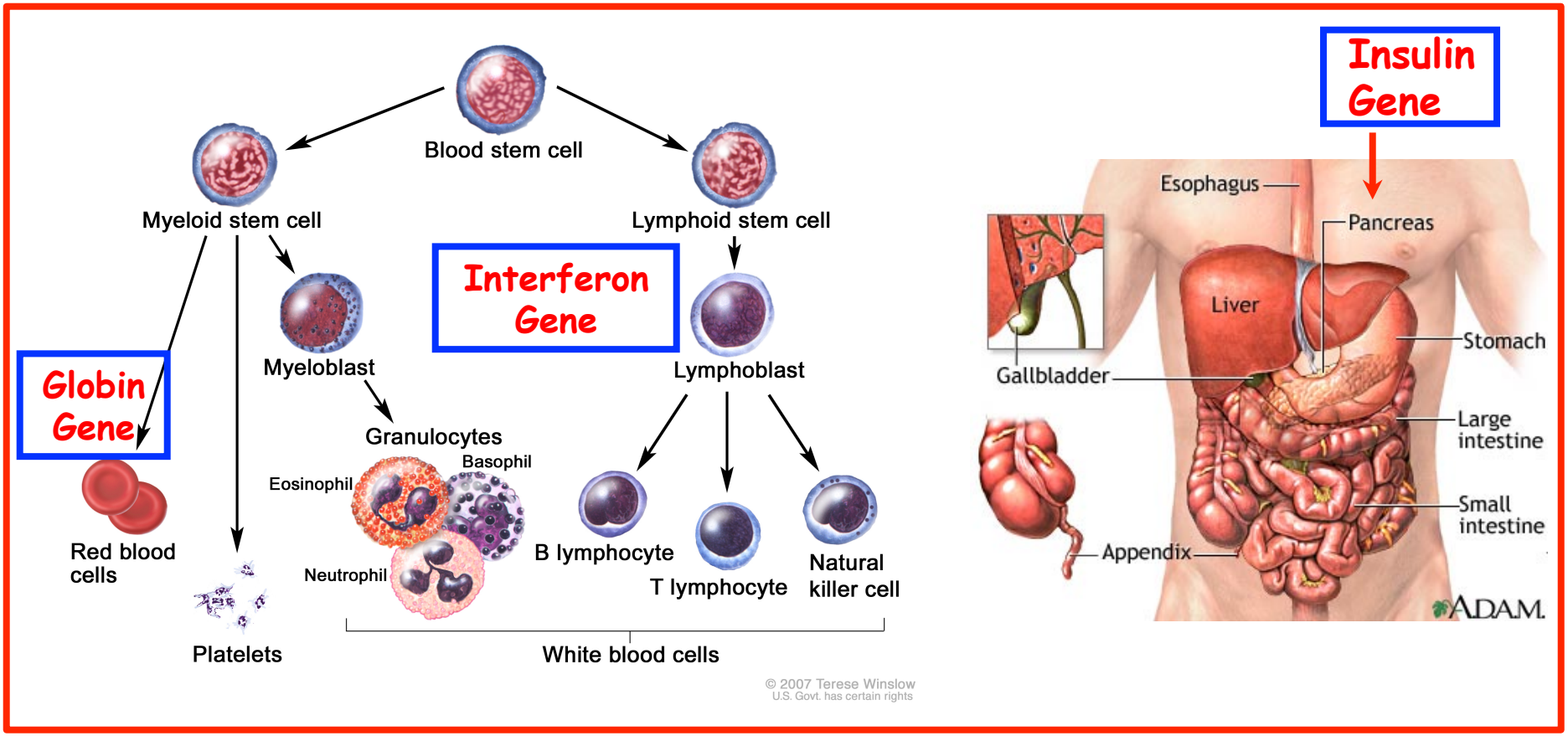


DNA to Protein



Switches Control Where & When A Gene Is Active
Unique Functions → Unique Cells





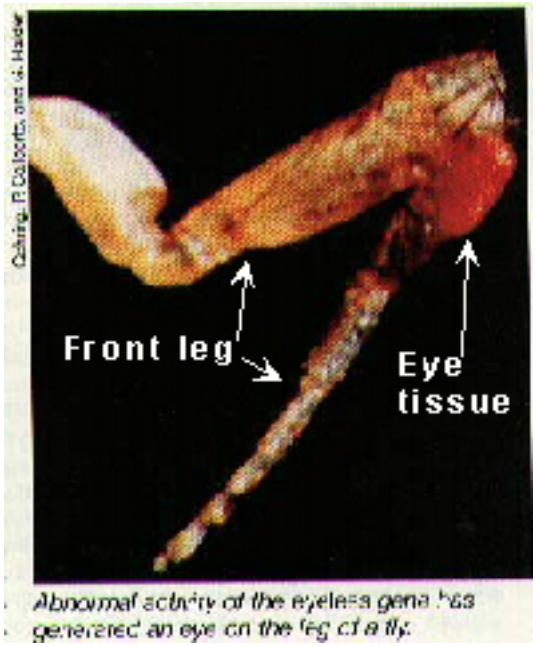
Different Switches!!!!

The Eye Gene Can Be Expressed in Different Parts of the Fly by Engineering the Eye Switch

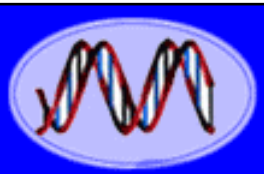
Eye Gene

Replace the Head Switch With the Leg Switch by Genetic Engineering

Eye Gene
+
Leg Switch



Abnormal activity of the eyeless gene has generated an eye on the leg of a fly.



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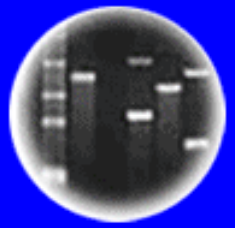


DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

Eye Regulatory Network

Control Genes Like The Eye Gene Control The Activity of Other Genes By Coding For a Protein That Interacts With Switches of Other Genes and Switches These Genes On!

Binds to Each Gene's Switch

Eye Proteins

5' Eye Switch | Eye Gene 3'

Eye Protein

Gene 1 → Protein 1
Gene 2 → Protein 2
Gene 3 → Protein 3
Gene 4 → Protein 4

Works in Head!

Eye Protein Binds to Switches to Turn Genes On!

Eye on Head!

Binds to Each Gene's Switch

Eye Proteins

Leg Switch | Eye Gene

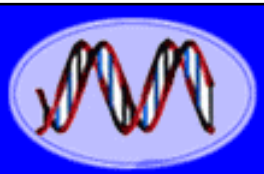
Eye Protein

Gene 1 → Protein 1
Gene 2 → Protein 2
Gene 3 → Protein 3
Gene 4 → Protein 4

Normally Eye Gene is OFF in Leg. Switch only Works in Leg.

Genes Act Like Legos!

Eye on Leg!



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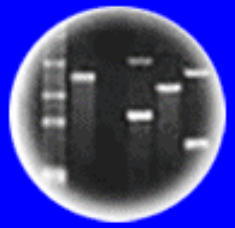

DNA Fingerprinting

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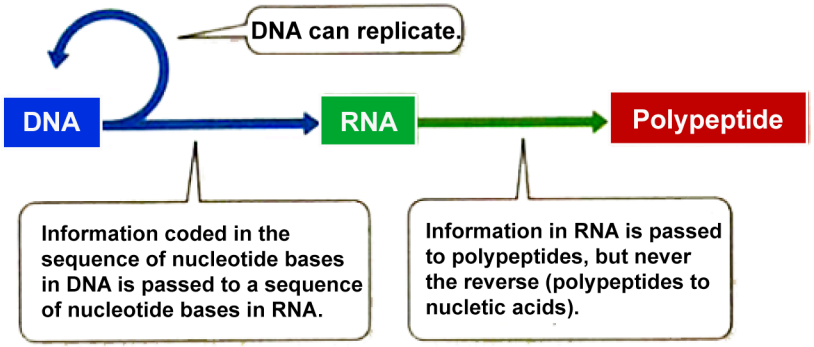
GENES AND SWITCHES ARE UNIQUE DNA SEQUENCES

1. They Can Be Cloned & "Shuffled" & Engineered Creating New Genes That Have No Counterparts in Nature
2. These New Genes Can Be Transcribed in New Cell Types (Switch Change) &/or Organisms &/or Both (e.g., Human Genes in Bacteria)
3. All Genes are Regulated & Controlled by Switches Genetic Engineering Can Uncover Genes & their Switches & the Wiring Together of All Switches in All Genes ⇨ Program of Life From Birth to Death

Yo! It's in the Sequences!!

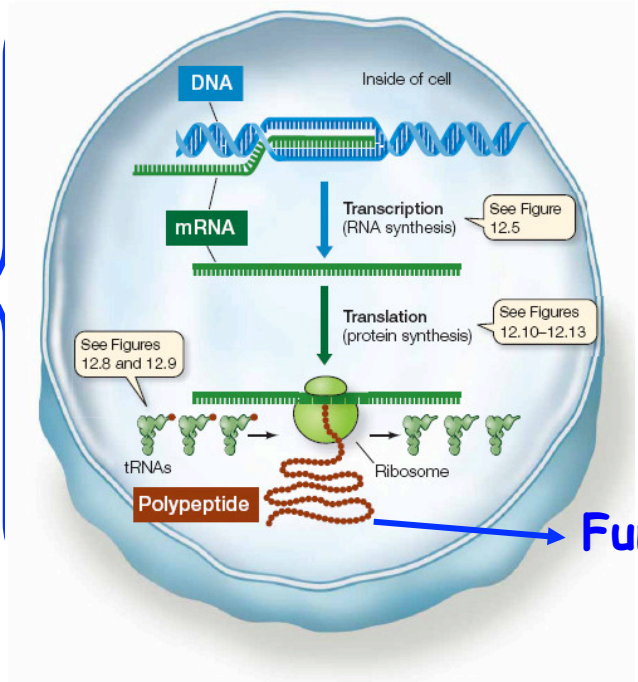
How Do Genes Work?

① Replication



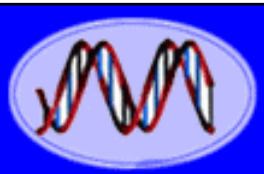
② Gene Activity to Function & Phenotype

Gene Activity → Protein → Function → Phenotype (Trait)



Function →

A Gene is NOT Expressed Unless A Functional Protein Produced!



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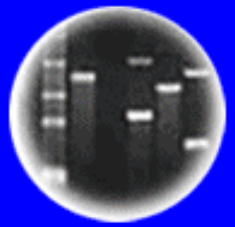

DNA Fingerprinting

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WHAT ARE THE PROPERTIES OF A GENE?

1. Replication

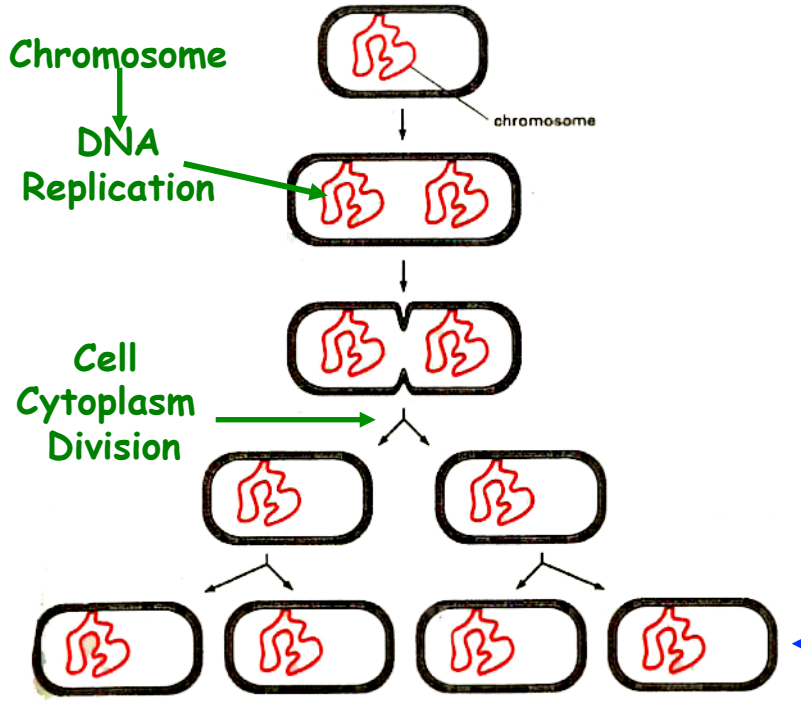
2. Stability (Mutations)

3. Universality
   a) All Cells
   b) All Organisms

4. Direct Cell Function/
   Phenotype

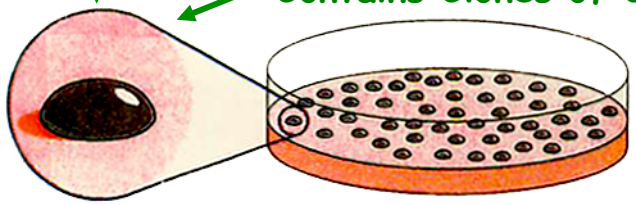
1

How Are Genes Replicated Each Cell Generation?



Clones

A Bacterial Colony Contains Many Copies of Same Cell, or Clones, Which are Genetically Identical!



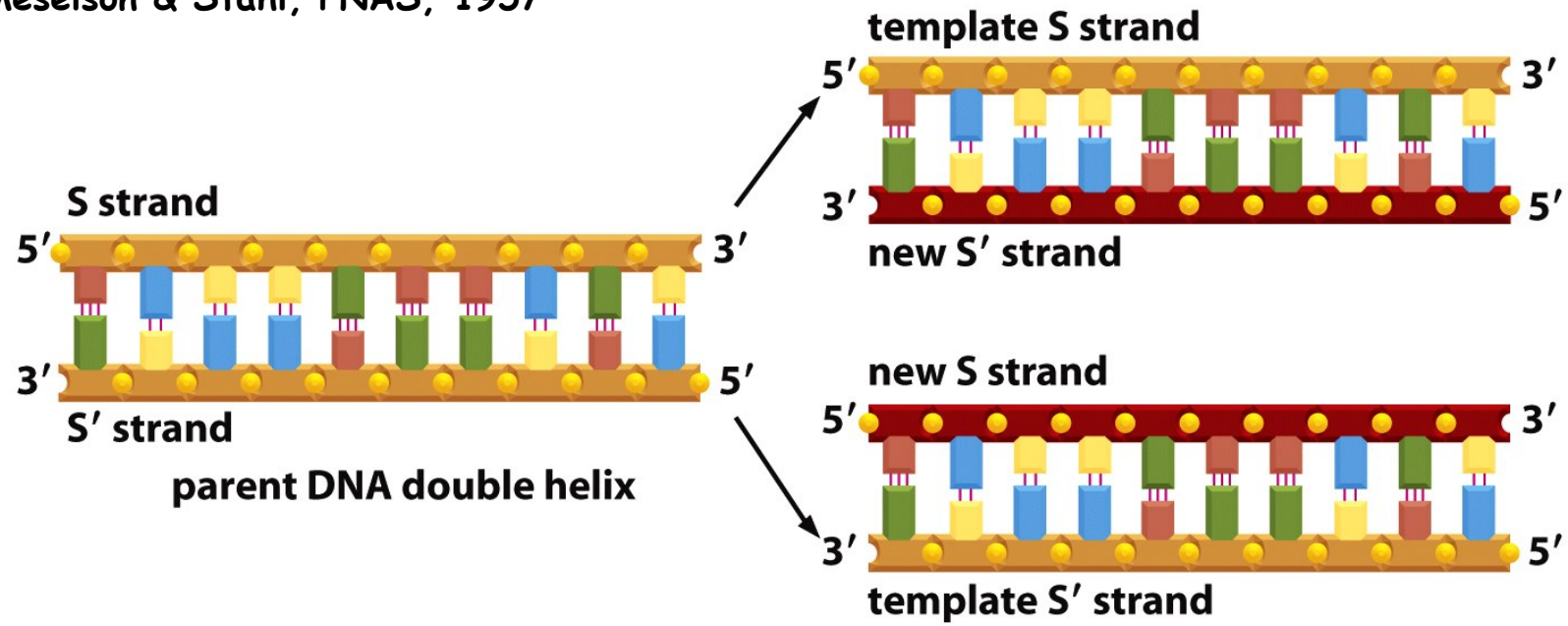
-10^6 cells per colony ~50 colonies per dish

Each Daughter Cell Contains The Same Collection of Genes

Clones!

DNA Replication Occurs Semi-Conservatively

Meselson & Stahl, PNAS, 1957



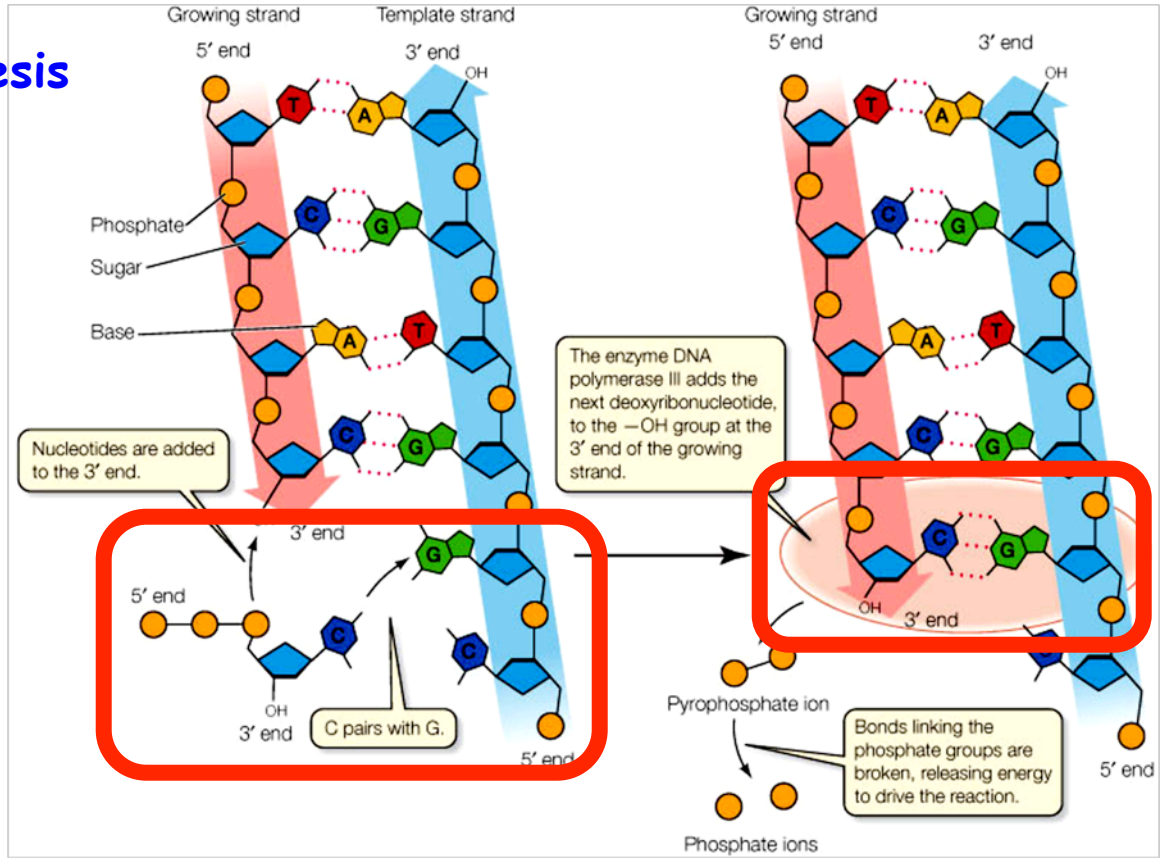
1. DNA Structure Allows DNA Sequence to Be Maintained by Complementary Base Pairing
2. Each Strand Serves as a Template for the Synthesis of a Complementary Strand
3. New DNA Molecules are Precise Copies of Parental DNA - Each Containing One Newly Synthesized Complementary Strand

DNA Sequence of One Strand is a Template For the New Strand

Synthesis

5'

3'

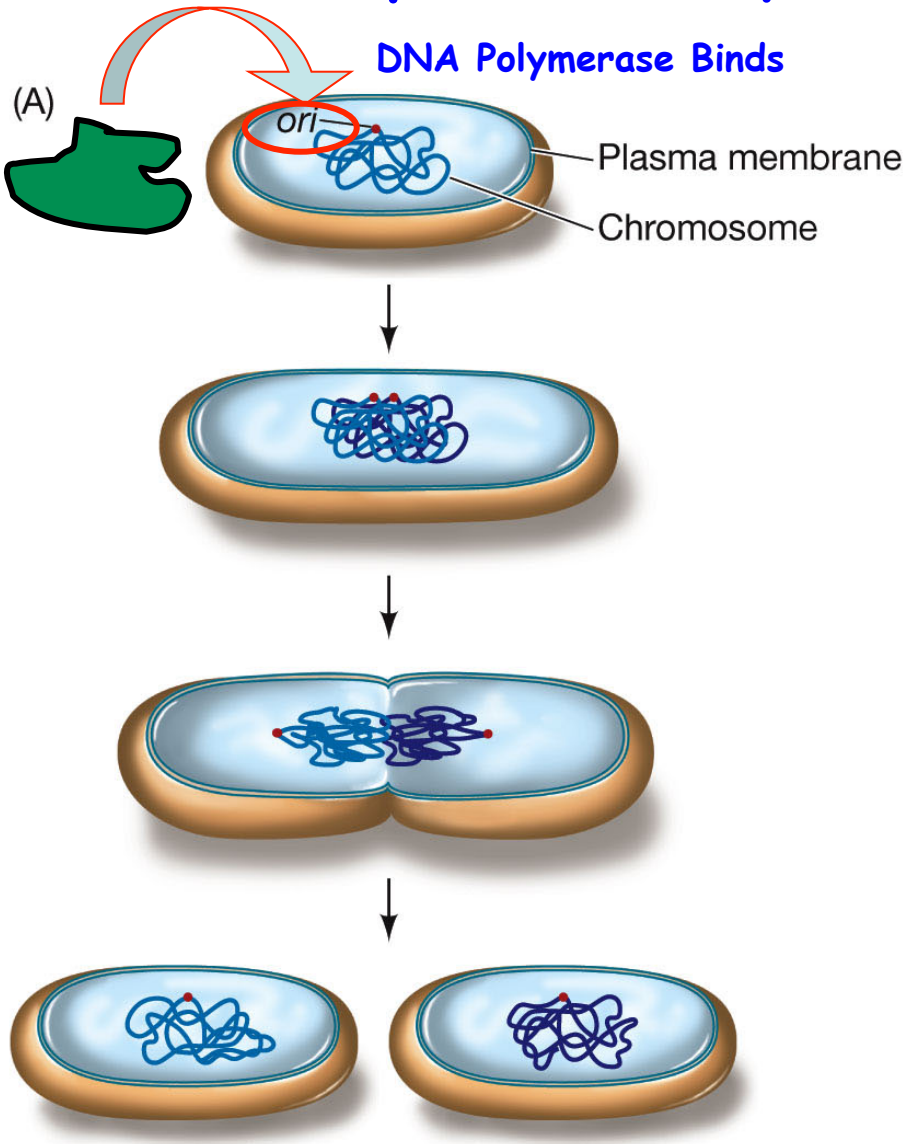


Sequence is Specified by Complementary Bases

Note: 5' (P) & 3' (OH)

5' to 3' Polarity Specifies Sequence

DNA Replication Requires An Origin of Replication



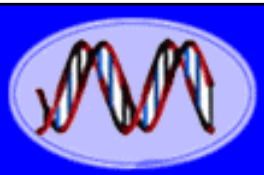
Two IDENTICAL Cells - Phenotypically & Genotypically - From One

(b)

DNA Replication Also Requires:

1. Template
2. Nucleotides
3. DNA Polymerase (Machine)
4. "Primer" to Start Replication

LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 9.2 Prokaryotic Cell Division



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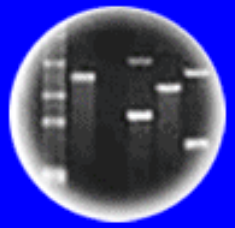

DNA Fingerprinting

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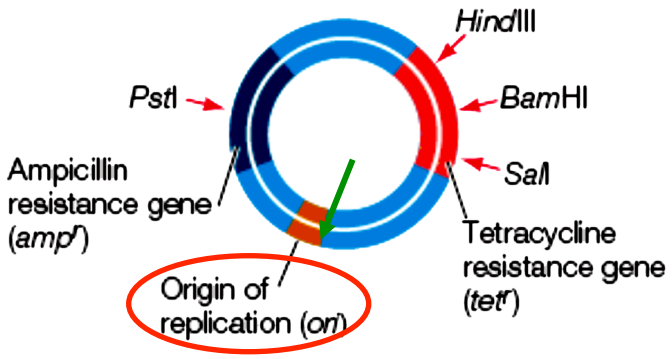
Vectors Are Needed To Replicate Genes In Transformed Cells

(A) **Plasmid pBR322**
Host: *E. coli*



1. Ori is a specific sequence
2. Ori is Genome & Organism Specific
3. DNA Polymerases are Specific For Each Organism Therefore, Need Correct Ori to Replicate Gene in a Specific Organism!

Note → Need Bacterial Ori to clone human gene in bacteria. Need human Ori to replicate a bacterial gene in human cells.

Ori Along Chromosomes Allows Gfp Gene to be Replicated. Uses Endogenous Ori!

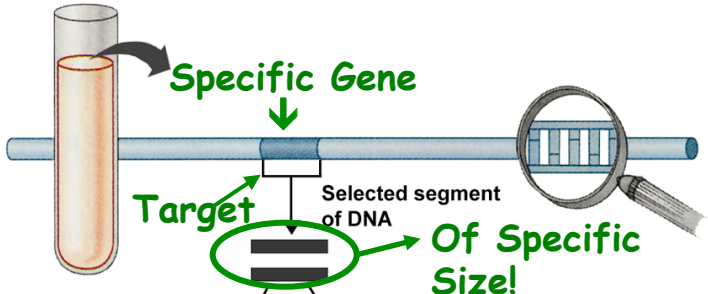
Yo! It's in the Sequence= Function

∴ Vectors can be Engineered!

Ori's can be cloned/synthesized!

MODULAR!!

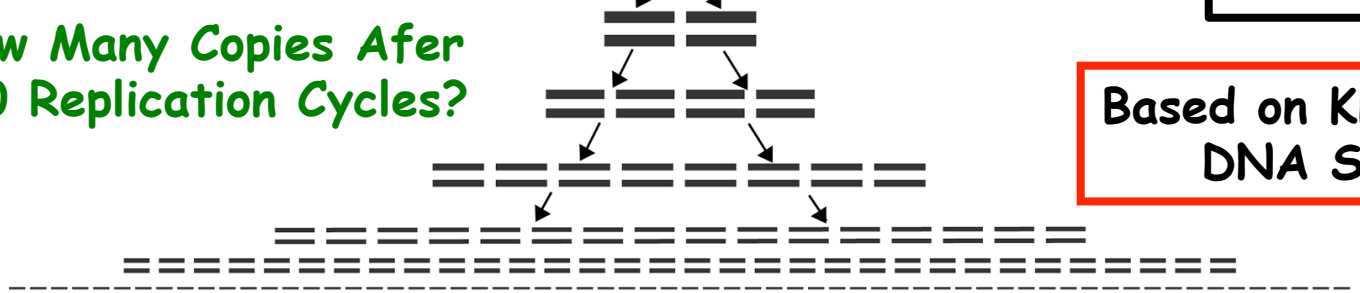
The Second Genetic Engineering Revolution - The Polymerase Chain Reaction (PCR) is a Molecular Xerox Machine That Can Amplify DNA Sequences in a Test Tube <u>Without Cloning!</u>



Kary Mullis

1993

How Many Copies Afer 10 Replication Cycles?



DNA Copies All The Same Size

Based on Knowledge of DNA Synthesis

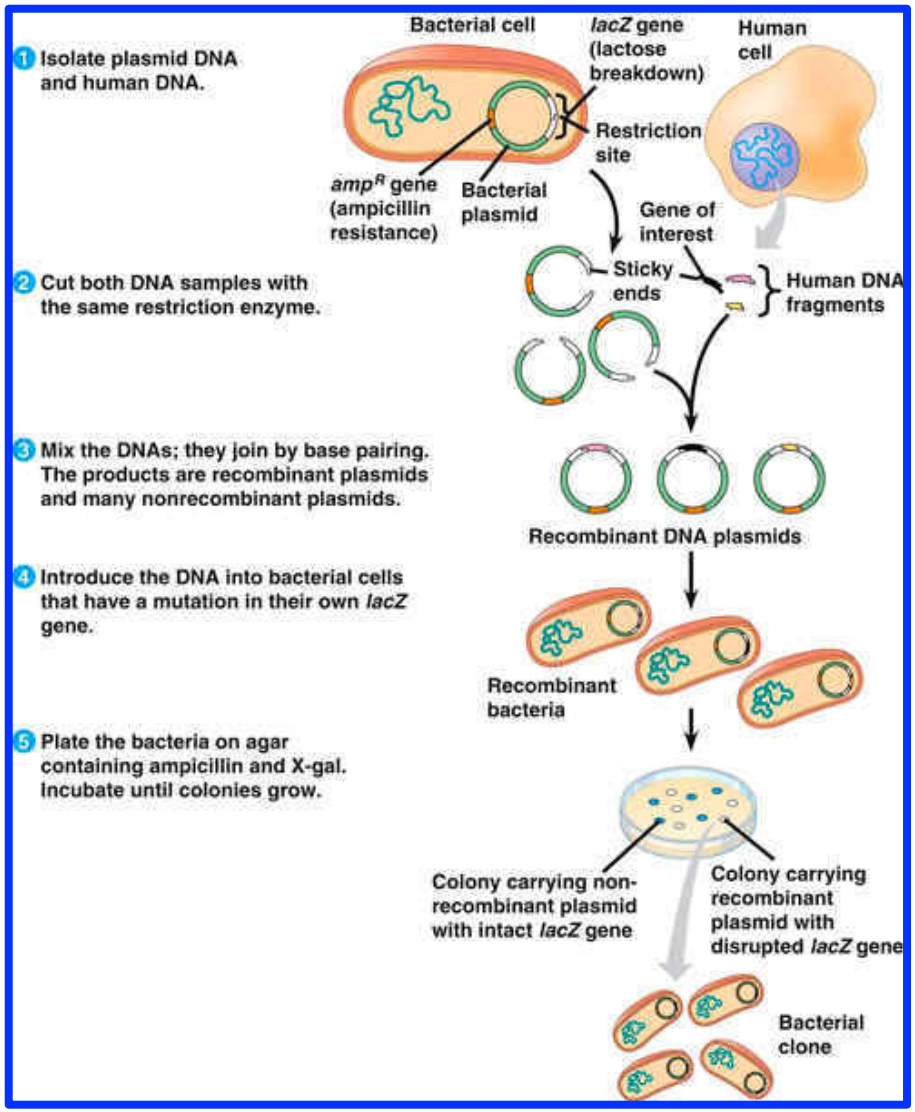
1. PCR Has **Revolutionized** DNA Analysis!

<u>Specific</u> DNA Sequences/Genes Can Be "Copied" Directly From "Tiny" Amount of DNA!

2. No Cloning Needed!

3. But Need Sequence! ⇨ Have to Clone "Gene" First

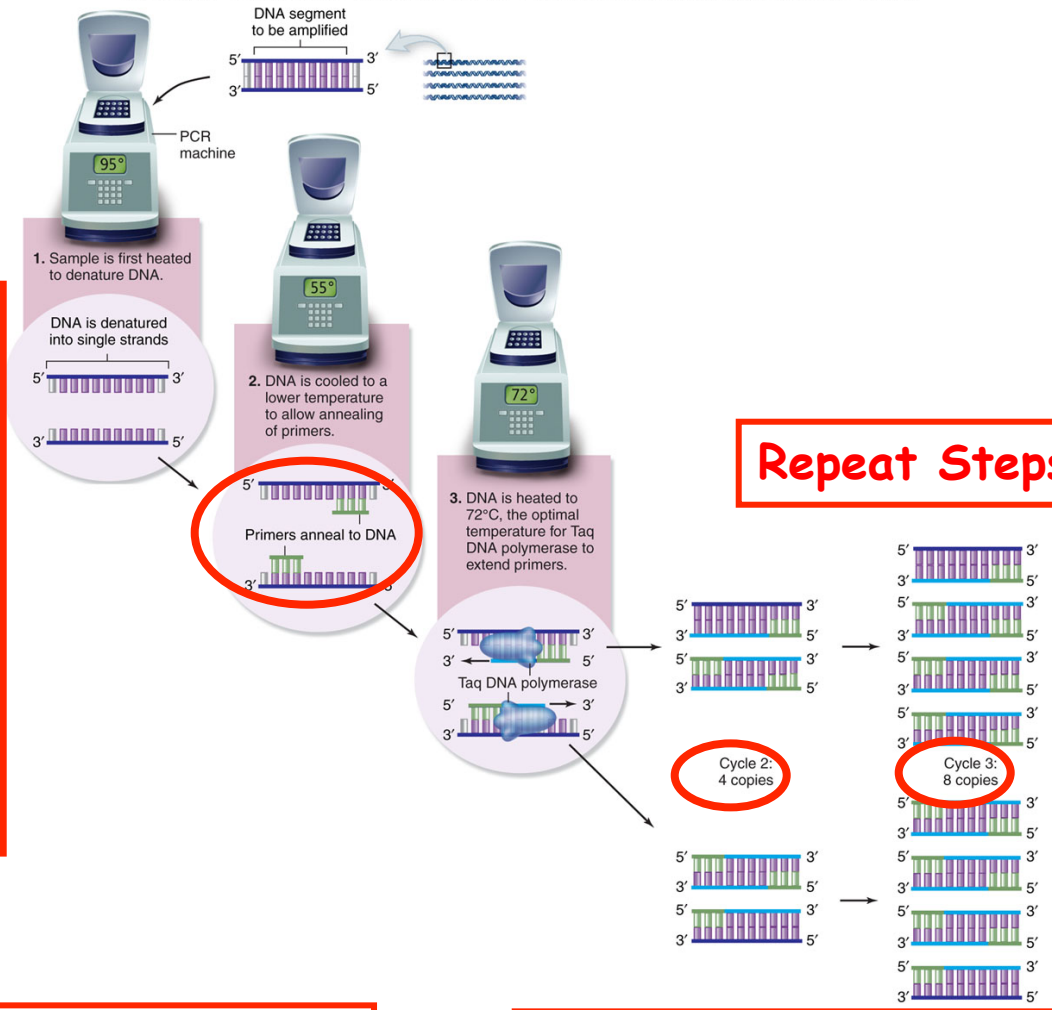
DNA Cloning the "Old Fashioned" Way is a Lot of Work!



PCR is A Cyclical Process of DNA Replication & Eliminates the Need For Vectors & Bacteria!

Requires

1. Template
2. Primers
3. Knowledge of Specific Sequence
4. Nucleotides
5. Heat-Stable DNA Polymerase
6. Thermo Cycler

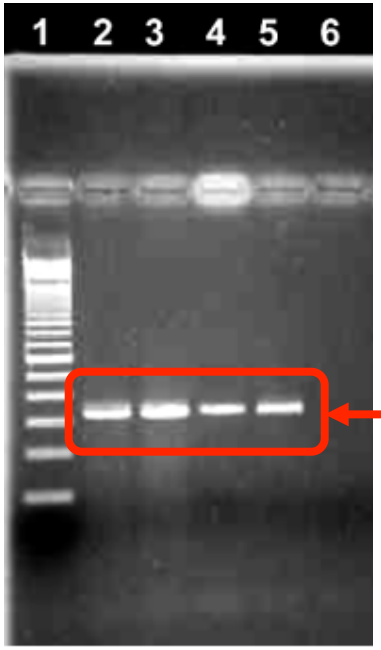


Repeat Steps or Cycle

2^n Molecules of DNA Where n = Number of Cycles

Diagnostic For Amplified DNA Sequence (Between Primers) → **DNA Fragments All The Same Size Primer-Sequence-Primer**

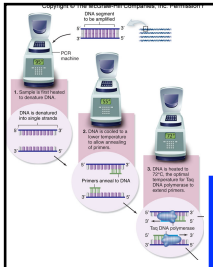
Using Gel Electrophoresis to Visualize PCR Products



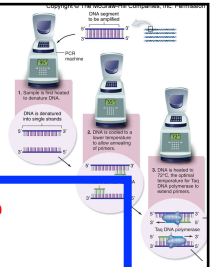
Specific Diagnostic DNA Band Unique to DNA Sequence Being Amplified

- Target-Specific Band
- Diagnostic For Specific DNA Sequence
- Band Size Unique For Specific Sequence
- Primers "Surround" the Target Sequence

Can Amplify One DNA Sequence From An Entire Genome *or an Entire Genome*!!!

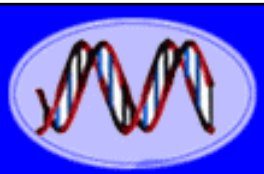


PCR Revolutionized Genetic Engineering & Working With DNA



1. Amplify Any DNA Sequence, or Gene, From "Tiny" Amounts of DNA or Biological Materials IF ORIGINAL SEQUENCE KNOWN
2. Study DNA From Limited and/or Degraded Sources Such As:
    1. A Single Human Hair or Cheek Cell
    2. An Ancient Fossil (e.g., Neanderthal Bone or Mammoth Hair)
    3. An Ancient Insect Trapped in Amber
    4. Human Remains (e.g., 9/11 Victims)
    5. A Single Human Embryo Cell
    6. Contaminated Meat To Determine the Causal Organism
3. Used In:
    1. DNA Fingerprinting-Individual Identification-Genetic Disease Screening
    2. Forensics (Crime Scenes, Mass Graves, Criminal Suspects, Wrongfully Convicted)
    3. Paternity & Family Relationships (e.g., Immigration, Tracing Lost Children)
    4. Disease Diagnosis & Pathogen Identification (Humans, Animals, & Plants)
    5. Human Origins & Migrations
    6. Ancient Genome Sequences & Evolutionary Studies
    7. Specific mRNA Detection
    8. "Cloning" Specific DNA Sequences
    9. Tracing Plant & Animal Sources (e.g., Poaching Stolen Cattle, Cactus)
4. Need as Little as One Molecule of DNA & Can Replicate an ∞ Amount of Specific Sequences


NIGHTLINE



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Entire Genetic Code
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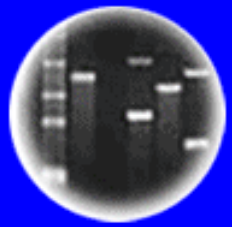

DNA Fingerprinting

Cloning: Ethical Issues
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WHAT ARE THE PROPERTIES OF A GENE?

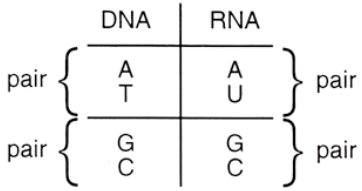
1. Replication

2. Stability (Mutations)

3. Universality
   a) All Cells
   b) All Organisms

4. Direct Cell Function/
   Phenotype

DNA Replication is Precise
But Mistakes or Mutations Can Occur!

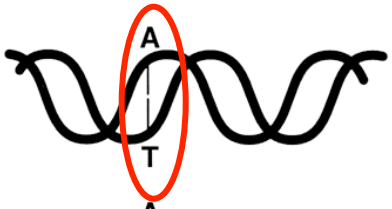


BASE PAIR RULES

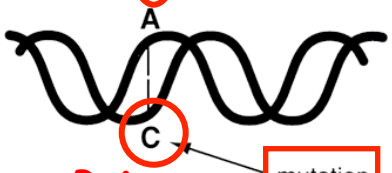
Think Tautomers!

Rare Base Mismatch

Gene A



Replication①



MUTATION DURING REPLICATION

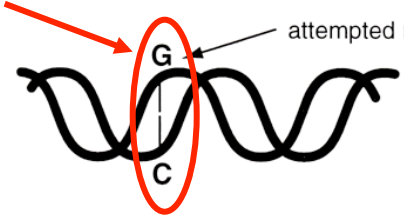
mutation

C mispairs with A

See Mutation As Change in Phenotype Creates Alleles

New Base Pair

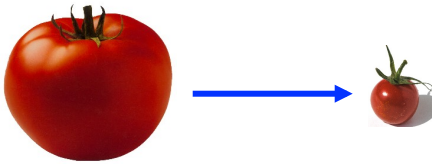
Replication②
Gene A'
Allelic Variant



RESULTING DEFECT

Change DNA Sequence From A = T to G ≡ C

∴ Change Protein Amino Acid Sequence ⇨ Alter Function!

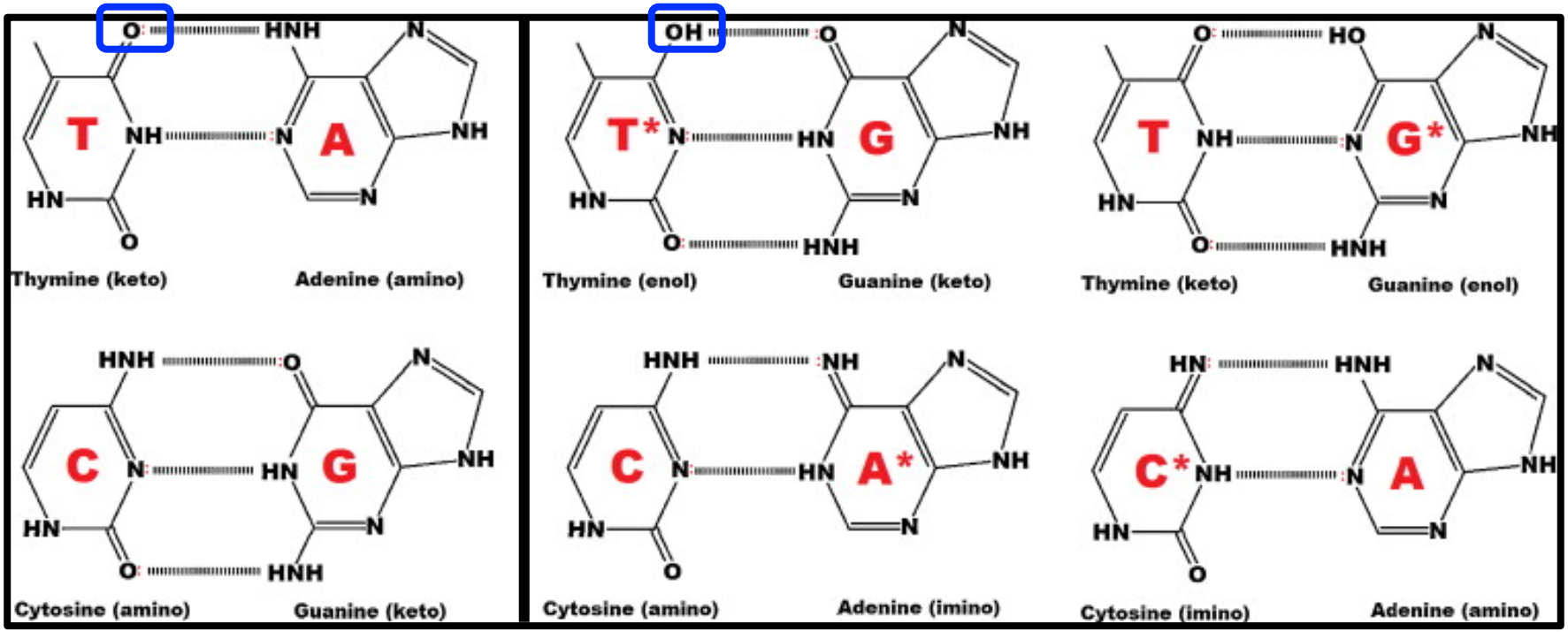


Big Tomato to Small Tomato

TAUTOMERS CHANGE BASE PAIRING RULES

Normal Forms – Keto & Amino

"Mutant" Forms – Enol & Imino

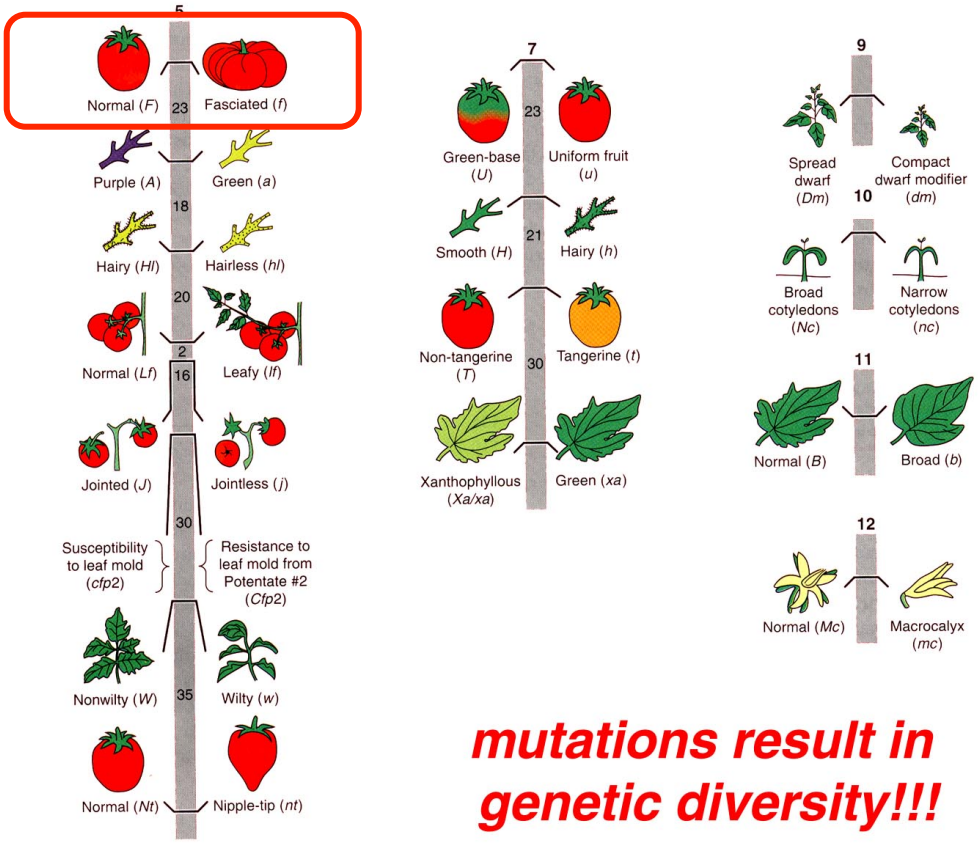


And Lead To Mistakes in DNA Replication & Mutations ➤ Genetic Diversity

Chemistry Leads to Biology!!

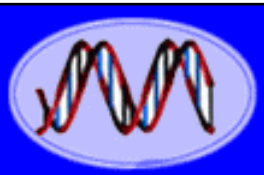
Alternative Forms of the Same Gene Lead to Genetic Diversity

Alleles



mutations result in genetic diversity!!!

Spontaneous Mutations Give Rise To Alleles, or Different Forms of the Same Gene, And result in Small DNA Sequence Changes (e.g., SNPs or Single Nucleotide Polymorphisms)



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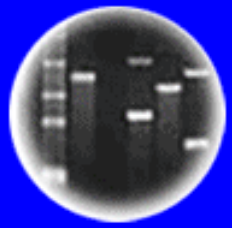

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ARTICLE

doi:10.1038/nature09534

A map of human genome variation from population-scale sequencing

The 1000 Genomes Project Consortium*

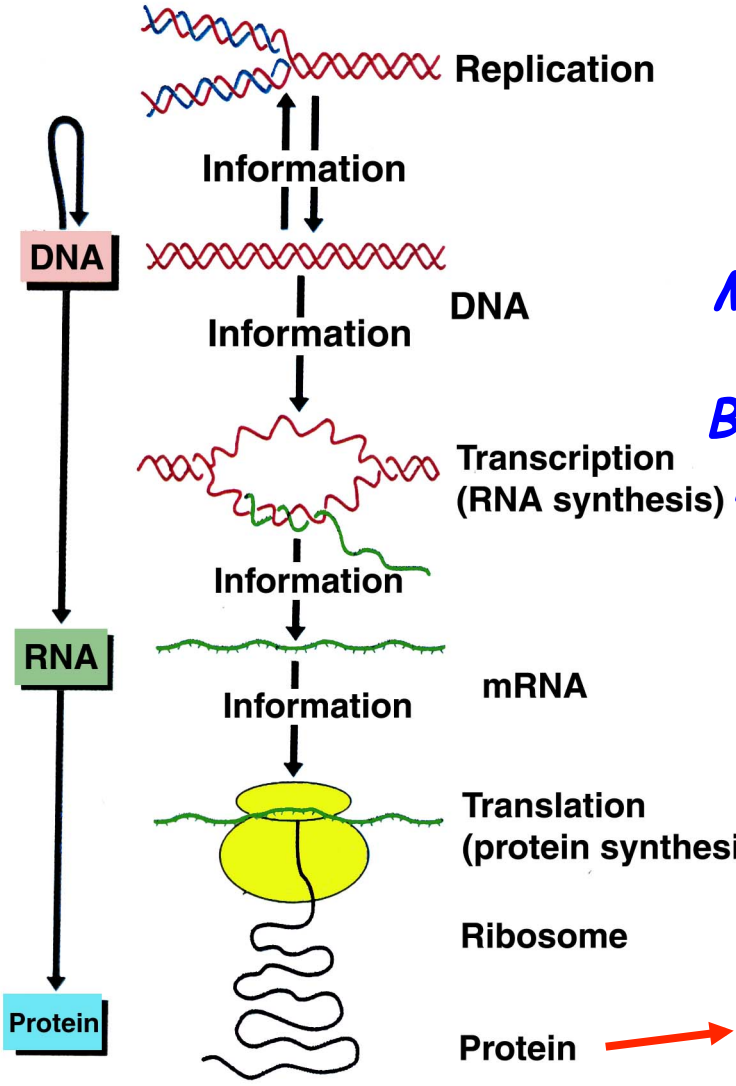
Nature, October 10, 2010

The 1000 Genomes Project aims to provide a deep characterization of human genome sequence variation as a foundation for investigating the relationship between genotype and phenotype. Here we present results of the pilot phase of the project, designed to develop and compare different strategies for genome-wide sequencing with high-throughput platforms. We undertook three projects: low-coverage whole-genome sequencing of 179 individuals from four populations; high-coverage sequencing of two mother–father–child trios; and exon-targeted sequencing of 697 individuals from seven populations. We describe the location, allele frequency and local haplotype structure of approximately 15 million single nucleotide polymorphisms, 1 million short insertions and deletions, and 20,000 structural variants, most of which were previously undescribed. We show that, because we have catalogued the vast majority of common variation, over 95% of the currently accessible variants found in any individual are present in this data set. On average, each person is found to carry approximately 250 to 300 loss-of-function variants in annotated genes and 50 to 100 variants previously implicated in inherited disorders. We demonstrate how these results can be used to inform association and functional studies. From the two trios, we directly estimate the rate of *de novo* germline base substitution mutations to be approximately 10^{-8} per base pair per generation. We explore the data with regard to signatures of natural selection, and identify a marked reduction of genetic variation in the neighbourhood of genes, due to selection at linked sites. These methods and public data will support the next phase of human genetic research.

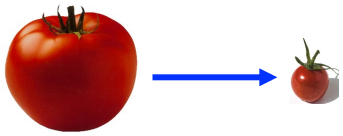
- Sequenced Genomes of 2500 individuals & From 26 Different Global Populations
- Found 84 Million Variants (SNPs) & <0.5% Unique to a Population!
- Evidence For Common Ancestry of All Humans
- Found 250-300 Loss-Of-Function Mutations (KOs) Per Person
- Found 50-100 Mutations Implicated in Genetic Disorders Per Person
- 10^{-8} bp Mutations Per Generation (30 per Genome)

Translating The Genetic Code Into Proteins is a Conserved Process

Mutations Are Inherited Because Altered Gene Replicates



Mutations Lead To Altered Protein Because mRNA and Protein Sequence Encoded By Gene Changes



Mutations Lead to Altered Traits/Phenotype Because Protein Structure Changed

Human Genetic Disorders Occur As a Result of Rare Mutations

TABLE 13.2 Some Important Genetic Disorders

Disorder	Symptom	Defect	Dominant/ Recessive	Frequency Among Human Births
Hemophilia	Blood fails to clot	Defective blood-clotting factor VIII	X-linked recessive	1/10,000 (Caucasian males)
Huntington disease	Brain tissue gradually deteriorates in middle age	Production of an inhibitor of brain cell metabolism	Dominant	1/24,000
Muscular dystrophy (Duchenne)	Muscles waste away	Degradation of myelin coating of nerves stimulating muscles	X-linked recessive	1/3700 (males)
Hypercholesterolemia	Excessive cholesterol levels in blood lead to heart disease	Abnormal form of cholesterol cell surface receptor	Dominant	1/500

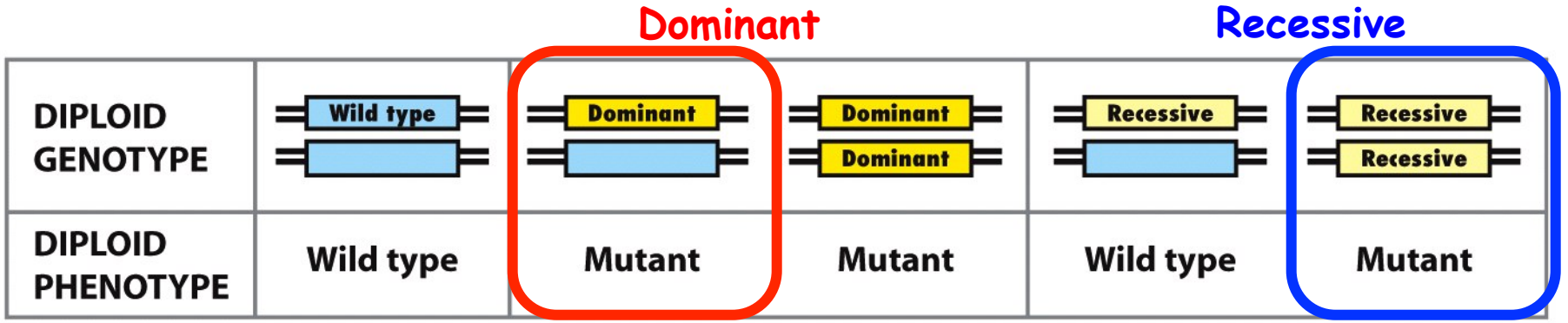
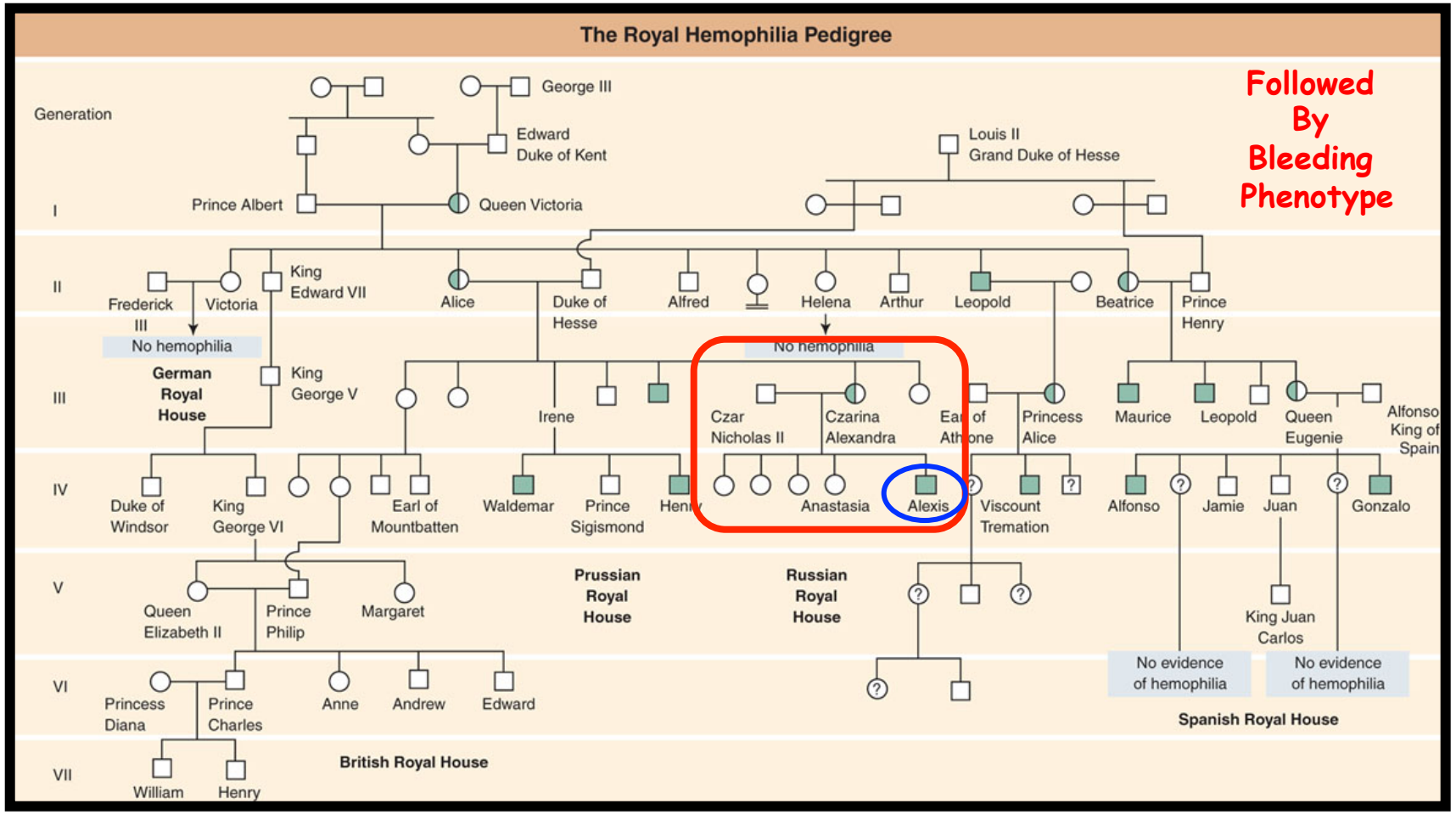


Figure 5-2
Molecular Cell Biology, Sixth Edition

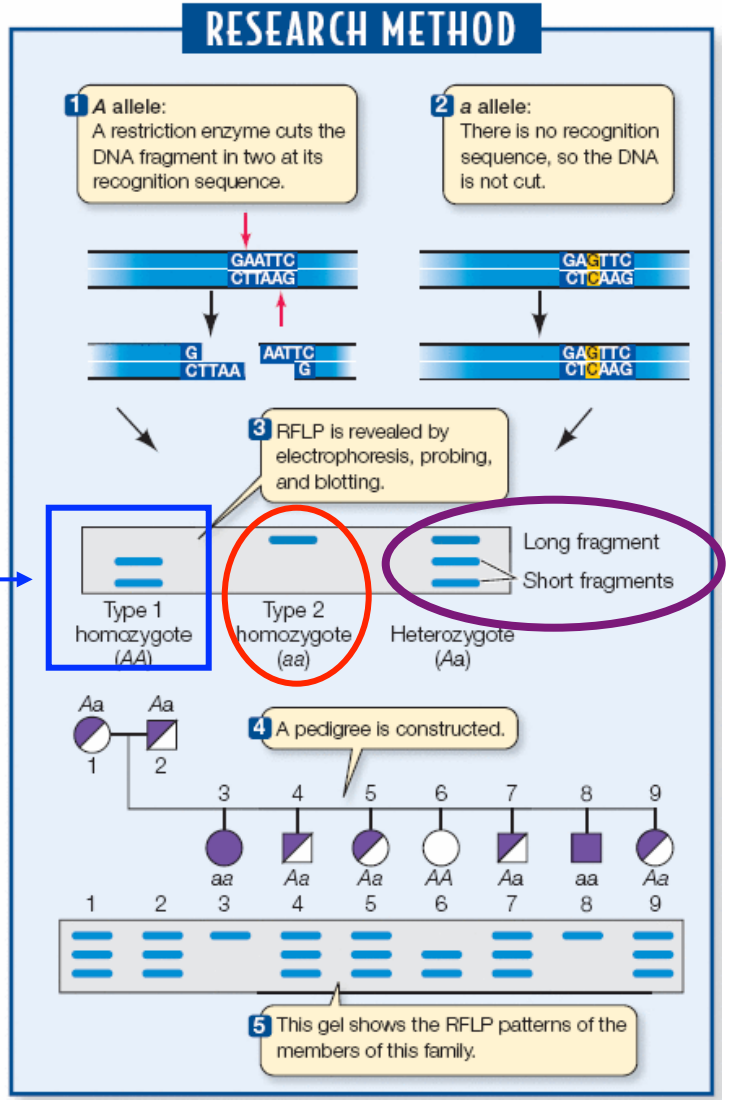
Pedigrees Can Be Used To Follow Disease Genes in Human Families



Recessive Sex Linked

Genetic Diseases Can Also Be Followed in Families Using DNA Methods (e.g., PCR) & Pedigrees – With DNA Markers Linked to the Disease Phenotype

DNA Fingerprints →



← RFLP – Restriction Fragment Length Polymorphism

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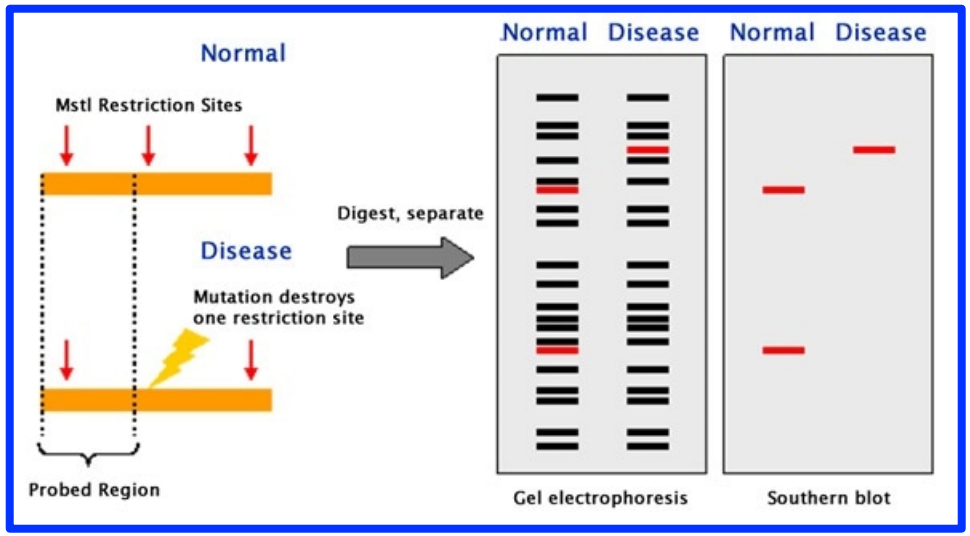

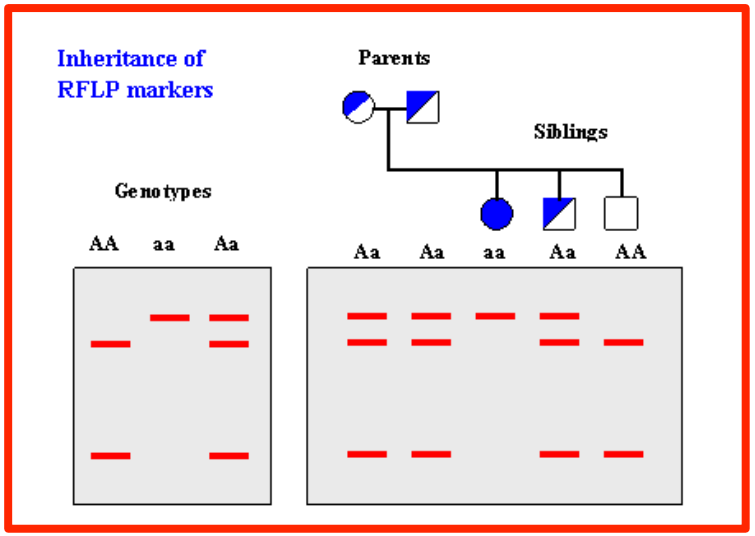

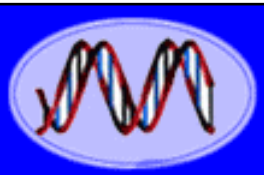

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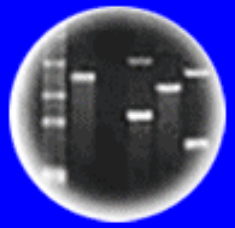

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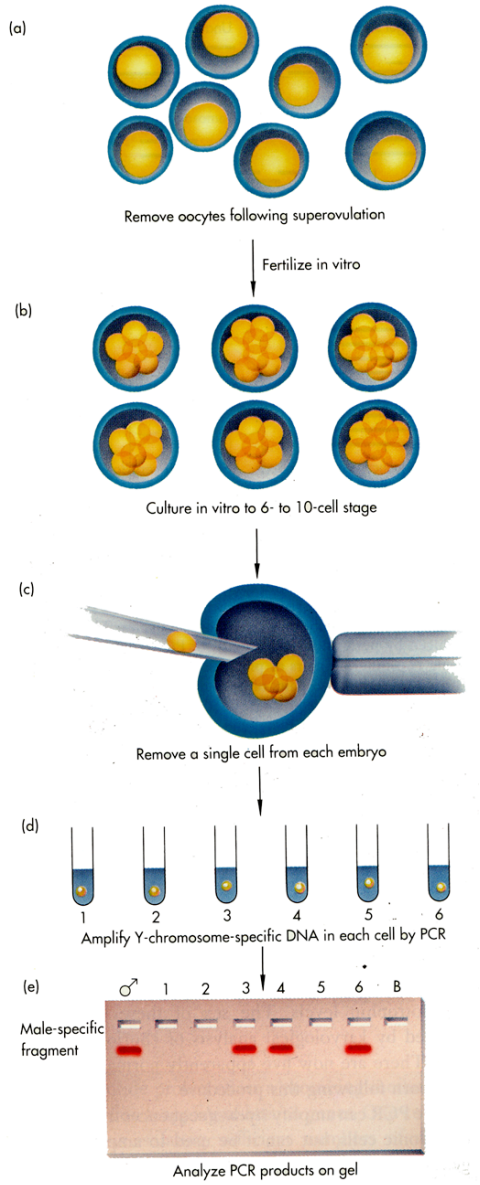
PCR Can Be Used To Analyze Gene in A Single Embryo Cell

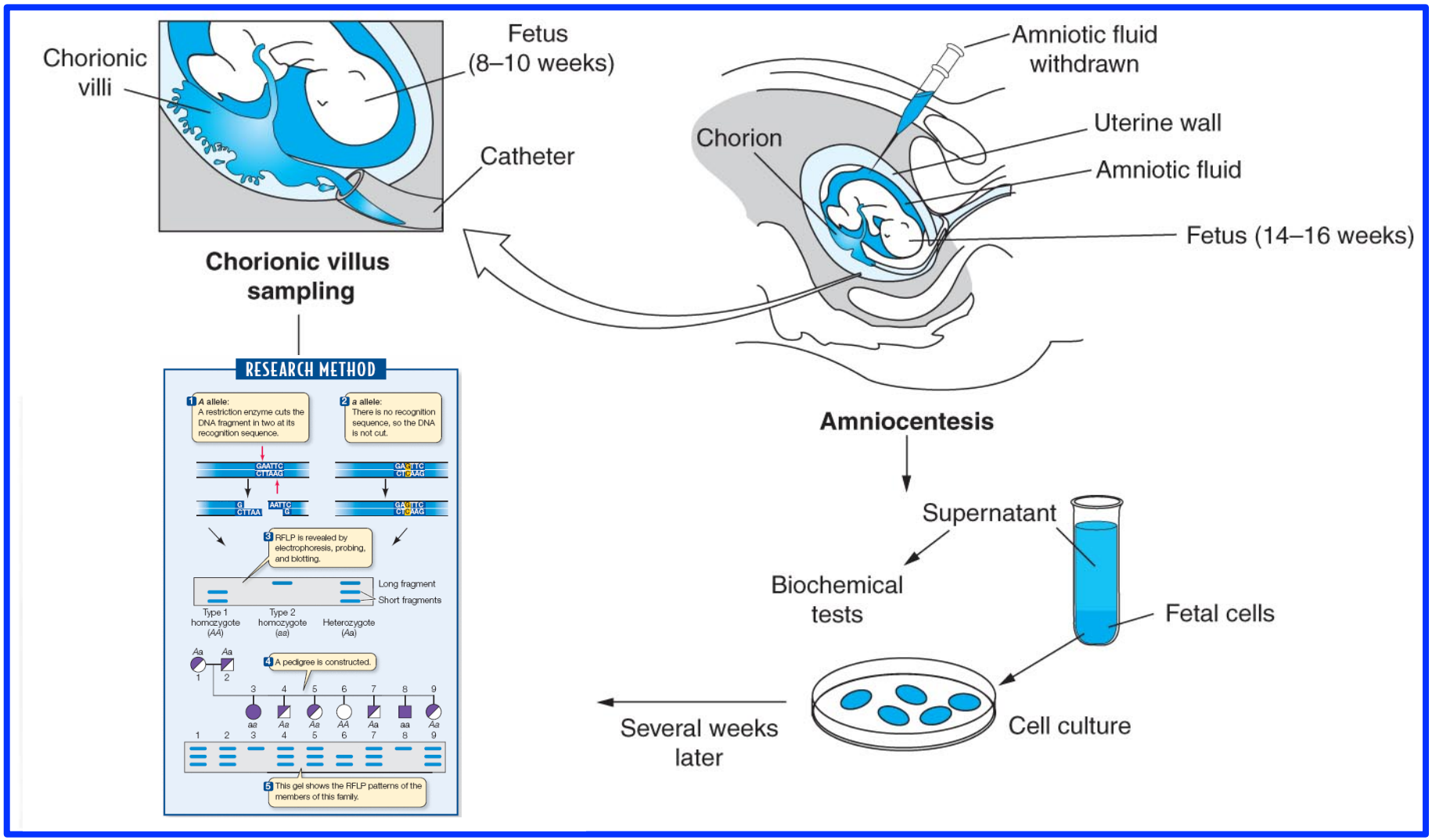
PGD
Pre-Implantation Genetic Diagnosis



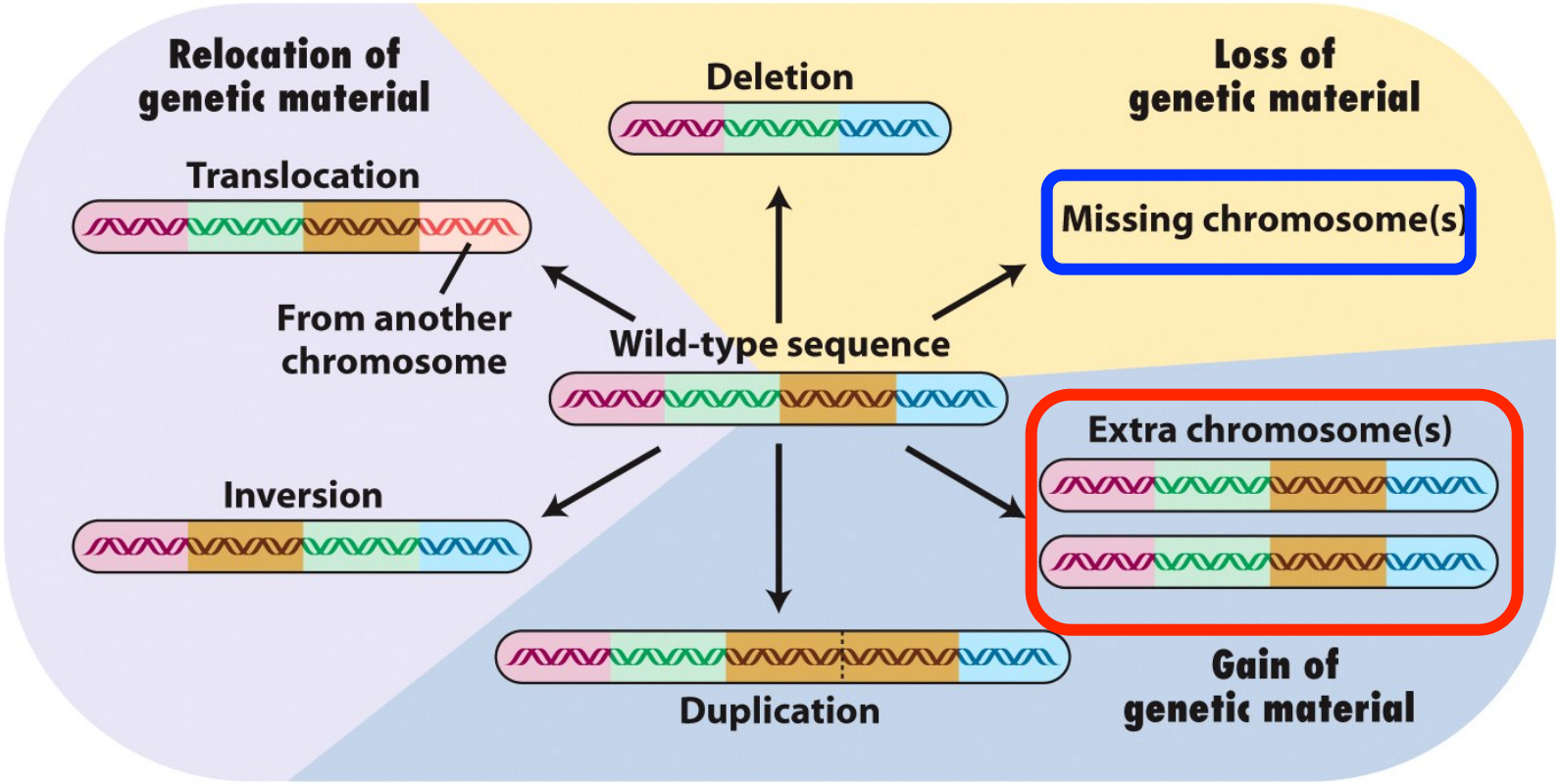
What is The Implication of This Procedure Considering That The Human Genome Has Been Sequenced?

Sex Determination in 8-cell Embryo!

DNA Testing Can Be Carried Out Before Child Birth During Pregnancy



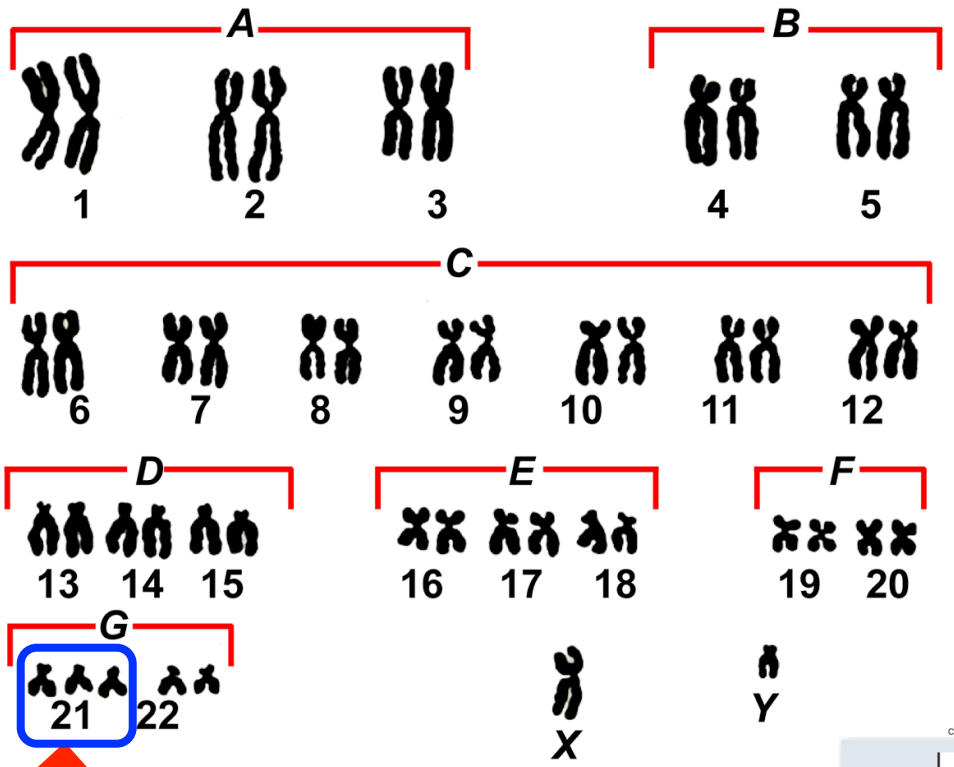
"Mutations" Can Also Occur By Large Chromosomal Changes



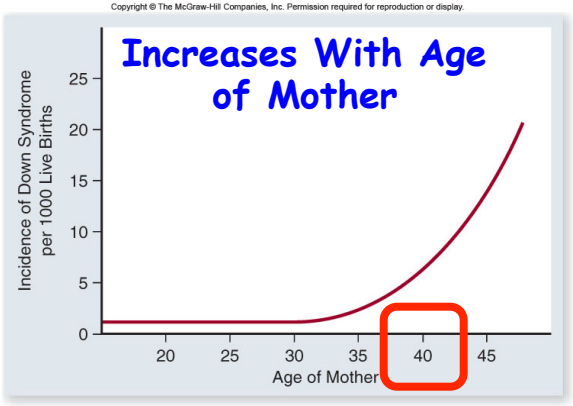
These changes affect many genes!

e.g. Down's Syndrome (3 Chromosome #21s)

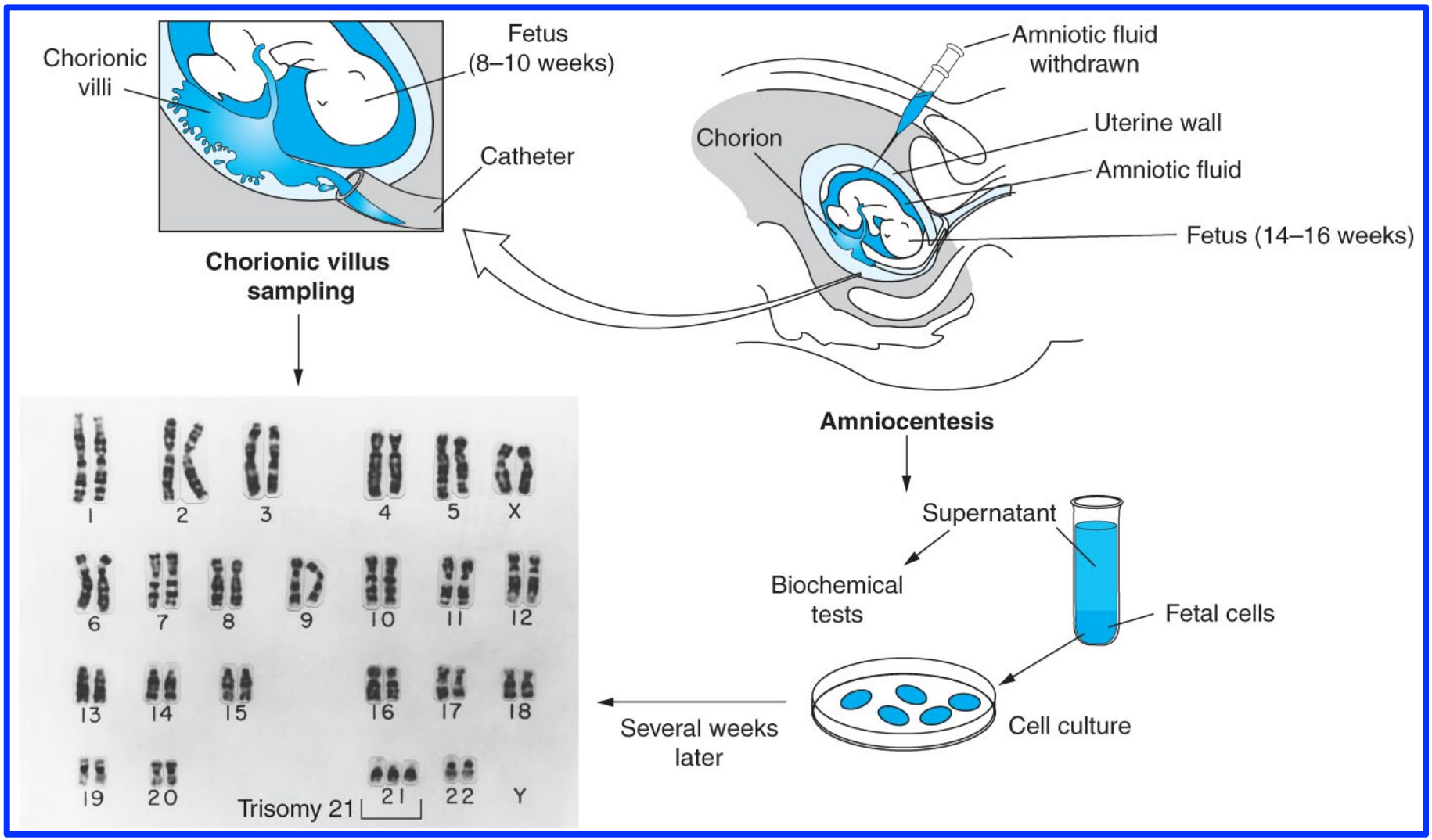
A Down's Syndrome Karyotype

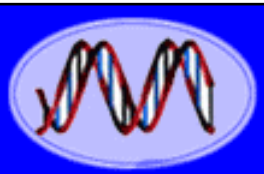


Three Chromosome # 21s



Chromosome Testing Can Be Carried Out During Pregnancy or Before (New DNA Tests)





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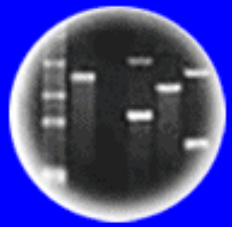

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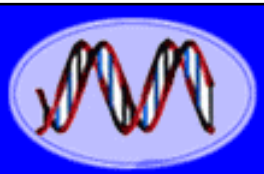
Genetic Screening Issues

- Why Screen For Genes?
- When is a Test Accurate Enough?
- Mandatory or Voluntary Screening?
- Who Should Be Tested?
- Employer & Insurance Company Testing?
- Protection From Genotype Discrimination?
- Testing for Genetic Diseases With No Cures?
- How Ensure Privacy & Confidentiality?
- Obligations to Inform Others (Spouse/Sibling) of Genetic Disorder Knowledge?
- Genetic Databases??
- Patents on Tests?



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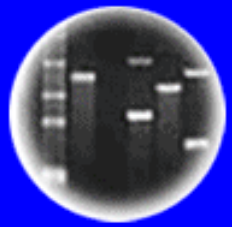

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WHAT ARE THE PROPERTIES OF A GENE?

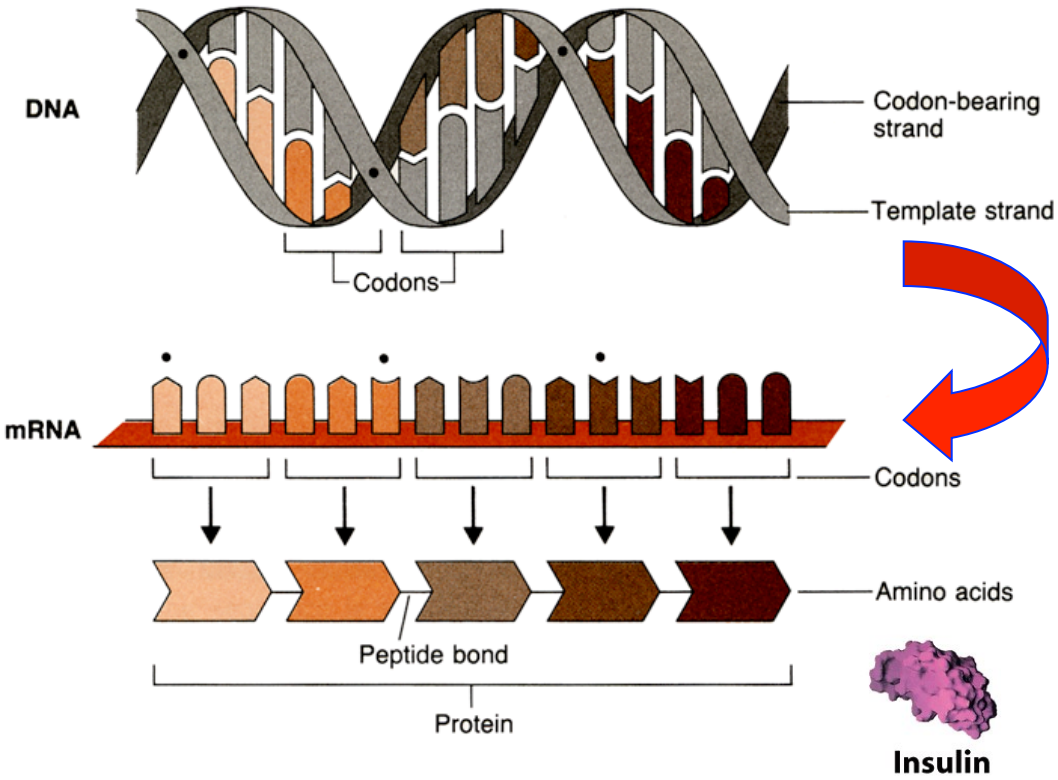
1. Replication

2. Stability (Mutations)

3. Universality
   a) All Cells
   b) All Organisms

4. Direct Cell Function/ Phenotype

② How Does A Gene Lead To A Phenotype?



① mRNA Synthesized by Transcription

- Complementary to Transcribed, Non-Sense Strand
- Same Sequence As Sense Strand

② mRNA Translated into Protein by Translation of The Genetic Code

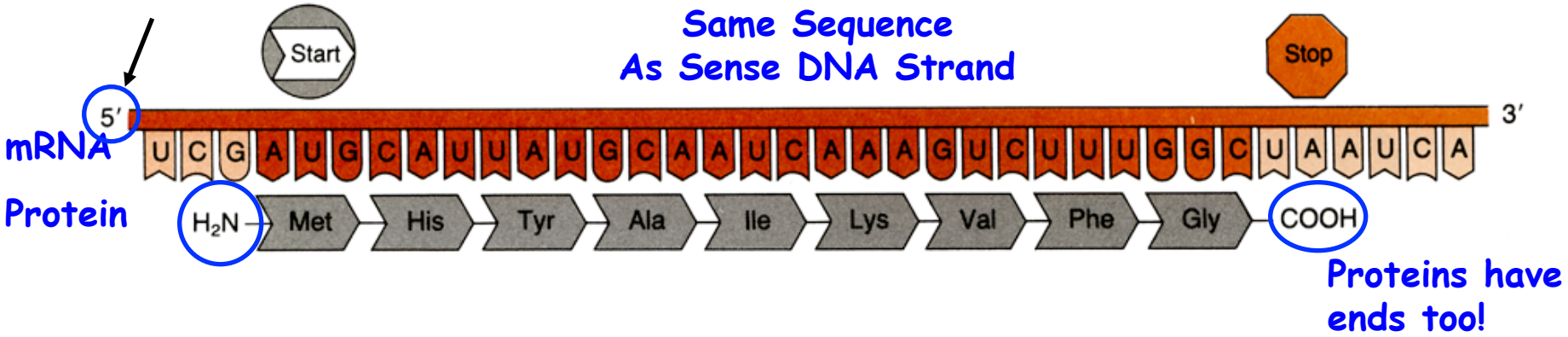
Genetic Code on mRNA Translated to Protein Sequence

∴ Sequence of Gene
↓
Sequence of mRNA
↓
Sequence of Protein

Colinearity of Sequences!

Know Sequence
Know Protein
→ Engineer New Protein

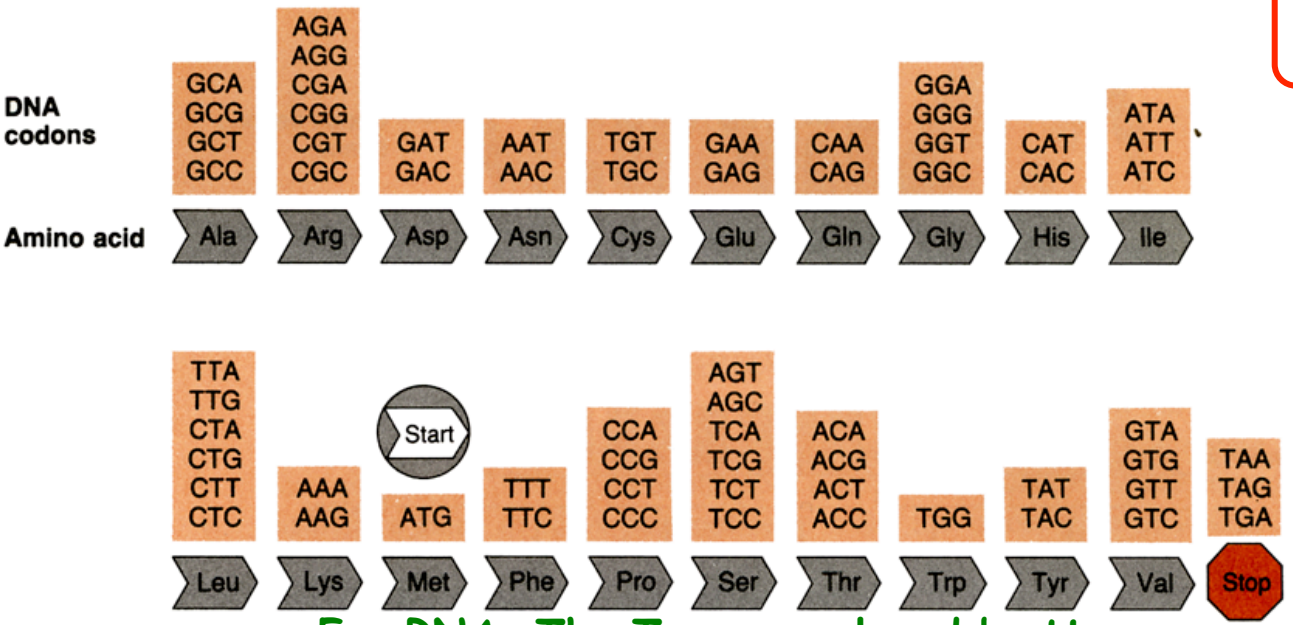
Genetic Code Allows The Sequence of Nucleotides in mRNA/Sense strand of Gene to be Translated into Sequence of Amino Acids in Proteins



Note: Sequence in mRNA (= Sense Gene Strand) is translated 5' →3' (= beginning of sense strand to end) & protein made in N→C direction – therefore: order nucleotides in gene specifies order of amino acids in protein!

The Genetic Code is Universal!

How Know?



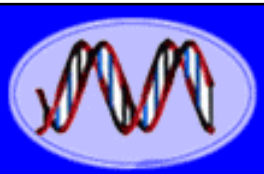
For RNA, The Ts are replaced by Us.

1. Universal
2. Triplet
3. Punctuation
4. Degenerate

Know Sequence of Gene-Know Sequence of Protein Using Genetic Code

Big Implication For Genetic Engineering! Can Make Genes, Genomes & Specify Proteins Wanted! Can Express Genes From One Organism in Another!

Design An Experiment to Show Code is Universal!



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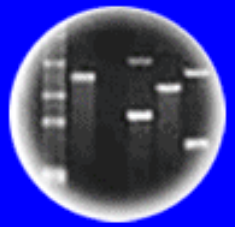

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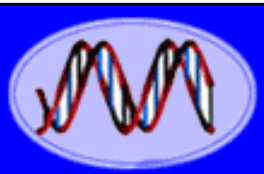
Expression of Jellyfish Green Fluorescence Protein (GFP) in Pigs Shows That Genetic Code is Universal!!



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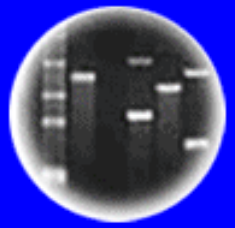

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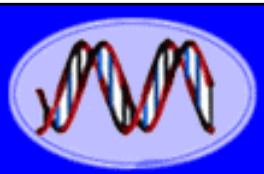
Implications For Genetic Engineering - "Yo - Its in The DNA!!"

Modular Organization of Sequences

1. DNA Replication
   - Ori
2. Transcription
   - Switch/Regulator
   - Terminator
3. Processing of RNA (Eukaryotes)
   - Splicing Sites
4. Translation
   - Start
   - Stop
   - Genetic Code/Codons
5. Coding Sequence
   - Genetic Code

Modules → Anything You Want To Do Using Genetic Engineering!



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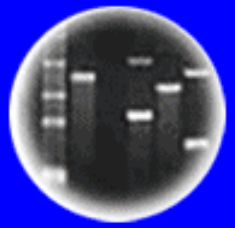

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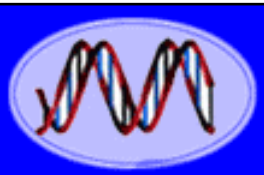
Summary: Engineering Genes Requires:

1. The Gene & Its DNA Sequences
2. A Roadmap of Where Coding Sequence & All Switches Located (Sequence, Restriction Site Map)
3. Transcription Start And Stop Switches
4. Coding Region of Gene (genetic code part)
5. Translation Start And Stop Switches
6. Kingdom-Specific Switches/ Signals

Note: The General Process of Gene→Protein is the same in ALL organisms, but the Specific Switches & Enzymes (e.g., RNA Polymerase) are Kingdom Specific

Bacteria Transcription On Switch + Human Insulin Coding Sequence + Bacteria Transcription Off Switch

→ *Human Insulin in Bacteria!!*



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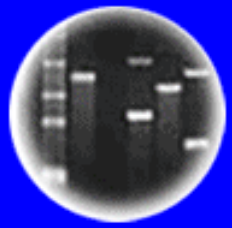

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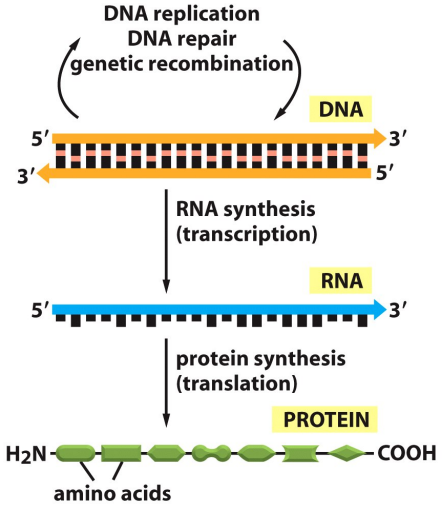
How Do Genes Work & What are Genes in Context of…

Thinking About The Consequences of GMOs



1. What is a Gene?
2. What is the Anatomy of a gene?
3. How Does the Gene Replicate?
4. How Does the Gene Direct Synthesis of a Protein?
5. Does the Gene Work Independently of other Genes?
6. What is the Sequence & Structure of the Protein?
7. How does it work in cell?
8. Does the Protein Structure imply any Potential "Harm"?
9. Does the Gene Change the organism? Fitness?

Need Science-Based Questions & Science-Based Solutions-NOT OPINIONS!

There's NO HOCUS POCUS
All Hypothesis Are Testable!!

"Behind" All Traits!

Same Processes!