

DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria

DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

HC70A

Spring 2021

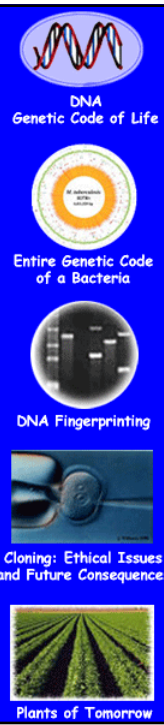
Genetic Engineering in Medicine, Agriculture, and Law

Professor Bob Goldberg

Lecture 3

What Are Genes & How Do They Work: Part One

1



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria

DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

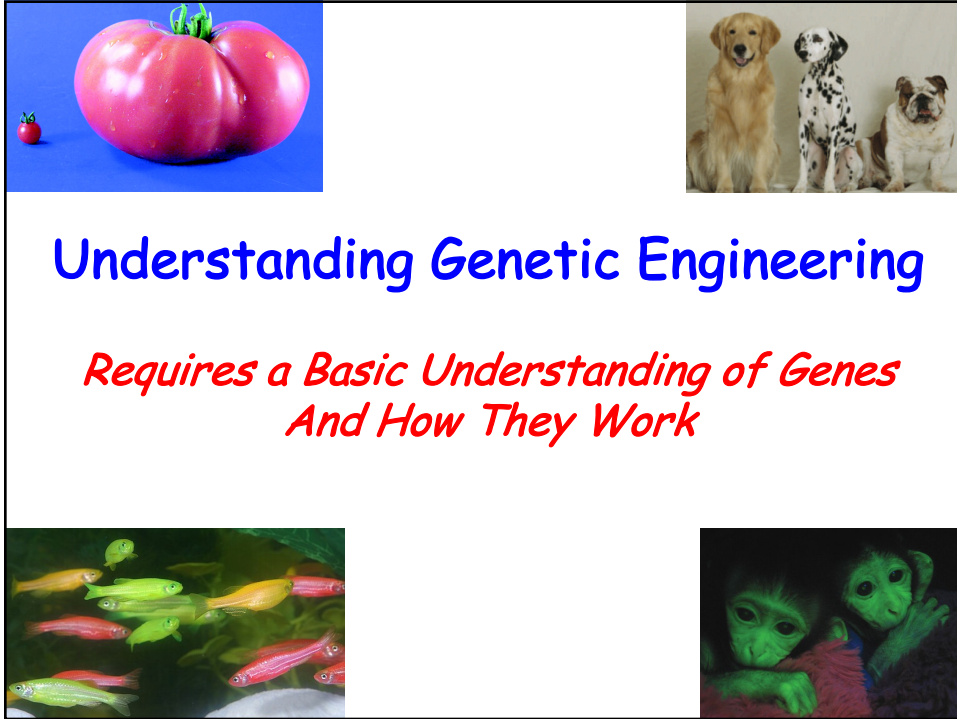
Plants of Tomorrow

THEMES

Gene Structure & Function Part One

- What is the Function of a *Gene*?
- What are the Properties of *Genes*?
- How Was DNA Discovered?
- What is the Evidence That DNA is the *Genetic Material* (Griffith and Avery Experiments)?
- Is Transformation Universal?
- What is the Structure of DNA?
- What is the Structure of a Chromosome?
- What is the Colinearity Between *Genes* & Proteins (how does DNA→protein)?
- How Do We Know That *Genes* Function Independently of One Another?
- What is the Anatomy of a *Gene*?
- How Do Switches Work to Control *Gene* Activity?
- What Are the Possibilities For Manipulating *Genes* in the Future?

2



Understanding Genetic Engineering

*Requires a Basic Understanding of Genes
And How They Work*

3

What Are the DNA Implications of Generating an *E. coli* Cell Producing GFP Protein?

pGLO Plasmid DNA

***E. coli* Producing GFP Protein**

1. DNA Replicates
2. DNA Directs the Cell to Produce a Specific Protein & Express a New Trait
3. DNA is Stable From Cell Generation to Generation - i.e. Cells Derived From the Original Transformed *E. coli* Express the *GFP* Gene
4. The *E. coli* *GFP* Gene Transformation Experiment Shows Directly That DNA is the Genetic Material!

4



DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

Other Experiments We Discussed Showing That DNA is the Genetic Material



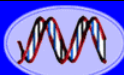



May 20, 2010


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

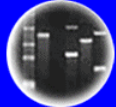
5




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

What Were Considered the Properties of a **Gene** **BEFORE** It Was Known That DNA Was the Genetic Material - In the 1930s and 40s?

1. Replication - Transmitted With Chromosomes
2. Stability (Mutations)
3. Universality
 - a) All Cells
 - b) All Organisms
4. Direct Cell Function/Phenotype

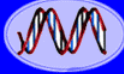
For First Half of 20th Century Proteins Were Considered the Genetic Material

- How Can These Properties Be Tested Experimentally?
- What **Predictions** Follow From These Properties?


If DNA is the Genetic Material, THEN What.....?

How Was DNA Shown to be the Genetic Material?


6




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting

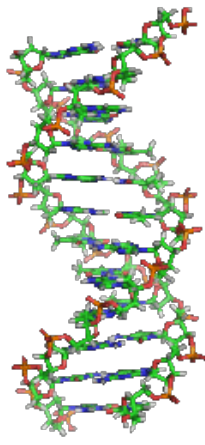


Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

How Was DNA Shown to be the Genetic Material?



7



DNA
Genetic Code of Life



Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

Frederick Miescher Discovered DNA in the Nuclei of White Blood Cells in 1869

150 Years Ago









*But..... The Function of DNA Was Not Understood Until
75 years Later in 1944!!!*

8

Evidence That DNA Is the Genetic Material Starts With Pneumonia



TO STOP SPREAD OF INFLUENZA STAY AT HOME
Amuse Yourself With One of the Best **Player Pianos**
We Sell for One Hundred Dollars Less Than Same Grade Offered Elsewhere

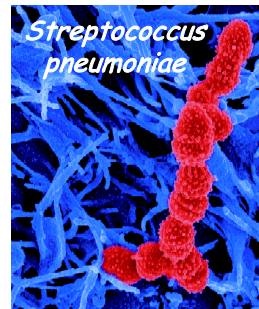
FIGHT THE 'FLU'
Rigid Quarantine Rules Established
YOU ARE ASKED TO AID IN ENFORCING THEM

Epidemic Closing Order Is Sweeping
The State Board of Health order, closing schools, theatres, churches, saloons, etc., in an effort to prevent a further spread of the Spanish influenza epidemic, is a sweeping one. All clubs must close, including bowling alleys and pool rooms. No society, club or organization meeting can be held, not even at homes.

Spanish Flu (H1N1) Killed 50-100 million People World-Wide from 1918 to 1920
Most From Secondary Bacterial Infections
No Vaccines or Antibiotics!!

INFLUENZA
FREQUENTLY COMPLICATED WITH **PNEUMONIA**
IS PREVALENT AT THIS TIME THROUGHOUT THE WORLD
THIS THEATRE IS COOPERATING WITH THE DEPARTMENT OF HEALTH
YOU MUST DO THE SAME
IF YOU HAVE A COUGH AND ARE COUGHING AND SNEEZING DO NOT ENTER THIS THEATRE
GO HOME AND GO TO BED UNTIL YOU ARE WELL
Coughing, Sneezing or Spitting Will Not be Permitted in The Theatre. If you are ill, please do not come to the theatre. If you are well, please leave the theatre at once.
This Theatre has agreed to cooperate with the Department of Health in demonstrating the truth about influenza and thus serve a great educational purpose.
HELP US TO KEEP CHICAGO THE HEALTHIEST CITY IN THE WORLD
JOHN DILL ROBERTSON
COMMISSIONER OF HEALTH

The Washington Times
WASHINGTON, FRIDAY EVENING, SEPTEMBER 27, 1918.
Gauze Mask to Halt Spread of Plague
This is the first picture of the new mask adopted and being made by the Red Cross to prevent the spread of Spanish influenza in the United States. The picture shows the mask being worn by a Red Cross worker, who is engaged in making the masks. The masks are designed to halt the exhaling or inhaling of the influenza germ. They are five inches wide and six inches across, and are composed of two thicknesses of gauze. They are not to be used.

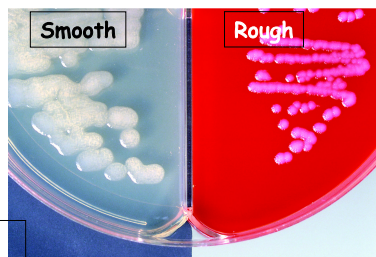
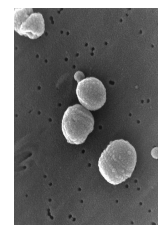
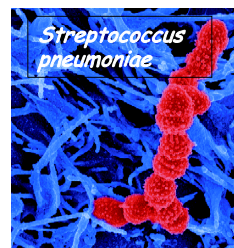
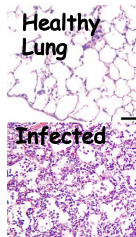


9

Frederick Griffith & The Transforming Principle *The First Genetic Engineering Experiment (unintentional!)*



Frederick Griffith
1879-1941



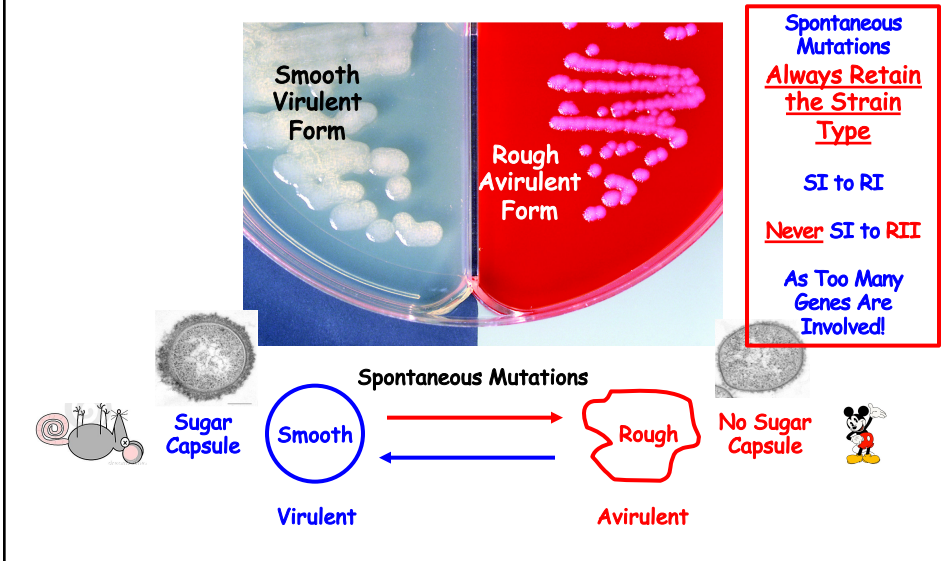
Note:
Different Strains of *Streptococcus Pneumoniae* Exist in Nature
Type I, II, etc.

Invented the Word "Transformation"
Not Understood For Another 50 Years

10

Griffith - J. Hygiene,
1928

Smooth Virulent Bacteria Can Mutate To Rough Avirulent Bacteria & Vice Versa!

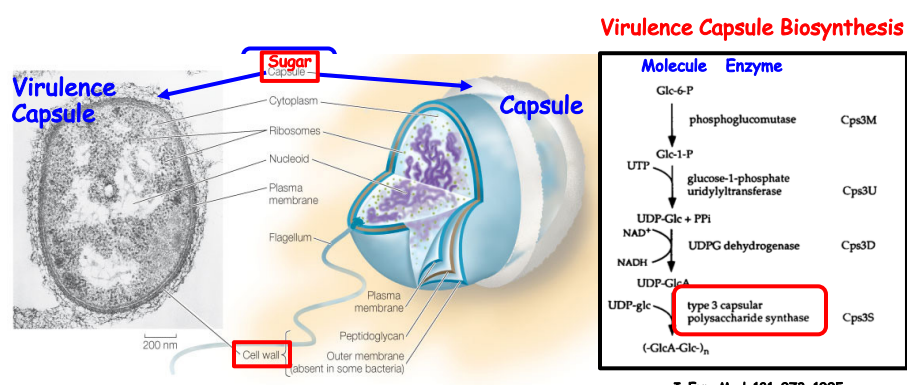


11

Streptococcus pneumoniae

Flash Forward to 2021!

50,000 Deaths/Year in the USA



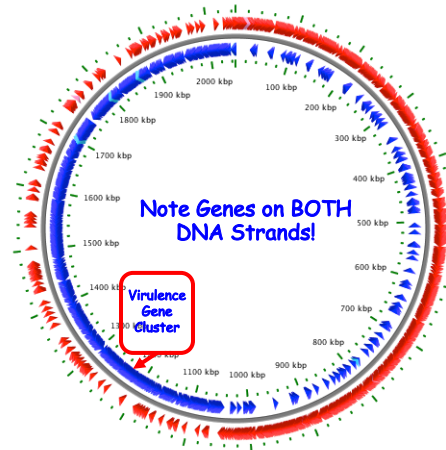
J. Exp. Med. 181, 973, 1995

Streptococcus Strains Depend On the Sugar Type in the Capsule - Which is a Product Of MANY Genes!

The Sugar Capsule Protects the Bacteria From Mammalian Host Antibodies
Capsule = Virulence No Capsule = Avirulence

12

Streptococcus pneumoniae Genome Has Been Sequenced!

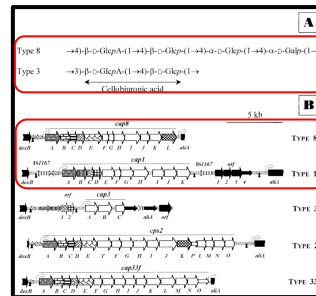
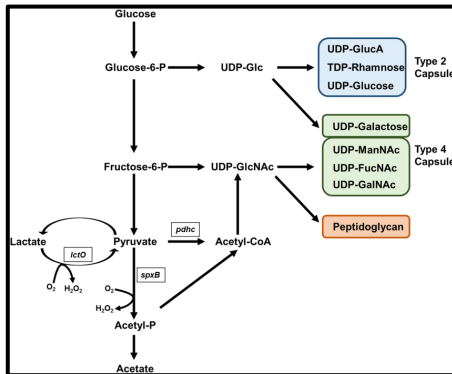


2,160,837 bp and 2,236 Genes
 At Least 13 Genes Specify Capsule Formation
 What Happens If One of These Genes Is Mutated?

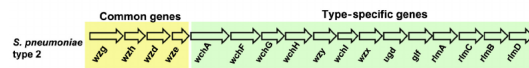
Science 293,498 (2001)

13

Streptococcus pneumoniae Virulence Capsule Sugars - Different Strains Have Different Sugars



Different Sugars - Different Sugar Genes!

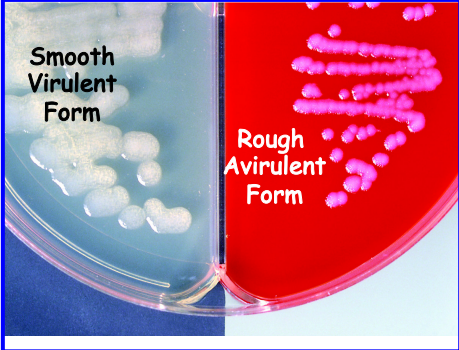


Different Strains Have Different Sugars Encoded By Shared & Distinct Genes Involved in Capsule Sugar Synthesis

Cannot Mutate From One Strain to Another - Too Many Genes Involved

14

Can Mutate Smooth to Rough But Never Smooth Strain X to Smooth Strain Y



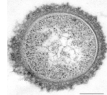
Smooth Virulent Form

Rough Avirulent Form

Smooth 8 & Smooth 3

No Smooth 8 to Smooth 3

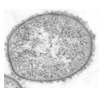
Spontaneous Mutations



Sugar Capsule

Smooth 8

Virulent



No Sugar Capsule

Rough 8

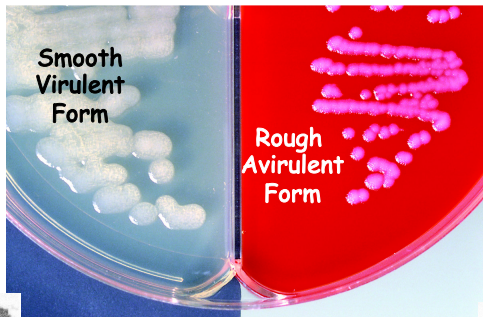
Avirulent

Only Smooth 8 to Rough 8

15

J. Hygiene, 1928

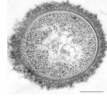
The Griffith Experiment With Smooth and Rough Pneumonia Bacteria



Smooth Virulent Form

Rough Avirulent Form

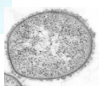
Spontaneous Mutations



Sugar Capsule

Smooth

Virulent



No Sugar Capsule

Rough

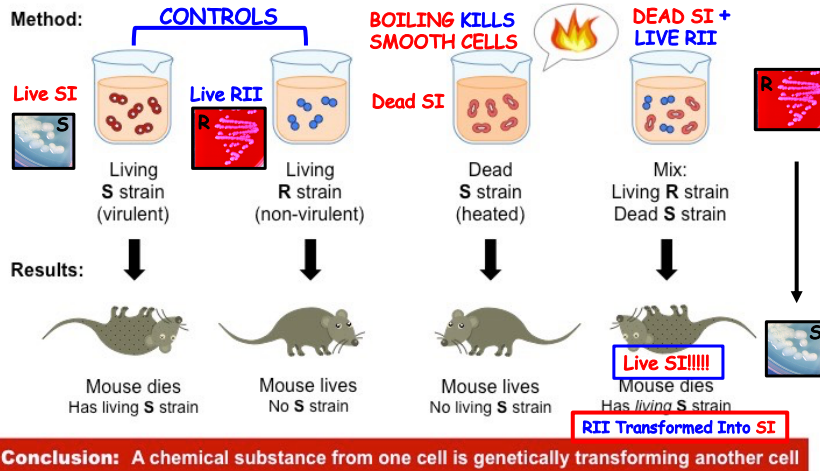
Avirulent

Always Same Strain!!!

16

The Griffith Experiment (1928)

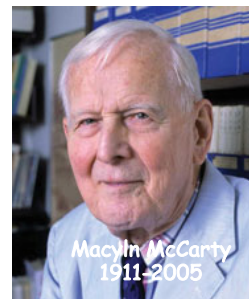
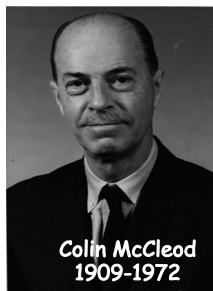
Hypothesis: Material in dead bacterial cells can transform living bacterial cells



LIVE Rough Cells **TRANSFORMED** by DEAD Smooth Cells!!!
HOW? What Was the Transforming Principle? Hypothesis?

17

What Was The Transforming Principle? Experiments of Avery, McCleod, & McCarty Fast Forward to the 1940s!



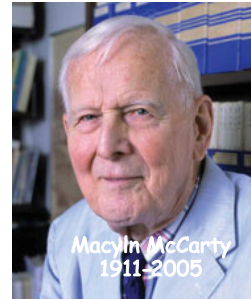
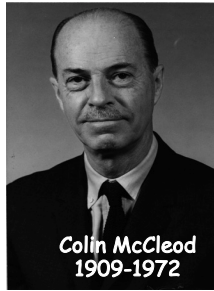
DNA is the Genetic Material!

One of the Major Reasons Watson and Crick
 Considered DNA As the Genetic Material
 In Order to Solve DNA Structure

J. Exp. Med., 1944

18

What Was The Transforming Principle? Experiments of Avery, McCleod, & McCarty Fast Forward to the 1940s!

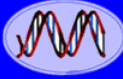


DNA is the Genetic Material!


One of the Major Reasons Watson and Crick
Considered DNA As the Genetic Material
In Order to Solve DNA Structure

J. Exp. Med., 1944

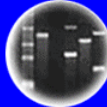
19




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

STUDIES ON THE CHEMICAL
NATURE OF THE SUBSTANCE
INDUCING TRANSFORMATION
OF PNEUMOCOCCAL TYPES

OSWALD T. AVERY, COLIN M. MACLEOD, AND
MACLYN McCARTY

J. Of Experimental Medicine, 79 (2), 137-158 (1944)

STUDIES ON THE CHEMICAL NATURE OF THE SUBSTANCE
INDUCING TRANSFORMATION OF PNEUMOCOCCAL TYPES

INDUCTION OF TRANSFORMATION BY A DESOXYRIBONUCLEIC ACID FRACTION
ISOLATED FROM PNEUMOCOCCUS TYPE III

BY OSWALD T. AVERY, M.D., COLIN M. MACLEOD, M.D., AND
MACLYN McCARTY,* M.D.

20

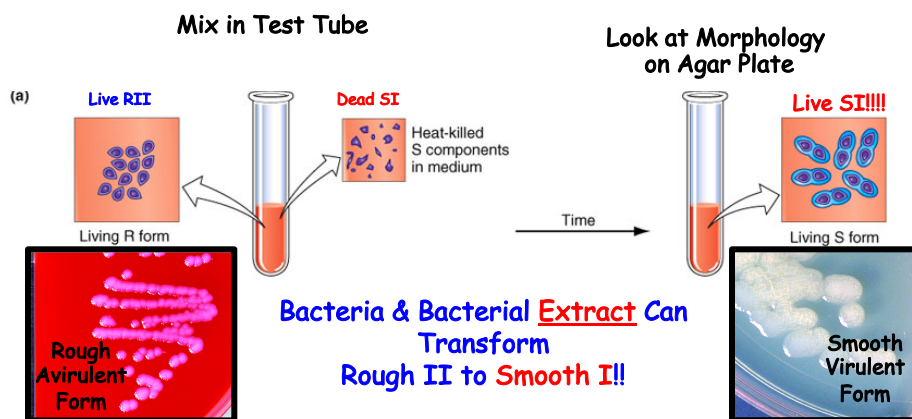
Avery et al. Questions?

1. Does the *Transforming Principle* Come From the Mouse or Bacteria?
2. If From the Bacteria -- What Substance?
3. How Devise Techniques to Determine What the *Transforming Principle* is
 - a) Transformation in Test Tube
 - b) Isolation of Macromolecules
 - c) Isolation of Enzymes (e.g., DNase, RNase)

Design Experiments To Show!!!

21

Does the Transforming Principle Come From the Mouse or *Bacteria*?



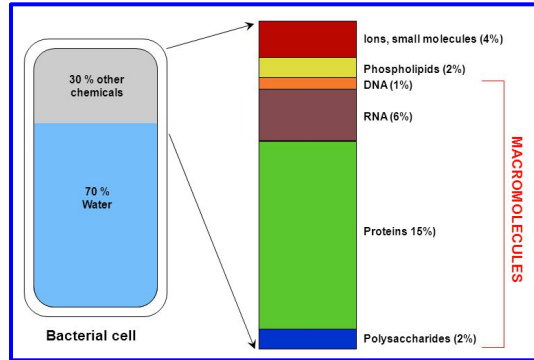
Conclude: (1) Mouse Not Involved & (2) Molecules Inside Bacteria Contain Transforming Principle

22

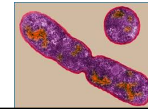
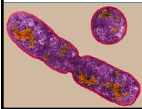
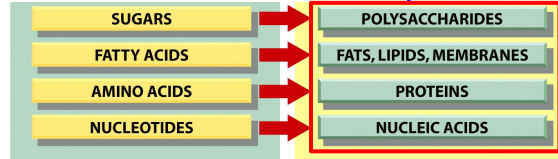
What Are the Major Chemical Components of a Bacterial Cell? *What Could Be the Transforming Principle?*

1. What is Predicted if DNA is the Genetic Material?

2. How Test Hypothesis?

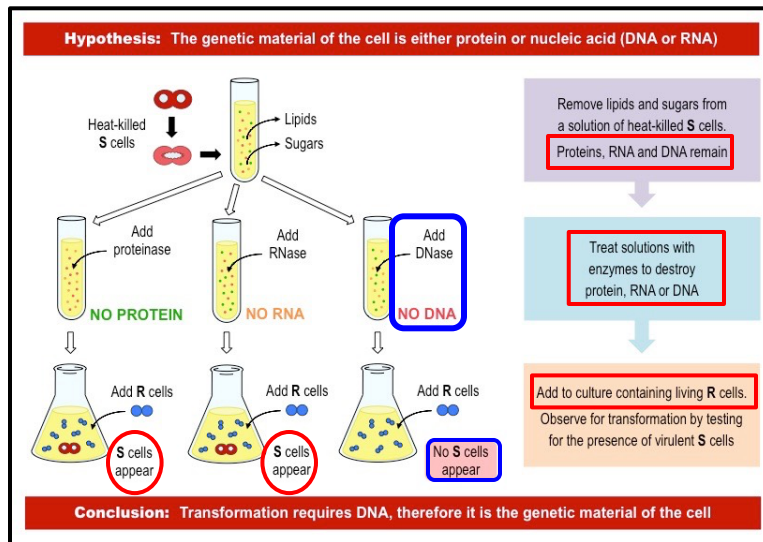


Monomers



23

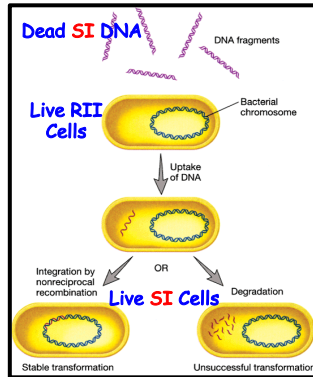
The Critical Experiment by Avery et al. Showing That DNA is the Genetic Material



No DNA - No Transformation!

24

How Did Avery et al. Experiments Verify the Hypothesis That DNA is the Genetic Material?



<u>Predictions</u>	<u>Results</u>
Replication	Yes
Phenotype	Yes
Stable	Yes

Cell Processes

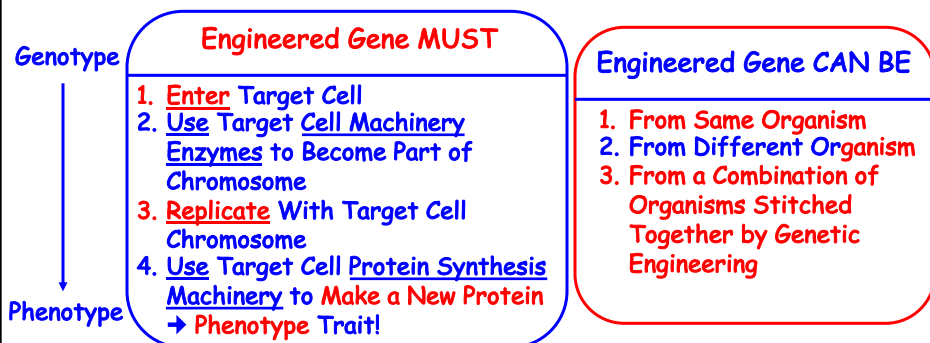
1. SII DNA Taken Up By RII-Cells & Incorporated Into Chromosomes
2. SII Genes Transcribed Into SII mRNAs
3. SII mRNAs Translated Into Smooth I Proteins
4. Smooth I Proteins Helps Construct Sugar Capsule and Protects Bacteria From Antibodies
∴ Cells Virulent

1. DNA Satisfies Criteria For Being the Genetic Material
2. Replicates
3. Directs Production of Strain/Capsule Type
4. In All Progenitor Cells

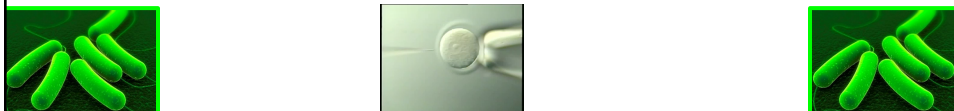
Transformation is a Basic Genetic Engineering Process Today!
Transformation=Ability of Cell Phenotype To Be Changed by DNA!

25

Genetic Engineering/Transformation Involves Incorporating Engineered DNA or Genes Into the Chromosomes of Different Organisms

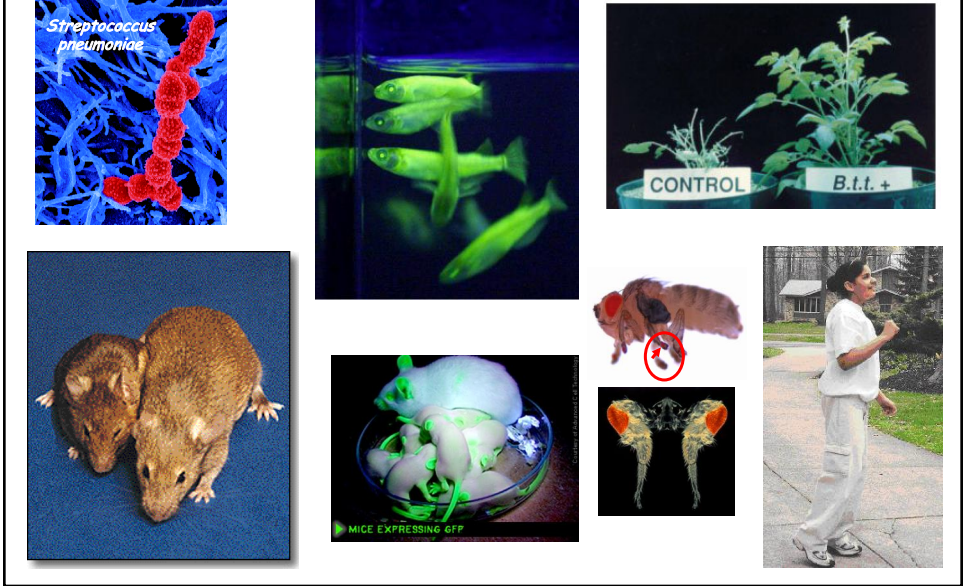


Gene Engineering Shows that Gene Processes Are Universal!!!



26

*All Organisms Can Be Transformed!!
Genetic Engineering Has Come a Long Way Since Griffiths
Experiments in 1928!!*



27

What is A Gene?

Begin 5'

Sequence or Order of Nucleotides Coding DNA Strand (Coding Strand)

```

TCARAATCCAAAAAATAGCA
GTTTGGTGTTTGGGTTTTRAGG
TAGCAATATATTTGGGCTTTT
TTTAGGTTTCGGGTTTGGGTT
ATTTGAGTGTTTGACATTTGA
AATTTCCGGTTCATCTTCG
TGGGTGCCAGTGGCGTGA
GTTTCCCGGTTTCGTCAACT
TAGGGTTTAGGGTTTACCAG
TTAGGGTTTAGGGTTTGGAT
GGCGCCATTCTCATGTTTG
AATCAAGCCCTGAAATCAAA
TGGGTGCCAGTGGCGTGA
CGTTCCCGGTTCCGTCAACT
ATCAGTACCCATGTTTGGGA
TGACGTCARATGACACGAAA
AAAAAATAGGAATCGACCC
AGAAAAGGGGGGTGGCCATT
ACTATCCGTAACACAAAAC
ATTTTTTGGGTGGGTGGCC
ATRAATAGATTTTTCCCTTGT
CCTTTTCCATGTTCAAGTACC
TTTCTCATGTTTGGAGTCAR
CCTGAAATCCAAAATATAG
CAGTGGCGTGAACATTTGGAG
GATACGTCARATGACACGAAA
CATGTTTGGATTTTTTCCG
AGAACCCAAAAAATAGTCT
GAATCGACCCTTTTCCATGT
GGCGCCATTCTCTTGTTT
AAAAAAGCCCTGAATATCTA
GTGAGTGTGCCAGTGGCGTGA
TCGTTCCCGGTTCCCTCAAC
GTTCAAGTACCCATGTTTGGG
TTGGAGCTCAAGGAAACAAA
CAAAAAATAGCAATTCACCC
AGAAAATGGAGCGGCCAAT
CTGACACGTAARAACAAAGCT
TTTTTCCGTTGGGTGGCCA
AAAAATAGTCCGTTCCCGGTT
TTTTCCATGTTCAATACCCA
TCTCATATTTGGAGTCARAAG
                    
```

3' **End**

The β-Globin Gene

Blood Protein Carries Oxygen to All Genes From Lungs ⇔ Energy

A Gene is a Unique Sequence of Nucleotides Specifying a Function

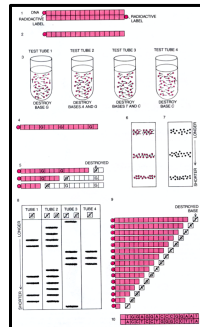
DNA Sequence = Biology!
What If Sequence Changed?

SEQUENCE → FUNCTION

Relative to Coding or Sense Strand of Gene

28

Genes and Genomes Can Be Sequenced!



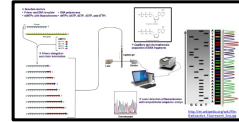
A new method for sequencing DNA
(DNA chemistry/Maxam-Gilbert cleavage/Sanger/sequencing)
ALLAN M. MAXAM AND WALTER GILBERT
PNAS February, 1977



Water Gilbert



Fred Sanger



DNA sequencing with chain-terminating inhibitors
(DNA polymerase, nucleotide sequences, hereditage 4370)
F. SANGER, S. NICKLEN, AND A. B. COLEMAN
PNAS December, 1977

The Nobel Prize in Chemistry 1980



Paul Berg
Prize share: 1/2



Walter Gilbert
Prize share: 1/4



Frederick Sanger
Prize share: 1/4

- One half awarded to Paul Berg "for his fundamental studies of the biochemistry of nucleic acids, with particular regard to recombinant DNA..."
- The other half jointly to Walter Gilbert and Frederick Sanger "for their contributions concerning the determination of base sequences in nucleic acids..."



29

Genes & Genomes Differ Because the Sequence of DNA Differs!!

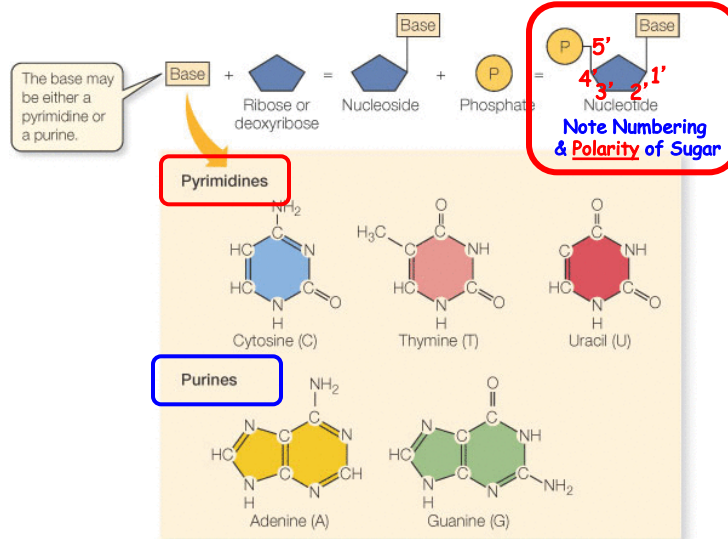
DNA Sequence
Beginning → End
5' → 3' → Biological Uniqueness

If You Know the DNA Sequence, You Can Engineer Anything! Even Make New Genes & Genome!

Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome

30

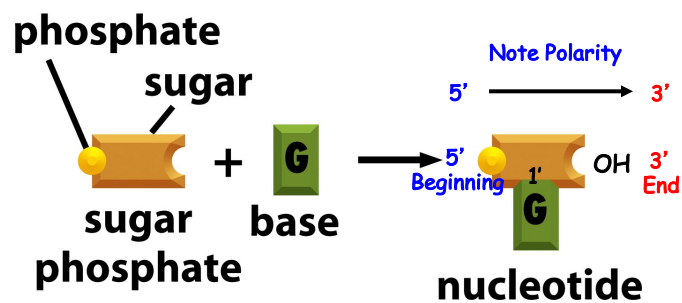
There Are Four Different Nucleotides in DNA



Polarity of Sugar Leads to Polarity of DNA (and RNA) - 5' to 3'

31

Nucleotides Have Polarity Based on What is Bonded to the Five-Carbon Sugar Phosphate on 5' Carbon and OH on 3' Carbon



The Sugar is the HUB

DNA Sequence Defined By Nucleotide Order

DNA Sequence = Functional Uniqueness = Biology

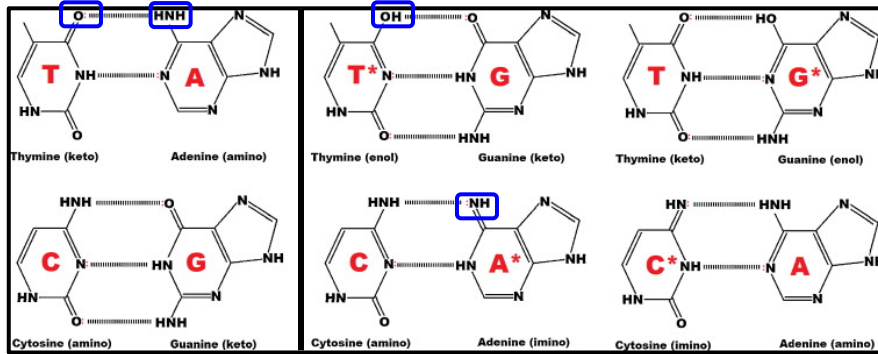
Figure 1-2a *Molecular Biology of the Cell*, Fifth Edition (© Garland Science 2008)

32

Tautomers Change Base Pairing Rules!!!

Normal Forms - Keto & Amino

"Mutant" Forms - Enol & Imino



[Tomato Genetic Diversity]



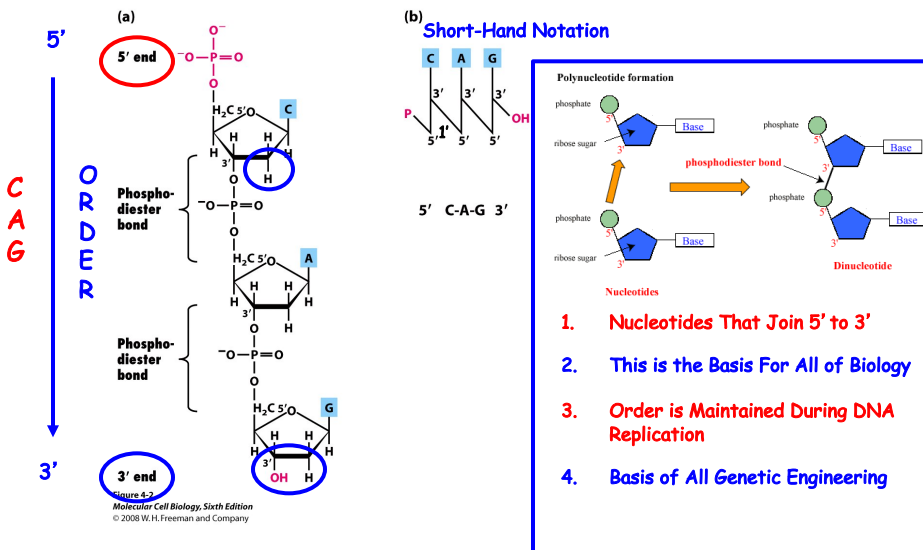
And Lead To Mistakes in DNA
Replication & Mutations → Genetic
Diversity
Chemistry Leads to Biology!!



33

Nucleotides Are Joined By 5' to 3' Phosphodiester Bonds

Polarity Defined By Sugars & Order Specified By Bases



34

Clues to the Double Helix-Chargaff's Rules

Purines = Pyrimidines

TABLE 6.1 Chargaff's Data on Nucleotide Base Composition in the DNA of Various Organisms

Organism	Percentage of Base in DNA				Ratios	
	A	T	G	C	A:T	G:C
<i>Staphylococcus afermentans</i>	12.8	12.9	36.9	37.5	0.99	0.99
<i>Escherichia coli</i>	26.0	23.9	24.9	25.2	1.09	0.99
Yeast	31.3	32.9	18.7	17.1	0.95	1.09
<i>Caenorhabditis elegans</i> *	31.2	29.1	19.3	20.5	1.07	0.96
<i>Arabidopsis thaliana</i> *	29.1	29.7	20.5	20.7	0.98	0.99
<i>Drosophila melanogaster</i>	27.3	27.6	22.5	22.5	0.99	1.00
Honeybee	34.4	33.0	16.2	16.4	1.04	0.99
<i>Mus musculus</i> (mouse)	29.2	29.4	21.7	19.7	0.99	1.10
Human (liver)	30.7	31.2	19.3	18.8	0.98	1.03

*Data for *C. elegans* and *A. thaliana* are based on those for close relative organisms.

Note that even though the level of any one nucleotide is different in different organisms, the amount of A always approximately equals the amount of T, and the level of G is always similar to that of C. Moreover, as you can calculate for yourself, the total amount of purines (A plus G) nearly always equals the total amount of pyrimidines (C plus T).

What Would You Predict For a Single-Stranded DNA?

THE COMPOSITION OF THE DESOXYRIBOSE NUCLEIC
ACIDS OF THYMUS AND SPLEEN*

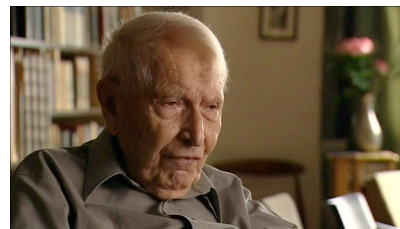
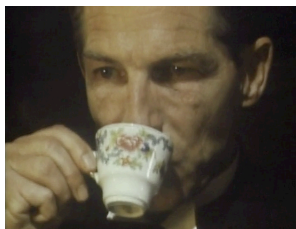
BY ERWIN CHARGAFF, ERNST VISCHER, † RUTH DONIGER, CHARLOTTE
GREEN, AND FERNANDA MISANI

J. Biological Chemistry,
July, 1948

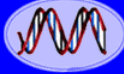
35

Clues to the Double Helix-Chargaff's Rules


Purines = Pyrimidines




36




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria




DNA Fingerprinting



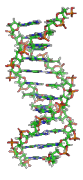
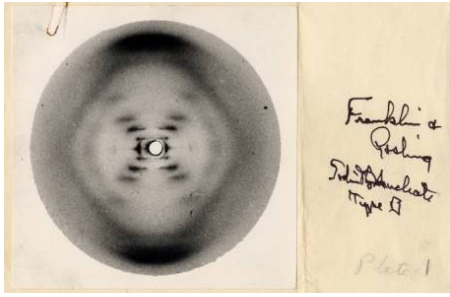
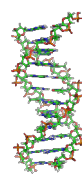
Cloning: Ethical Issues
and Future Consequences



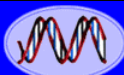
Plants of Tomorrow




Reflections on *The Double Helix*

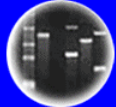
37




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

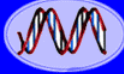
MOLECULAR STRUCTURE OF NUCLEIC ACIDS

A Structure for Deoxyribose Nucleic Acid


WE wish to suggest a structure for the salt of deoxyribose nucleic acid (D.N.A.). This structure has novel features which are of considerable biological interest. **Nature, April 25, 1953**

We are much indebted to Dr. Jerry Donohue for constant advice and criticism, especially on inter-atomic distances. We have also been stimulated by a knowledge of the general nature of the unpublished experimental results and ideas of Dr. M. H. F. Wilkins, Dr. R. E. Franklin and their co-workers at


38




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

GENETICAL IMPLICATIONS OF THE STRUCTURE OF DEOXYRIBONUCLEIC ACID

By J. D. WATSON and F. H. C. CRICK

Medical Research Council Unit for the Study of the
Molecular Structure of Biological Systems, Cavendish
Laboratory, Cambridge *Nature*, May 30, 1953

No. 4361 May 30, 1953 NAT

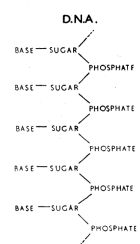


Fig. 1. Chemical formula of a single chain of deoxyribose nucleic acid

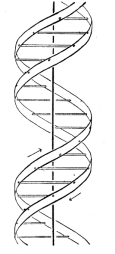


Fig. 2. This figure is purely schematic. The two ribbons symbolize the two phosphate-sugar chains, and the horizontal lines the pairs of bases holding the chains together. The vertical line marks the fibre axis.


Our model suggests possible explanations for a number of other phenomena. For example, spontaneous mutation may be due to a base occasionally occurring in one of its less likely tautomeric forms. Again, the pairing between homologous chromosomes at meiosis may depend on pairing between specific bases. We shall discuss these ideas in detail elsewhere.

For the moment, the general scheme we have proposed for the reproduction of deoxyribonucleic acid must be regarded as speculative. Even if it is correct, it is clear from what we have said that much remains to be discovered before the picture of genetic duplication can be described in detail. What are the polynucleotide precursors? What makes the pair of chains unwind and separate? What is the precise role of the protein? Is the chromosome one long pair of deoxyribonucleic acid chains, or does it consist of patches of the acid joined together by protein?


Despite these uncertainties we feel that our proposed structure for deoxyribonucleic acid may help to solve one of the fundamental biological problems—the molecular basis of the template needed for genetic replication. The hypothesis we are suggesting is that the template is the pattern of bases formed by one chain of the deoxyribonucleic acid and that the gene contains a complementary pair of such templates.

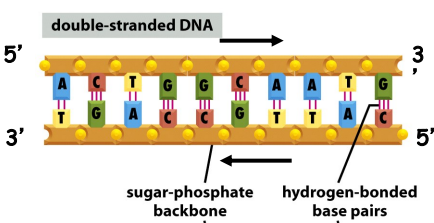
Explained Replication
Explained Spontaneous Mutation

39



DNA is a Double Helix of Two Complementary Chains of DNA Wound Around Each Other



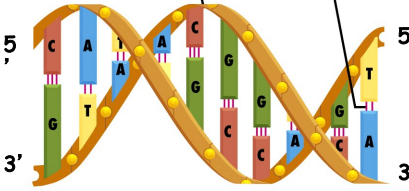


double-stranded DNA

5' 3' 3' 5'

A C T G G C A A T G
T G A C C G T T A C

sugar-phosphate backbone hydrogen-bonded base pairs



DNA double helix

5' 5' 3' 3'

1. Complementary Strands
2. A=T and G=C (Four Bases)
3. Sequence of Strands Differ
4. Bases to Interior
5. Phosphate-Sugar Backbone on Exterior
6. DNA Strands in Opposite Direction (Only Way Helix Fits)
7. Sequence of One Chain Automatically Specifies Sequence of Complementary Chain (Basis of Replication!)
8. No Constraint on Sequence
($4^n = n$ base combinations = Diversity)

DNA has dimensions (Know # bp Know Length: 20Å diameter, 3.4Å/bp, 10bp/turn)

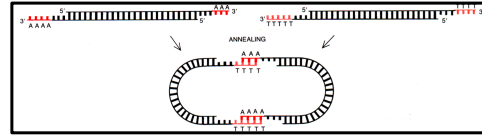
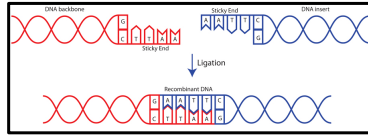
9. Sequence = Biology

Watson and Crick, *Nature*, 1953

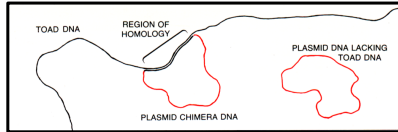
40

Complementary Base Pairs Are **Essential** For Genetic Engineering Engineering, Analysis of Recombinant Plasmids, and Polymerase Chain Reaction (PCR)

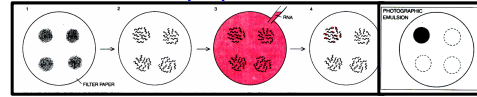
1. Annealing Two Two Molecules Together ("Cut & Splice")



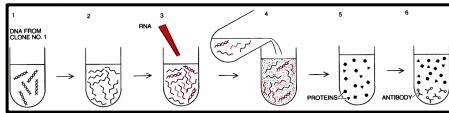
2. Heteroduplex Analysis



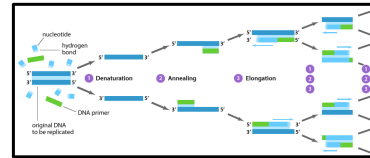
3. Colony Hybridization



4. Hybrid-Arrested Translation



5. Polymerase Chain Reaction

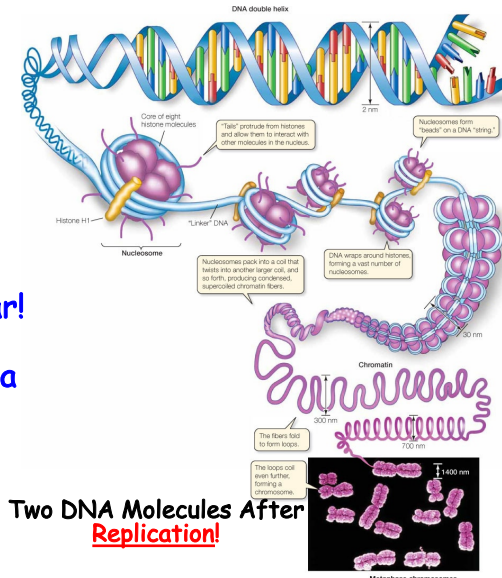


41

A Chromosome Contains One (or Two!!) Continuous DNA Molecule(s)

DNA in Human & Eukaryotic Chromosomes is **Linear!**

DNA in Most Bacteria is **Circular!**

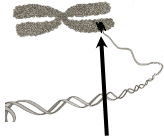


Two DNA Molecules After **Replication!**

42

A Chromosome Contains Many Genes Operating Independently

What is the Evidence?



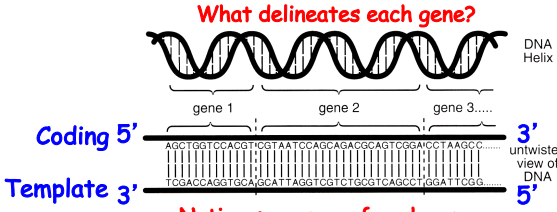
Position of Genes 1, 2, & 3 in chromosome

Discrete Units!

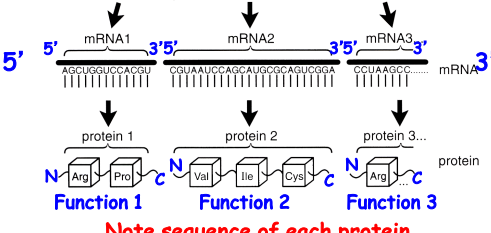
Notice- Each gene, mRNA, & protein has a unique order/sequence of monomeric units

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

What delineates each gene?



Notice sequence of each gene



Note sequence of each protein

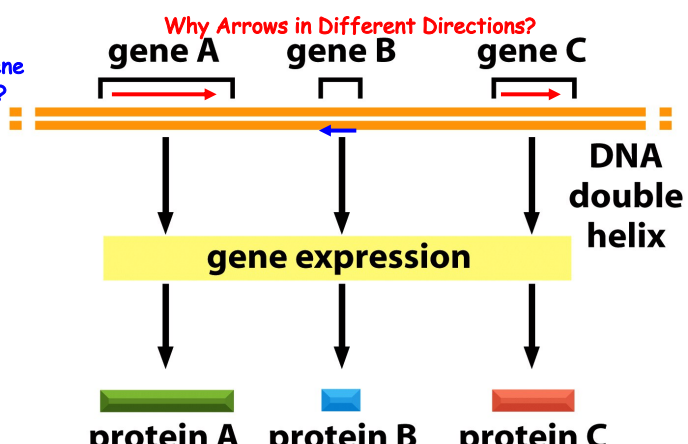
VERY IMPORTANT CONCEPT!
COLINEARITY BETWEEN GENE SEQUENCE AND PROTEIN SEQUENCE

43

A Chromosome Contains Many Genes That Reside at Specific Positions, or Loci, and Have Unique Functions

What Defines Gene Positions?

Why Arrows in Different Directions?

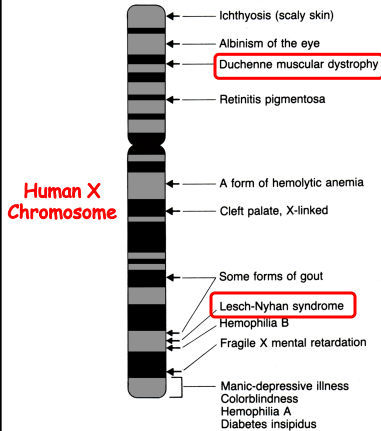


DNA double helix

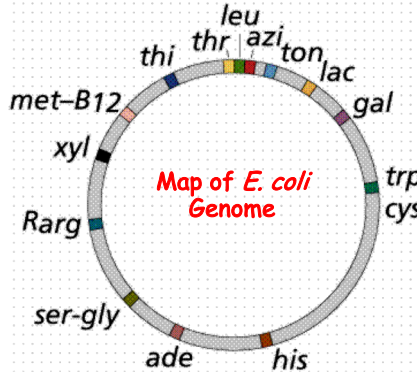
Because DNA Contains Two Strands--Genes Can Be Transcribed From Either Strand--But Only One Per Gene

44

Genes Reside at Specific Locations That Can Be Mapped



Linear DNA
How Know?

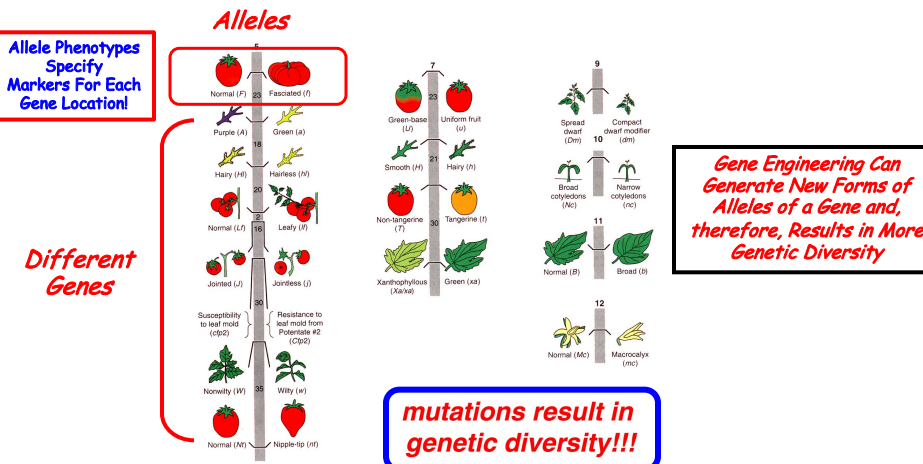


Circular DNA
How Know?

- Note **Marker Bands** - What are these? How are they useful?
- How Determine Gene Positions? Chromosome Number?

45

Alleles Reside at the Same Position on a Chromosome



46

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

Organization of Genes on Human Chromosome 22

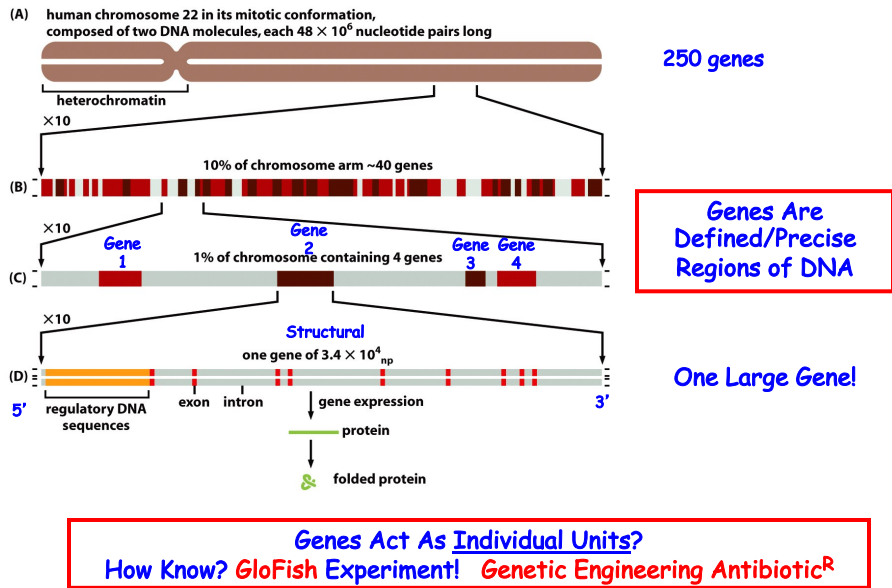


Figure 4-15. *Molecular Biology of the Cell* (© Garland Science 2008)

47

A Conceptualized Gene

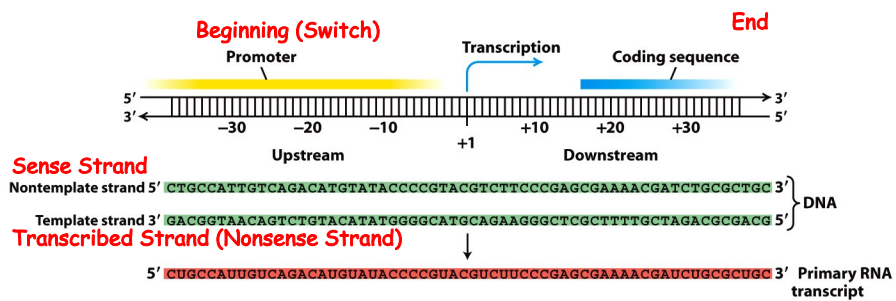
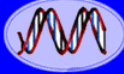



Figure 4-10b
Molecular Cell Biology, Sixth Edition
© 2008 W. H. Freeman and Company

Major Concept in "Making Proteins in Recombinant Bacteria" Article by Gilbert


48




DNA
Genetic Code of Life




Entire Genetic Code
of a Bacteria



DNA Fingerprinting



Cloning: Ethical Issues
and Future Consequences



Plants of Tomorrow

A "Simple" Gene Reviewed

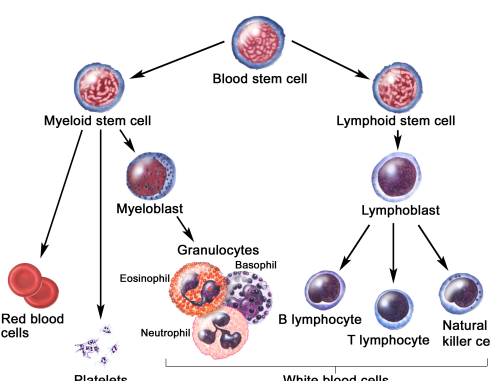
1. **Sense Strand = Genetic Code**
2. **Sense Strand = 5' → 3' Direction** (all DNA sequences specified 5' → 3')
3. **Anti Sense Strand = Complement of Sense Strand & is Transcribed Strand**
4. **mRNA = Same Sequence As Sense Strand & Complementary to AntiSense Strand**
5. **mRNA = 5' → 3'**
6. **Switch Turns Gene On - Not Transcribed But Upstream of Coding Region**

Genes Function As Independent Units! How Know? Design Experiment to Show!

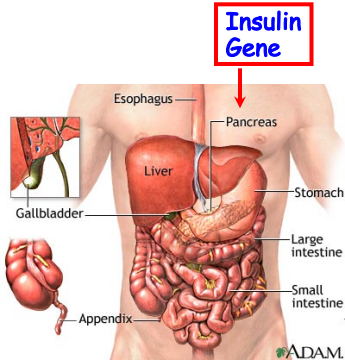
"Everything" Follows the Double Helix & Its Rules - Anti-parallel Chains & Complementary Base Pairing!

49

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



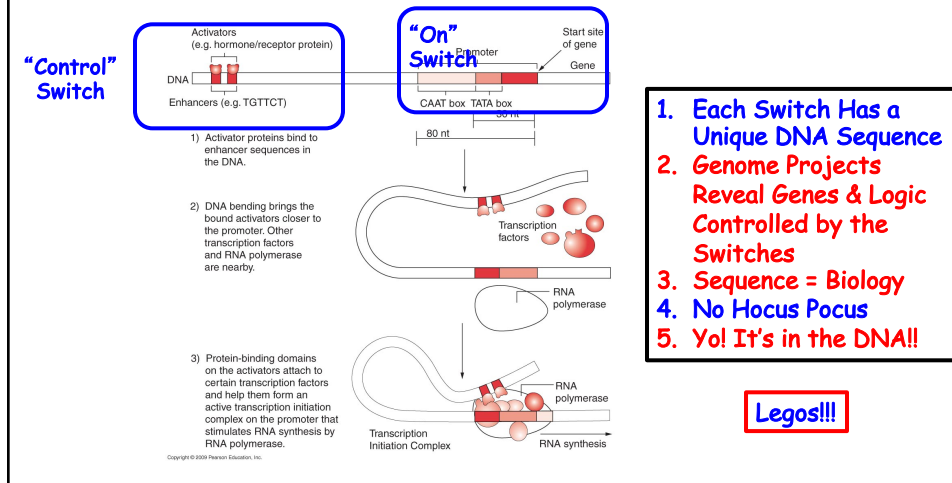
© 2007 Teresa Winslow
US Gov. has certain rights



50

Control Switches Are Unique DNA Sequences & Can Be Cloned

**AND used to Re-Engineer Organisms!!
Switches Act Independently of Gene!!**



51

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

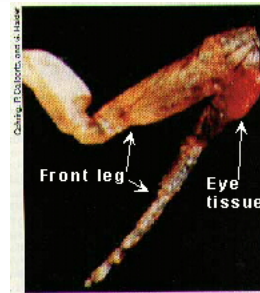
Eye Gene



Replace the Head Switch With the Leg Switch by Genetic Engineering

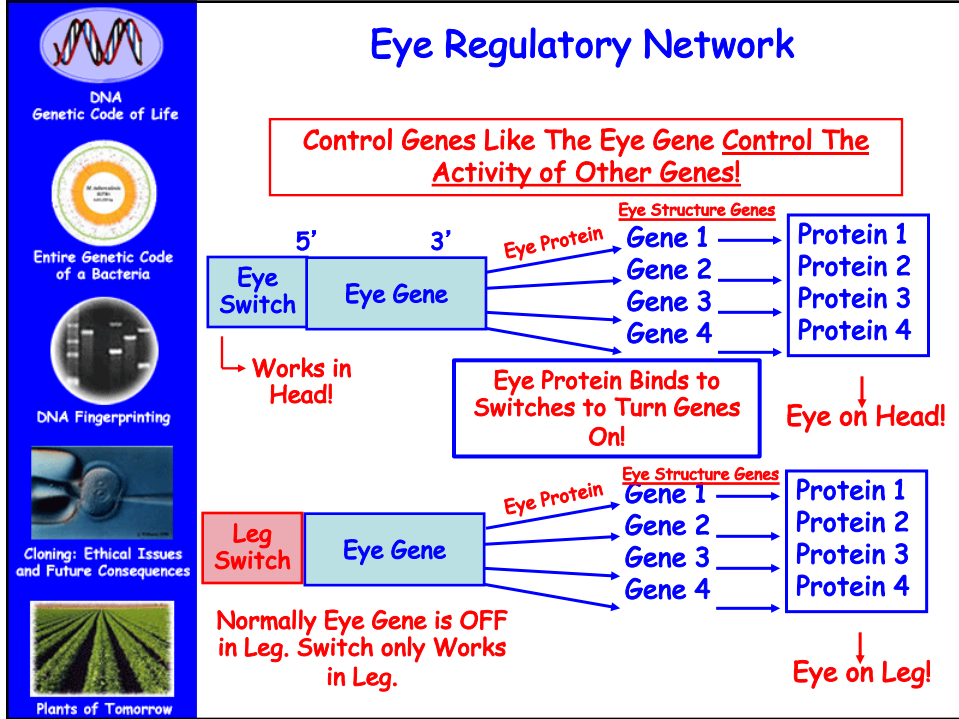


Eye Gene
+
Leg Switch



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

52



53

100 Years Into The Future

1. **If the Entire Human Genome is Sequenced?**
2. **If the Function/Protein of All Genes Are Known?**
3. **If All the Switches Are Identified & How They Go On & Off From Birth to Death?**
4. **If We Understand How Genes Are Choreographed & All the Sequences That Program them**

What Does the Future Hold?

We Will Know at the DNA Level What Biological Information Programs Life to Death!

What Does This Mean For The Future of Humanity?

Remember - Mendel's Law Were Only Rediscovered 120 Years Ago & Look What We Can Do & Now!

54