NUCLEOTIDES HAVE POLARITY

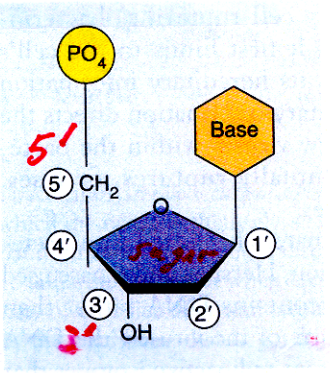


FIGURE 14.7
Numbering the carbon atoms in a nucleotide. The carbon atoms in the sugar of the nucleotide are numbered 1′ to 5′, proceeding clockwise from the oxygen atom. The "prime" symbol (′) indicates that the carbon belongs to the sugar rather than the base.

BASED ON what is bonded to Sugar

The Sugar is the Hub !!

ORder of DNA defined by nucleotide
↳ DNA Sequence
↳ Biology

NUCLEOTIDES ARE JOINED by Phosphodiester Bonds

5' ORDER

B_1
↓
B_2

3'
Defined by sugars!!
Specified by Bases!

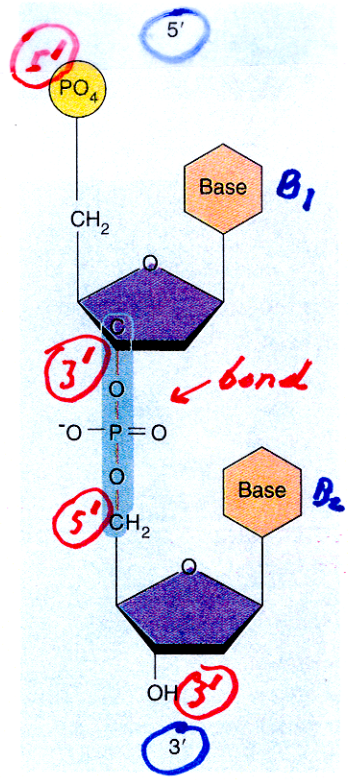


FIGURE 14.8
A phosphodiester bond.

The order is specified by the nucleotides which join 5'→3'

BASIS of all Genetics & Genetic Engineering

Order = Biology!

ORDER IS MAINTAINED DURING Replication

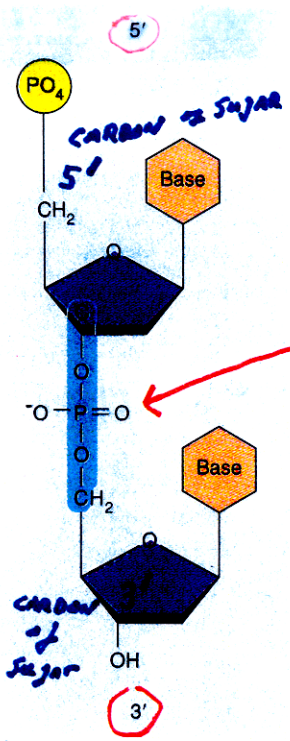
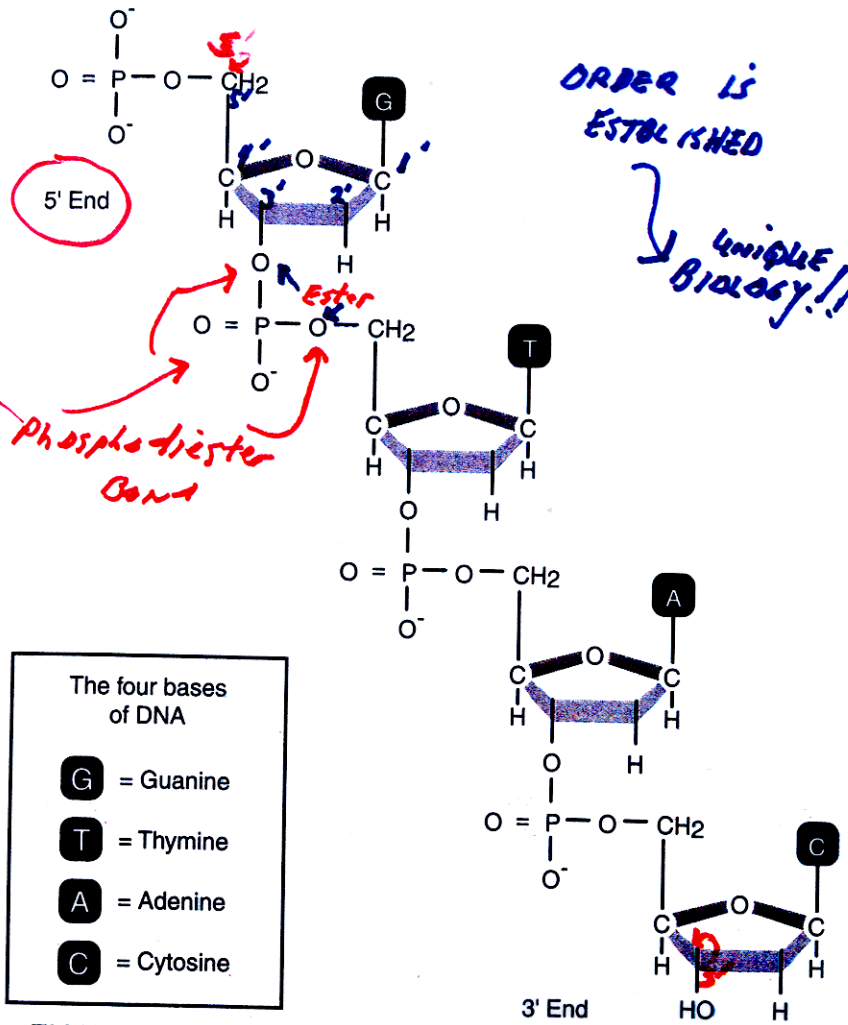


FIGURE 14.8
A phosphodiester bond.



ORDER IS ESTBLISHED → UNIQUE BIOLOGY!!

FIGURE 3.1 A single strand of DNA composed of four nucleotides.

BASIS OF A cell generating the same cell!

U Replaces T in RNA

ribose replaces deoxyribose

There Are Four Nucleotides in DNA

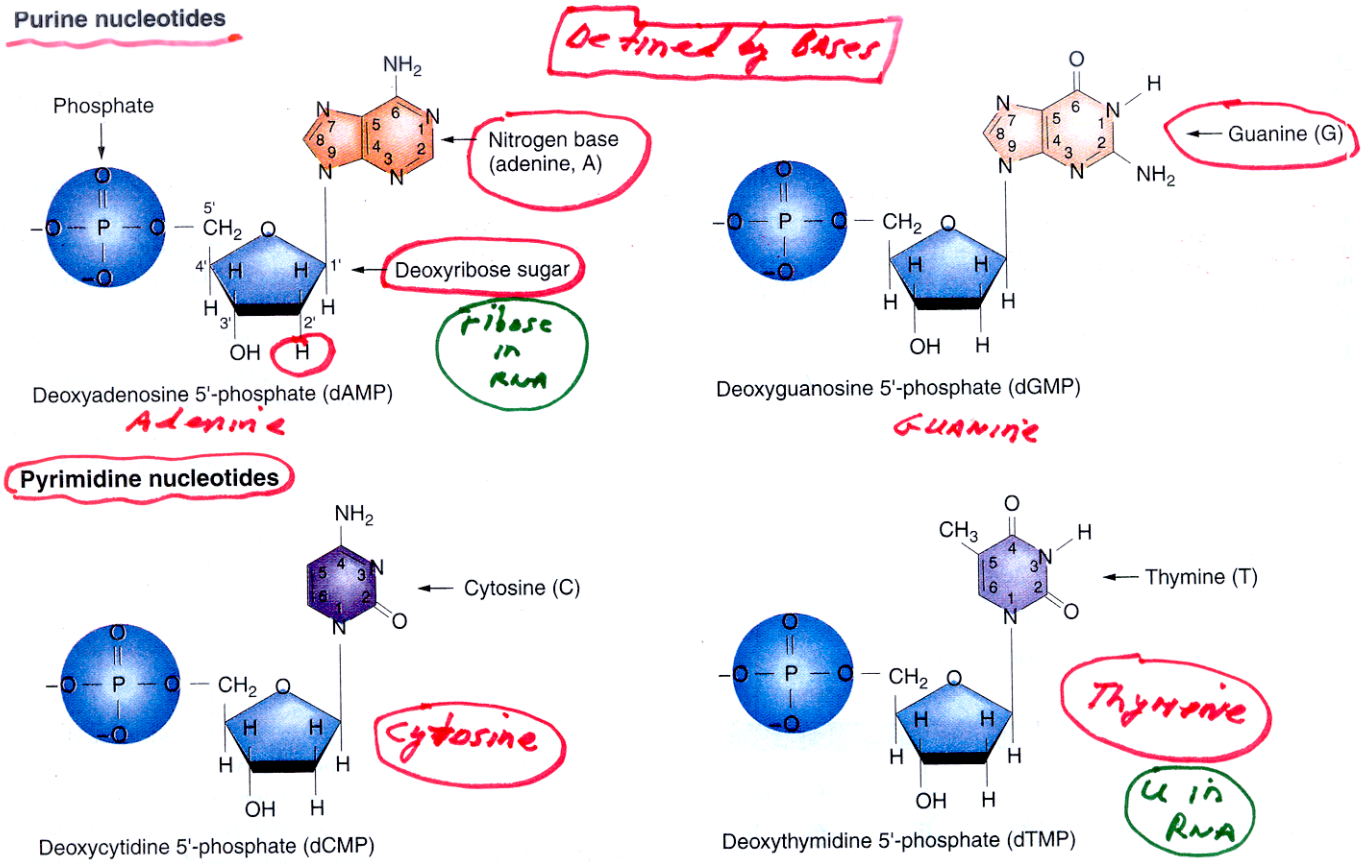
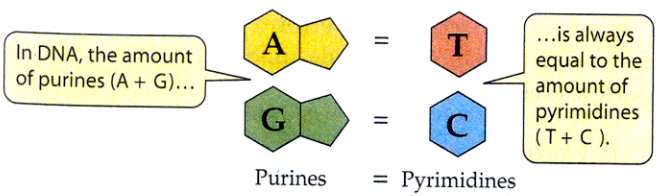


Figure 8-4 Chemical structure of the four nucleotides (two with purine bases and two with pyrimidine bases) that are the fundamental building blocks of DNA. The sugar is called *deoxyribose* because it is a variation of a common sugar, ribose, that has one more oxygen atom.

Chemistry → Biology
Know order of Bases → Do anything!

Purines = Pyrimidines in DNA
Chargaff's Rules

A = T
G = C



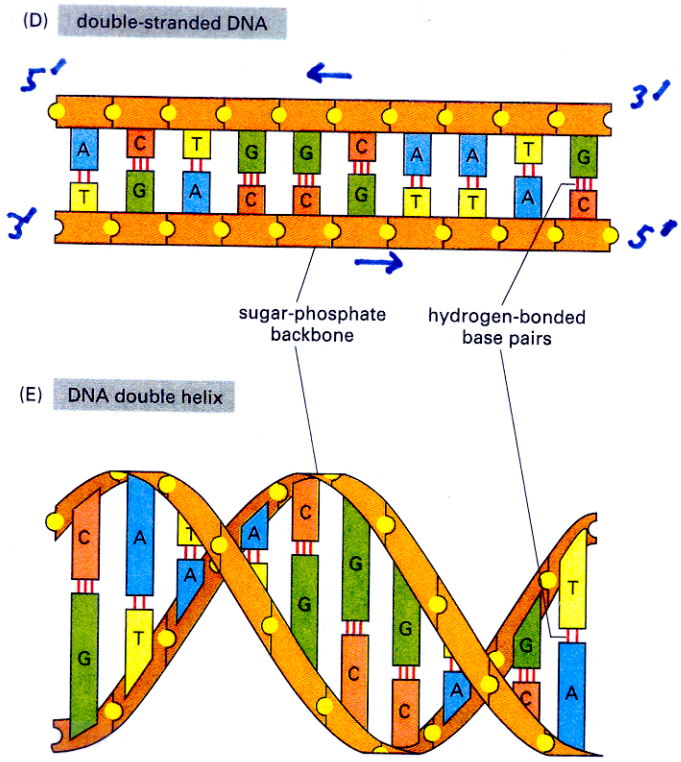
11.5 Chargaff's Rule
The total abundances of purines and pyrimidines are equal in DNA.

11.1 Percentages of Bases in the DNA of Some Well-Studied Species

DNA ORIGIN	AMOUNT OF BASE (PERCENTAGE OF TOTAL DNA) A	T	G	C
Human (*Homo sapiens*)	31.0	31.5	19.1	18.4
Corn (*Zea mays*)	25.6	25.3	24.5	24.6
Fruit fly (*Drosophila melanogaster*)	27.3	27.6	22.5	22.5
Bacterium (*Escherichia coli*)	26.1	23.9	24.9	25.1

What would you predict for a single strand of DNA?

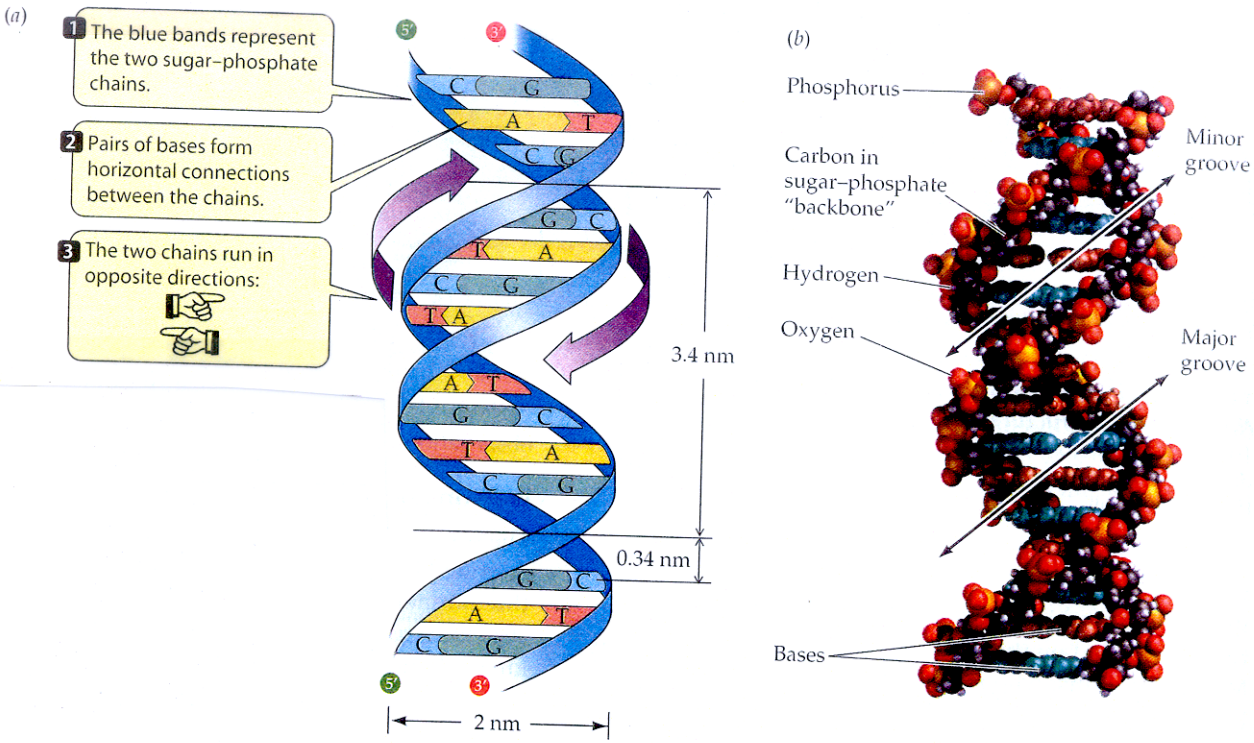
DNA IS A DOUBLE HELIX OF TWO COMPLEMENTARY CHAINS OF DNA WOUND AROUND EACH OTHER



1. Complementary strands
2. A = T, G ≡ C (H-bonds)
3. Sequence of strands differs
4. Bases to interior
5. phosphate/sugar backbone
6. strands in opposite direction

WATSON & CRICK 1953

The Double Helix



READ BOOK/TEXT BY SAME NAME!

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
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
7. DNA has dimensions:

20Å diameter
3.4Å/bp
10bp/turn

   know # bp ∴ know length!
8. order → Biology

A Chromosome Contains one (or two!) continuous DNA Molecule

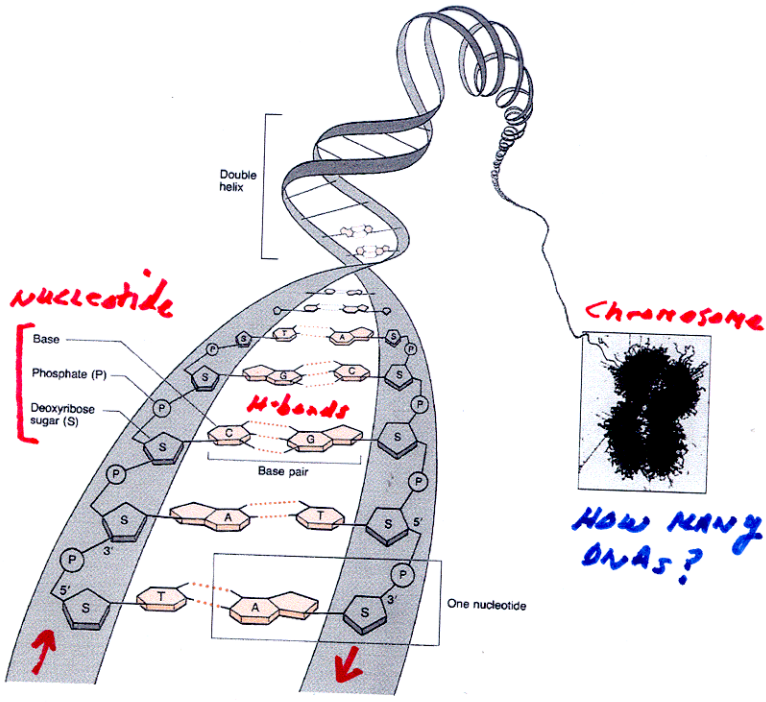


Figure 2.5 The arrangement and association of nucleotides in the DNA double helix.

DNA in Higher Organisms is linear!
DNA in Bacteria is Circular!

The Circular E. coli Chromosome
one DNA Circle

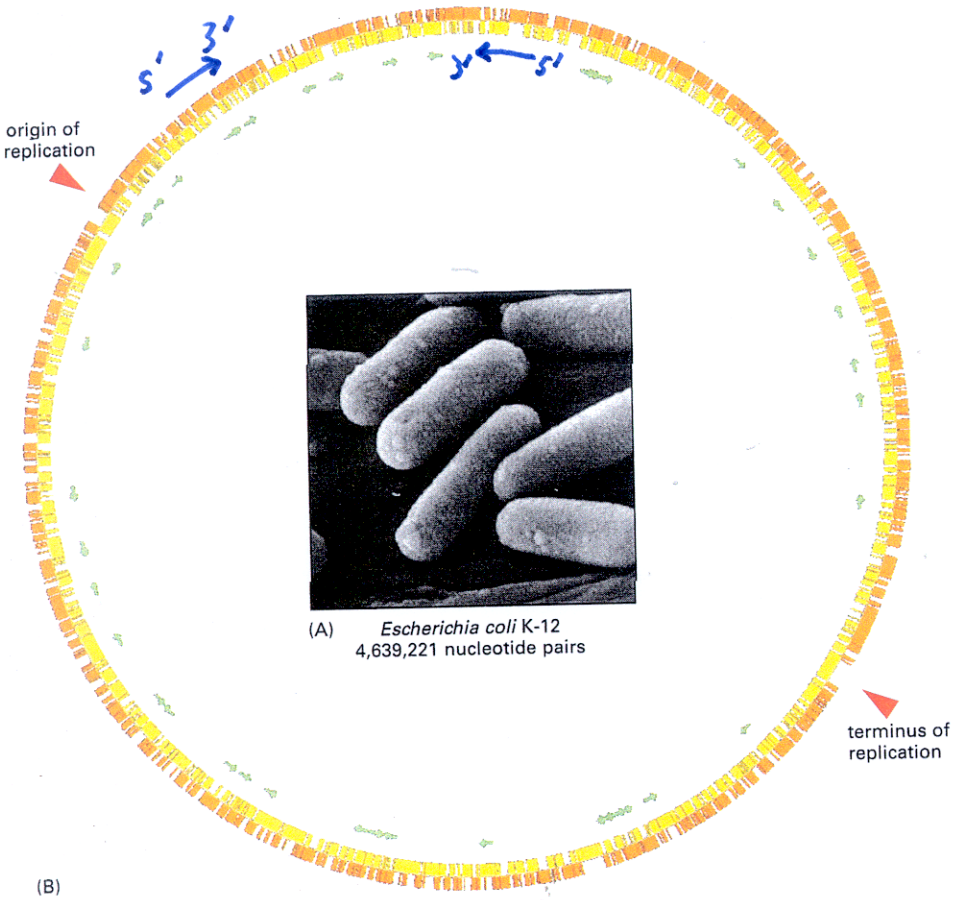
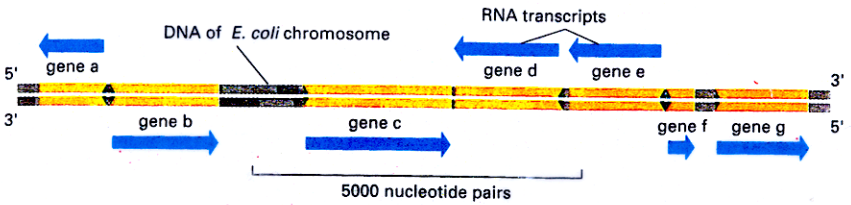


Figure 1–30 The genome of *E. coli*. (A) A cluster of *E. coli* cells. (B) A diagram of the *E. coli* genome of 4,639,221 nucleotide pairs (for *E. coli* strain K-12). The diagram is circular because the DNA of *E. coli*, like that of other procaryotes, forms a single, closed loop. Protein-coding genes are shown as *yellow* or *orange bars*, depending on the DNA strand from which they are transcribed; genes encoding only RNA molecules are indicated by *green arrows*. Some genes are transcribed from one strand of the DNA double helix (*in a clockwise direction in this diagram*), others from the other strand (counterclockwise). (A, courtesy of Tony Brain and the Science Photo Library; B, after F. R. Blattner et al., *Science* 277:1453–1462, 1997. © AAAS.)

A Chromosome contains MANY Genes That Reside at Specific Positions And have unique functions

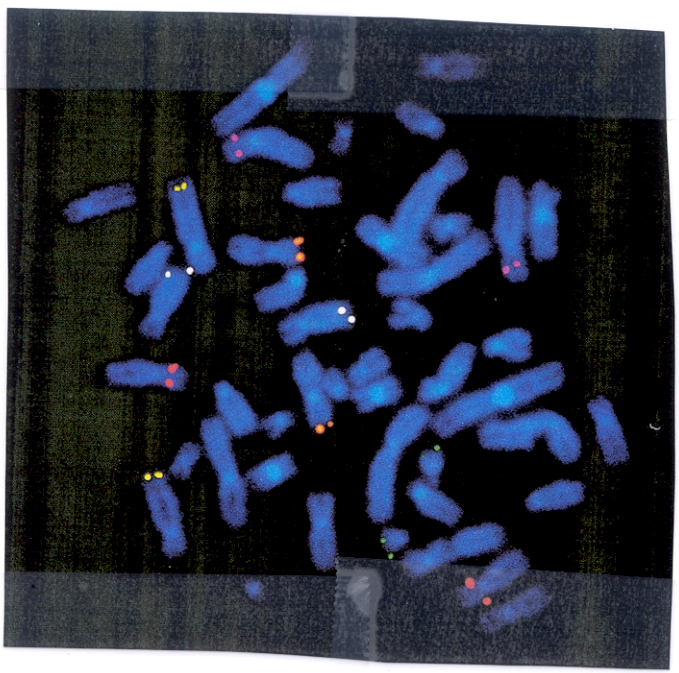


What defines the gene position?

Because DNA consists of two strands genes CAN be transcribed from either strand but only one/gene!

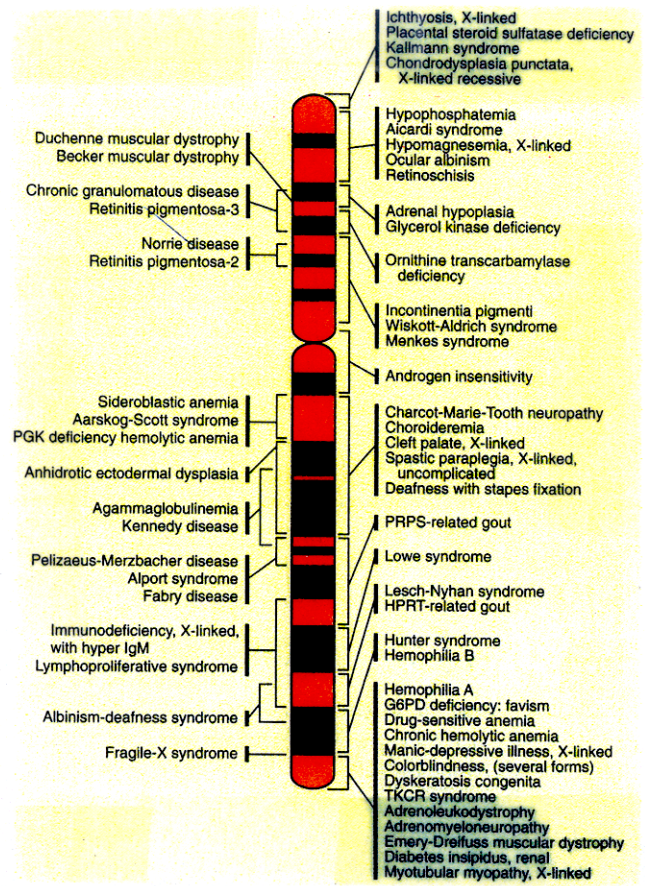
How do you know when one Gene starts & the other Ends?

Genes Reside at Specific Positions or Loci

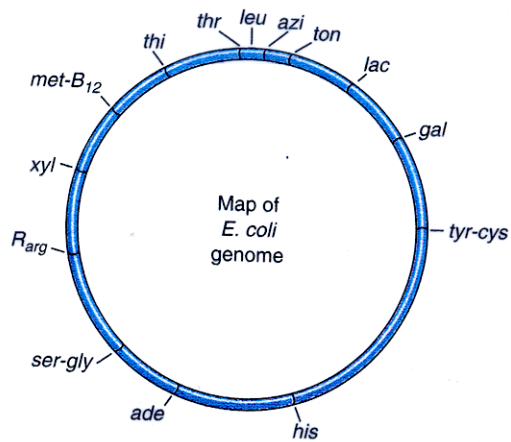


Gene Position = LOCUS = UNIQUE DNA Sequence

Genes reside at specific locations

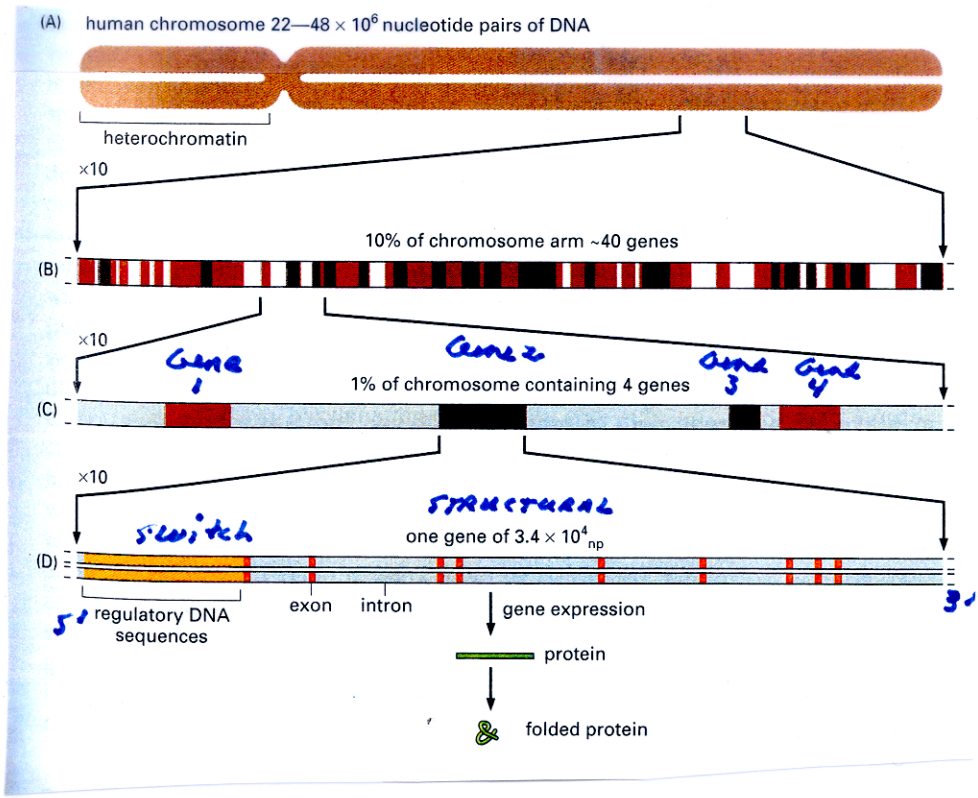


Linear DNA
How know?

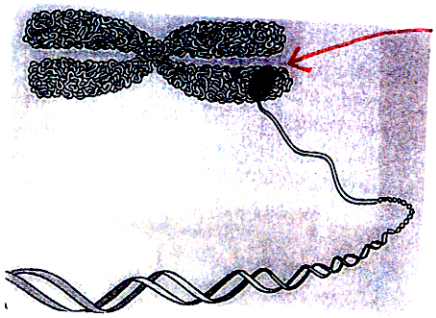


CIRCULAR DNA
How know?

ORGANIZATION OF GENES ON HUMAN CHROMOSOME 22



A Chromosome Contains Many Genes



Position of Genes 1, 2, & 3 in Chromosome

Discrete Units!

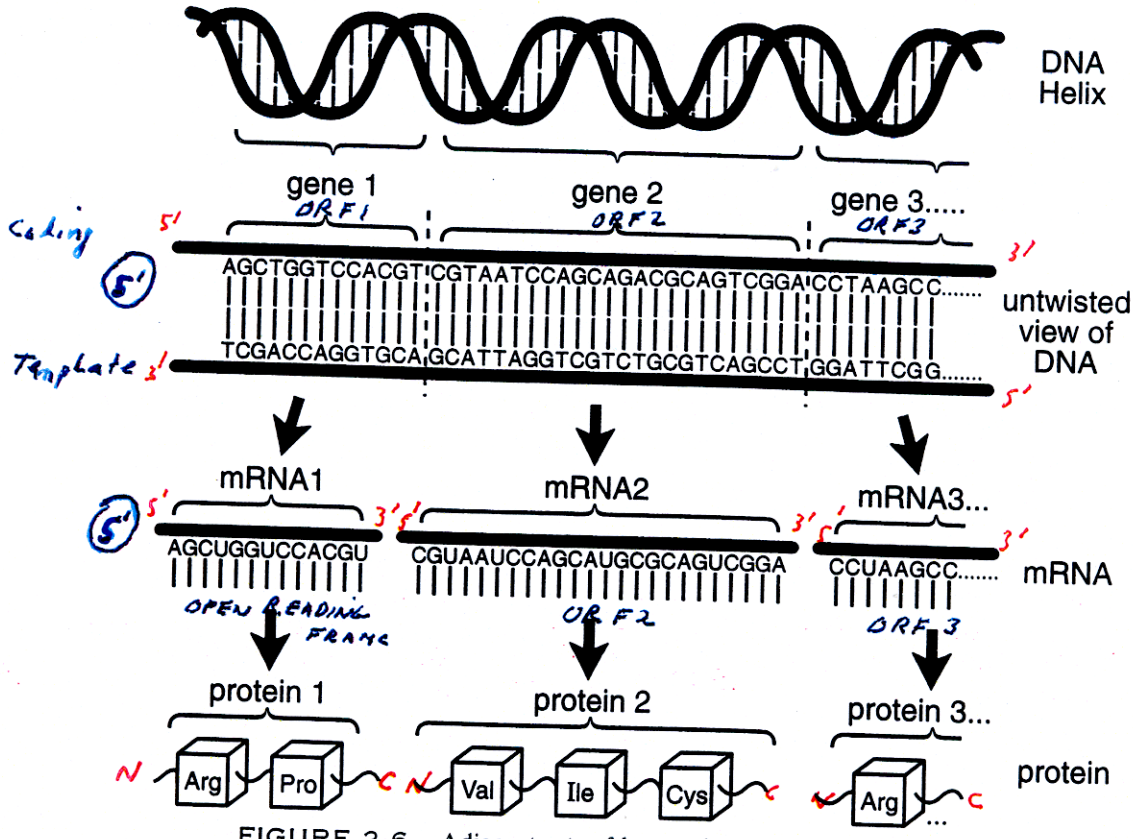


FIGURE 2.6 Adjacent sets of base pairs comprising different genes.

Function 1 Function 2 Function 3

What delineate each gene?

Notice Sequence of each gene

Notice Sequence of each protein

Central Dogma

∴ Genes → Functions in Cells via Proteins

Cells duplicate & stay the same → DNA Replication

Notice – Each gene, mRNA, & protein has a unique order / sequence of Monomeric Units

A Simple Gene = A DOUBLE HELIX

ONLY ONE STRAND TRANSCRIBED

Gene X

Beginning 5' END

End 3' END

Upstream ← next gene

TATAAT

SWITCH OR PROMOTER

ATATTA

A G C T C G A A C

SENSE STRAND

FUNCTION Genetic Code

TRANSCRIBED STRAND

T C G A G C T T G

ATTTT

TERMINATION SWITCH

TAAAA

Downstream → next gene

controls when & where a gene becomes active → unique cells!

$_{p}$A G C U C G A A C$_{OH}$

5' end

mRNA$_x$

3' end

COMPLEMENTARY TO TRANSCRIBED STRAND = TEMPLATE FOR RNA

Start TRANSCRIPTION

END TRANSCRIPTION

NOTICE: Specific Sequences Specify Beginning & End of Gene & CONTROL ITS ACTIVITY!

NOTICE: mRNA Sequence = SEQUENCE OF SENSE STRAND

A Simple Gene = A DOUBLE HELIX

ONLY ONE STRAND TRANSCRIBED

Gene X

Beginning
5' END

End
3' END

upstream
← next gene

TATAAT

SWITCH OR PROMOTER

ATATTA

A G C T C G A A C

SENSE STRAND
function
Genetic code

TRANSCRIBED STRAND

T C G A G C T T G

ATTTT

TERMINATION SWITCH

TAAAA

Downstream
→ next gene

controls when + where a gene becomes active
→ unique cells!

$_{P}$A G C U C G A A C$_{OH}$

5' end

mRNA$_x$

3' end

COMPLEMENTARY TO TRANSCRIBED STRAND = TEMPLATE FOR RNA

Start TRANSCRIPTION

END TRANSCRIPTION

NOTICE! Specific Sequences specify Beginning + End of Gene + CONTROL ITS ACTIVITY!

NOTICE: mRNA Sequence = SEQUENCE OF SENSE STRAND

Control Switches are unique DNA Sequences & CAN be Cloned!

AND USED TO Re-Engineer ORGANISMS!! Switches ACT independently of Gene!!

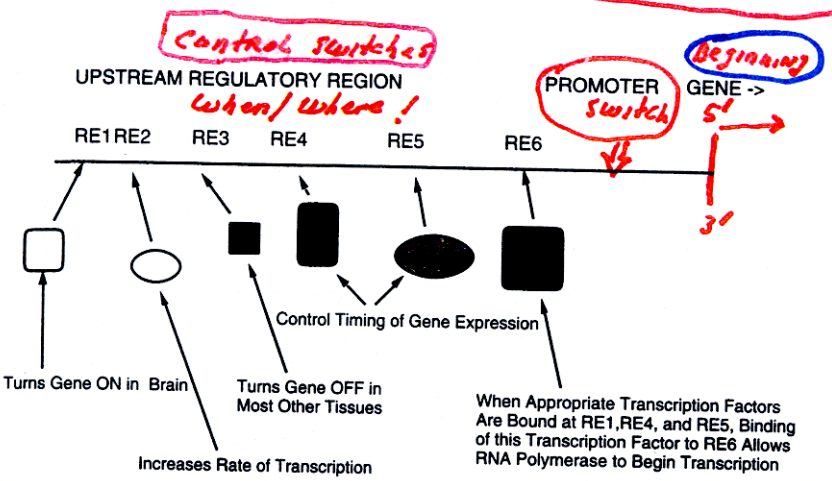


FIGURE 3.13 Enhancers and transcription factors in eukaryotic cells. A schematic diagram of the upstream regulatory region for a brain specific transcript is provided.

Each Switch = Unique DNA Sequence!

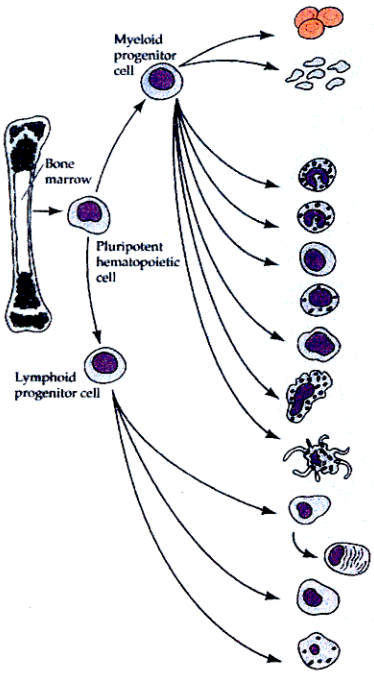
Genome Projects Reveal BOTH the Genes & the Logic that Controls them!

RULE! SEQUENCE → BIOLOGY!!

NO "HOCUS POCUS"

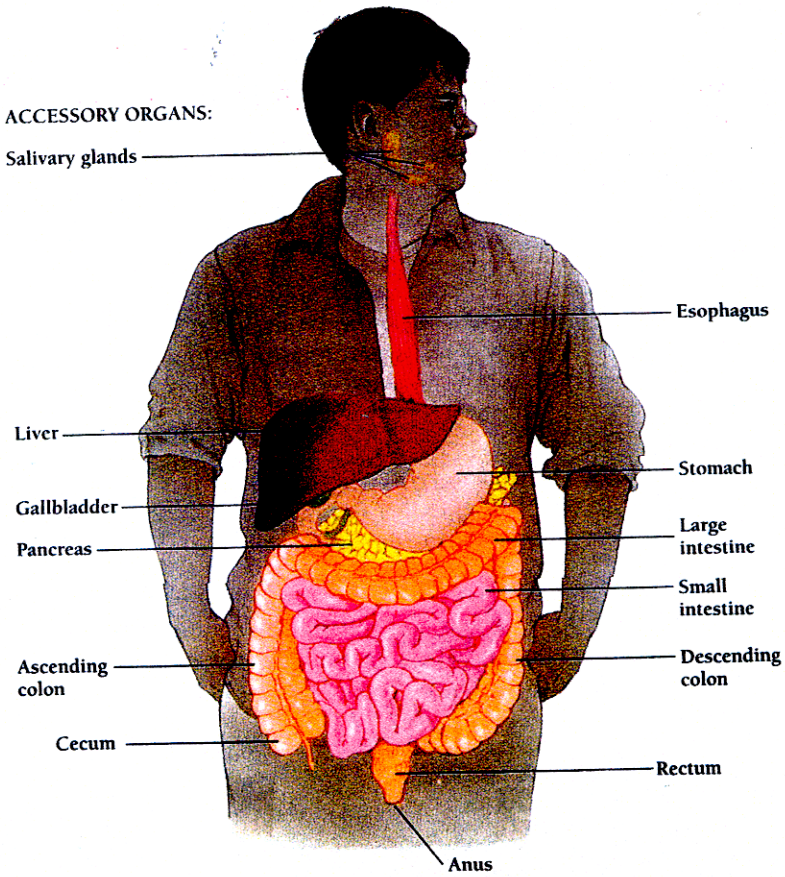
YO! IT'S in the DNA!

SWITCHES CONTROL WHERE + WHEN A GENE IS ACTIVE → UNIQUE FUNCTIONS → UNIQUE CELLS!



TYPE OF CELL	FUNCTION
Red blood cells (erythrocytes)	Transport oxygen and carbon dioxide
Platelets (cell fragments without nuclei)	Initiate blood clotting
White blood cells (leukocytes)	
PHAGOCYTES	
Basophils	Release histamine; may promote the development of T cells
Eosinophils	Kill antibody-coated parasites
Neutrophils	Phagocytize antibody-coated pathogens
Mast cells	Release histamine when they are damaged
Monocytes	Develop into macrophages
Macrophages	Engulf and digest microorganisms; activate T cells
Dendritic cells	Present antigens to T cells
LYMPHOCYTES	
B cells	Differentiate to form antibody-producing cells and memory cells
Plasma cells	Secrete antibodies
T cells	Kill virus-infected cells; regulate activities of other white blood cells
Natural killer cells	Attack and lyse virus-infected or cancerous body cells

19.2 Blood Cells
Pluripotent stem cells in the bone marrow can differentiate into red blood cells, platelets, and the various types of white blood cells.



THE GENE AND SWITCHES ARE UNIQUE DNA SEQUENCES

They CAN be Cloned & "Shuffled" & Engineered

① CREATING $\boxed{\text{new}}$ 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 gene ⊕ plant leaf switch

③ ALL genes are regulated & controlled by Switches. The Genome Projects reveal both the genes & the switches & wiring together of all switches in gene

→ Program of life from birth to death

An Eye of a Fly CAN be Produced at other PLACES on the Fly's Body by Genetic Engineering

CAN USE Switches to Engineer where/when Gene Active in an organism
↓
Controls ON/OFF

18–25 *The red-eyed fruit fly at the right is the offspring of the brown-eyed fly at the left.* Drosophila *transposons bearing a gene for red eyes were injected into the brown-eyed fly when it was an early embryo. Transposons with the gene for red eyes were incorporated into chromosomes of the cells that ultimately formed its gametes. The gene for red eyes was therefore passed on to its offspring.*

1. Control Genes Activate Switches of other Genes
2. These genes can Specify Proteins that tell cells to develop into complex organs (e.g., eye!)

∴ genes that do the "work" are connected to genes that control them → regulatory circuits / logic

Use the Appropriate Switch with a Master Control Gene that Switches on other Switches to activate genes needed to Make an eye!

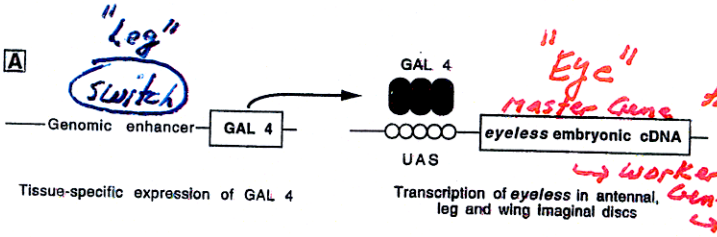
Age of Developmental Engineering is Beginning

This is the ultimate outcome of the Genome Projects! Unraveling our Developmental Gene Networks!

New Genes
↳ Master Genes
↳ Direct Cells → Organs

ALL in the DNA Sequence

Engineered Master Gene to Be Activated in Different Body Parts



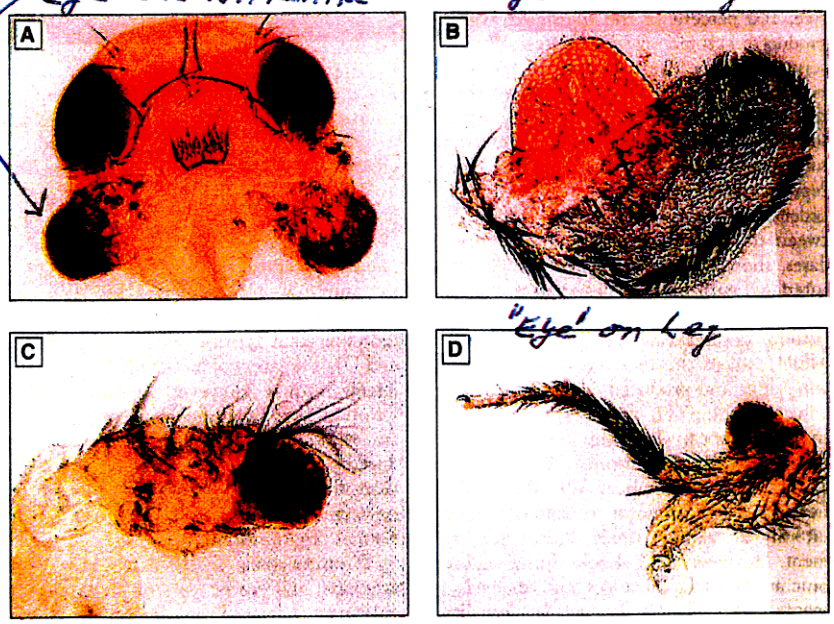


Fig. 2. GAL4 driven ectopic expression of *ey* induces the formation of eye structures in various tissues. The sites at which ectopic eyes form correspond to the regions in the imaginal discs, in which GAL4 is expressed as assayed by the activation of a *lacZ* reporter construct (Fig. 1, B, C, and D). The ectopic eye structures show ommatidial arrays, interommatidial bristles, and red pigmentation (*29*). (**A**) Cuticle of an adult head in which both antennae formed eye structures. (**B**) Dissected wing with a large outgrowth of eye tissue. The ectopic eye contains about 350 facets. Many interommatidial bristles are also apparent. The normal eye contains approximately 800 ommatidia. The wing is reduced in size. The anterior margin with its characteristic triple row of bristles occupies most of the circumference, whereas the more posterior structures are absent and replaced by eye tissue. The characteristic venation pattern of the wing is disturbed by the formation of the ectopic eye structures. (**C**) Dissected antenna in which most of the third antennal segment is replaced by eye structures. (**D**) Dissected middle leg with an eye-outgrowth on the base of the tibia.

BIG IMPLICATIONS

SHOWS Function of eyeless gene

Where does this lead to?
organ growth in culture?

Transplants?
Organ Design?
Organism Design?

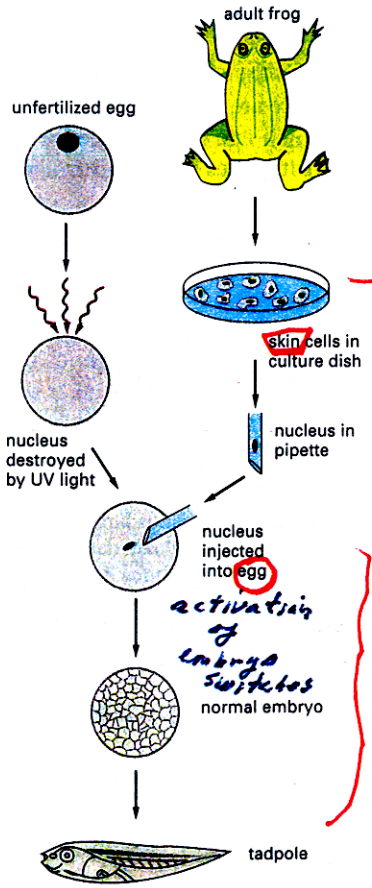
CLONING AN ANIMAL FROM a DIFFERENTIATED CELL NUCLEUS SHOWS THAT Gene Switches contain....

"The Logic" for all of life is contained in the Genome!

Prediction?

Experiment?

What is Hypothesis Being tested?



Skin cells express specific genes due to their skin cell switches

Development of an organism from a fertilized egg requires all switches of genes to work at correct times to allow animal to form!

∴ all genes + switches present in skin cell!!

THE LOGIC TO PROGRAM ALL OF DEVELOPMENT!

If the Logic of how switches are connected is understood → life can be programmed!