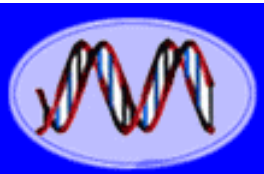
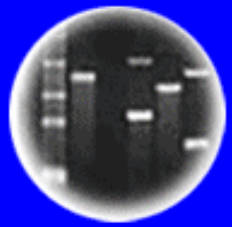


DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

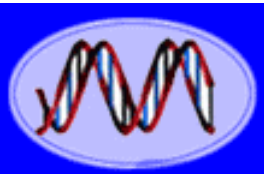
HC70A & SAS70A Winter 2010
Genetic Engineering in Medicine, Agriculture, and Law

Professors John Harada & Bob Goldberg

Lecture 2
What Are Genes & How Do They Work: Part One

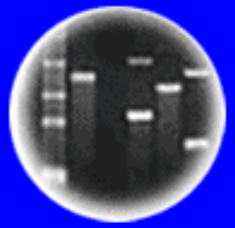
UCLA

UCDAVIS
UNIVERSITY OF CALIFORNIA



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

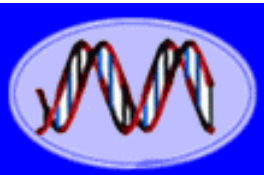
Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

Last Lecture -- Age of DNA & Genetic Engineering

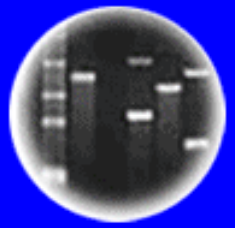
Today's Class -- What ARE Genes & How Do They Work? PART ONE

Demonstration
Gel Electrophoresis & Bacterial "Cloning"



DNA
Genetic Code of Life

Entire Genetic Code of a Bacteria



DNA Fingerprinting

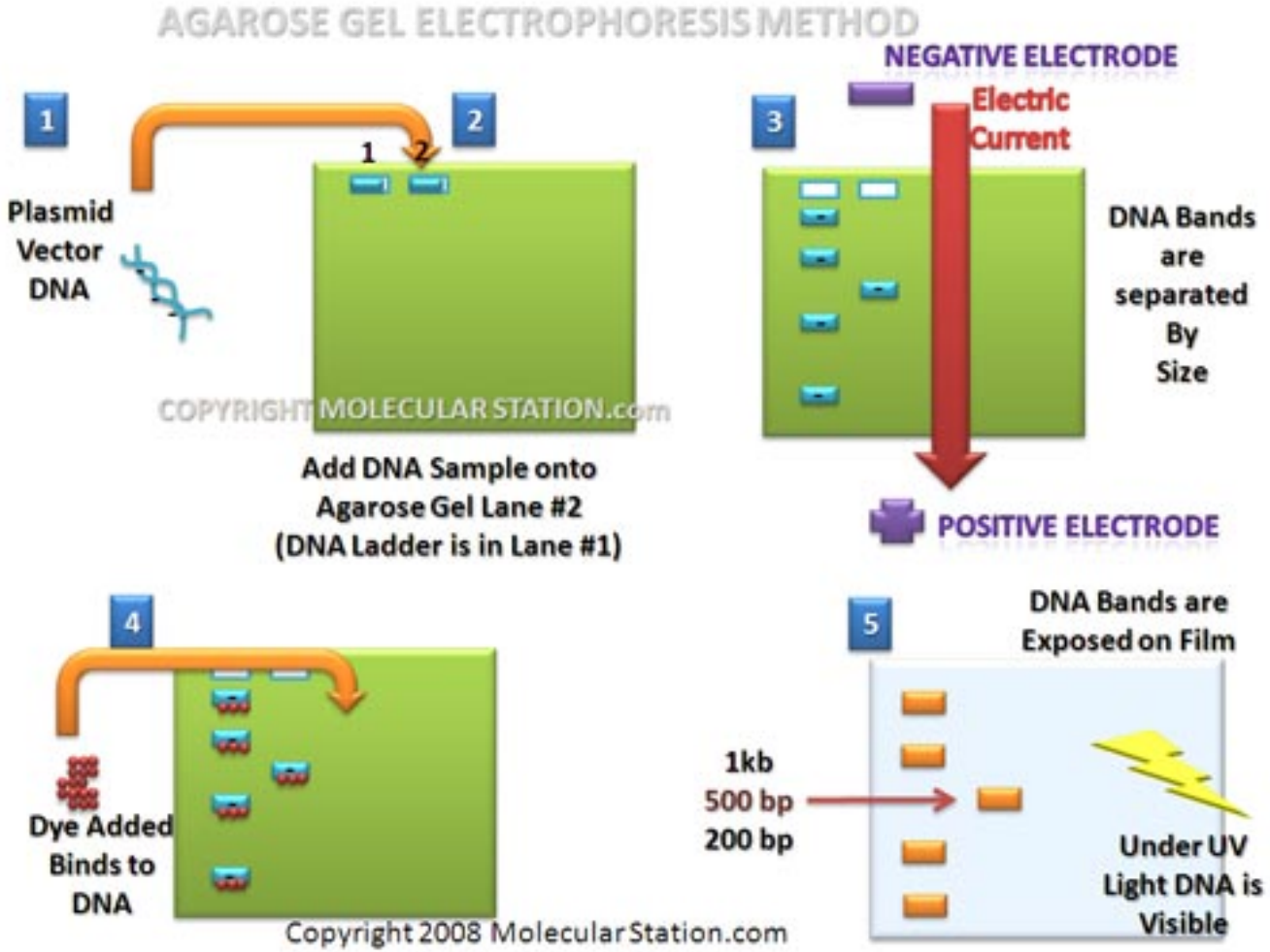
Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

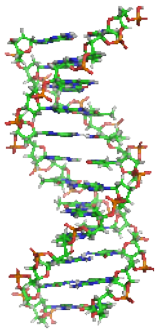
THEMES

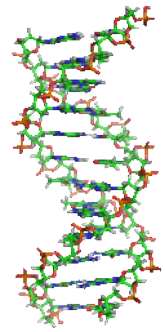
1. What is the Function of a Gene?
2. What are the Properties of Genes?
3. What is the Evidence That DNA is the Genetic Material (Griffith and Avery Experiments)?
4. Is Transformation Universal?
5. What is the Structure of DNA?
6. What is the Structure of a Chromosome?
7. What is the Anatomy of a Gene?
8. What is the Colinearity Between Genes & Proteins (how does DNA→protein)?
9. How Do Switches Work to Control Gene Activity?
10. What Are the Possibilities For Manipulating Genes in the Future?

Gel Electrophoresis Experiment



1. Plasmid DNA cut with restriction enzymes
2. DNA will be separated by size using gel electrophoresis
3. DNA fragments are visualized in the gel with a florescent dye.

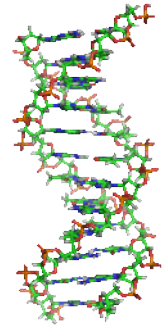




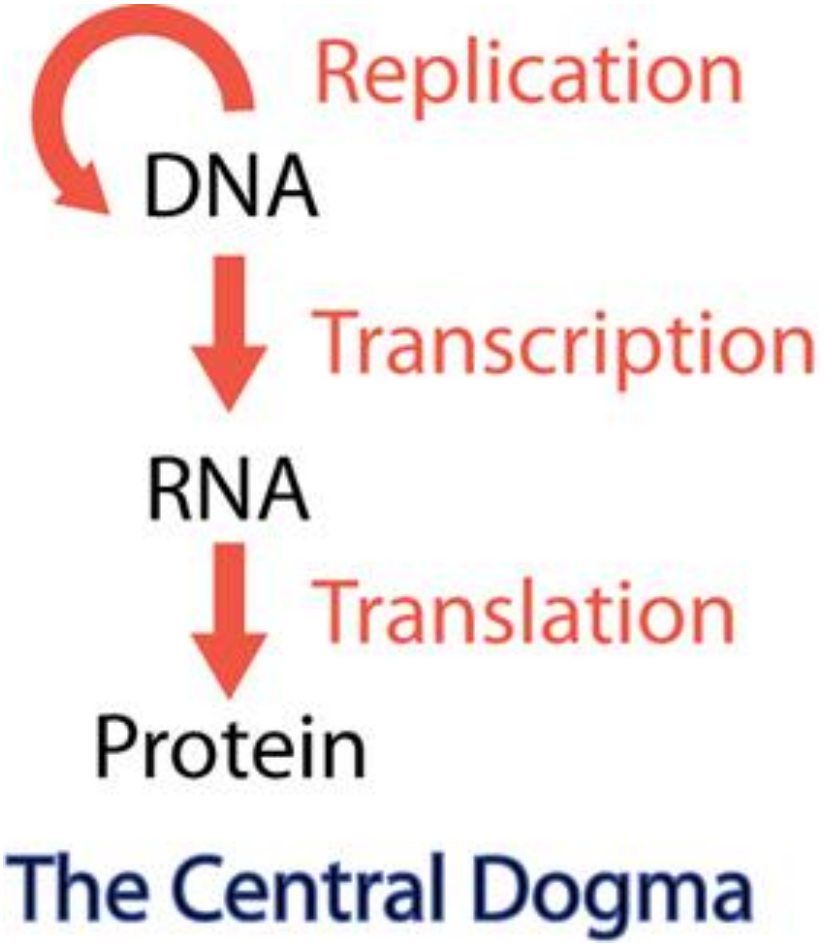
Recall: We Live in the The Age of DNA!

Genetic Engineering Is Manipulating DNA!

Understanding Genetic Engineering Requires a Basic Understanding of Genes And How They Work



What Are the Functions of a Gene?



The Central Dogma

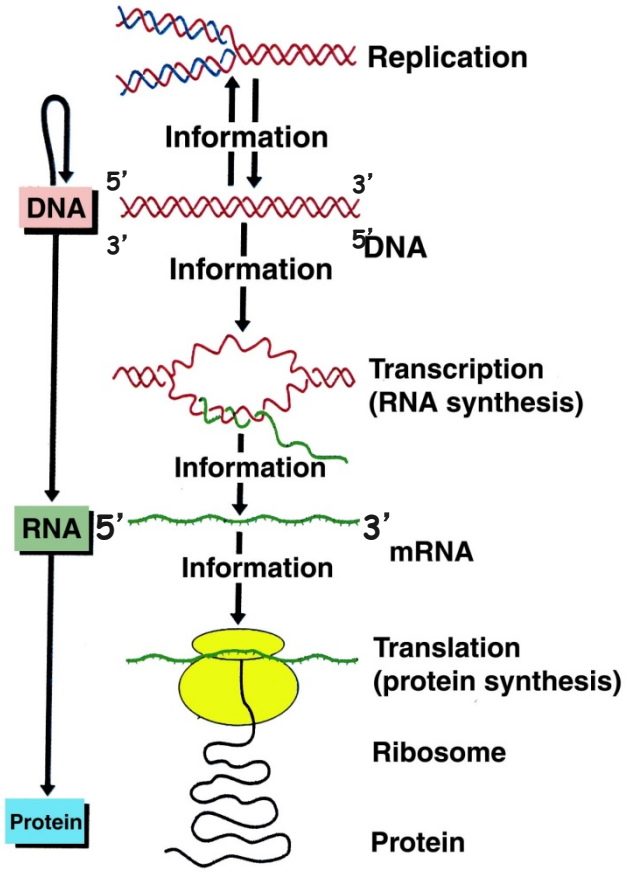
Gene Action Leads to Specific Traits – The Action of All Genes Specifies Phenotype

Genotype

Collection of Genes

Phenotype

Collection of Traits



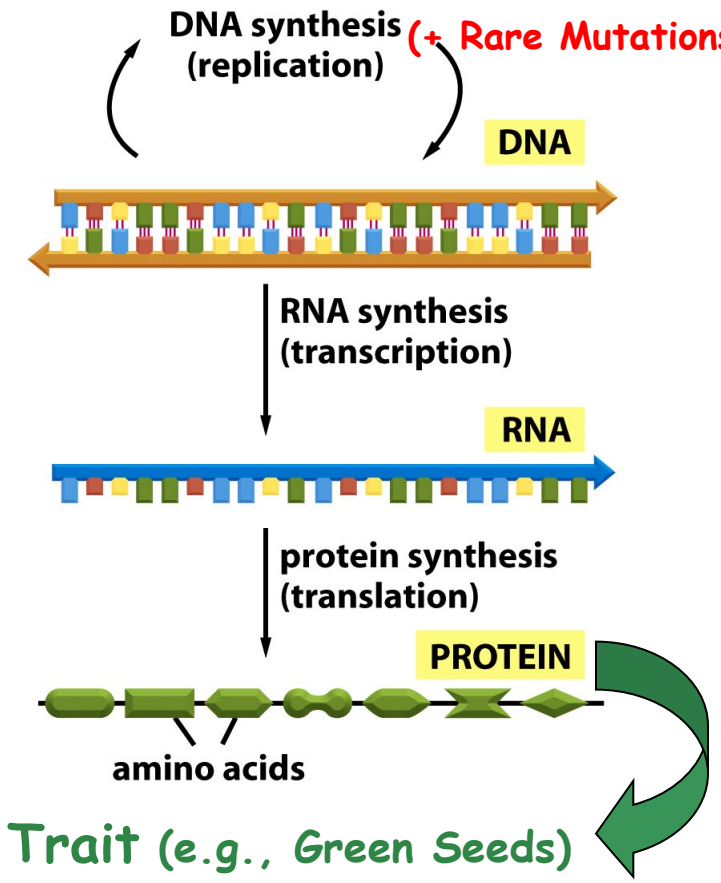
1. Replication
2. Gene Action
3. Cell Function (Trait)

Genetic Engineering Alters Cell Function By Changing the Genotype

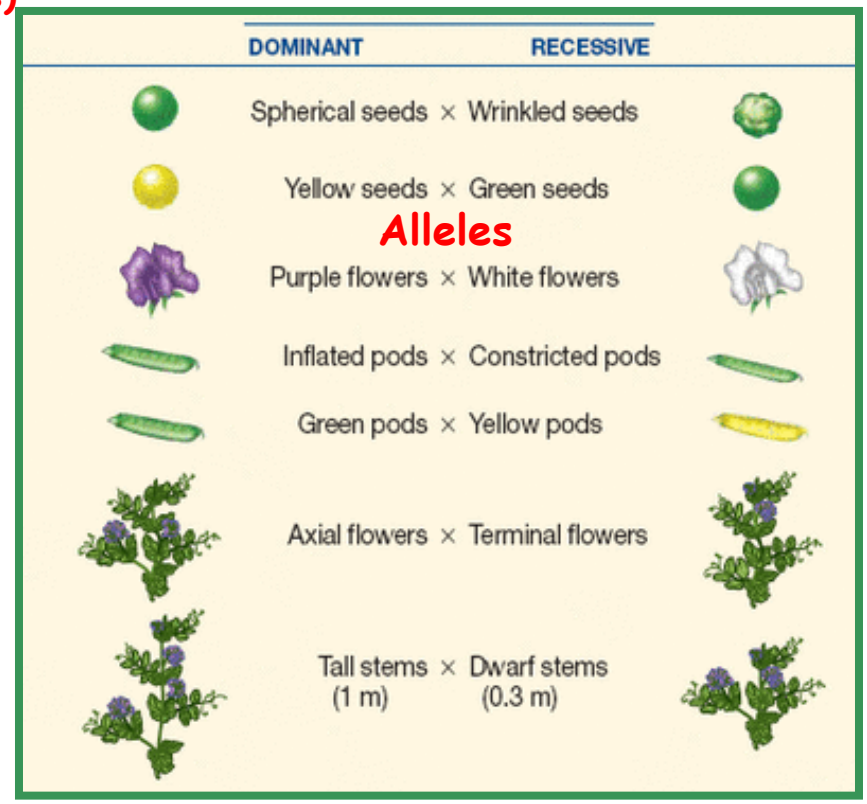
How is this Demonstrated Experimentally?

Design an Experiment!

Different Alleles of a Gene Underlie Variations in Specific Traits



Mendel's Traits



Mutations Lead to Different Forms of the SAME Gene (Alleles) and Generate Genetic Variability in a Population of Organisms (e.g., yellow and green peas)

Genetic Engineering Can Create Infinite Amounts of Genetic Variability NOT Found in Nature

Different Alleles of a Gene Can Have Different Functions

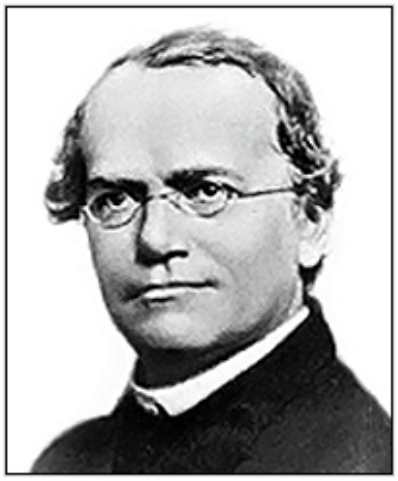
ScientificAmerican.com > News > Basic Science > Genetics

January 5, 2007 | 0 comments

Gene Behind Mendel's Green Pea Seeds Finally Identified

More than a century later, researchers isolate a gene manipulated by the Austrian monk in his groundbreaking experiments

By JR Minkel



BACK IMAGE 2 of 2

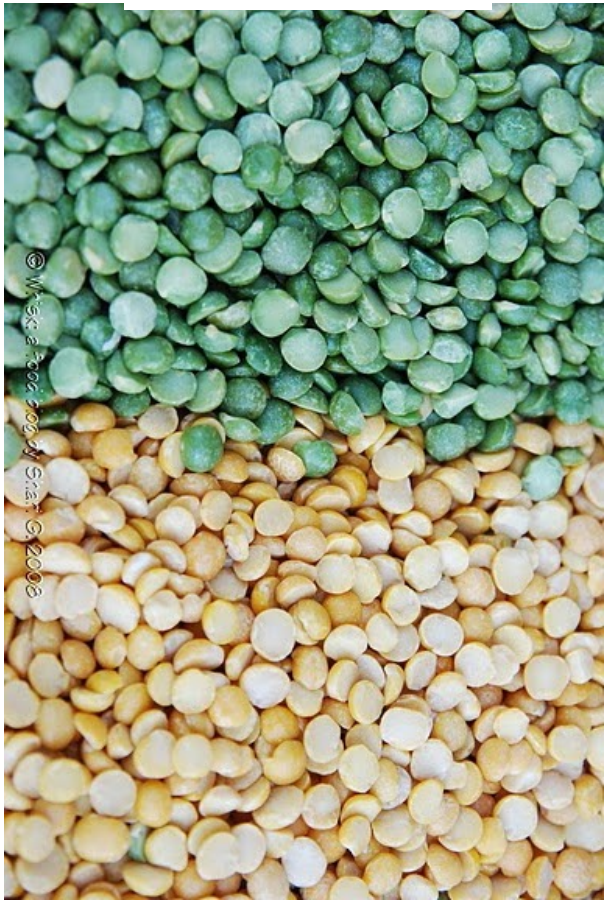
QUITE MENDELIAN: Gregor Mendel (1822-1884), the founder of genetics.

It only took 141 years, but researchers report they have finally pinpointed one of the genes that Austrian monk Gregor Mendel manipulated in his pioneering experiments that established the basic laws of genetics--specifically, the gene that controlled the color of his peas' seeds. A team identified the sequence of a gene common to several plant species, which use it to break down a green pigment molecule, and found that it matches Mendel's gene.

E-MAIL PRINT COMMENT Digg submit Like it? Thumbs-up Stumble!

This marks the third of the monk's seven genes that researchers have precisely identified, and the first since the late 1990s, before the genome sequencing boom.

Green Peas



Yellow Peas

Two different alleles of the *Staygreen* gene encode different forms of an enzyme that degrades chlorophyll

Breeding Takes Advantage of Natural Genetic Variability – Gene Variability is Generated by Mutations

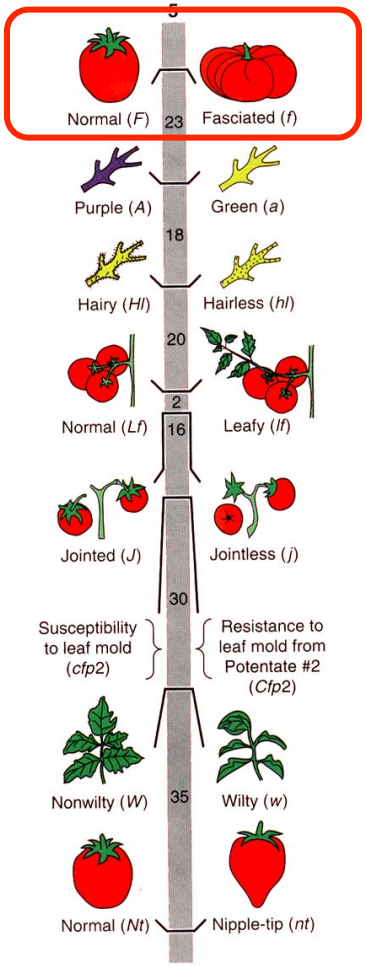
This Genetic Variability Arose Spontaneously By RARE Mutations

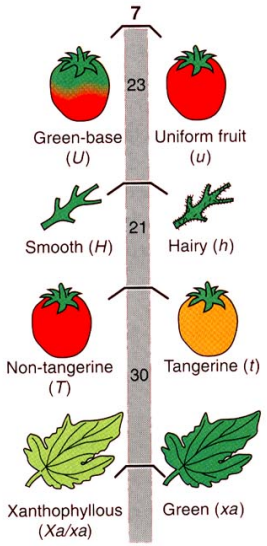
Tomato Genetic Diversity

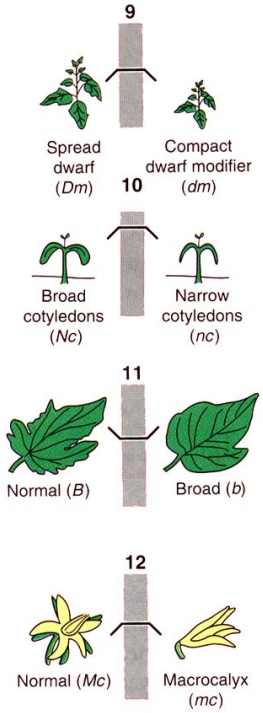
Gene Mutations Alter DNA Sequences,
Slightly Change Gene Functions (e.g., fruit size, color),
& Create Alleles -- Different Forms of the Same Gene

Alleles Reside at the Same Position on a Chromosome

Alleles







mutations result in genetic diversity!!!

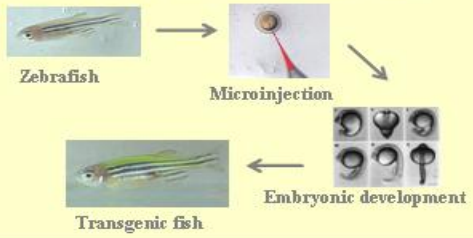
Alleles Are Different Forms of the Same Gene That Arise By Mutation & Can be Made in a Laboratory By Modern Genetic Engineering!

How Does the GloFish Experiment Show That Genes Direct the Production of Traits?

What's Your Hypothesis?

Fluorescent transgenic zebrafish were developed by a research team, led by Dr. Z. Gong, in Department of Biological Sciences, National University of Singapore.

Fig. 1. The basic procedure to produce transgenic fish. Briefly, fluorescent color genes, originally isolated from a jellyfish and a sea anemone, were microinjected into zebrafish eggs and these foreign genes later become a part of the genetic make-up of injected zebrafish. Thus the fluorescent color acquired by these transgenic zebrafish can be stably transmitted to all future generations. This technology can also be applied to other ornamental fish species.



Phenotypes

Fig. 2. Florescent transgenic zebrafish in a rainbow array (top to bottom): Red, rfp fish; Orange, rfp/gfp fish; Yellow, yfp fish; Green, gfp fish; and Wild Type fish. The picture on the far left was taken under a daylight and the picture on the left in the dark with a uv light.

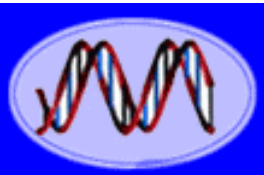
rfp – red fluorescent protein
yfp – yellow fluorescent protein
gfp – green fluorescent protein

Traits

Different Colors!!

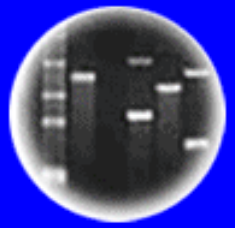
Fig. 3. Swimming fluorescent transgenic zebrafish under the daylight (top) and in the dark (bottom, with a uv light)

GloFish®



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

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

How Show That DNA is The Genetic Material?

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

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

Major Causes of Death

1920	2002
1. Typhoid Fever	1. Heart Disease
2. Malaria	2. Infectious & Parasitic Diseases
3. Small Pox (virus)	3. Cancer
4. Measles	4. Stroke
5. Scarlet Fever	5. Respiratory Diseases
6. Whooping Cough	6. Unintended Injuries (e.g., Cars)
7. Diphtheria	7. HIV/AIDS
8. Flu	8. Digestive Diseases
9. Mumps	9. Diarrheal Diseases
10. Cholera	10. Intentional Injuries (Murder, War, etc.)

The Spanish Flu Pandemic - 1918 to 1920

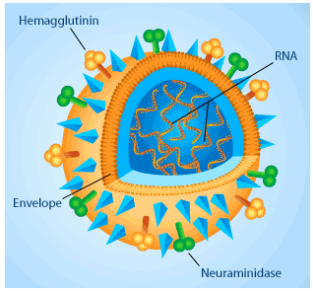
It is estimated that anywhere from 20 to 100 million people were killed worldwide,or the approximate equivalent of one third of the population of Europe, more than double the number killed in World War I. This extraordinary toll resulted from a high death rate of up to 50%.

Characterization of the 1918 "Spanish" influenza virus neuraminidase gene PNAS June 6, 2000

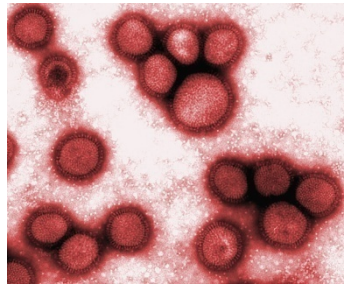
Ann H. Reid,* Thomas G. Fanning, Thomas A. Janczewski, and Jeffery K. Taubenberger

Researchers detect deadly Spanish flu genes

A team of researchers in Japan and the United States have determined the causative genes for the Spanish flu that reportedly claimed the lives of some 40 million people around the world in 1918. PNAS January, 2009



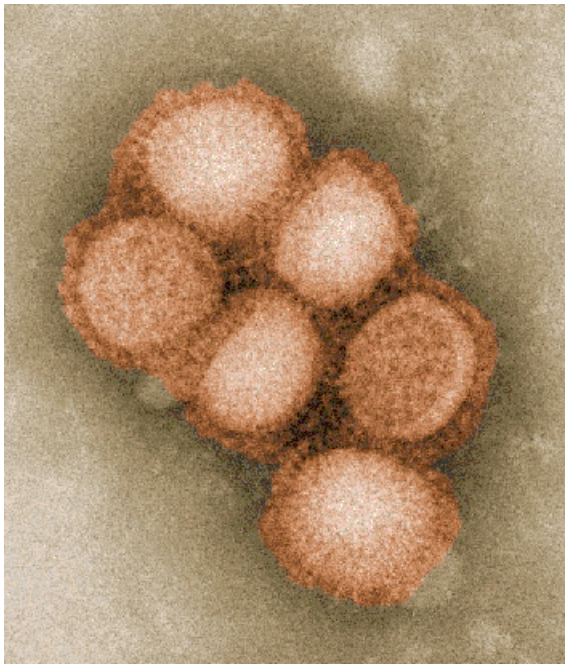
By Sequencing the Virus Genome From Victims Dead For 80 Years & Synthesizing the "Original" Flu Virus By Genetic Engineering



How Many People Have Died Worldwide During the Current H1N1 Pandemic?

A.130
B.1,300
C.13,000
D.130,000
E.1,300,000

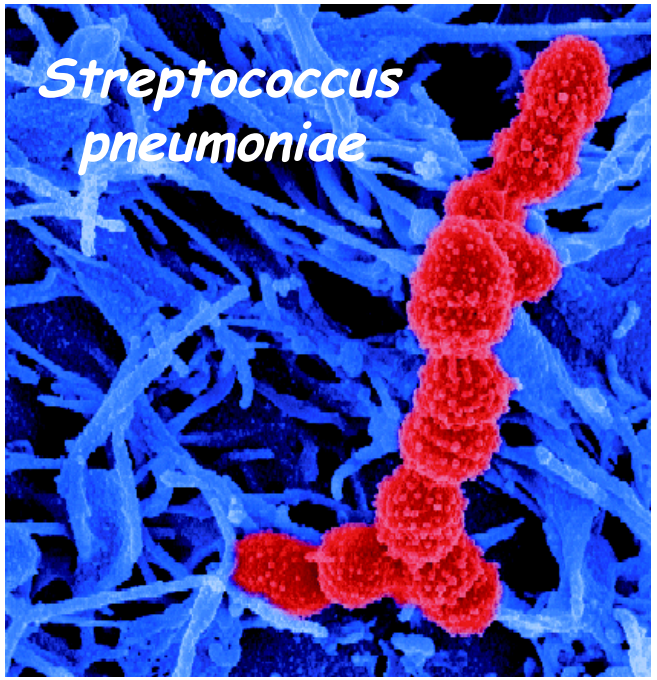
H1N1 Virus



January 29, 1922 - New York City

PNEUMONIA KILLS 990 IN CITY SINCE JAN. 1; Forty-Eight Die in Twenty-Four Hours, Four Fewer Than on Previous Day. 387 INFLUENZA CASES Six More Deaths Reported, but Copeland Sees Chief Danger in First-Named Disease.

Bacterial Pneumonia Was Also a "Killer" at This Time!

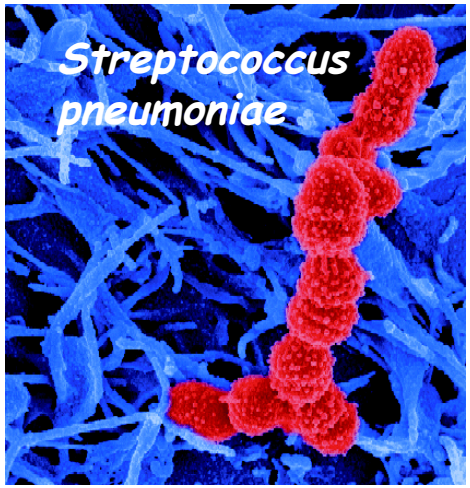


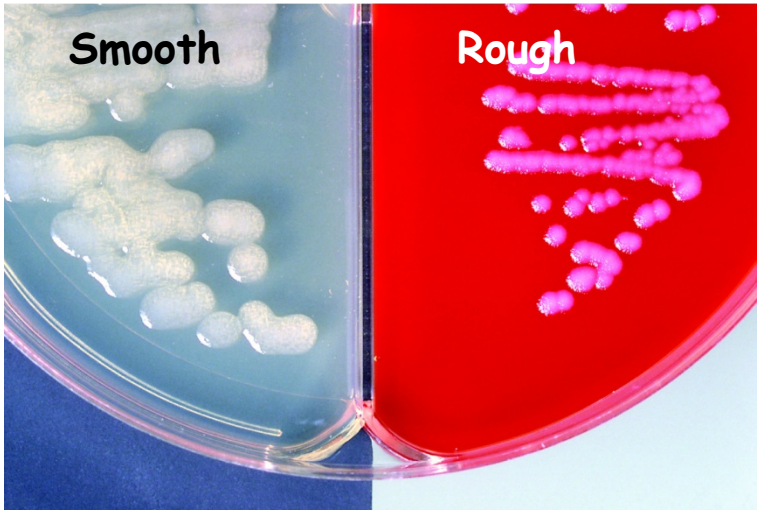
1,000,000 Deaths/Year TODAY!

Frederick Griffith & The Transforming Principle

The First Genetic Engineering Experiment

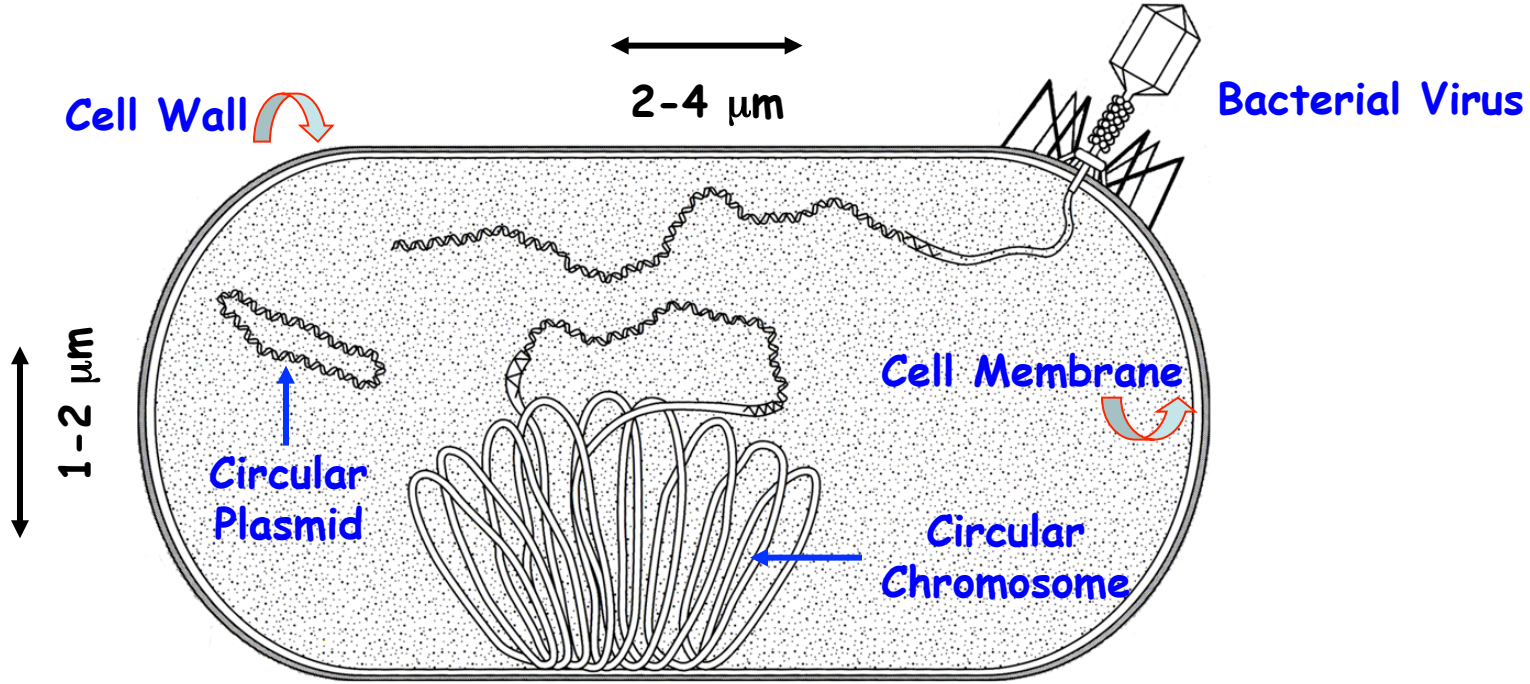
1879-1941





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

A Typical Bacterial Cell



Plasmids: 2,000-150,000 bp (1-100 genes)
Chromosome: 500,000-5,000,000 bp (500-5,000 genes)

Plasmid DNA: ~1.4 μm (10^{-6} m) in circumference (Genetic Engineering Vectors)
Chromosome: ~ 1.4 mm (10^{-3} m) in circumference

1 μm = 3.94×10^{-5} inches

Diversity in Bacterial Cell Morphology

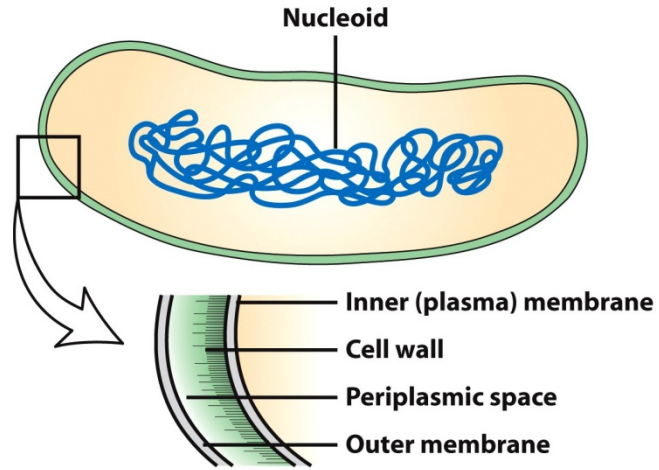


Figure 1-2a part 2
Molecular Cell Biology, Sixth Edition

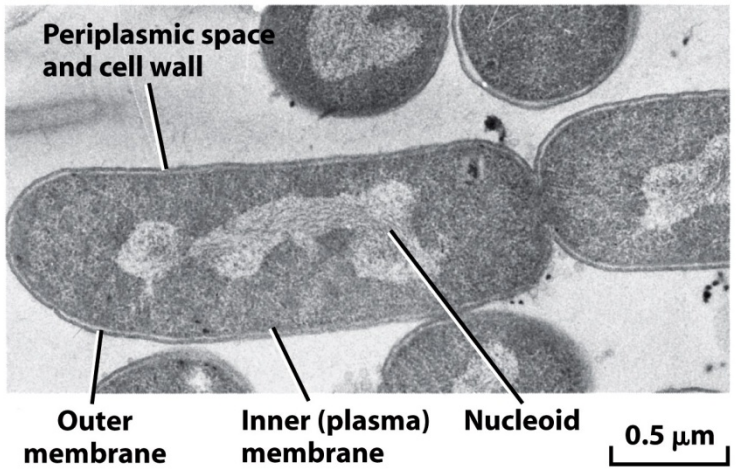


Figure 1-2a part 1
Molecular Cell Biology, Sixth Edition

spherical cells
e.g., *Streptococcus*

rod-shaped cells
e.g., *Escherichia coli,*
Vibrio cholerae

the smallest cells
e.g., *Mycoplasma,*
Spiroplasma

spiral cells
e.g., *Treponema pallidum*

Bacterial Genome Projects Have Provided Remarkable Insight Into Bacterial Genomes and Cell Functions

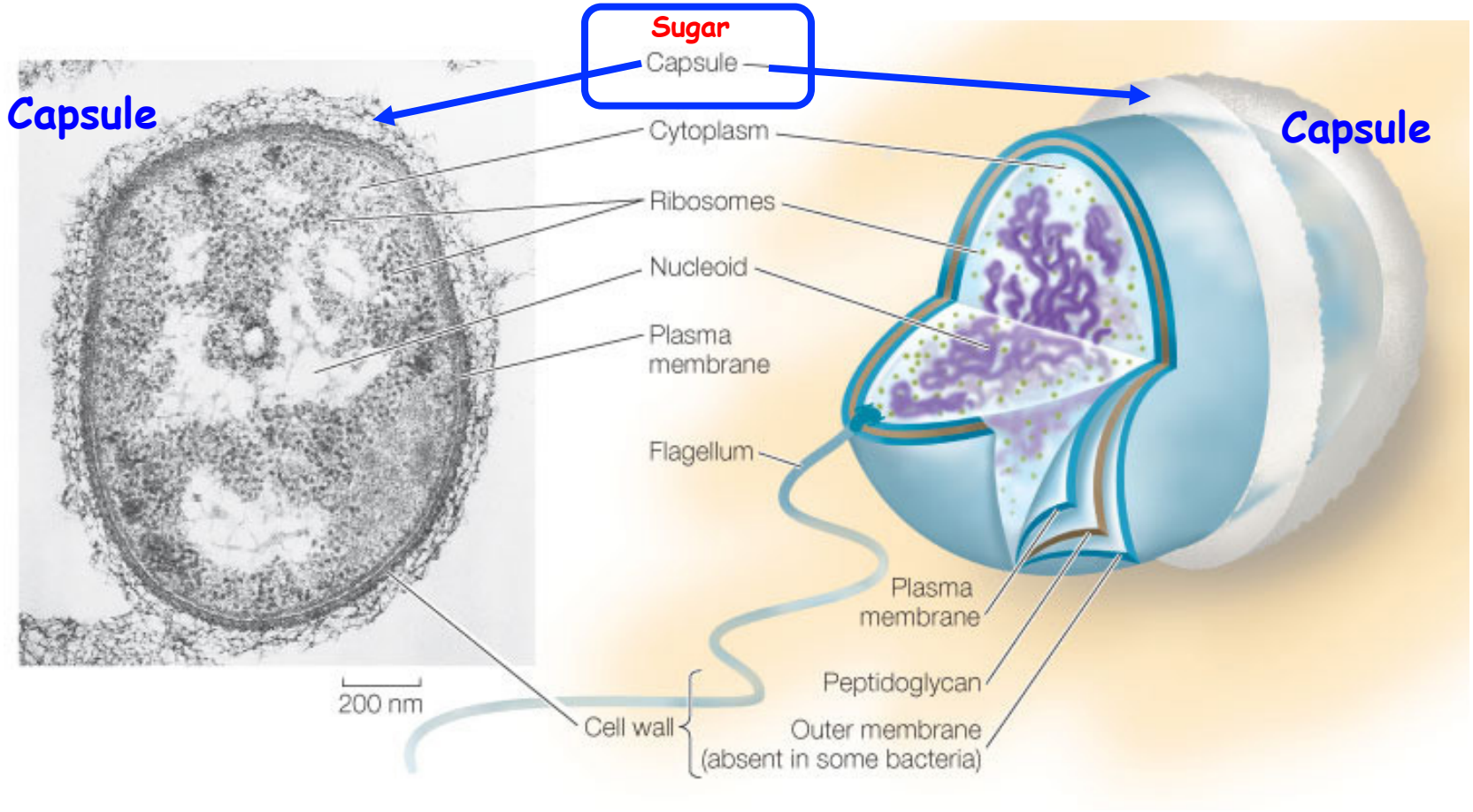
Table 1–1 Some Genomes That Have Been Completely Sequenced

SPECIES	SPECIAL FEATURES	HABITAT	GENOME SIZE (1000s OF NUCLEOTIDE PAIRS PER HAPLOID GENOME)	ESTIMATED NUMBER OF GENES CODING FOR PROTEINS
BACTERIA				
Mycoplasma genitalium	has one of the smallest of all known cell genomes	human genital tract	580	468
Synechocystis sp.	photosynthetic, oxygen-generating (cyanobacterium)	lakes and streams	3573	3168
Escherichia coli	laboratory favorite	human gut	4639	4289
Helicobacter pylori	causes stomach ulcers and predisposes to stomach cancer	human stomach	1667	1590
Bacillus anthracis	causes anthrax	soil	5227	5634
Aquifex aeolicus	lithotrophic; lives at high temperatures	hydrothermal vents	1551	1544
Streptomyces coelicolor	source of antibiotics; giant genome	soil	8667	7825
Treponema pallidum	spirochete; causes syphilis	human tissues	1138	1041
Rickettsia prowazekii	bacterium most closely related to mitochondria; causes typhus	lice and humans (intracellular parasite)	1111	834
Thermotoga maritima	organotrophic; lives at very high temperatures	hydrothermal vents	1860	1877

There is currently a major effort to generate
The Genomic Encyclopedia of Bacteria and Archaea

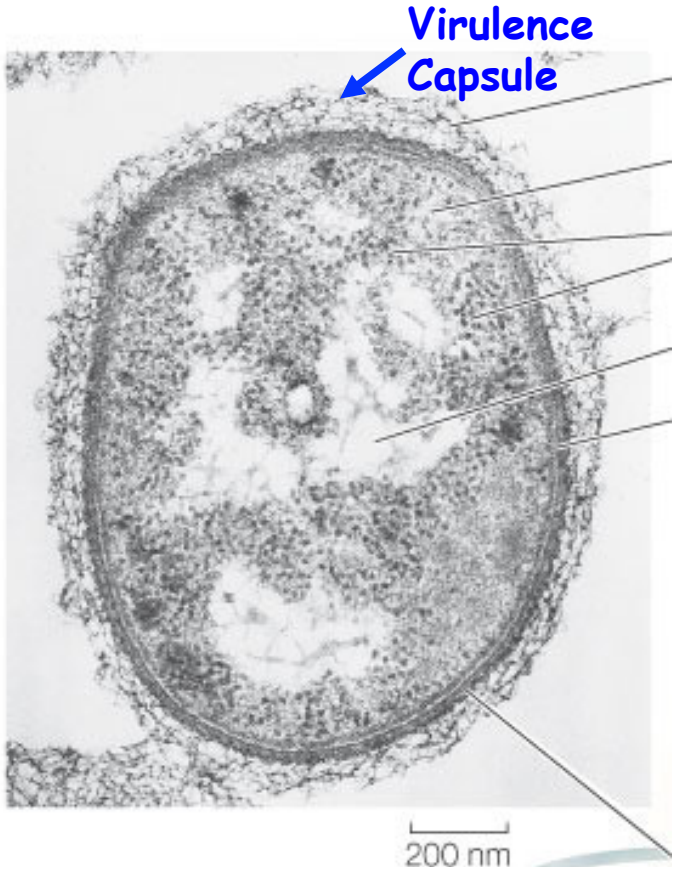
Table 1-1 (part 1 of 2) *Molecular Biology of the Cell*, Fifth Edition (© Garland Science 2008)

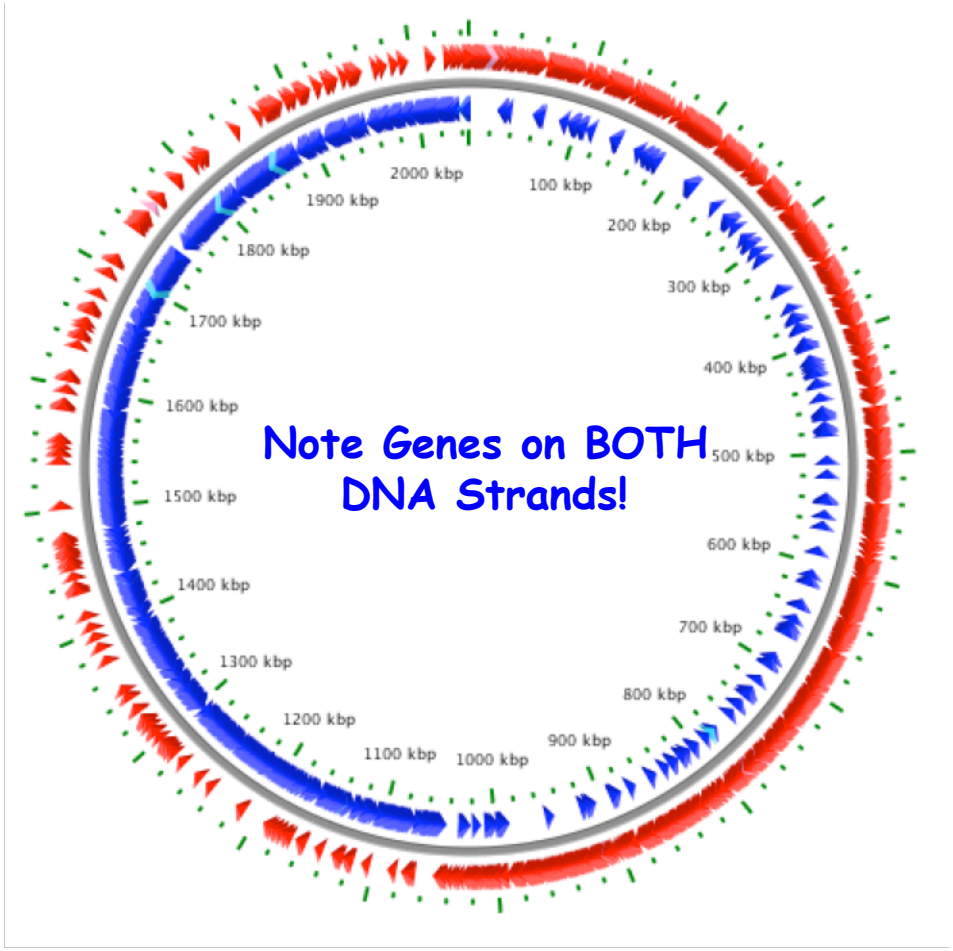
Streptococcus pneumoniae



The Sugar Capsule Protects the Bacteria From Mammalian Host Antibodies

Streptococcus pneumoniae Genome Has Been Sequenced!

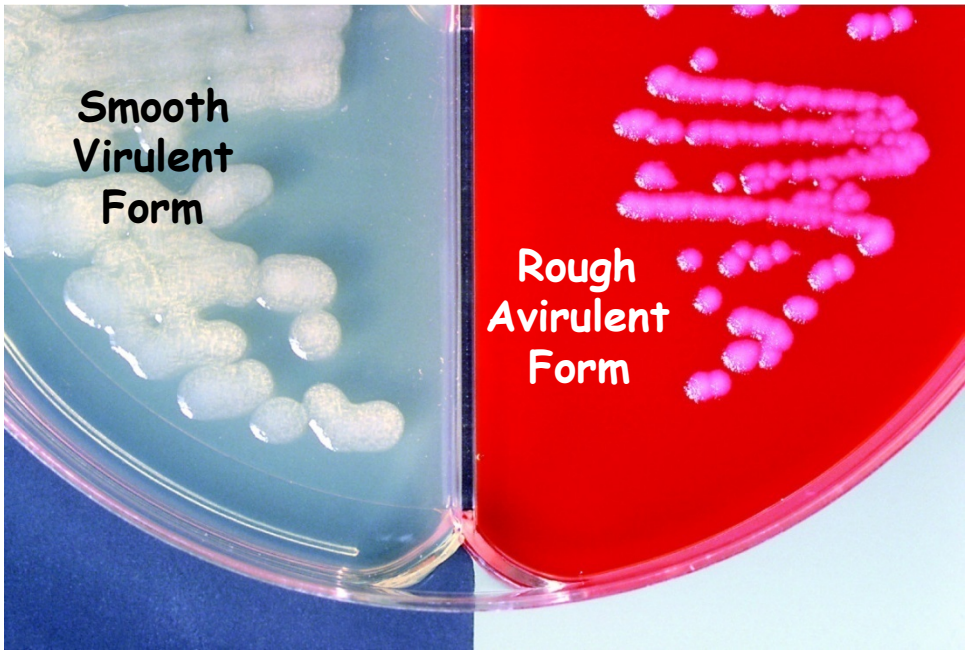


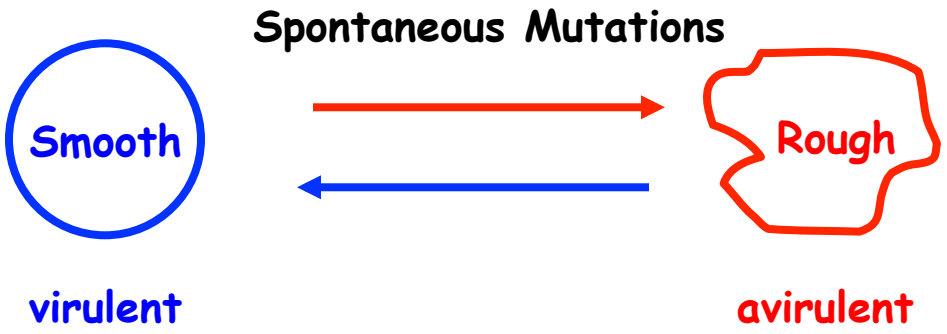


2,046,115 bp and 1,987 Genes

J. Bacteriology
2001

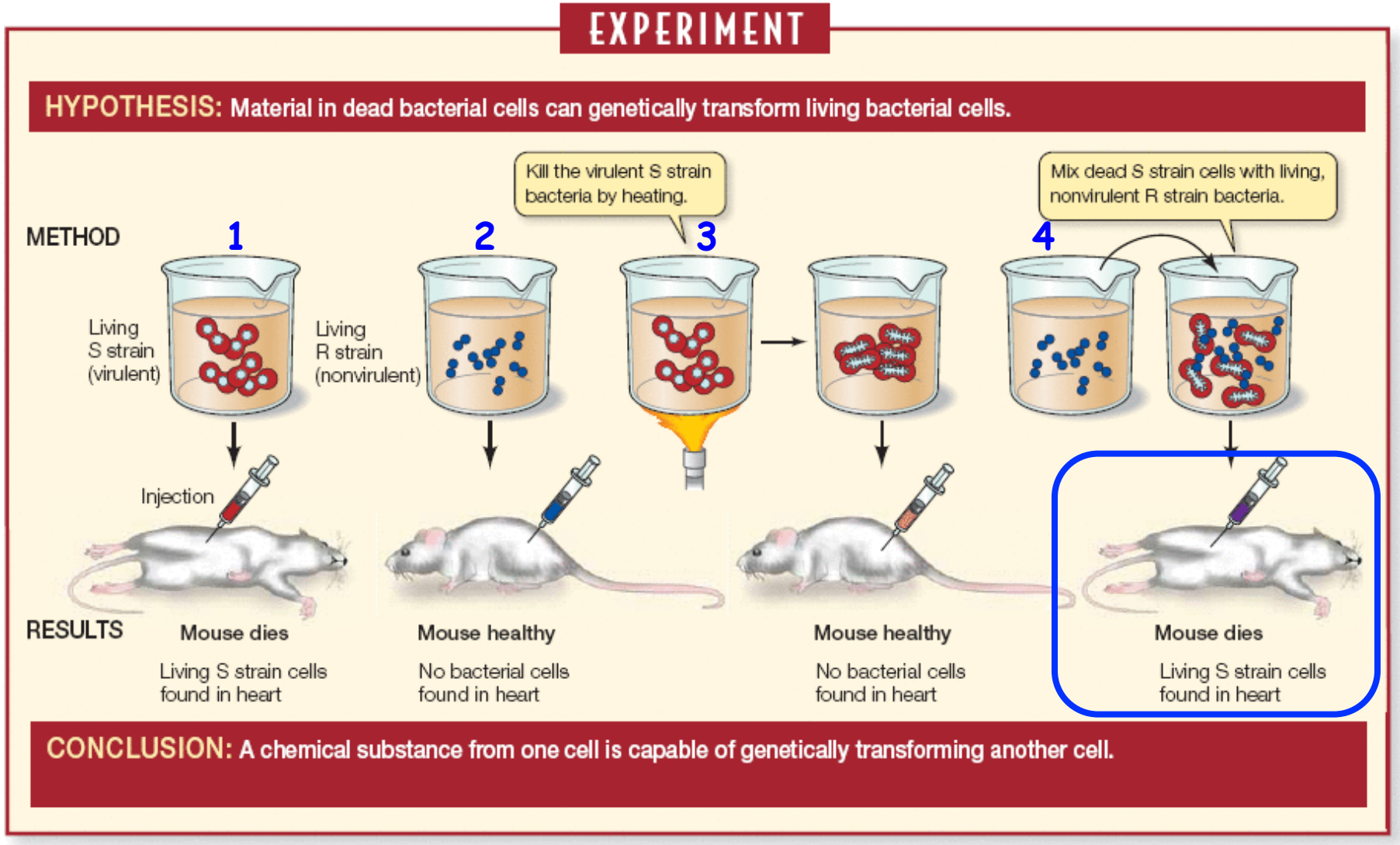
The Griffith Experiment
With Smooth and Rough Pneumonia Bacteria





J. Hygiene, 1928

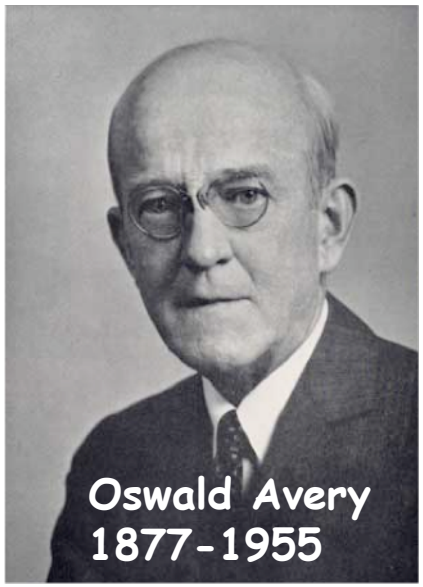
The Griffiths Experiment

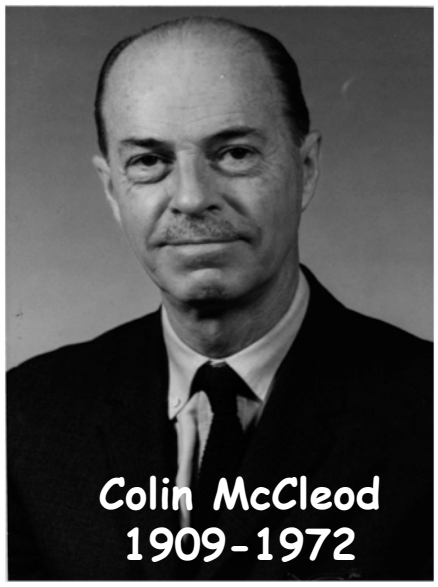


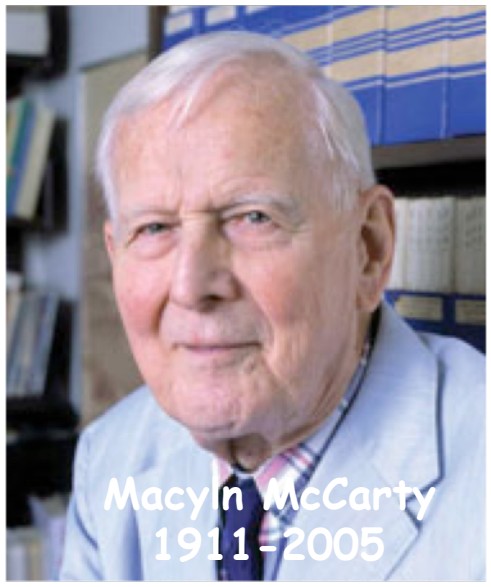
LIVE Rough Cells TRANSFORMED by DEAD Smooth Cells!!!

HOW? What Was the Transforming Principle? Hypothesis?

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







DNA is the Genetic Material!

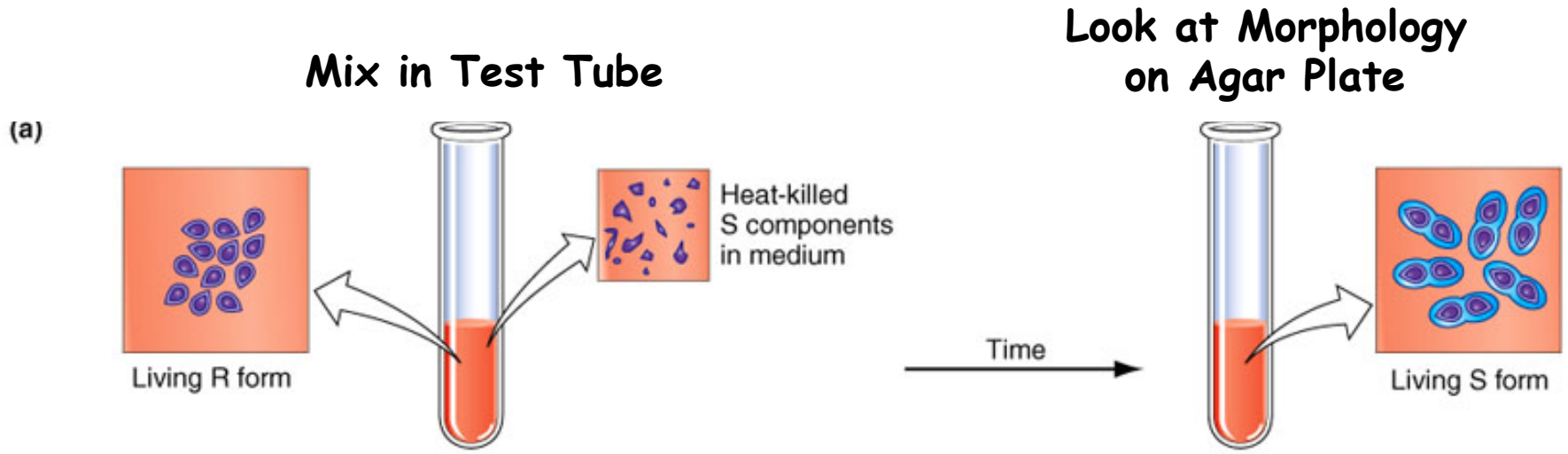
One of the Major Reasons Watson and Crick
Considered DNA As the Genetic Material
In Order to Solve DNA Structure

J. Exp. Med.,1944

Avery et al. Experiments

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

Does the Transforming Principle Come From the Mouse or Bacteria?



Hypothesis? Predictions? Experiment?

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?

Table 2–2 The Approximate Chemical Composition of a Bacterial Cell

	PERCENT OF TOTAL CELL WEIGHT	NUMBER OF TYPES OF EACH MOLECULE
Water	70	1
Inorganic ions	1	20
Sugars and precursors	1	250
Amino acids and precursors	0.4	100
Nucleotides and precursors	0.4	100
Fatty acids and precursors	1	50
Other small molecules	0.2	~300
Macromolecules (proteins, nucleic acids, and polysaccharides)	26	~3000

Macromolecules

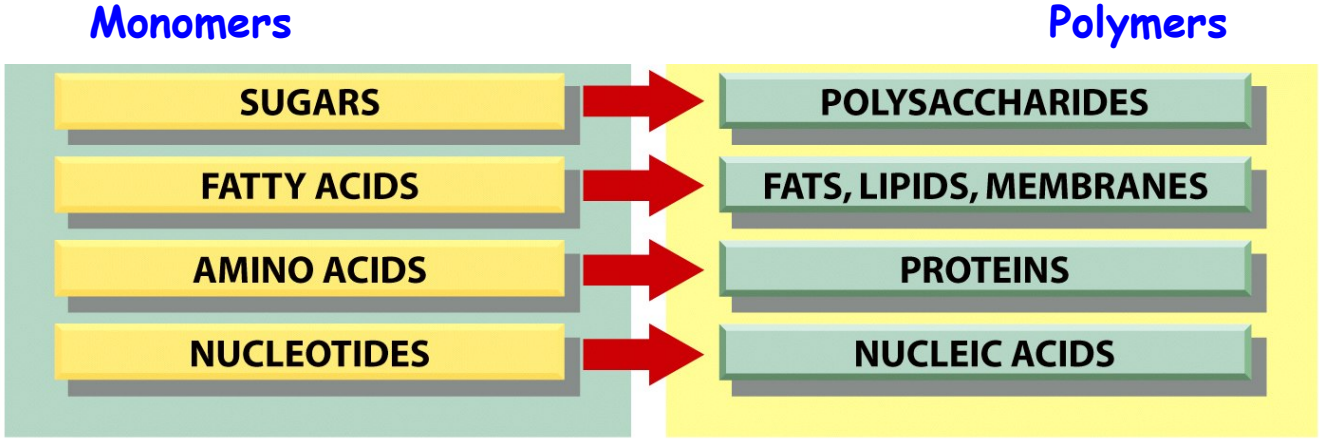


Table 2-2 *Molecular Biology of the Cell* (© Garland Science 2008)

Macromolecules and Their Cellular Functions

TABLE 3.1	Macromolecules		
Macromolecule	**Subunit**	**Function**	**Example**
CARBOHYDRATES			
Starch, glycogen	Glucose	Energy storage	Potatoes
Cellulose	Glucose	Plant cell walls	Paper; strings of celery
Chitin	Modified glucose	Structural support	Crab shells
NUCLEIC ACIDS			
DNA	Nucleotides	Encodes genes	Chromosomes
RNA	Nucleotides	Needed for gene expression	Messenger RNA
PROTEINS			
Functional	Amino acids	Catalysis; transport	Hemoglobin
Structural	Amino acids	Support	Hair; silk
LIPIDS			
Fats	Glycerol and three fatty acids	Energy storage	Butter; corn oil; soap
Phospholipids	Glycerol, two fatty acids, phosphate, and polar R groups	Cell membranes	Phosphatidylcholine
Prostaglandins	Five-carbon rings with two nonpolar tails	Chemical messengers	Prostaglandin E (PGE)
Steroids	Four fused carbon rings	Membranes; hormones	Cholesterol; estrogen
Terpenes	Long carbon chains	Pigments; structural support	Carotene; rubber

Testing Macromolecules For Transforming Activity

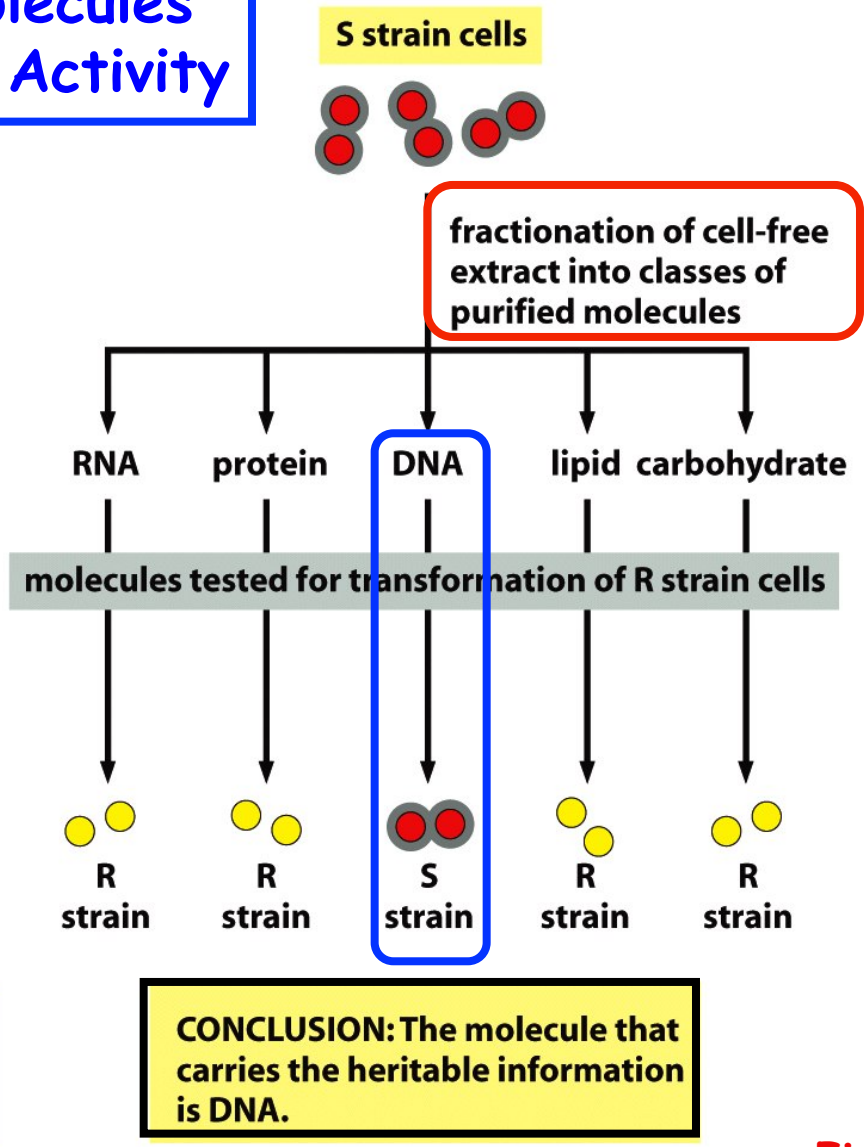


Figure 4-2 *Molecular Biology of the Cell* (© Garland Science 2008)

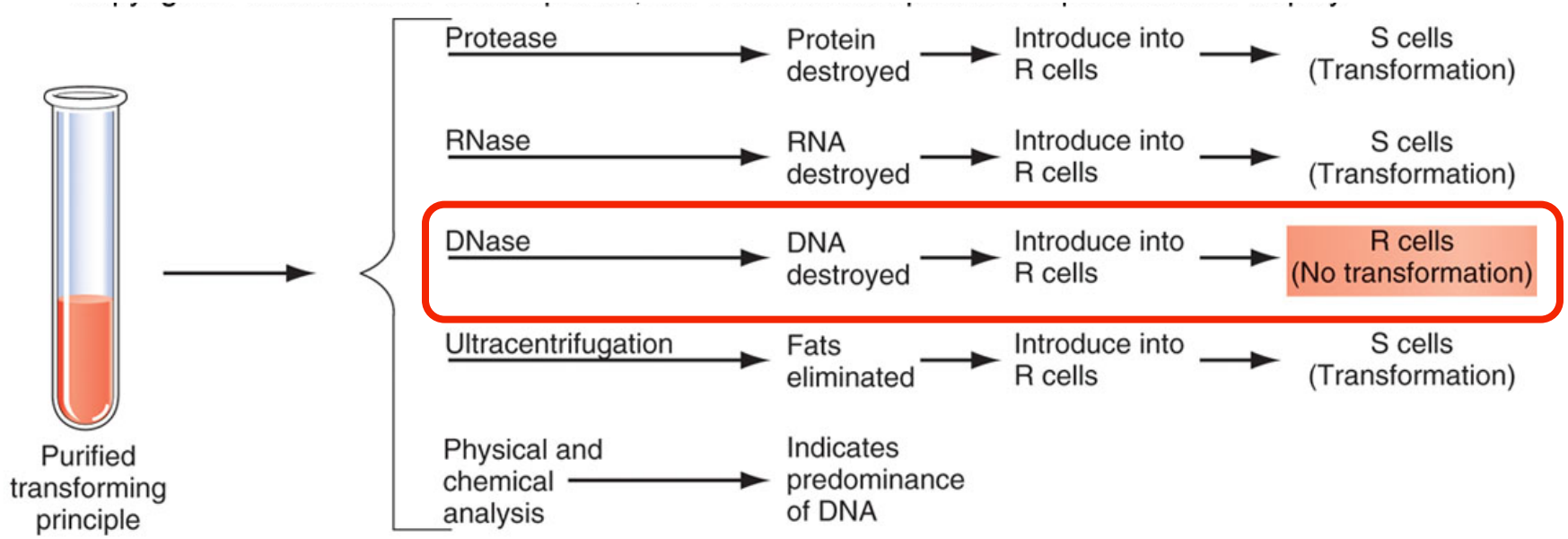
First Transformation Experiment With Purified Molecules!!

Does the Avery et al. experiment show conclusively that DNA is the genetic material?

a. YES

b. NO

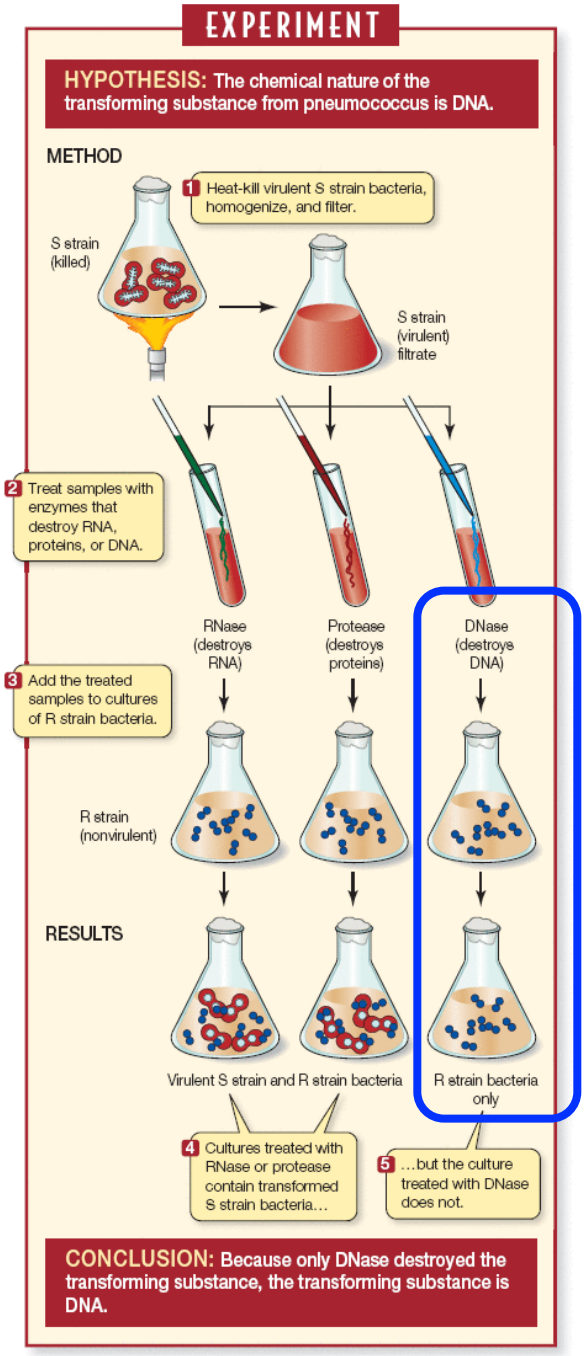
THE Critical Experiment by Avery et al. Showing That DNA IS THE GENETIC MATERIAL



When DNase Destroyed DNA There Was No Transformation & Only Rough Cells Were Found in the Culture

If Smooth DNA Not Present, Rough Cells Cannot Be Transformed Into Smooth Cells!

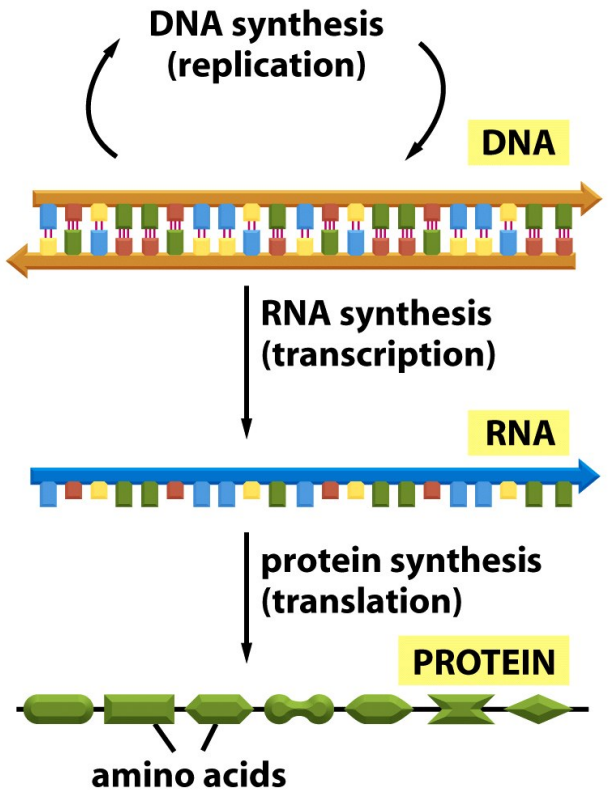
THE Critical Experiment by Avery et al. Showing That DNA Is the Genetic Material



When Dnase Destroyed DNA There Was No Transformation & Only Rough Cells Were Found In Culture

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

Predictions	Results
Replication	Yes
Phenotype	Yes
Stable	Yes



Cell Processes

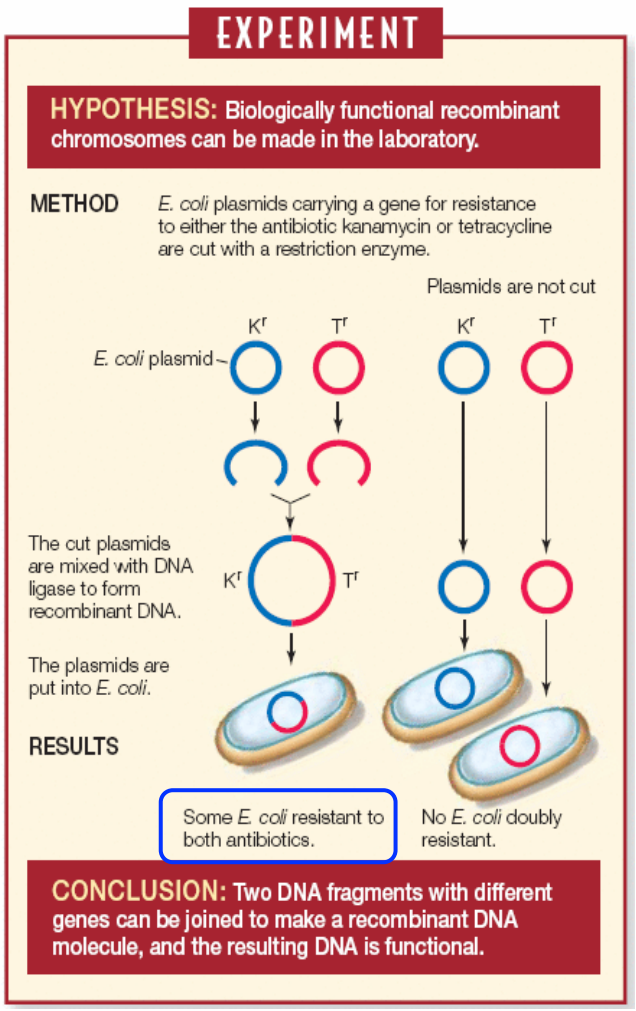
1. S DNA Taken Up By R-Cells
2. S Gene Transcribed Into S mRNA
3. S mRNA Translated Into Smooth Protein
4. Smooth Protein Helps Construct Sugar Capsule and Protects Bacteria From Antibodies ∴Cells Virulent

Transformation is a Basic Genetic Engineering Process Today!

Transformation=Ability of Cell Phenotype To Be Changed by DNA!

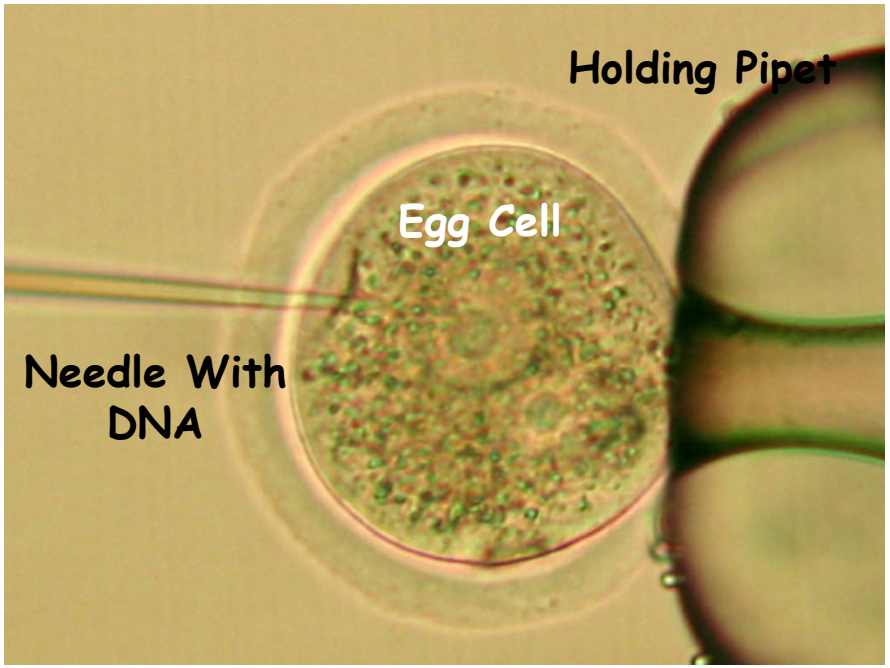
Can Bacteria Be Transformed With Other Genes/Traits?

Cohen & Boyer Experiment That "Invented" Genetic Engineering



Because the Transforming Principle is DNA
Any Gene Can Be Transformed (e.g., Antibiotic^{R} to Antibiotic^{S})

Engineering "Mighty Mouse" With a Rat Growth Hormone Gene



DNA → Specifies a Trait & Replicates

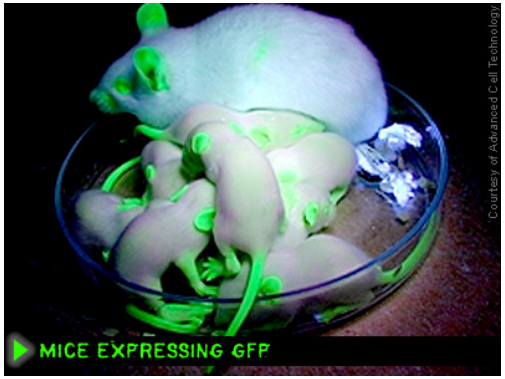
All Organisms Can Be Transformed!!
Genetic Engineering Has Come a Long Way Since Griffiths Experiments in 1928!!

Gene Transplants Seen Helping Farmers and Doctors;

By VICTOR K. McELHENY
May 20, 1974, Monday
Page 61, 1335 words

NY Times-1974

Biochemists working in California have developed a practical method of transplanting genes, the chemical units of heredity, from cells as complex as those of animals into the extremely simple, fast-multiplying cells known as bacteria. [END OF FIRST PARAGRAPH]



Even Plants Can Be Transformed With "Naked" DNA!

Genetically Engineered Traits

Improving Pest and Weed Management

- Herbicide tolerance
- Virus resistance
- Insect resistance
- Bacterial resistance
- Fungal resistance

**Chemical Free* Crops*

Improving Agronomic Properties

- Altering cold sensitivity
- Improving water stress tolerance
- Improving salt tolerance
- Improving nutrient uptake
- Drought Resistance*

Crops in Desert & Drought

Improving PostHarvest Qualities

- Delay of fruit ripening
- Delay of flower senescence/timing
- High-solids tomatoes
- High-starch potatoes
- Sweeter vegetables

Longer Lasting Crops

Improving Plant Breeding

- Male sterility; production of hybrid seeds

Improving Nutritional Quality

- High-methionine and high-lysine seeds
- Decaffeinated Coffee*
- Vitamin-enriched grains
- Allergen-free seeds/grains*

**Healthier* Crops*

Molecular Farming

- Oils
- Starch
- Plastic
- Enzymes, Pharmaceuticals
- Ethanol/Transportation Fuel*

*Crops as Factories & *Vaccines**

Detoxifying Contaminated Soils

Crops to Clean Environment

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

Genotype

↓

Phenotype

Engineered Gene MUST

1. Enter Target Cell
2. Use Target Cell Machinery Enzymes to Become Part of Chromosome
3. Replicate with Target Cell Chromosome
4. Use Target Cell Protein Synthesis Machinery to Make a New Protein → Phenotype Trait!

Engineered Gene CAN BE

1. From Same Organism
2. From Different Organism
3. From a Combination of Organisms stitched together by Genetic Engineering

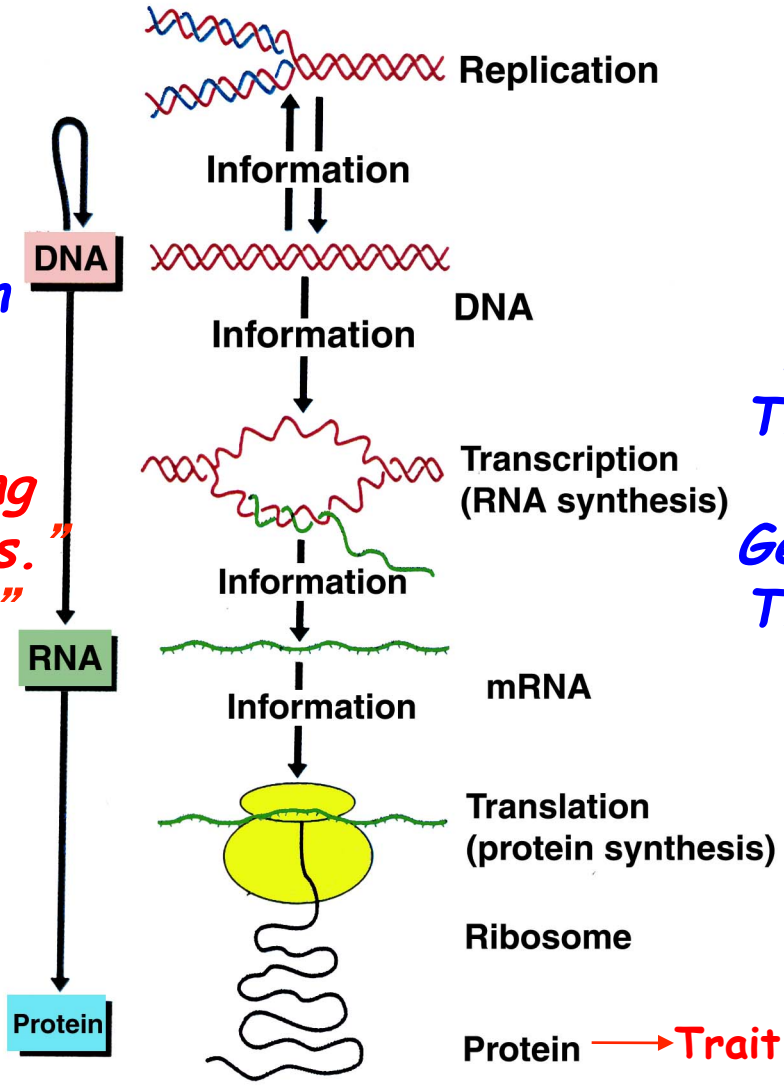
Gene Engineering Shows that Gene Processes Are Universal !

Just Like The GlowGene Experiments !!!

Transformation of Cells With DNA Uses Normal Cellular Processes to Produce a New Phenotype

Can Intervene in This Process in Cells

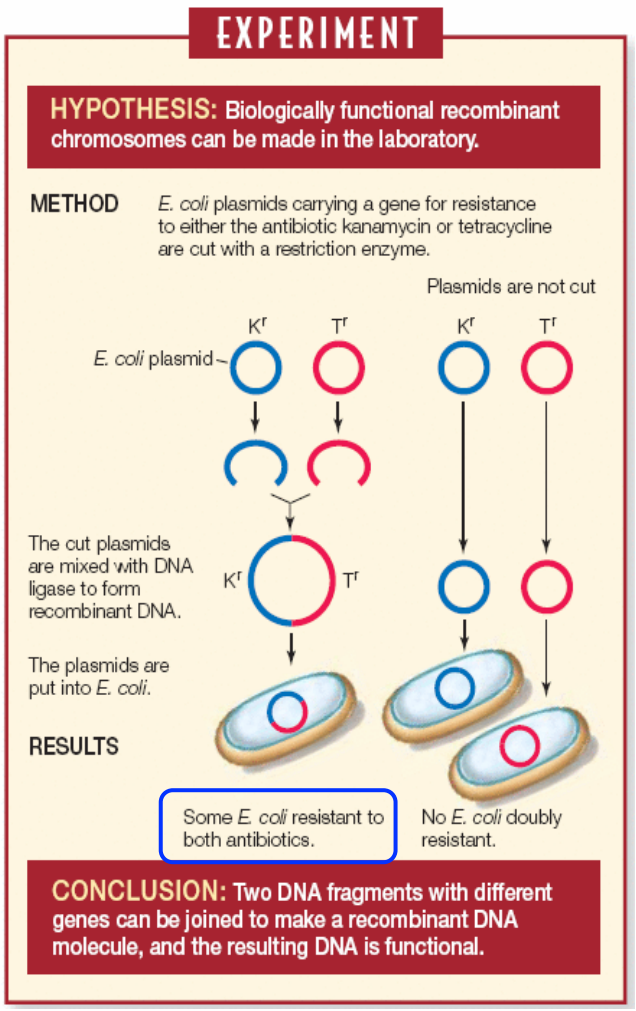
Genetic Engineering Is not "Hocus Pocus." It Uses "Natural" Cell Processes!!!!



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

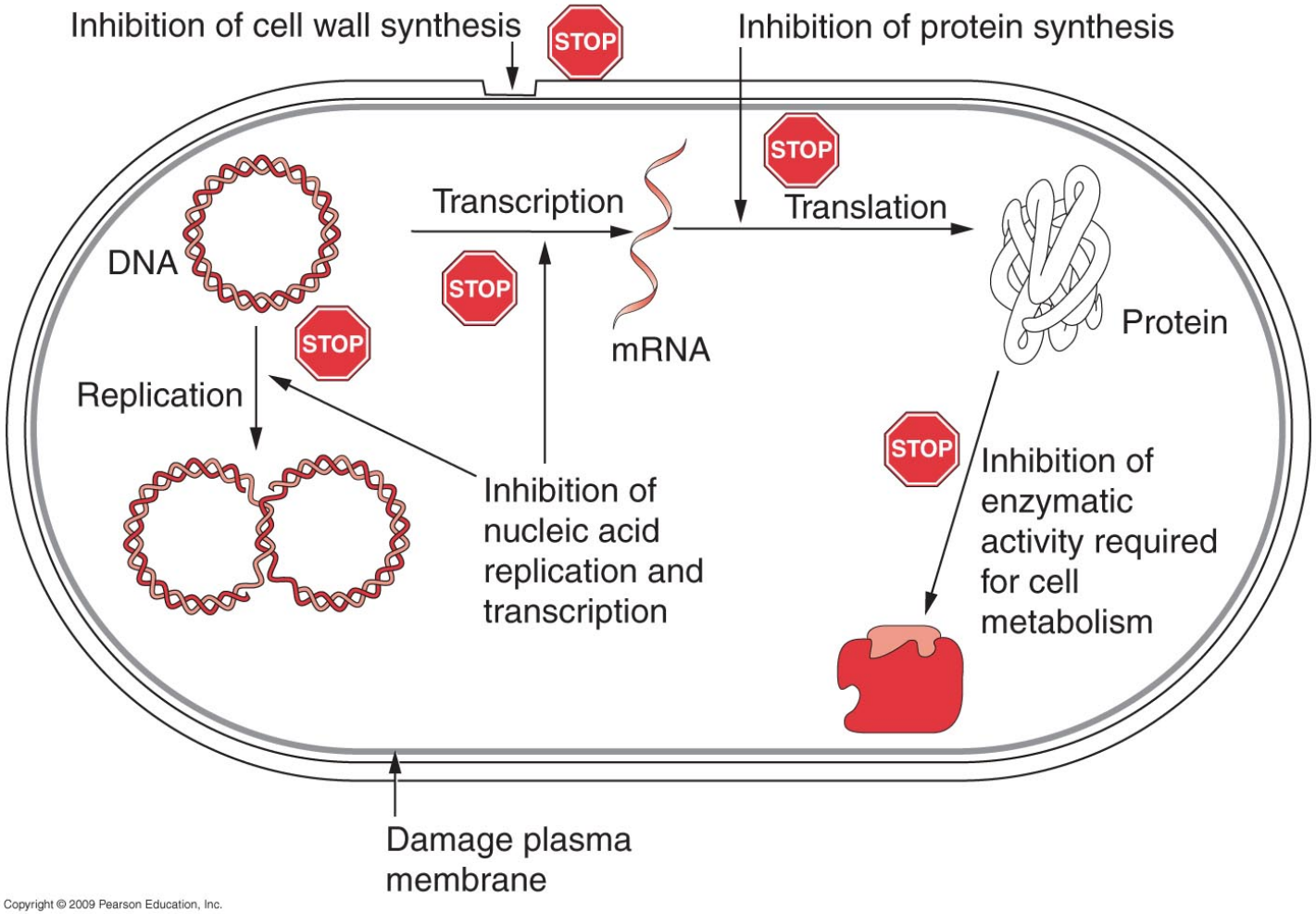
Can Bacteria Be Transformed With Other Genes/Traits?

Cohen & Boyer Experiment That "Invented" Genetic Engineering



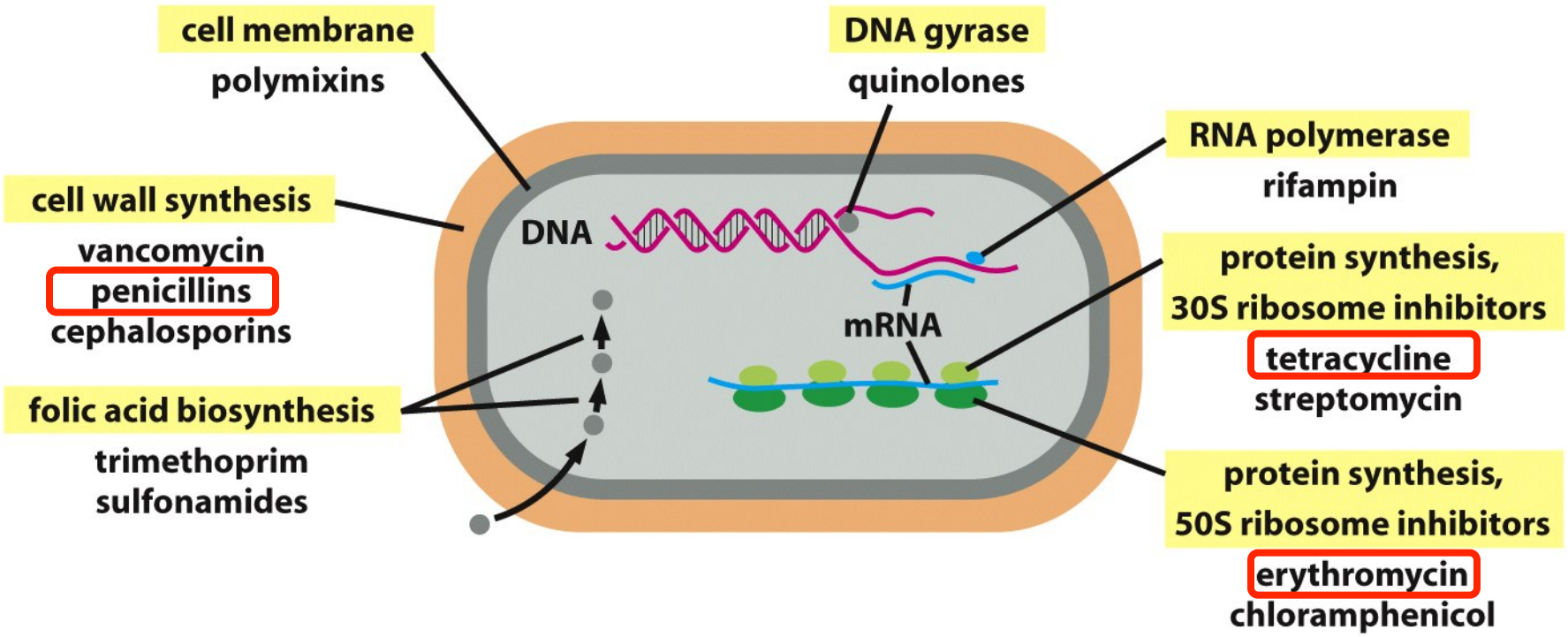
Because the Transforming Principle is DNA
Any Gene Can Be Transformed (e.g., $Antibiotic^S$ to $Antibiotic^R$)

How Do Antibiotics Kill Bacterial Cells?

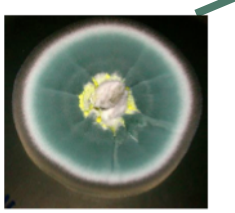


By Inhibiting Basic Microbial Cell Processes

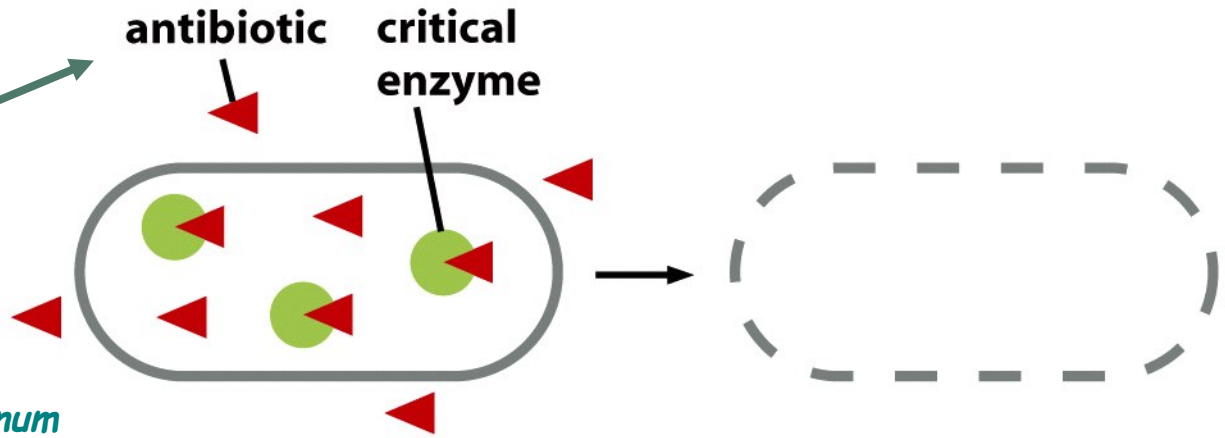
Selected Antibiotics and Their Cell Targets



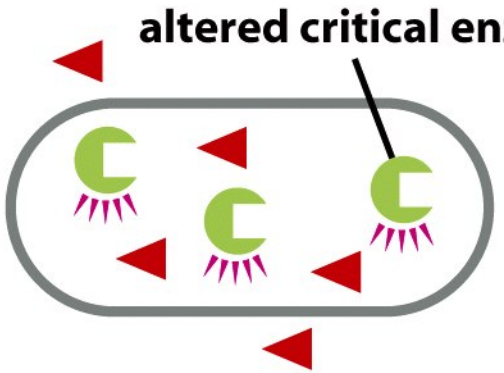
How Do Bacterial Plasmid Antibiotic Resistance Genes Work?



Penicillin chrysogenum

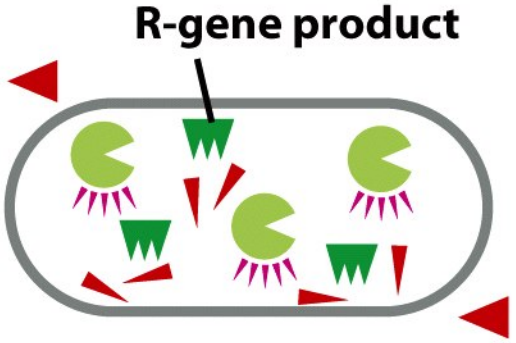


(A) antibiotic kills wild-type bacterium



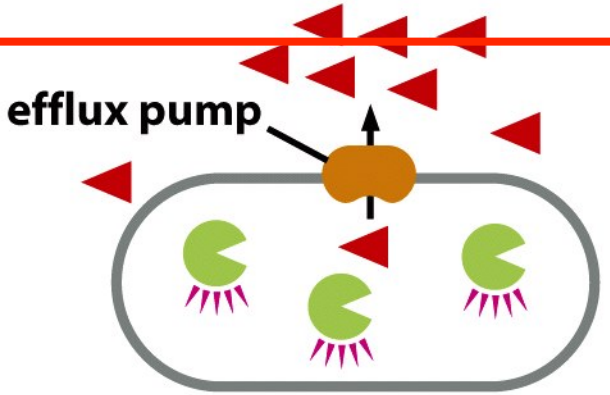
(B) antibiotic resistance

Bacterial Enzyme Alters Target Enzyme So Antibiotic Can't Affect It



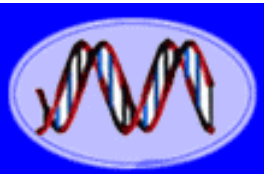
(C) antibiotic resistance

Bacterial Protein Alters Antibiotic Making it Inactive



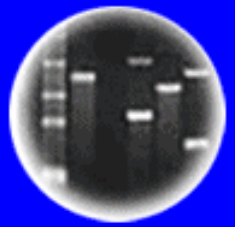
(D) antibiotic resistance

Bacterial Protein Pumps Antibiotic Out of Cell



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



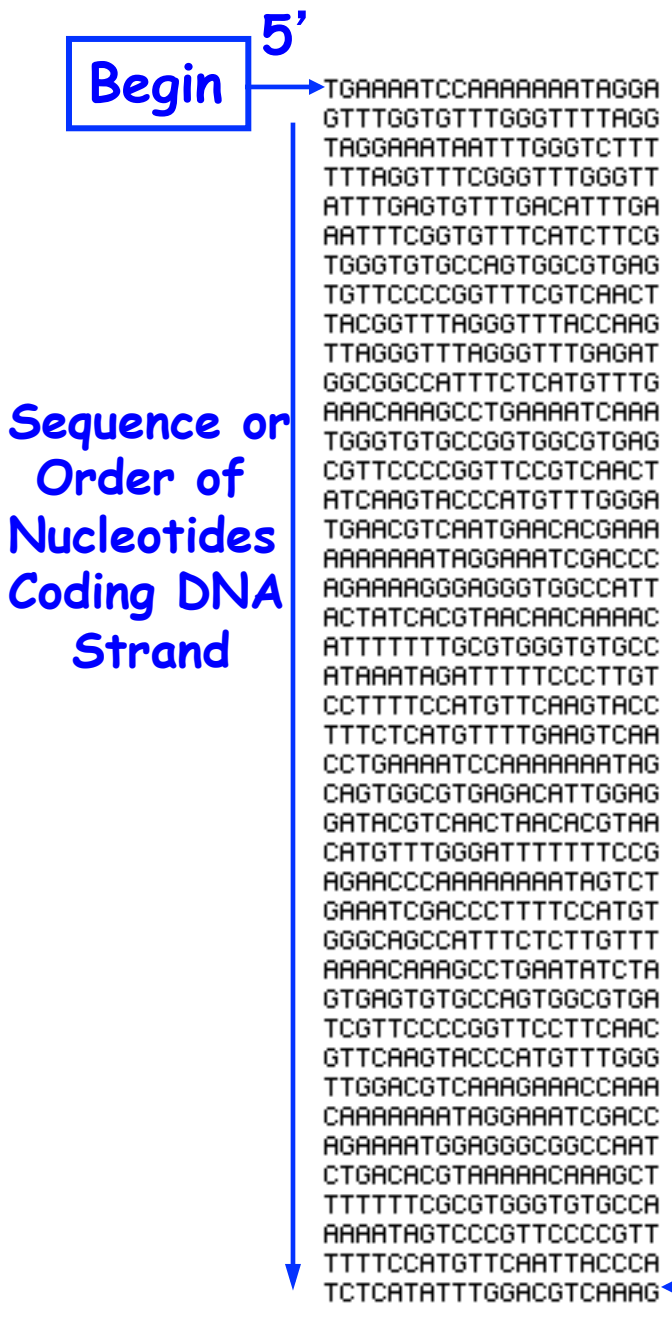
DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

"Bacterial Cloning" Experiment

What is A Gene?



The β-globin Gene

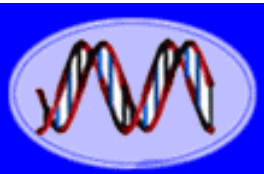
Blood Protein Carries Oxygen to All Genes From Lungs ⇨ Energy

A Gene is a Unique Sequence of Nucleotides Specifying a Function

SEQUENCE → FUNCTION

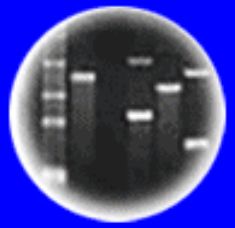
DNA Sequence = Biology!
What If Sequence Changed?

Relative to Coding or Sense Strand of Gene



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

Different Genes Have Different DNA Sequences

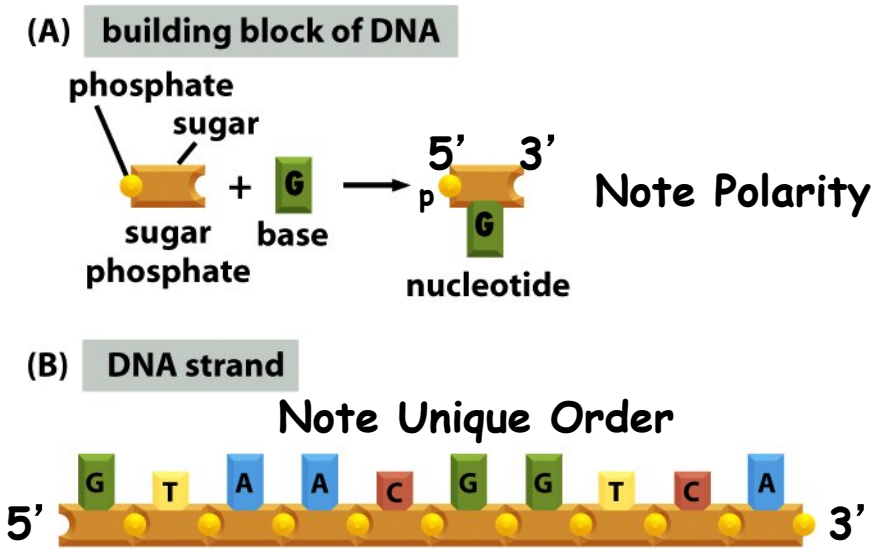
Alleles of a Gene Differ By at Least One Nucleotide

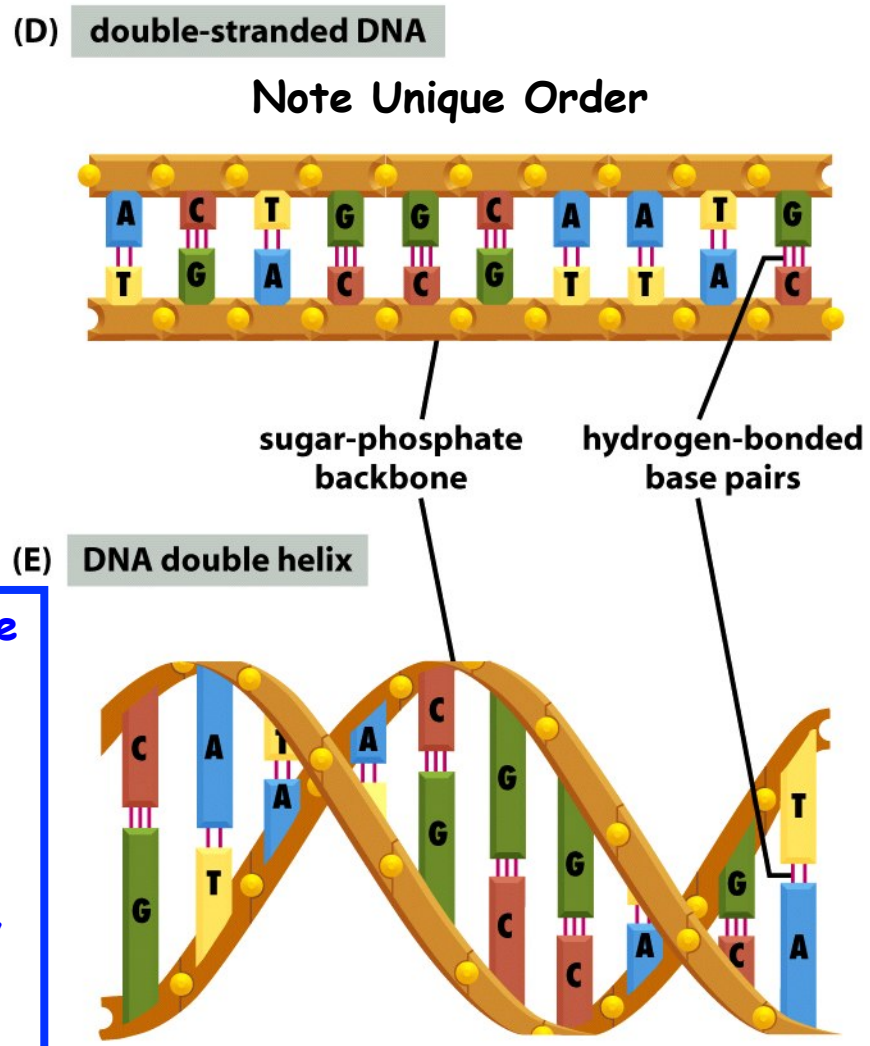
DNA Sequence
Beginning → End
5' 3'

→ Biological Uniqueness

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

Nucleotides are the Building Blocks of DNA and Genes





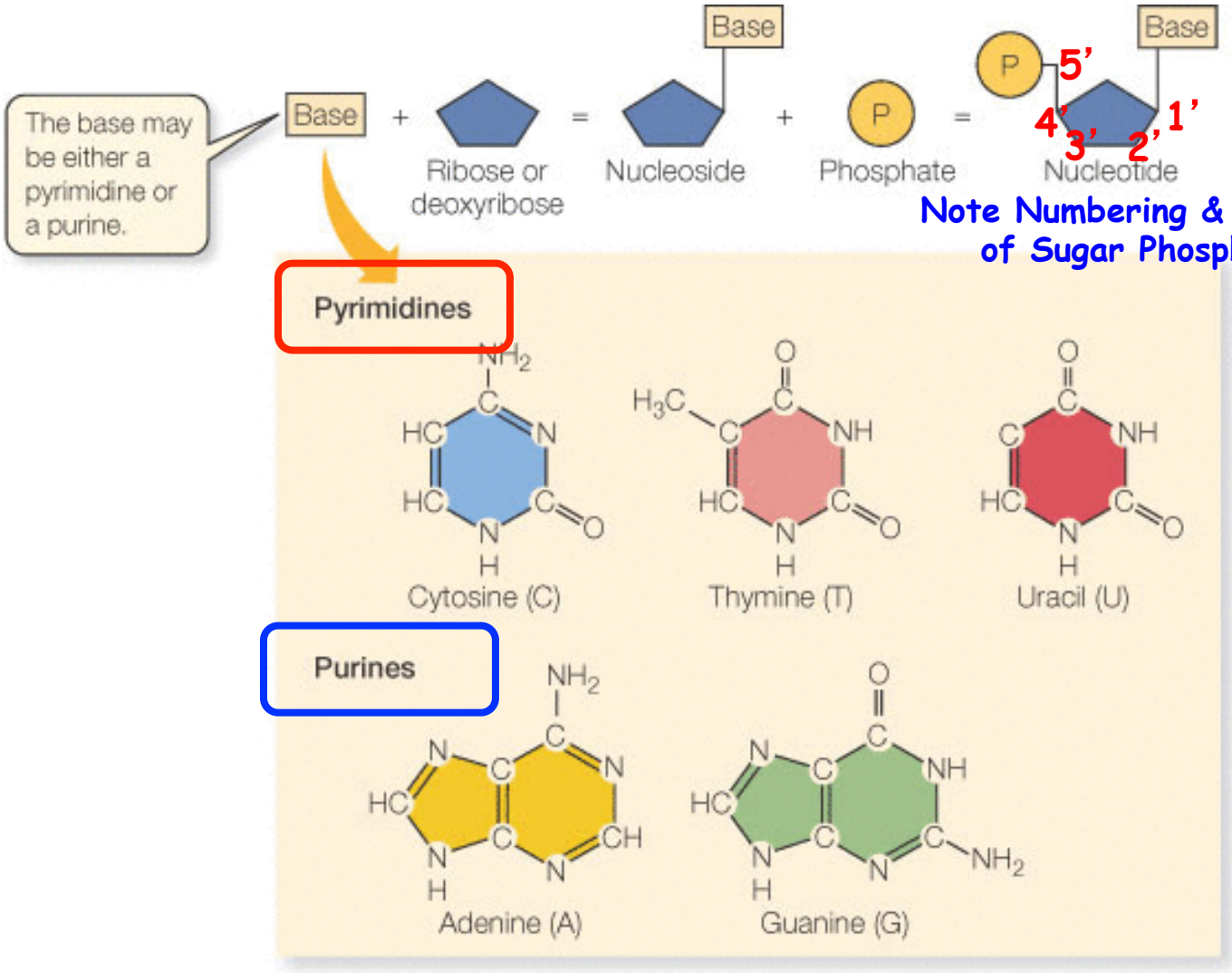
1. A Nucleotide = Sugar + Base + Phosphate

2. Nucleotides Are Linked In Order By 5' to 3' Phosphodiester Bonds

3. Two Strands of DNA Are Complementary And Have Different Sequences!

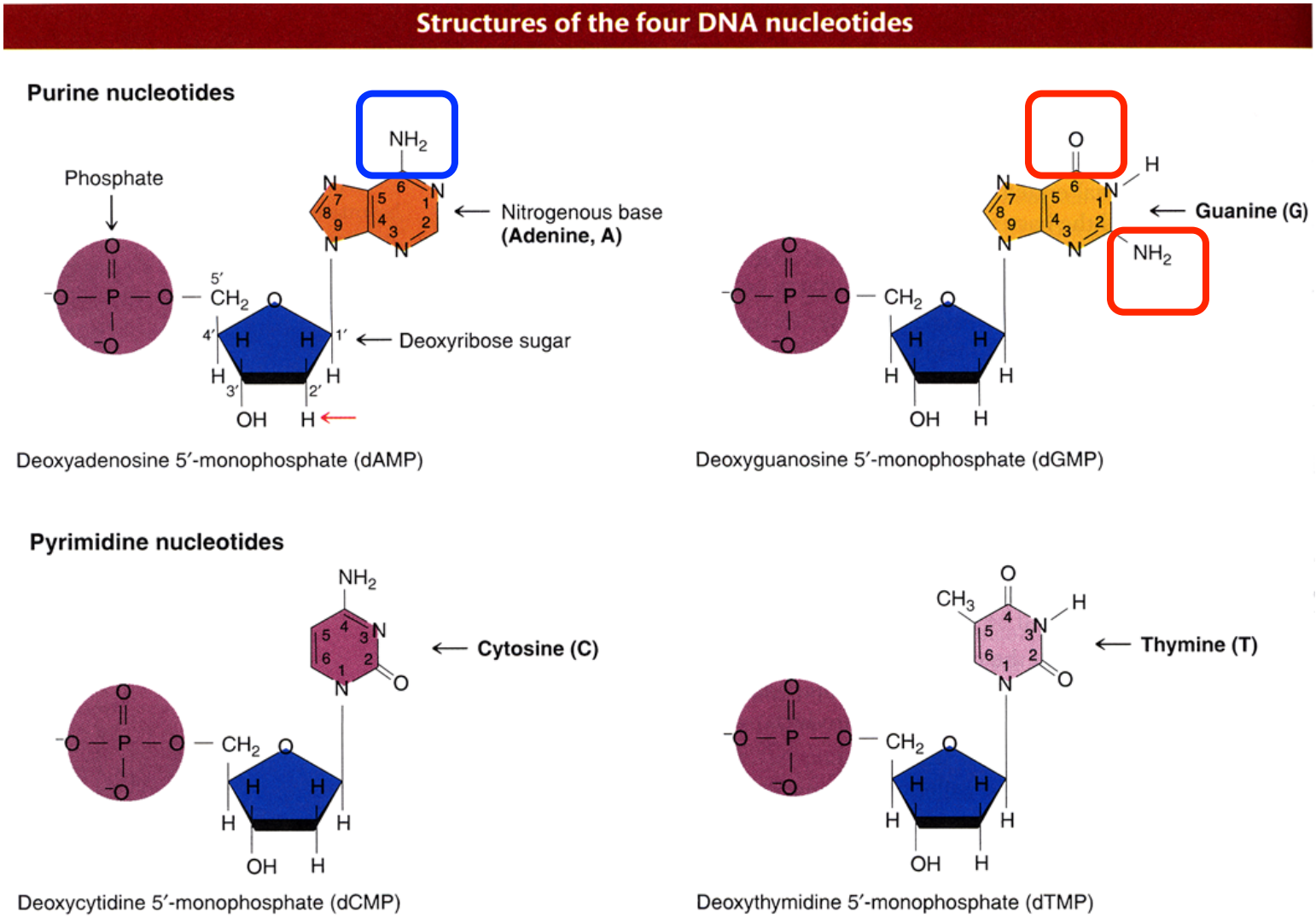
Figure 1-2 *Molecular Biology of the Cell*, Fifth Edition (© Garland Science 2008)

There Are Four Different Nucleotides in DNA



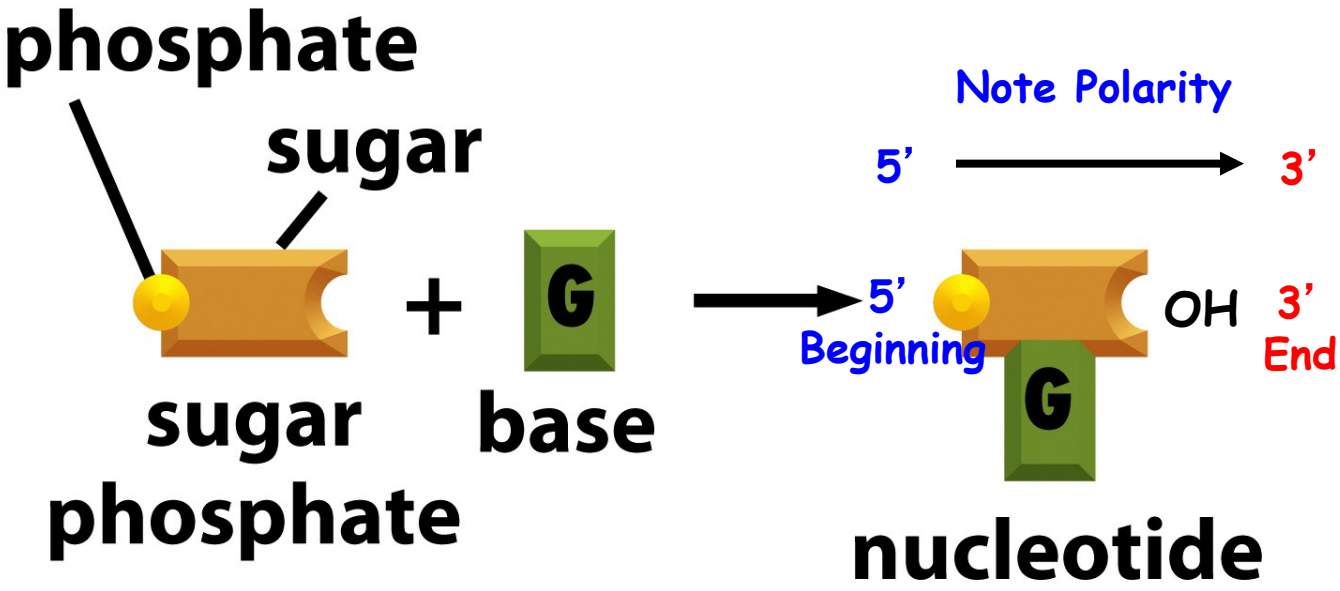
Nucleotides Consist of a Sugar Phosphate and a Base

The Chemical Structures of the Four Nucleotides Differ Because of Differences in the Bases



Chemical Differences in Bases -- Chemistry Leads to Biology!!

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



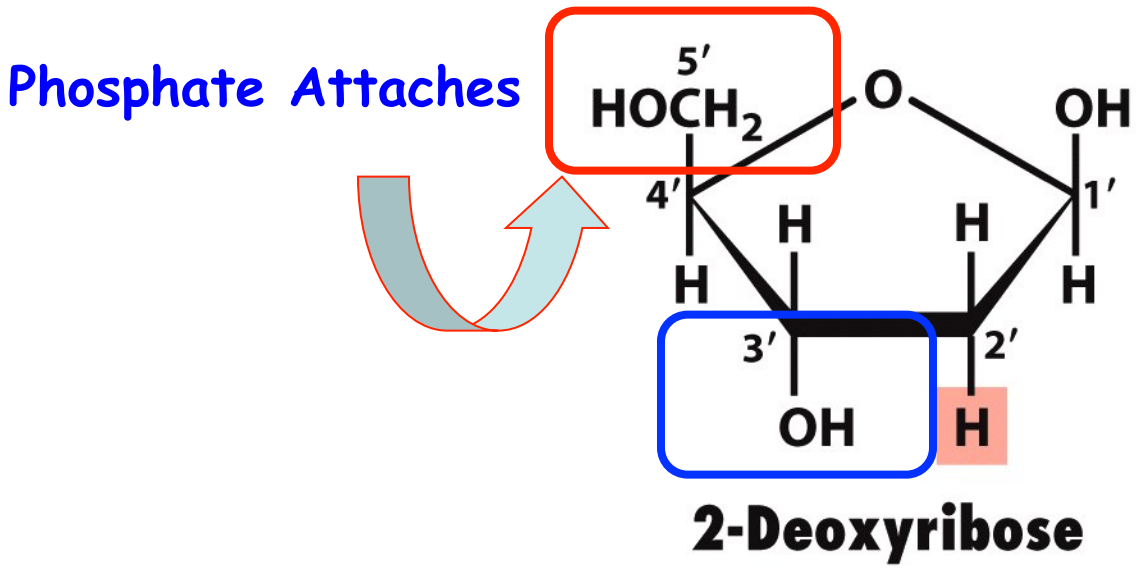
The Sugar is the HUB

DNA Sequence Defined By Nucleotide Order

DNA Sequence = Functional Uniqueness = Biology

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

Note Structure and Polarity of Deoxyribose Sugar



Nucleotides Are Joined By 5' to 3' Phosphodiester Bonds

5'

Nucleotide sequence

C
A
G

ORDER

3'

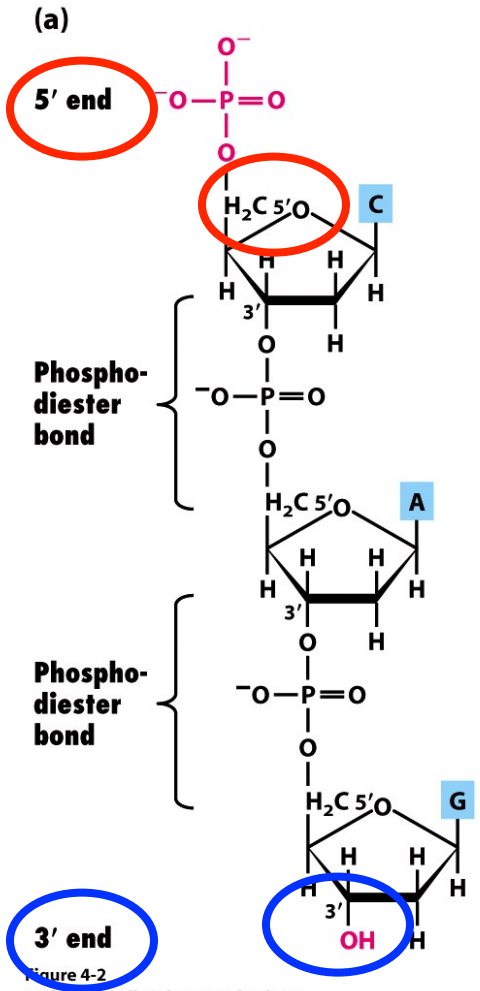
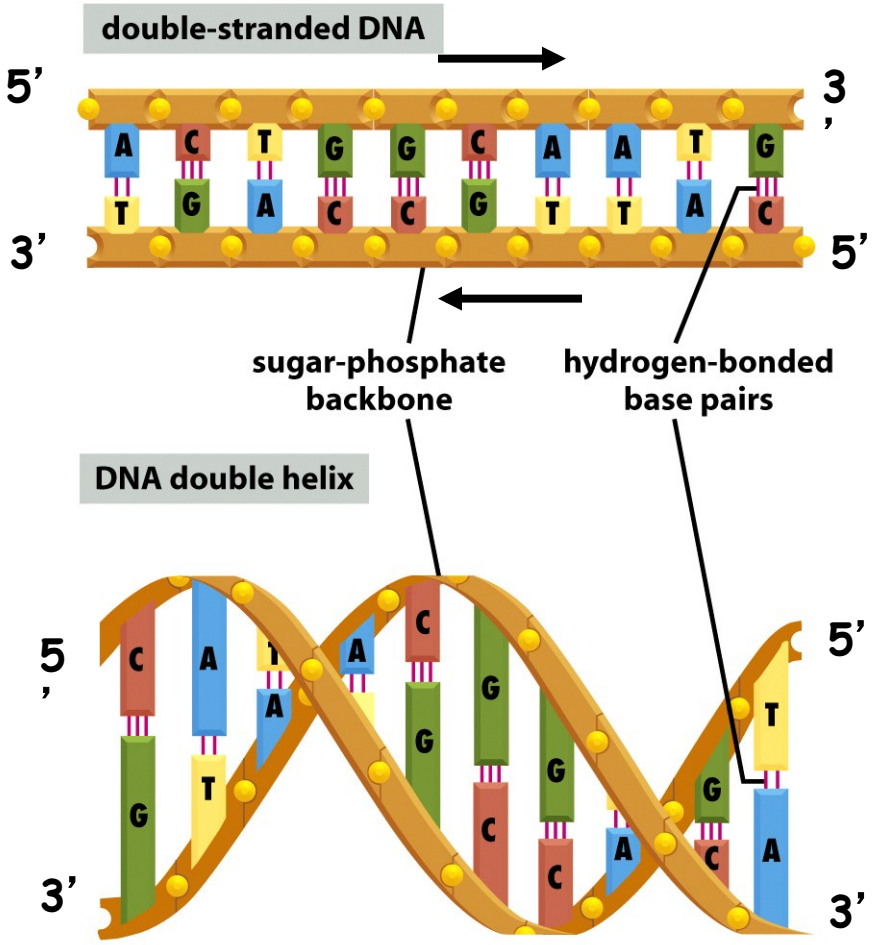


Figure 4-2
Molecular Cell Biology, Sixth Edition

1. The Order is Specified by the Nucleotides That Join 5' to 3'
2. This is the Basis For All of Biology
3. Order is Maintained During DNA Replication
4. Basis of All Genetic Engineering

Polarity Defined By
Sugars & Order Specified By Bases

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



1. Complementary Strands
2. A=T and G=C
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!)

Watson and Crick, Nature, 1953

Chargaff's Rules
Purines = Pyrimidines

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

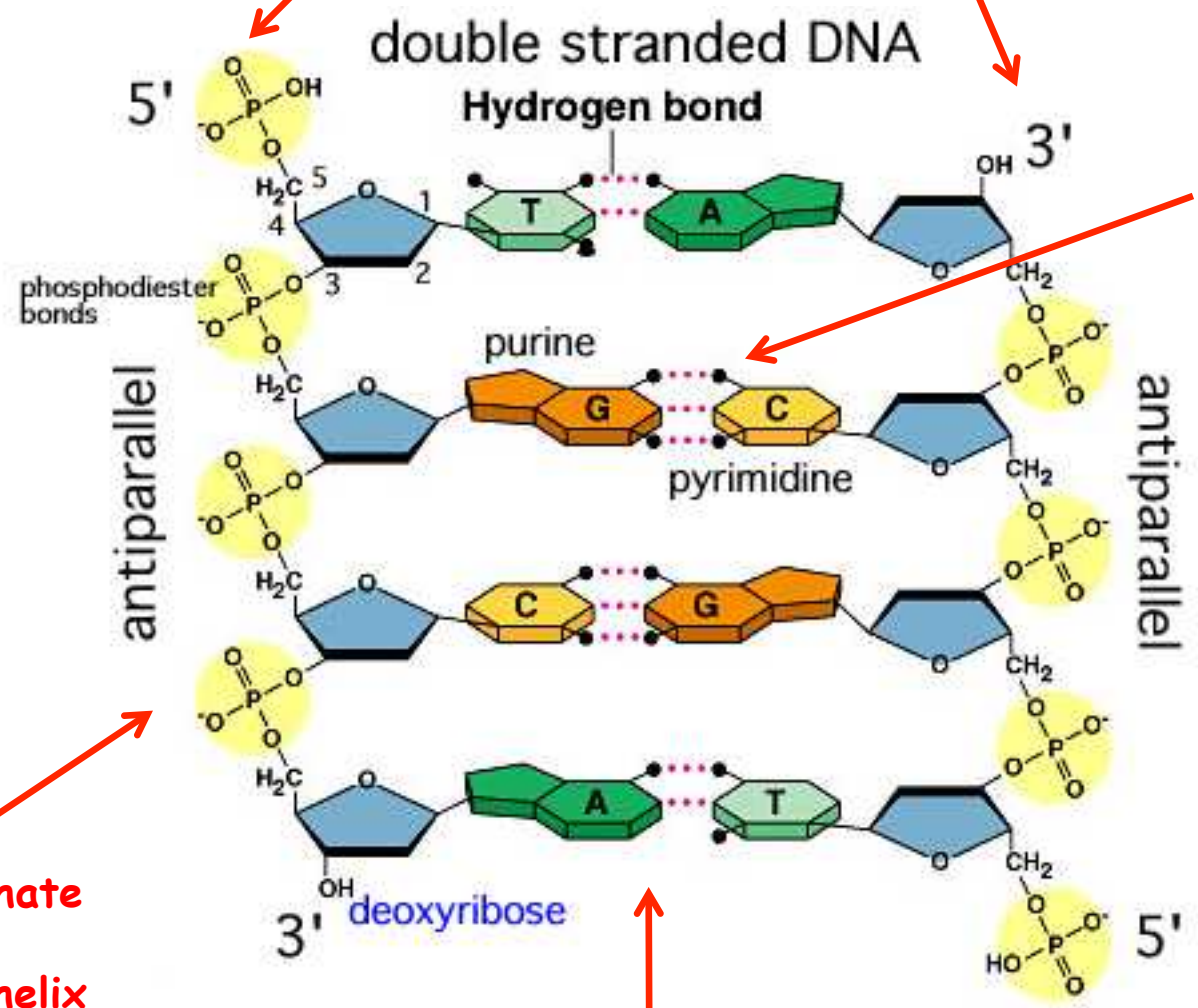
	Percentage of Base in DNA				Ratios	
Organism	*A*	*T*	*G*	*C*	*A:T*	*G:C*
Staphylococcus afermentams	12.8	12.9	36.9	37.5	0.99	0.99
Escherichia coli	26.0	23.9	24.9	25.2	1.09	0.99
Yeast	31.3	32.9	18.7	17.1	0.95	1.09
*Caenorhabditis elegans**	31.2	29.1	19.3	20.5	1.07	0.96
*Arabadopsis thaliana**	29.1	29.7	20.5	20.7	0.98	0.99
Drosophila melanogaster	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
Mus musculus (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?

DNA is Double Stranded

DNA strand polarity is antiparallel

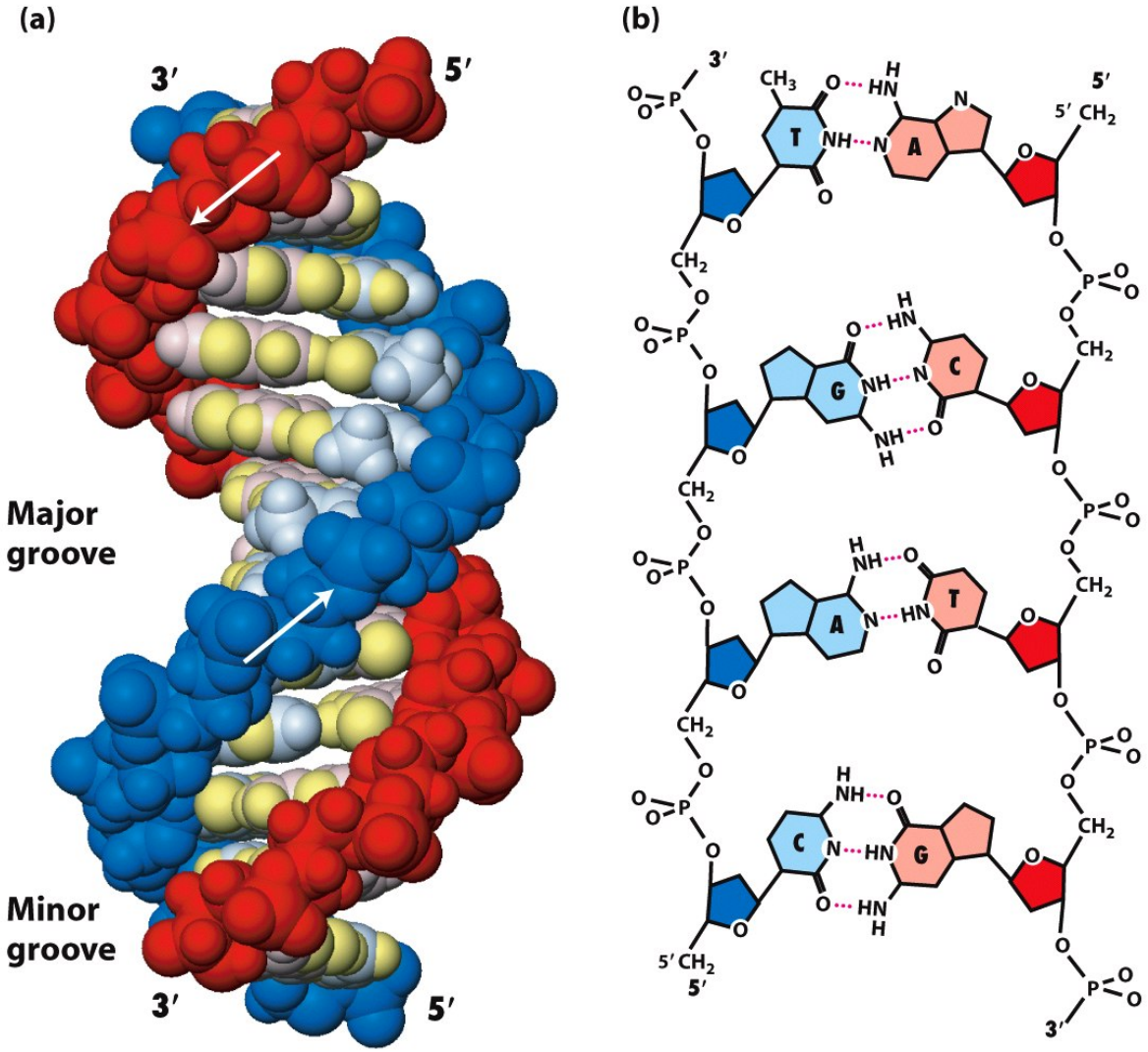


Bases in the interior the helix

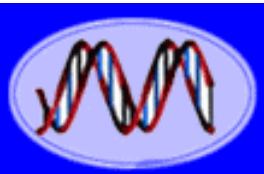
Sugar phosphate backbone on exterior of helix

Complementary bases pair: A-T & G-C

The Double Helix

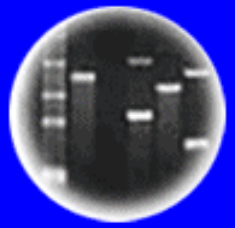


Read Book by Same Name!



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

Properties of DNA

1. Four Different Nucleotides
2. Nucleotides Linked by Phosphodiester Bonds
3. Nucleotides Linked in Order 5' → 3'
4. Two Chains Complementary in Antiparallel
   Direction
   5' ⟶ 3'
   3' ⟵ 5'
   Sequence differs & only way bases fit in "middle".
5. Bases In Interior Stacked & Bonded by H-bonds
   - Complementary "rungs" on "Ladder".
6. BACKBONE - Sugar/Phosphate Bonds
7. No Constraint on Sequence
   4^n = n # Sequences
8. DNA has dimensions:
   From X-Ray Diffraction Pictures →
   Know # bp → Know length!
9. Order → Biology

- 20Å diameter
- 3.4Å/bp
- 10bp/turn

The Circular *E. Coli* Chromosome
One DNA Circle

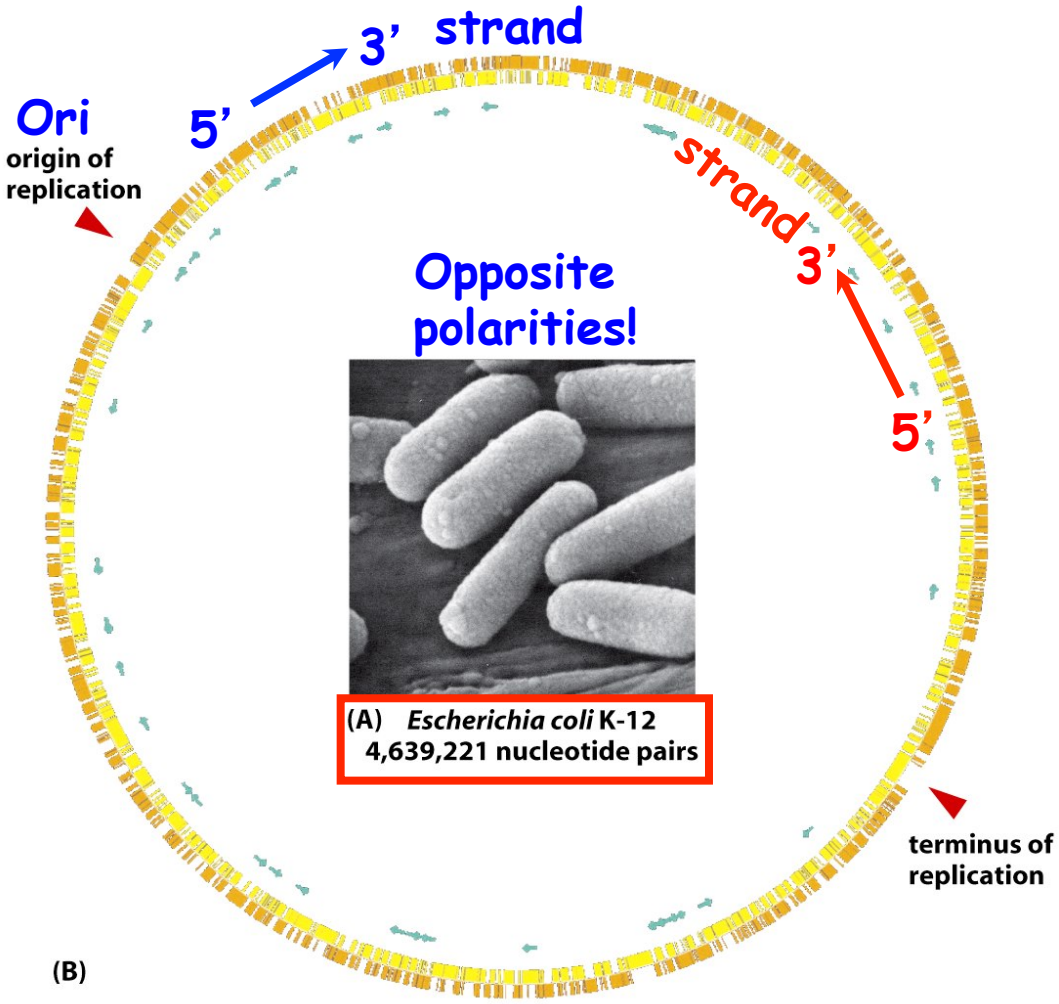
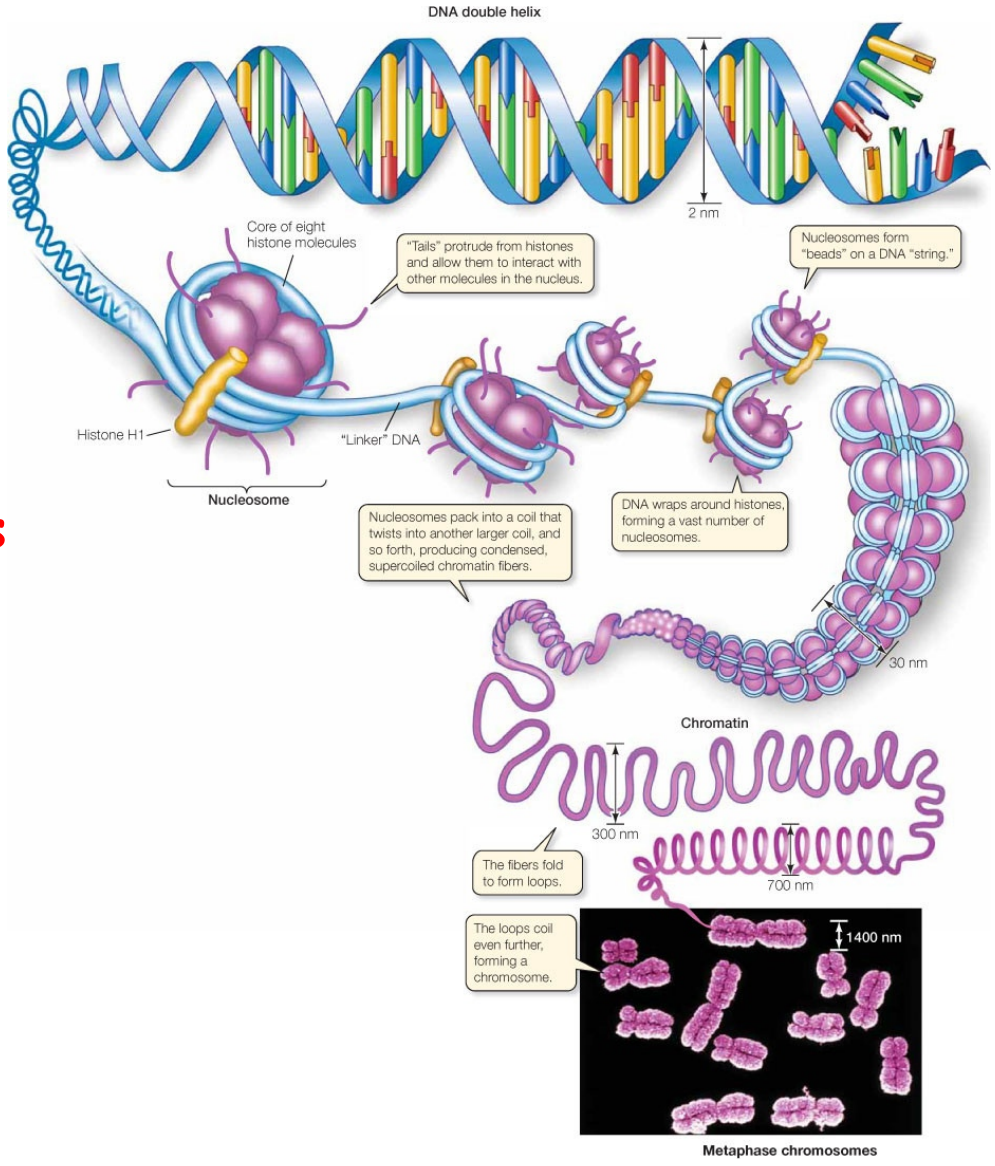


Figure 1-29 *Molecular Biology of the Cell*, Fifth Edition (© Garland Science 2008)

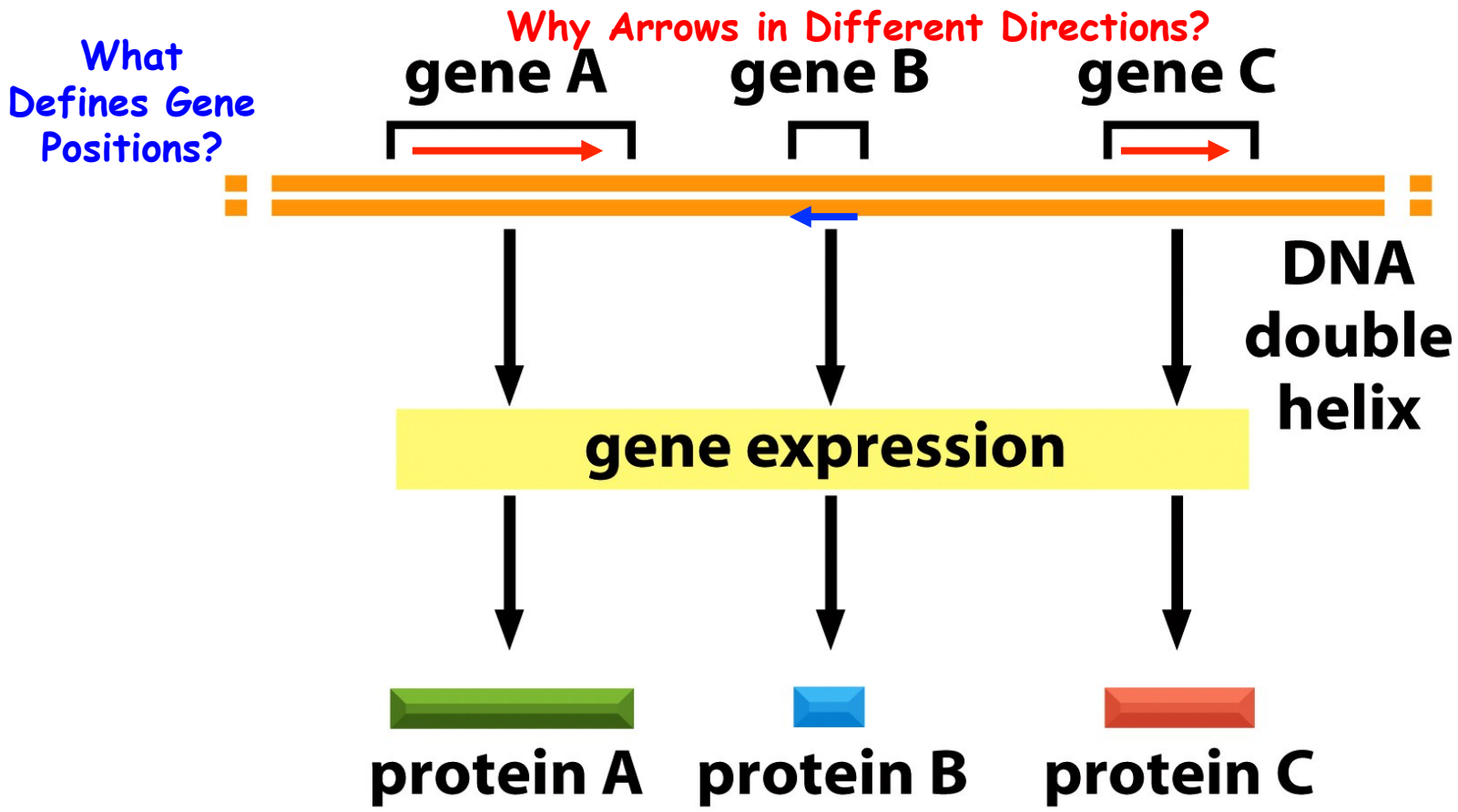
A Chromosome Contains One (or Two!!) <u>Continuous</u> DNA Molecule(s)

DNA in Human & Eukaryotic Chromosomes is Linear!

DNA in Most Bacteria is Circular!



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

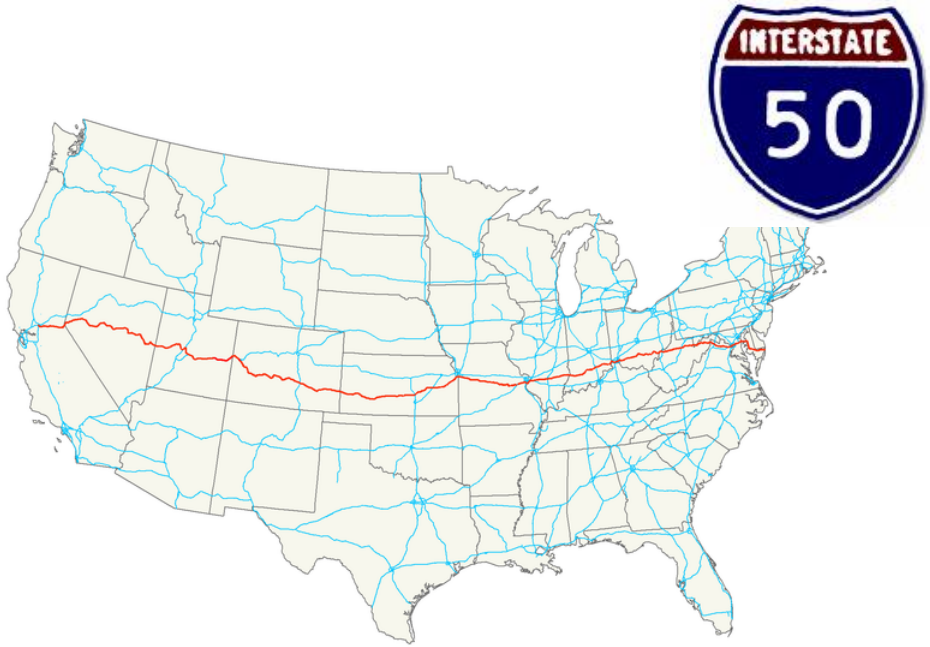


Because DNA Contains Two Strands--Genes Can Be Transcribed From Either Strand--But Only One Per Gene

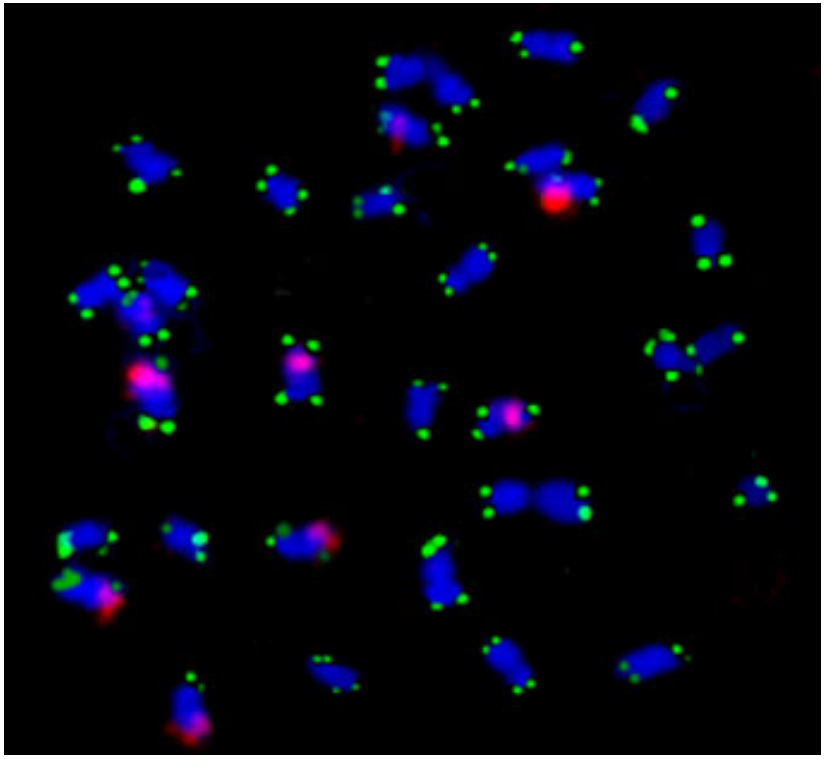
Relative Size of a Gene in the Genome

1. There are approximately 3,000 million base pairs in the human genome.
2. I-10 and I-50 are approximately 3,000 miles in length.
3. If the Interstates were the genome and 1 mile = 1 million base pairs , WHAT WOULD BE THE LENGTH OF AN AVERAGE GENE IN MILES?

A. 0.04 (200 ft) B. 1 C. 3 D. 20 E. 100

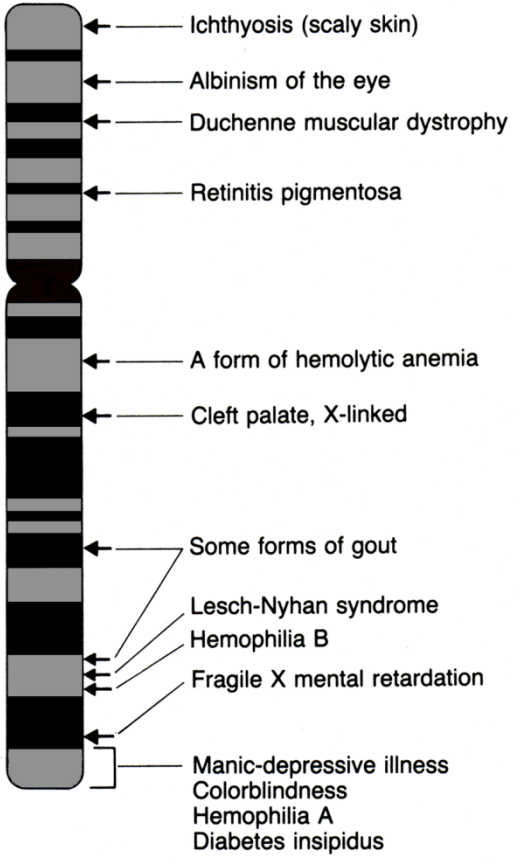


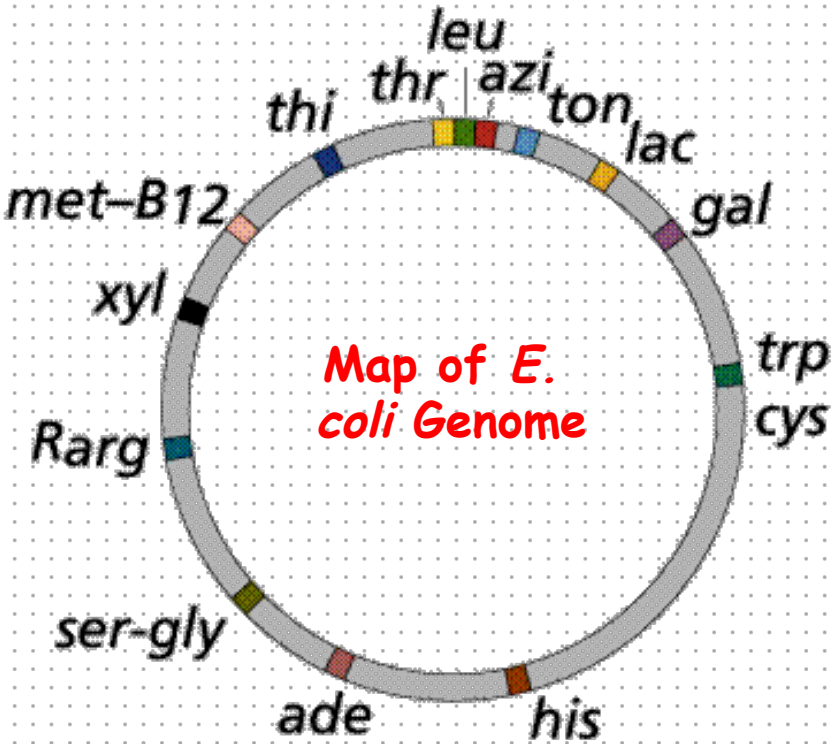
Genes Reside at Specific Positions or Loci



Gene Position = Locus = Unique DNA Sequence

Genes Reside at Specific Locations





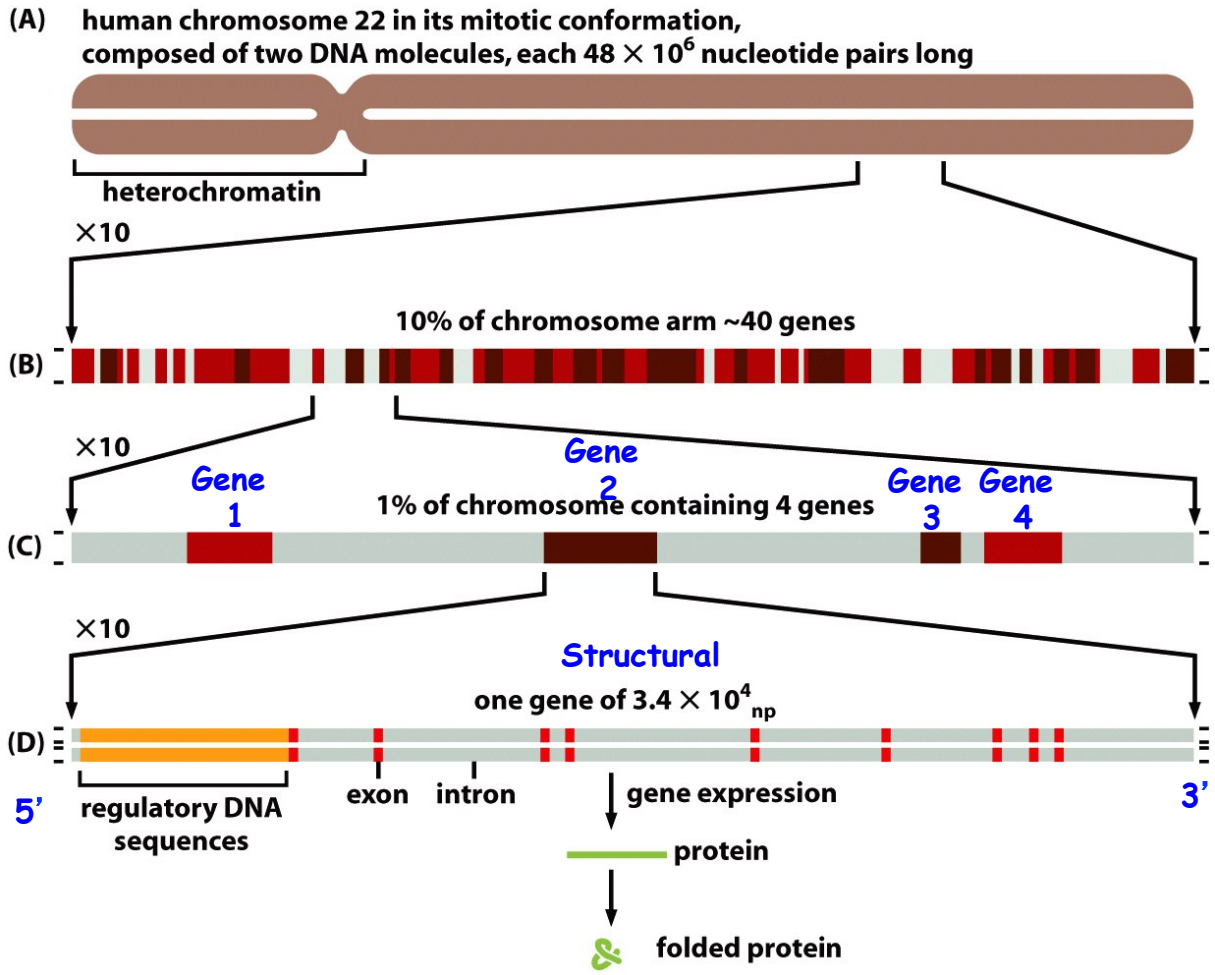
Linear DNA
How Know?

Circular DNA
How Know?

Note Bands - What are these?

How Know Gene Positions? Chromosome #?

Organization of Genes on Human Chromosome 22



Genes Are Defined/ Precise Regions of DNA

One Large Gene!

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

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

A Conceptualized Gene

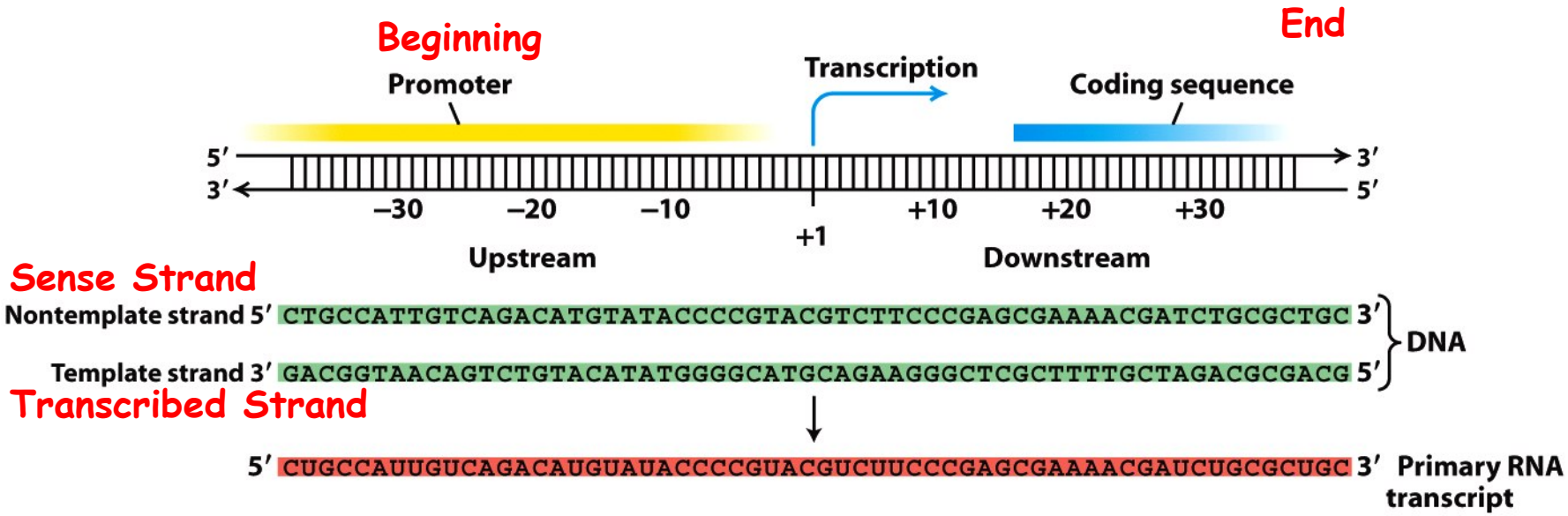
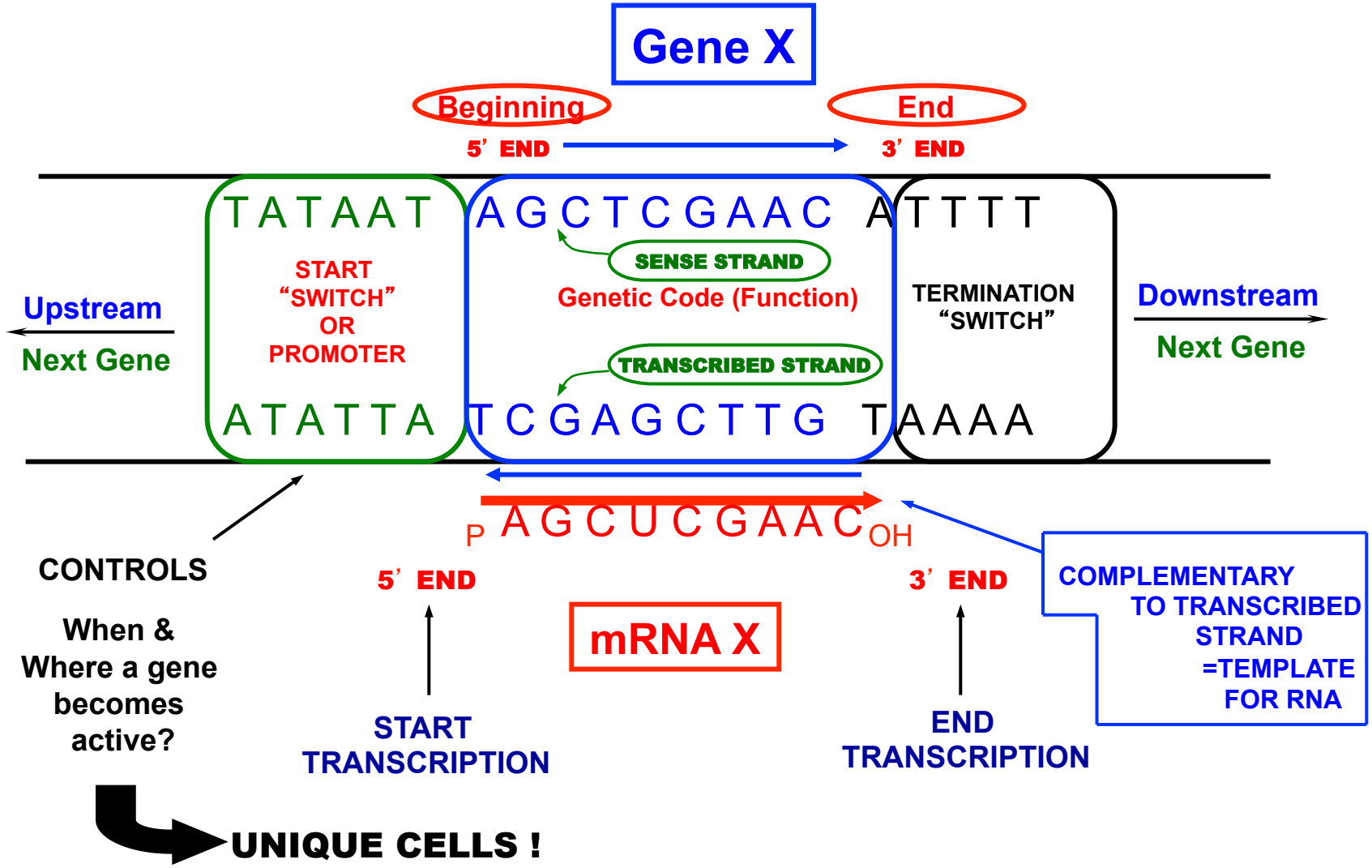
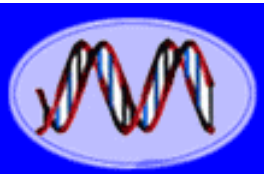


Figure 4-10b
Molecular Cell Biology, Sixth Edition

A Gene is a Specific DNA Sequence That Directs the Expression of a Unique Trait

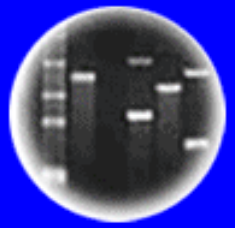


Note: mRNA Sequence = Sense Strand Sequence



DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

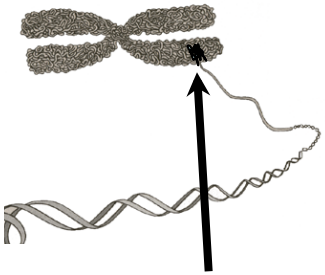
A "Simple" Gene Reviewed

1. Sense Strand = Genetic Code
2. Sense Strand = 5' → 3' Direction (all DNA sequences specified 5' → 3')
3. AntiSense 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 -
Design Experiment to Show!

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

A Chromosome Contains Many Genes



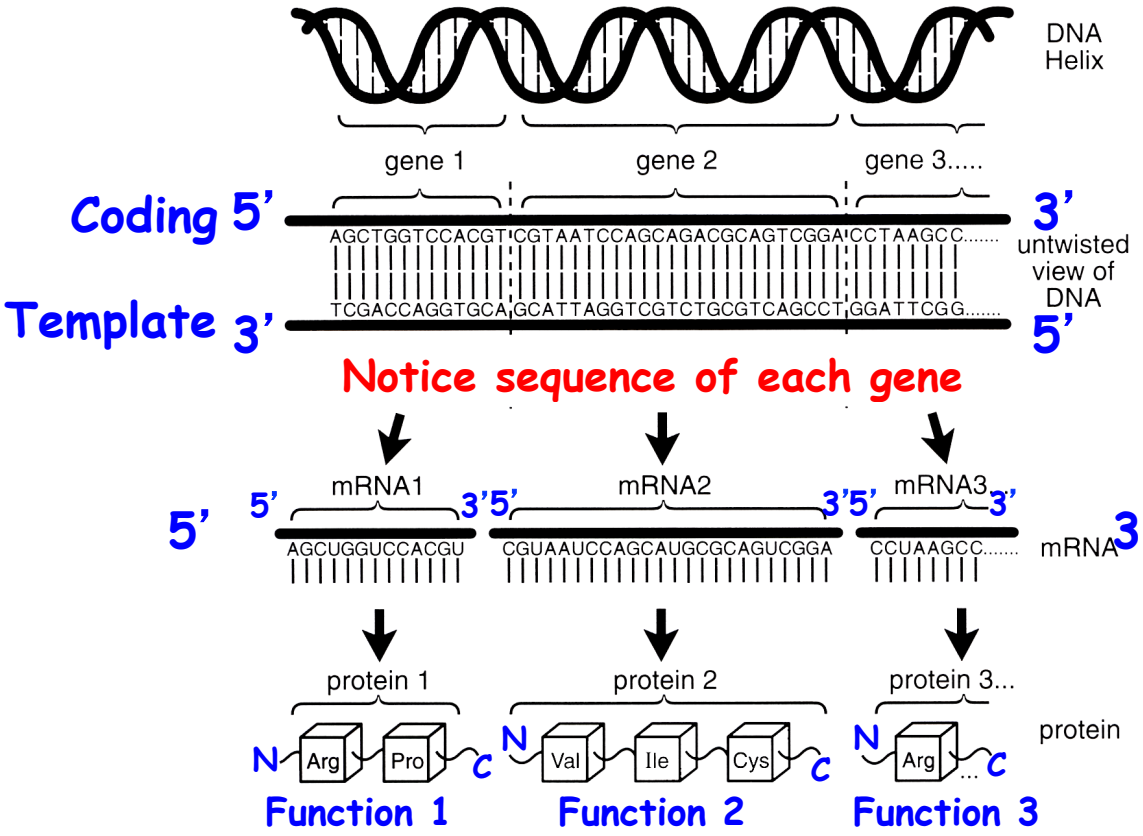
Position of Genes 1, 2, & 3 in chromosome

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?

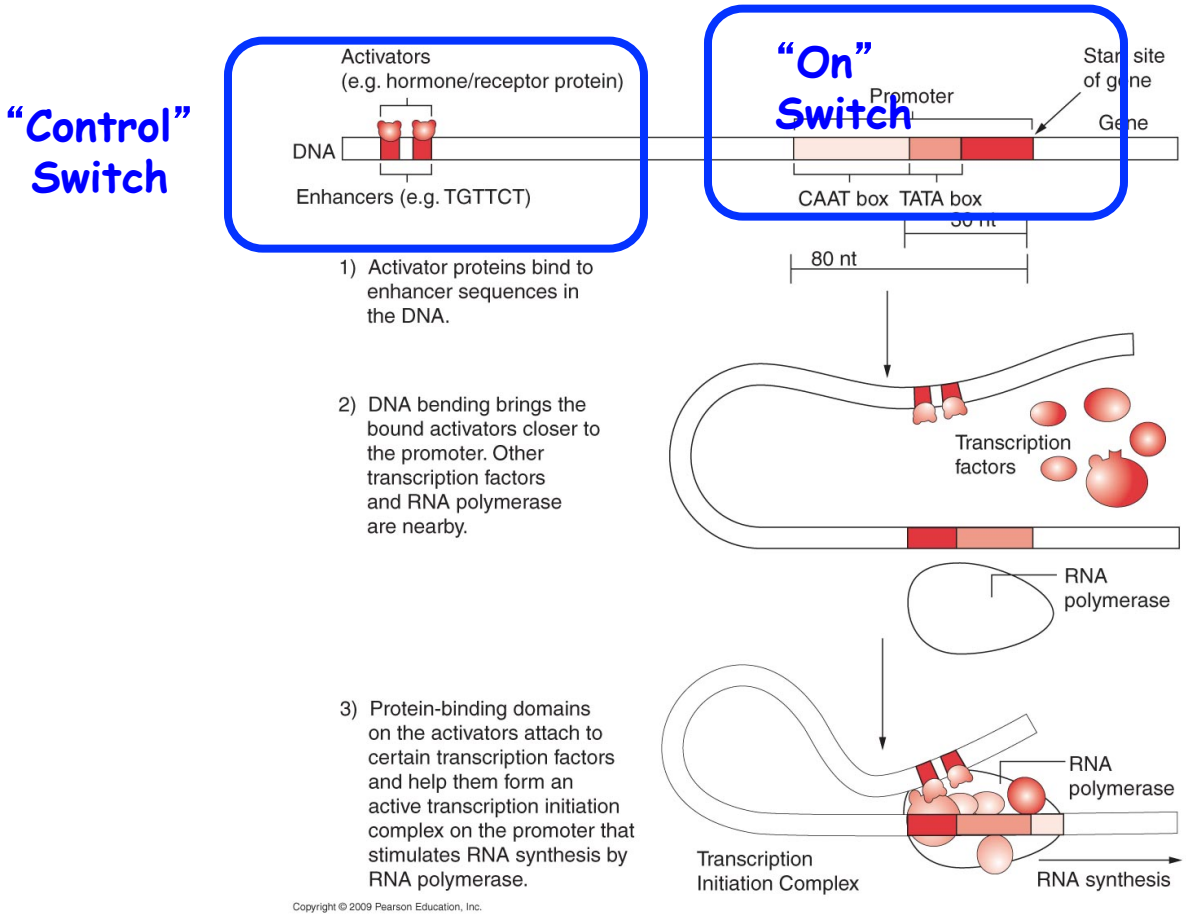


Note sequence of each protein

VERY IMPORTANT CONCEPT!
COLINEARITY BETWEEN GENE SEQUENCE AND PROTEIN SEQUENCE

Control Switches Are Unique DNA Sequences & Can Be Cloned

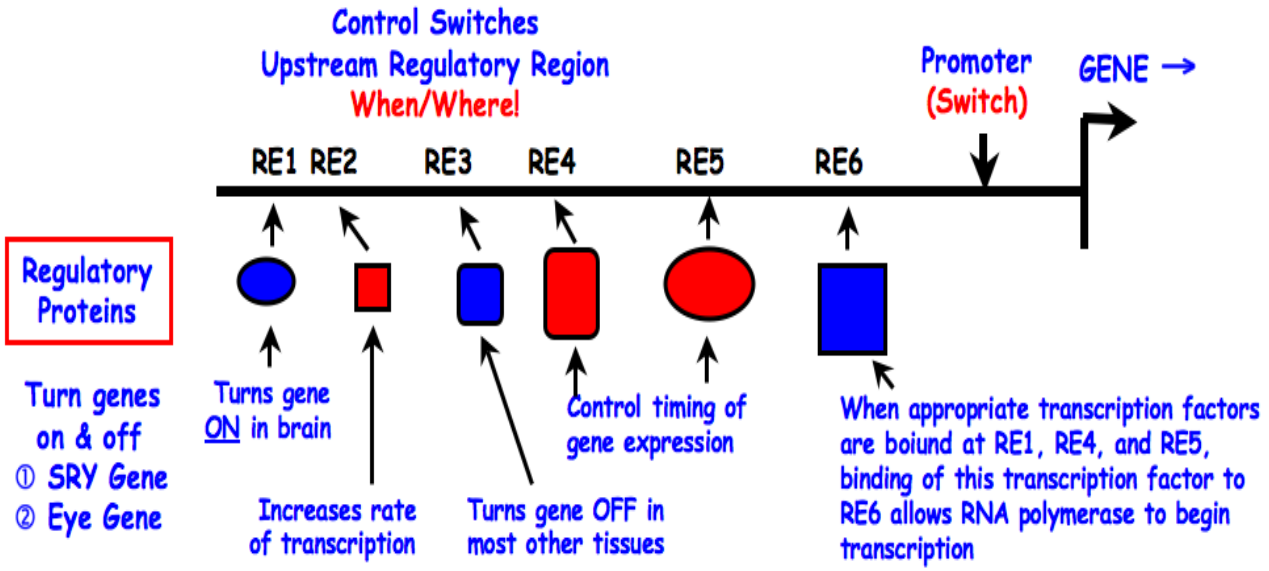
AND used to Re-Engineer Organisms!! Switches Act Independently of Gene!!



Control Switches Are Unique DNA Sequences & Can Be Cloned

AND used to re-engineer organisms!!

Switches act independently of gene!!



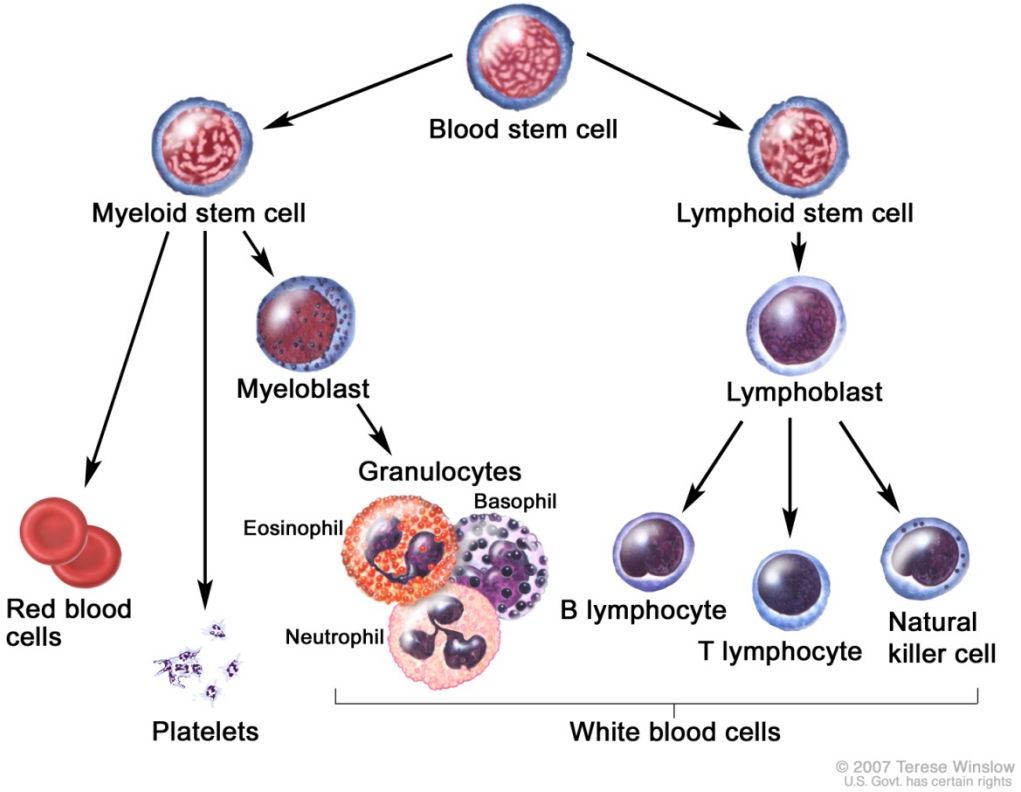
Genome Projects Reveal Both the Genes & the Logic that Controls them!

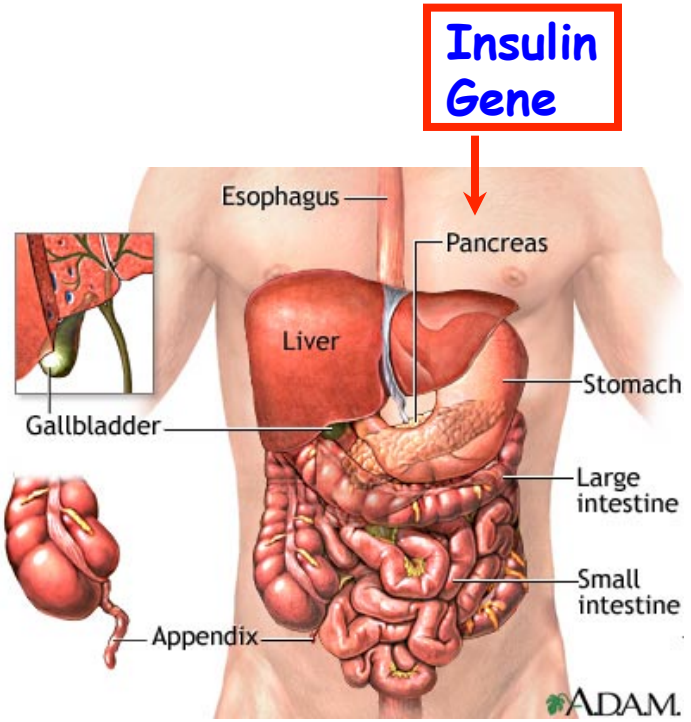
Each Switch = Unique DNA Sequence

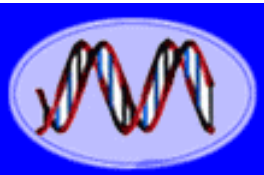
RULE: Sequence → Biology!!

No "Hocus Pocus" Yo! It's in the DNA!

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

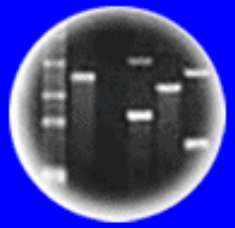






DNA
Genetic Code of Life

Entire Genetic Code of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues and Future Consequences

Plants of Tomorrow

THE GENE AND SWITCHES ARE UNIQUE DNA SEQUENCES

1. They Can Be Cloned & "Shuffled" & Engineered Creating New Genes That Have No Counterparts in Nature. ⇨ **Genetic Engineering**
2. These New Genes Can Be Transcribed in New Cell Types (Switch Change) &/or Organisms &/or Both. (e.g., Human Genes in Plant Leaves)

   ⇩

   Human Genes + Plant Leaf Switch
3. All Genes are Regulated & Controlled by Switches. Genome Projects Reveal Both The Genes & The Switches & Wiring Together of All Switches in Gene. ⇨ Program of Life From Birth to Death

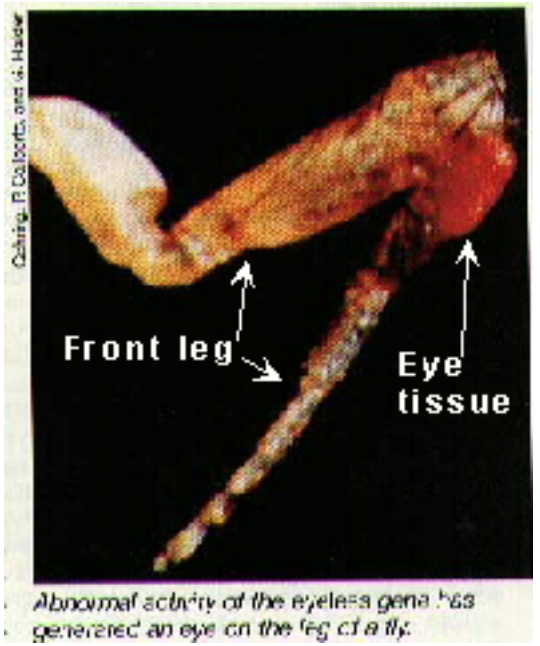
Yo! It's in the Sequences!!

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

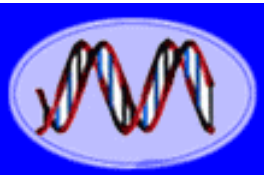
Eye Gene

Replace the Head Switch With the Leg Switch by Genetic Engineering

Eye Gene
+
Leg Switch

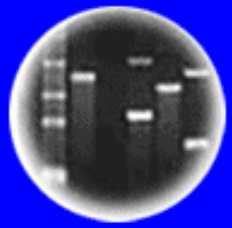


Abnormal activity of the eyeless gene has generated an eye on the leg of a fly.



DNA
Genetic Code of Life

Entire Genetic Code of a Bacteria



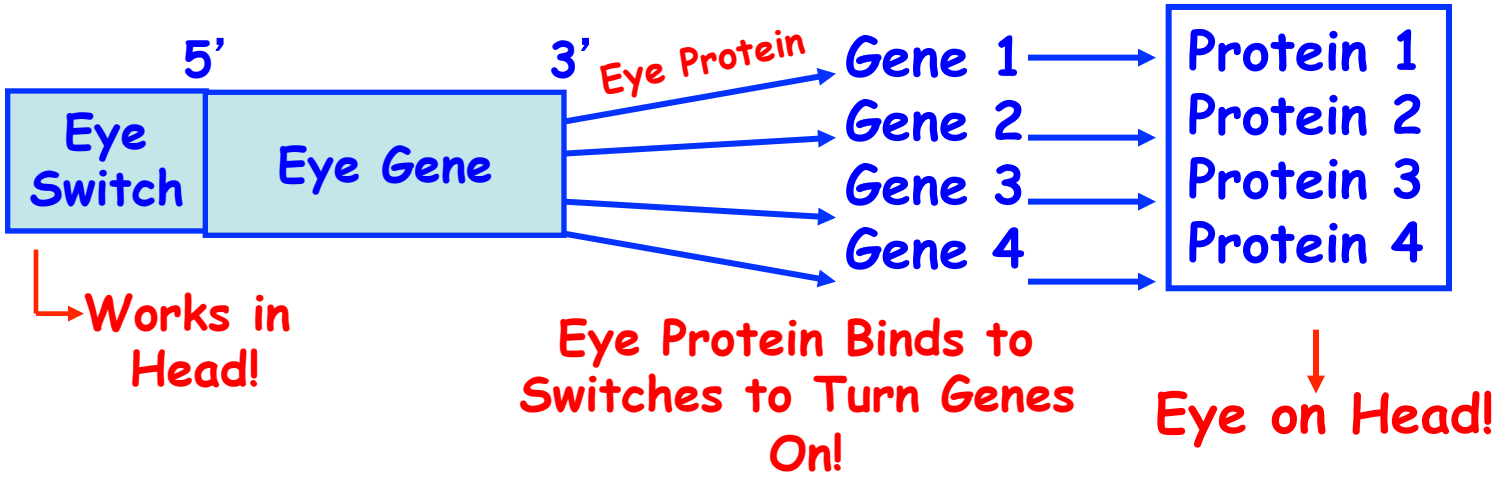
DNA Fingerprinting

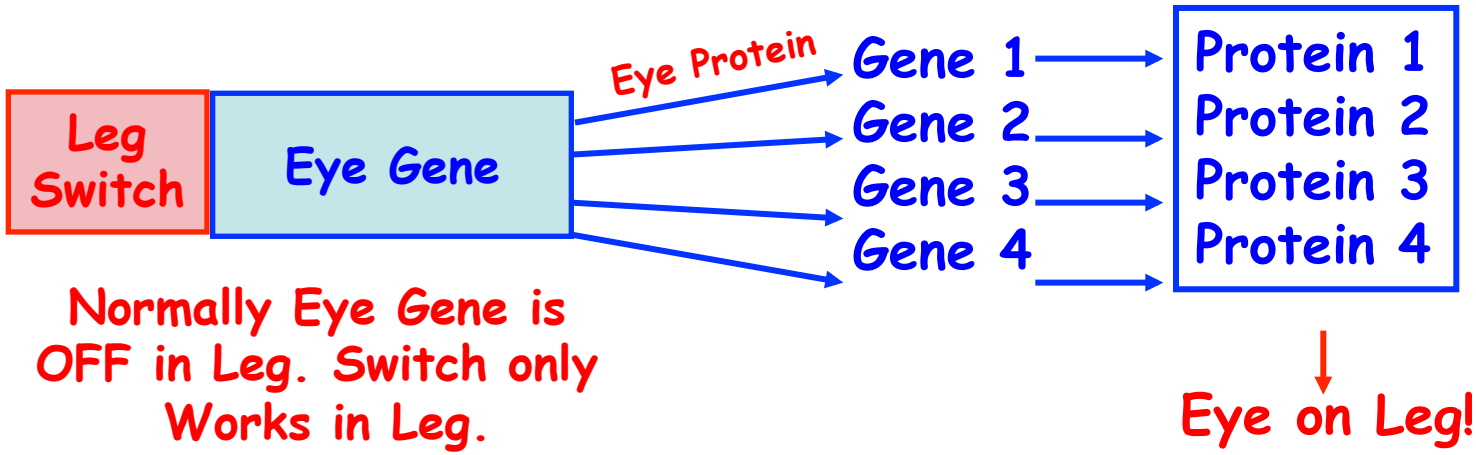
Cloning: Ethical Issues and Future Consequences

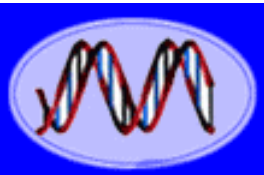
Plants of Tomorrow

Eye Regulatory Network

Control Genes Like The Eye Gene Control The Activity of Other Genes!

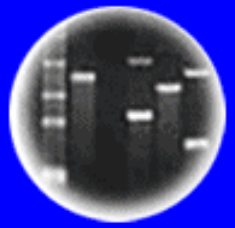






DNA
Genetic Code of Life

Entire Genetic Code
of a Bacteria



DNA Fingerprinting

Cloning: Ethical Issues
and Future Consequences

Plants of Tomorrow

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 100 Years Ago & Look What We Can Do & Now!