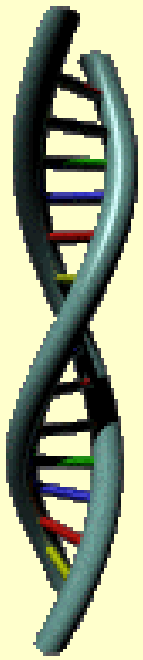
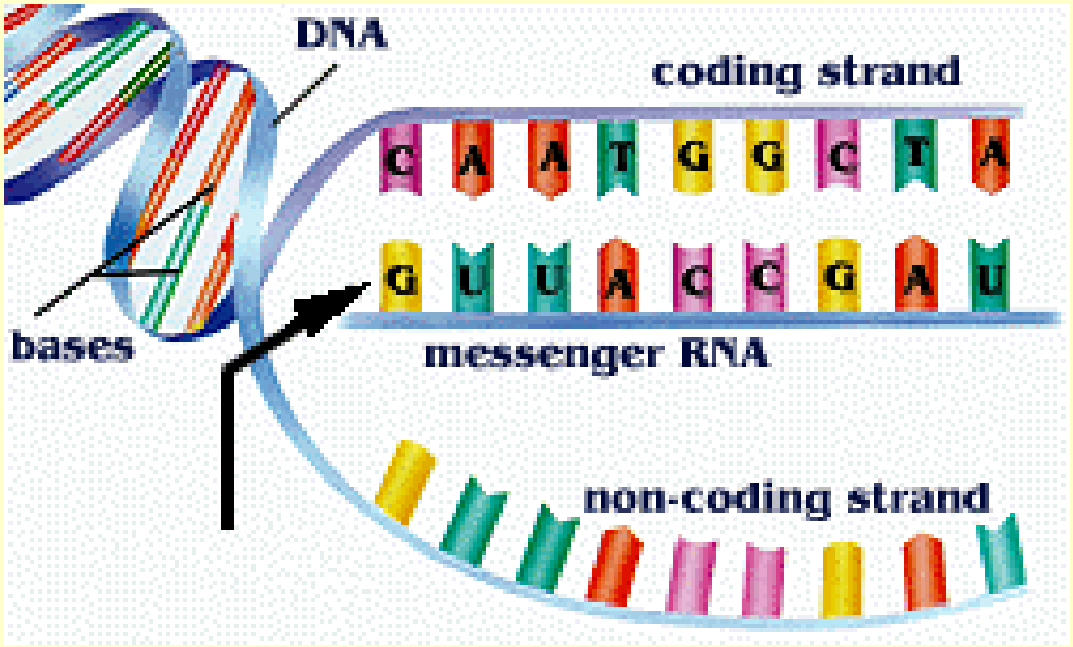
DNA and RNA

Chapter 12-1





GENETIC MATERIAL

In the middle of the 1900's scientists were asking questions about genes.

What is a gene made of?

How do genes work?

How do genes determine characteristics of organisms?

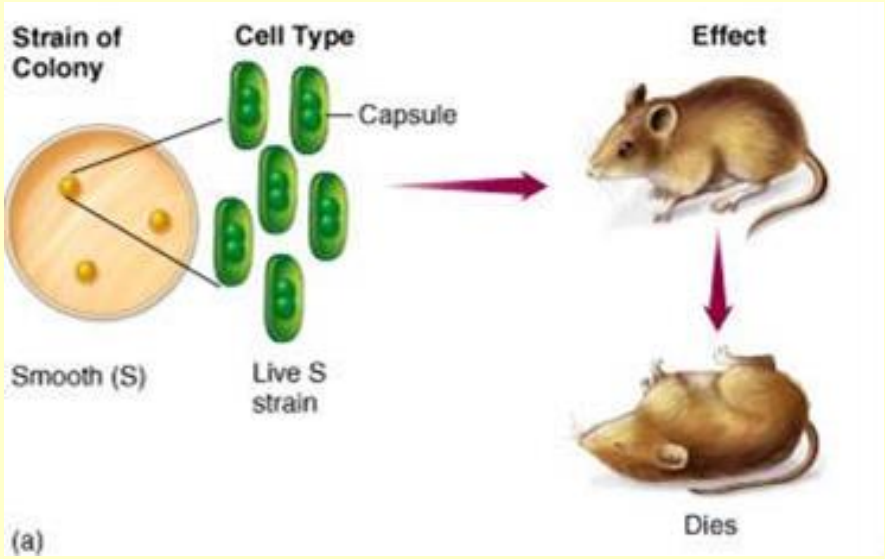
DO PROTEINS CARRY THE GENETIC CODE?

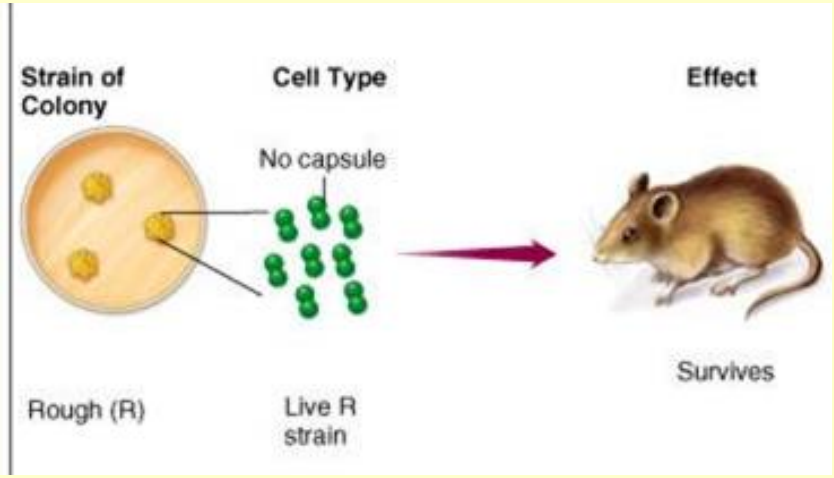
At the time most scientists believed that _proteins_ had to be the molecules that made up genes.

There were so many different kinds proteins and DNA seemed to be too monotonous . . . repeating the same _4_ subunits.

Griffith's experiment

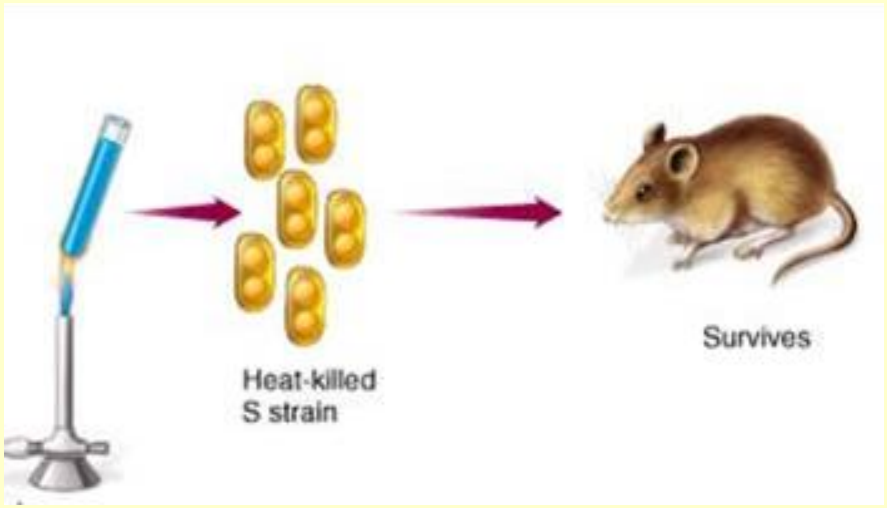
1928 – Frederick Griffith looked at pneumonia bacteria trying to figure out what made people die





S (SMOOTH) strain - killed mice

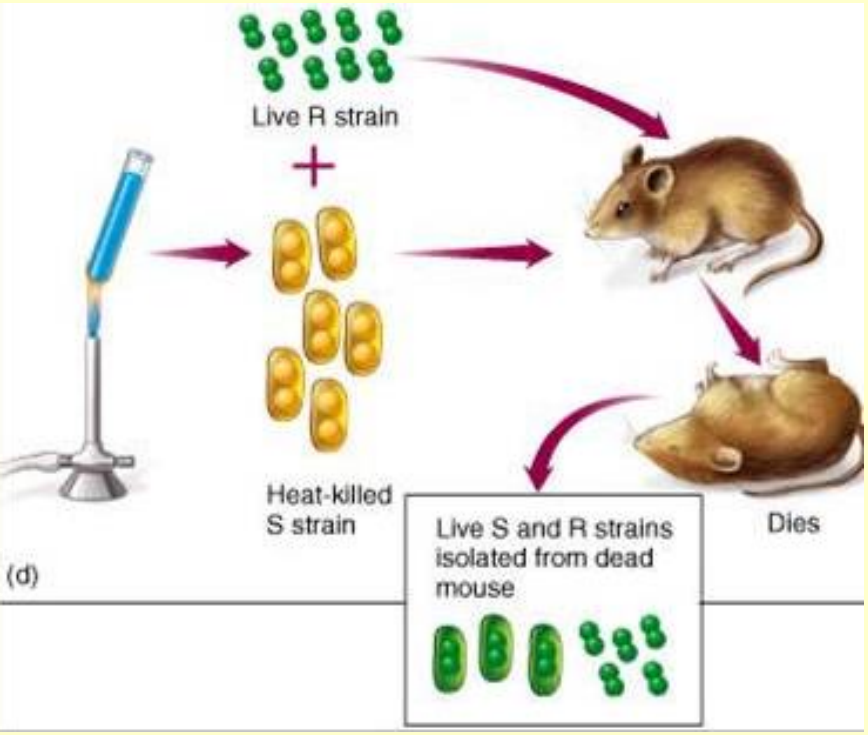
R (Rough) strain -mice lived



If he heated the LETHAL strain first

. . . mice lived.

The heat killed bacteria were no longer LETHAL.



BUT. . .

If he mixed heat-killed LETHAL bacteria with live harmless bacteria

. . . mice DIED !

When he looked inside dead mice, he found LIVE LETHAL bacteria!

Somehow the heat killed LETHAL bacteria passed their characteristics to the harmless bacteria.

Griffith called this process TRANSFORMATION because one strain of bacteria had been changed permanently into another.

SEE GRIFFITH's EXPERIMENT

But what was the factor that caused the transformation?

A protein ? A lipid ? A carbohydrate ?

A nucleic acid ?

1944-

Oswald Avery's team of scientists repeat Griffith's experiments looking for the transforming molecule.

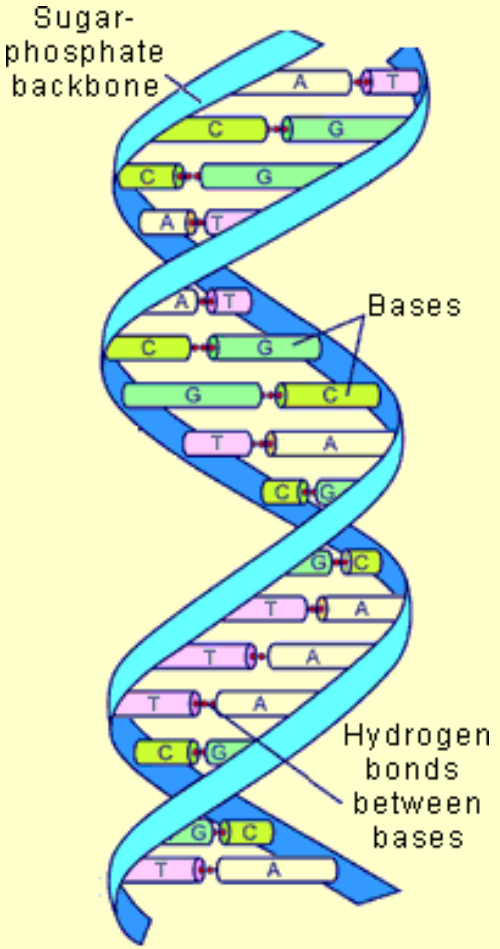
After heat killing the LETHAL Pneumonia bacteria, he treated them with digestive enzymes that destroy specific kinds of molecules.

If proteins, polysaccharides, lipids, or RNA's were destroyed .. .

Transformation still occurred!

But when they treated the heat-killed LETHAL bacteria with enzymes to destroy DNA there was NO transformation!

. . . the mice lived!



DNA was the molecule that caused the genetic change.

GRIFFITH EXPERIMENT

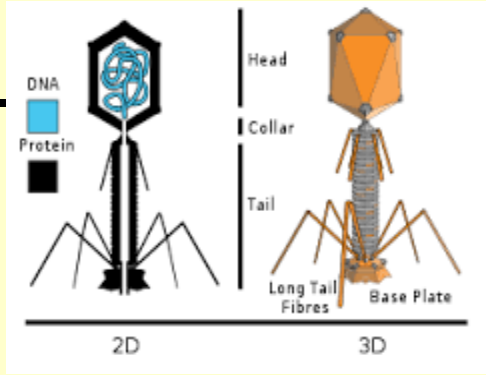
(PNEUMONIA-RAT)

Showed genetic material could be passed between bacteria & cause a change.

AVERY EXPERIMENT (Digestive enzymes) showed that the genetic material was DNA

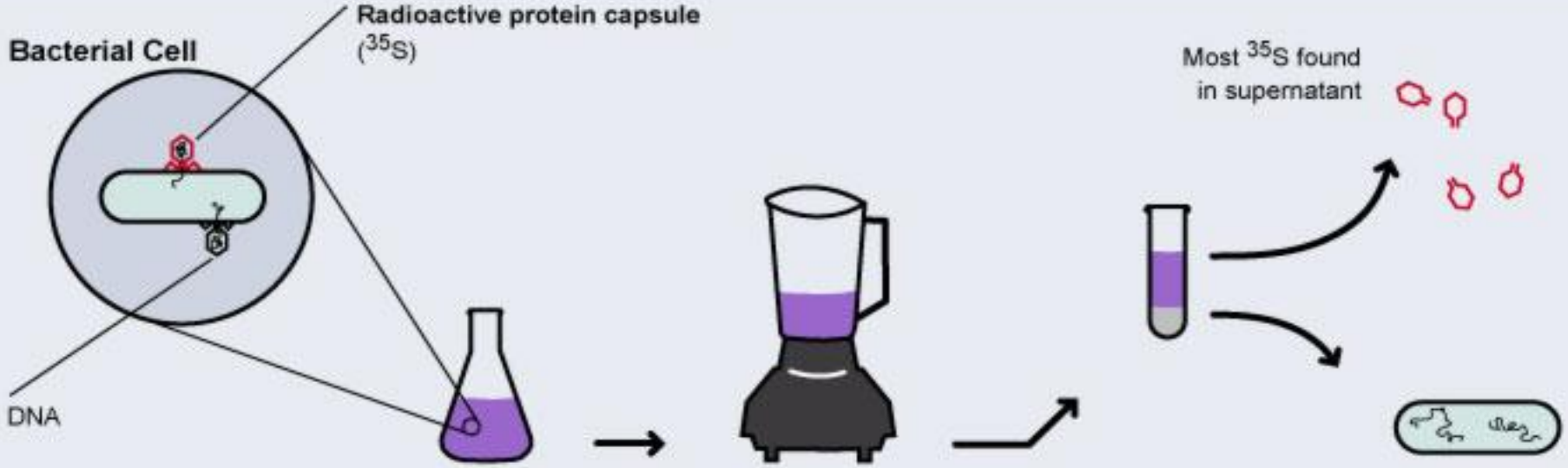
Scientists are skeptical… it takes more than one experiment to convince them.

1952-Alfred Hershey and Martha Chase experimented with viruses that infect bacteria = bacteriophages



Knew bacteriophages were made of proteins and DNA

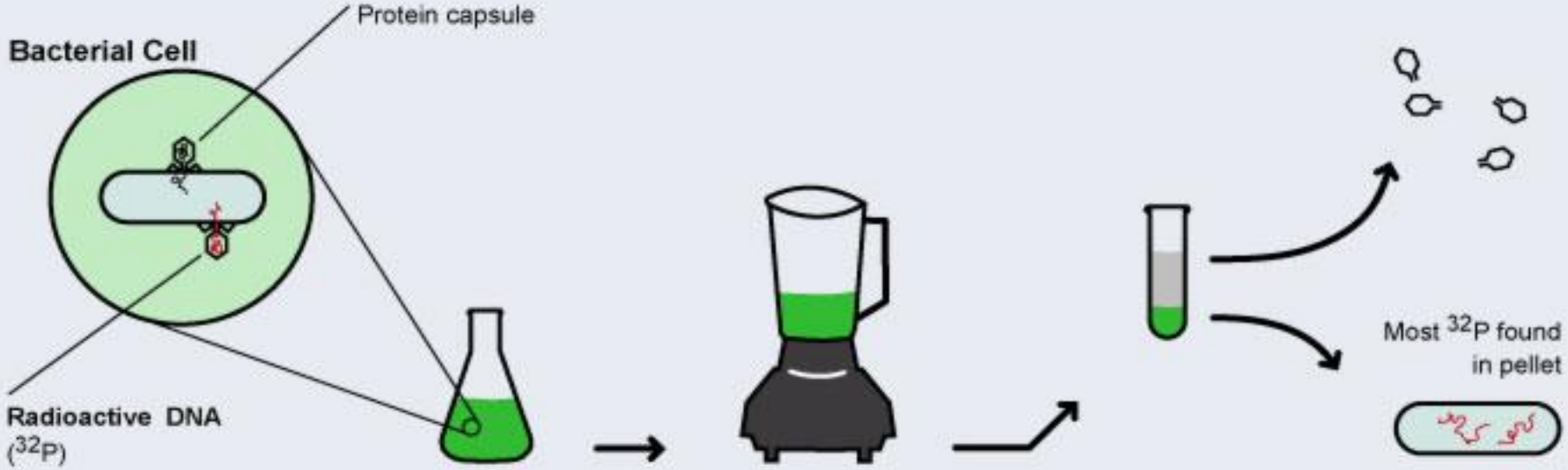
Hear about their cool experiment



Labeled phages infect bacteria.

Blender separates phages outside the bacteria from the cells and their contents

Cells and Phages are separated by centrifugation.



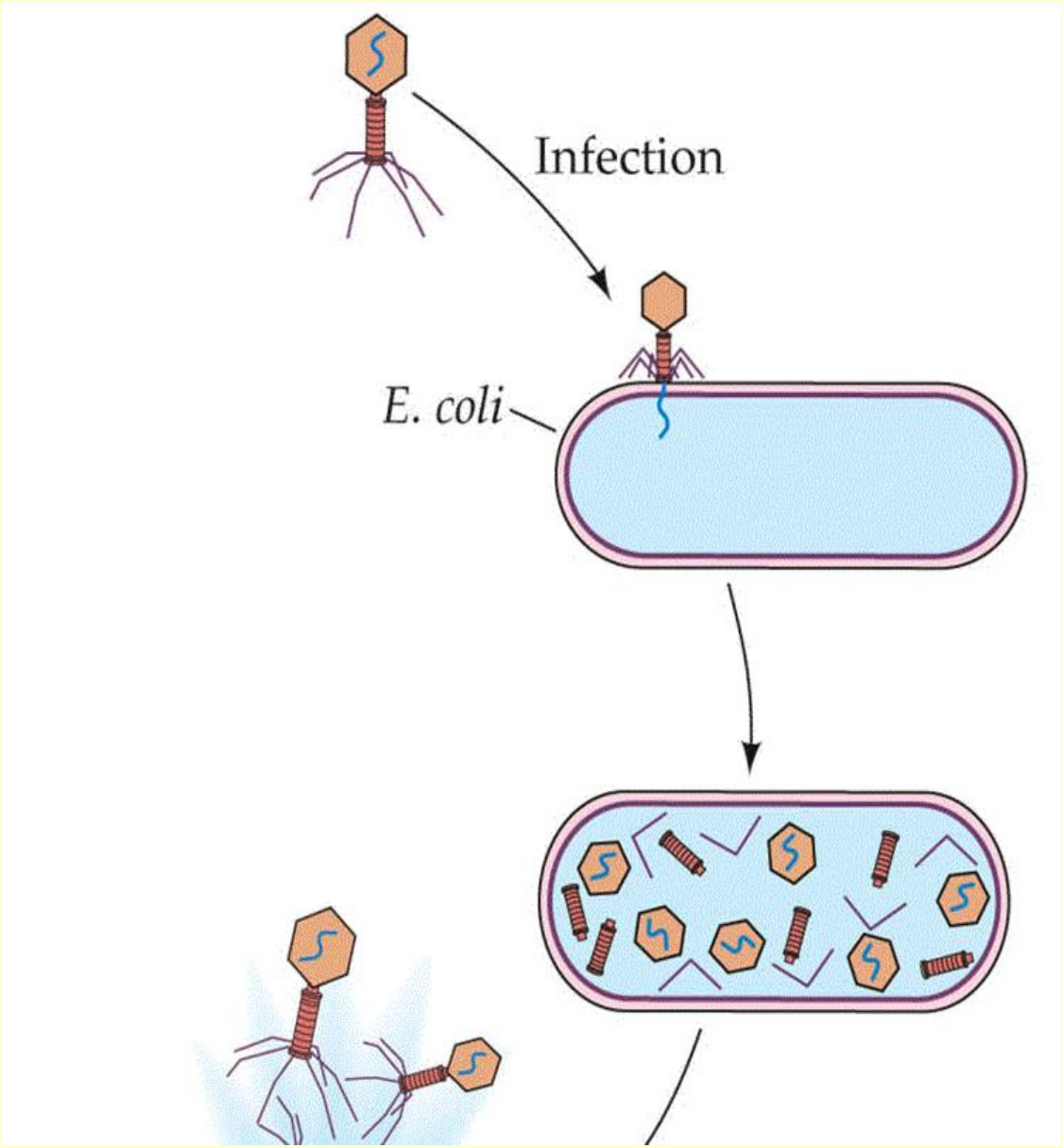
HERSHEY-CHASE BLENDER EXPERIMENT

Showed only DNA not protein entered cell during infection.

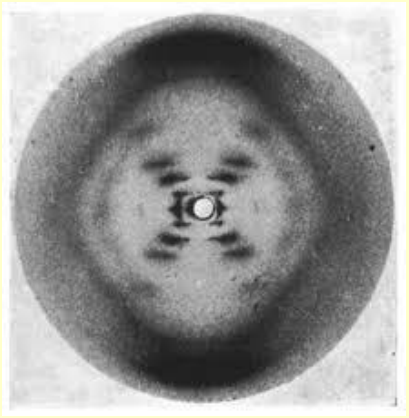
Conclusion:

Genetic material in virus was DNA not protein

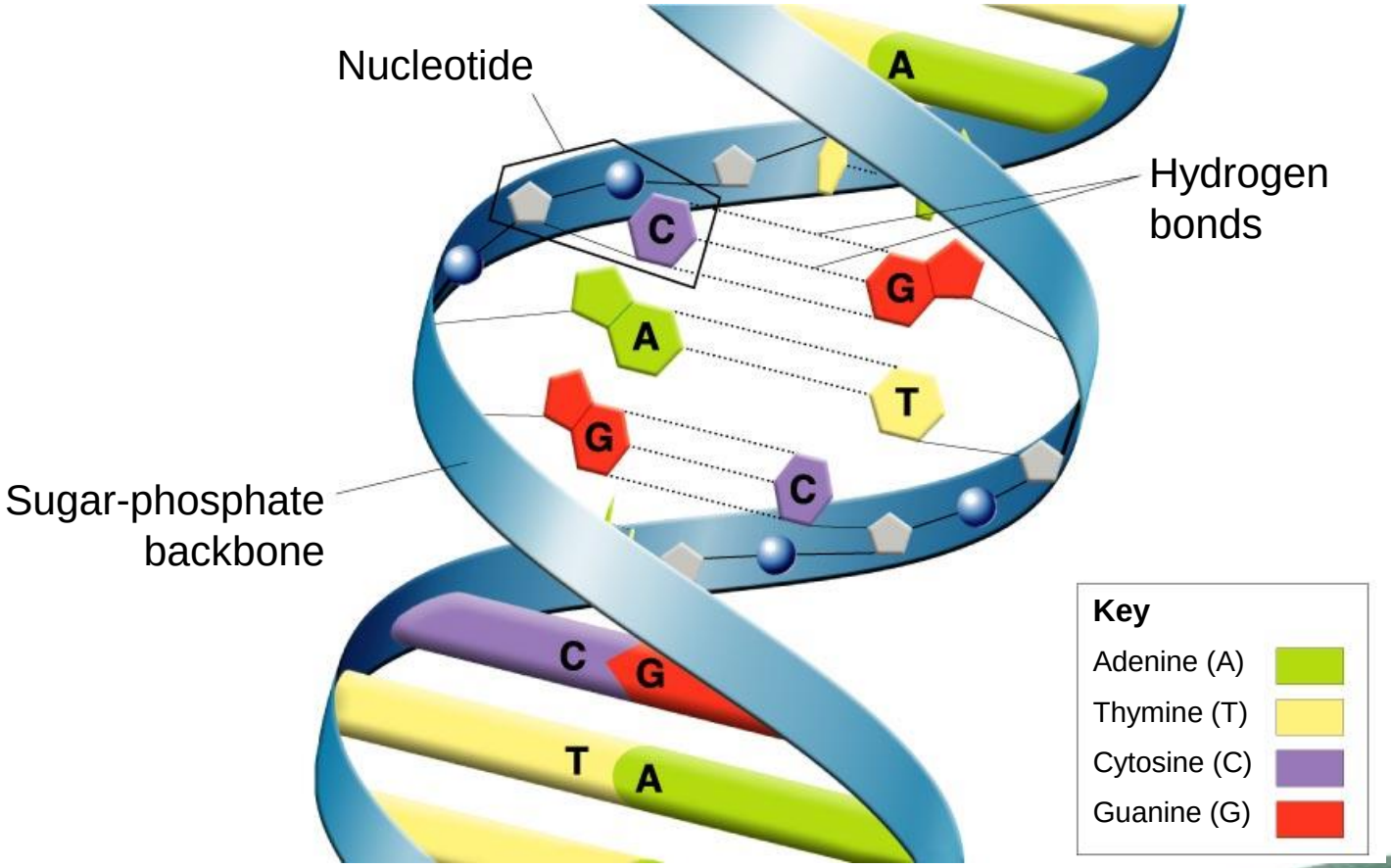
BACTERIAL VIRUSES



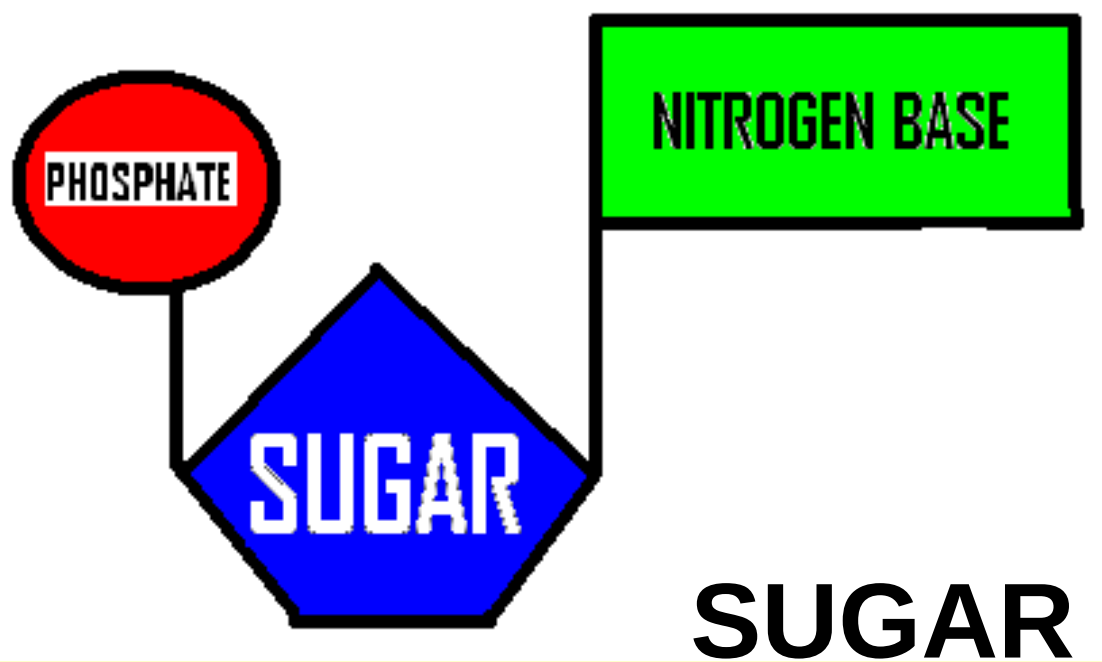
DNA is a DOUBLE HELIX



X-ray experiments by Rosalind Franklin led James Watson and Francis Crick to the discovery of the structure of DNA in 1953



NUCLEIC ACIDS are built from subunits called NUCLEOTIDES



SUGAR in DNA is deoxyribose

NITROGEN BASES in DNA

ADENINE = A

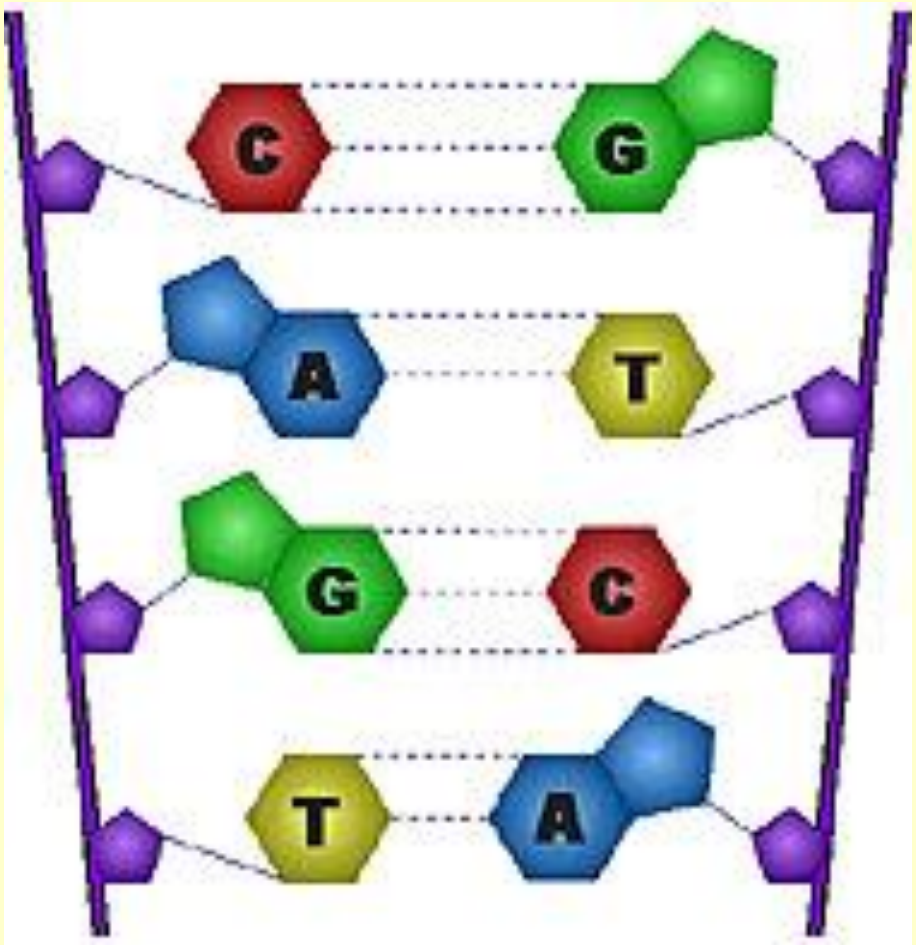
GUANINE = G

CYTOSINE = C

THYMINE = T

No URACIL

DEOXYRIBONUCLEIC ACID



DOUBLE

STRANDED

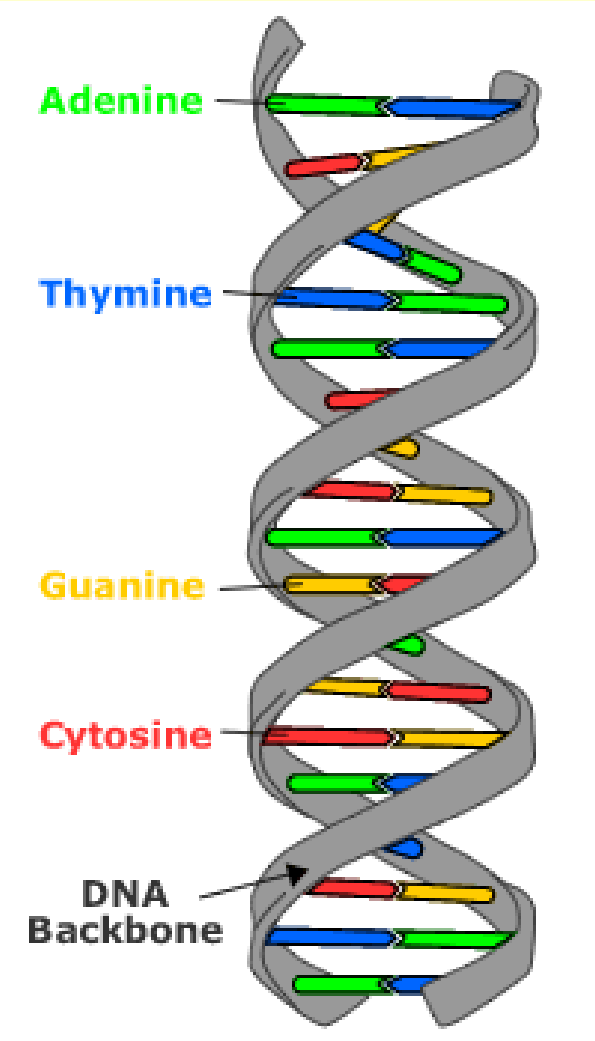
Backbone (sides of ladder) made of

PHOSPHATES

and

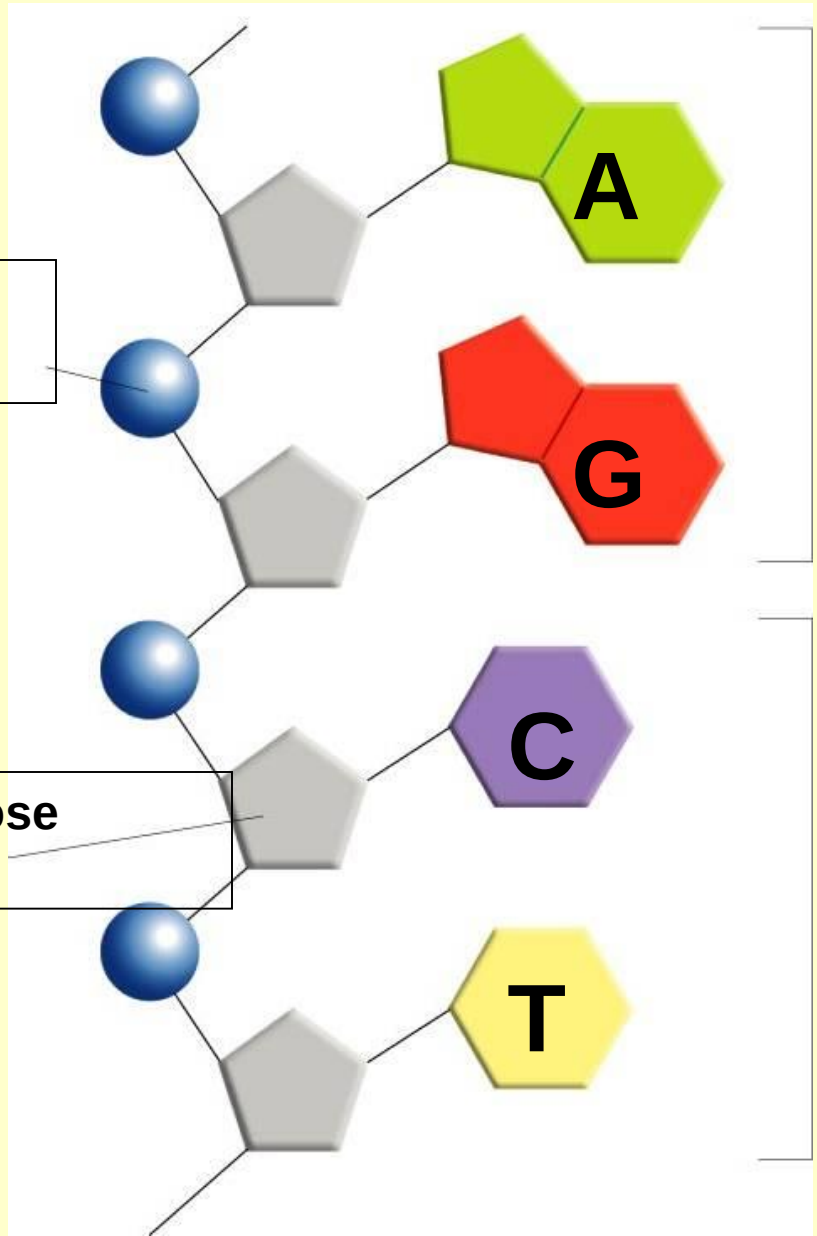
sugars

DOUBLE HELIX



Hydrogen bonds between nitrogen bases hold the two strands together.

Nitrogen bases ="Steps of ladder"



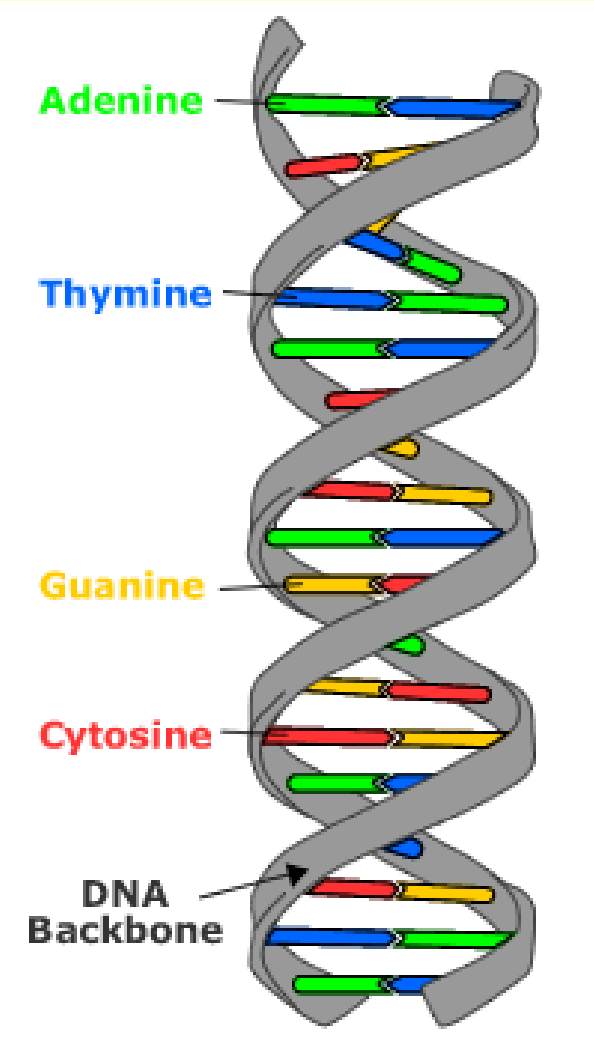
Phosphate group

Deoxyribose sugar

Purines (2 rings)

Pyrimidines (1 ring)

CHARGAFF'S RULES



A = T G = C

At time no one knew why…

now we know its because Adenine always bonds across with THYMINE

Guanine always bonds across with CYTOSINE

Prentice Hall Biology

Interest Grabber Answers

1. On a sheet of paper, draw a curving or zig-zagging line that divides the paper into two halves. Vary the bends in the line as you draw it. Without tracing, copy the line on a second sheet of paper.
2. Hold the papers side by side, and compare the lines. Do they look the same?

Lines will likely look similar.

3. Now, stack the papers, one on top of the other, and hold the papers up to the light. Are the lines the same?

Overlaying the papers will show variations in the lines.

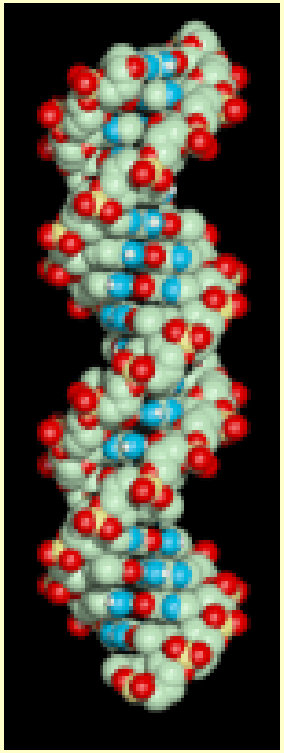
4. How could you use the original paper to draw exact copies of the line without tracing it?

Use 1st line as a template to draw the line on another sheet of paper.

5. Why is it important that the copies of DNA that are given to new daughter cells be exact copies of the original?

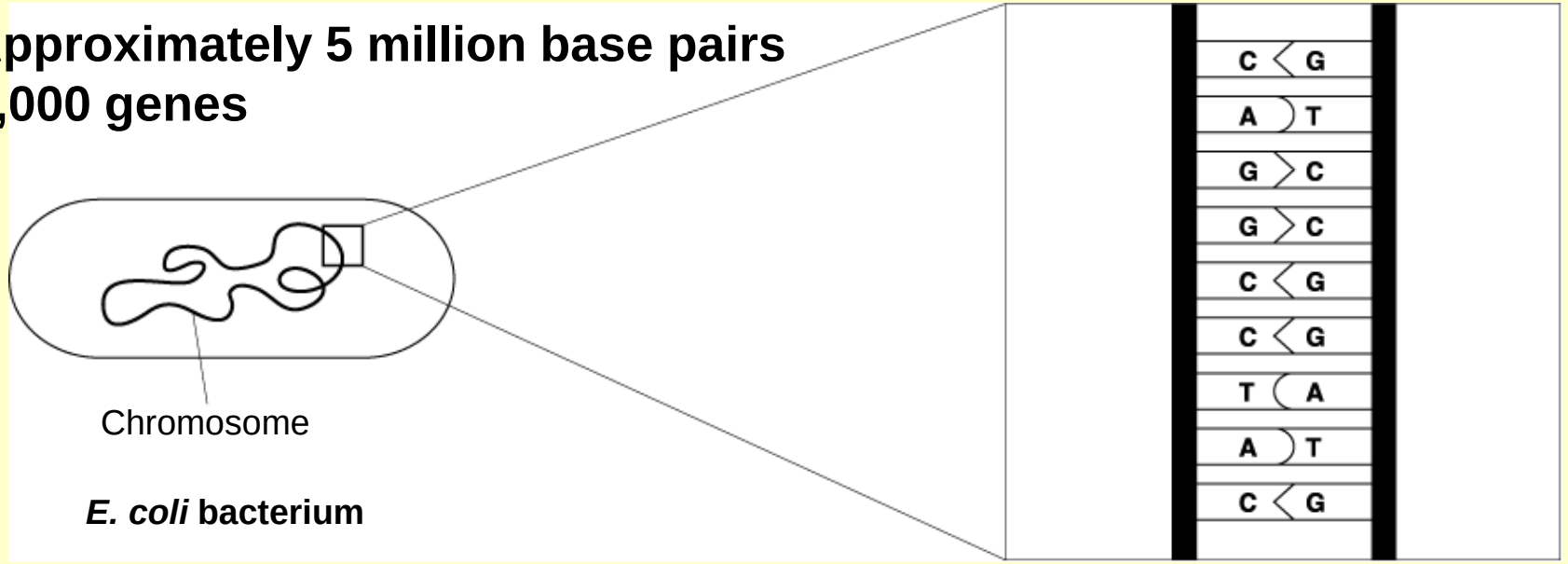
Each cell must have the correct DNA, or the cell will not have the correct characteristics.

CHROMOSOMES & DNA REPLICATION 12-2



Chromosome Structure in Prokaryotes

Approximately 5 million base pairs
3,000 genes



Bases on the chromosome

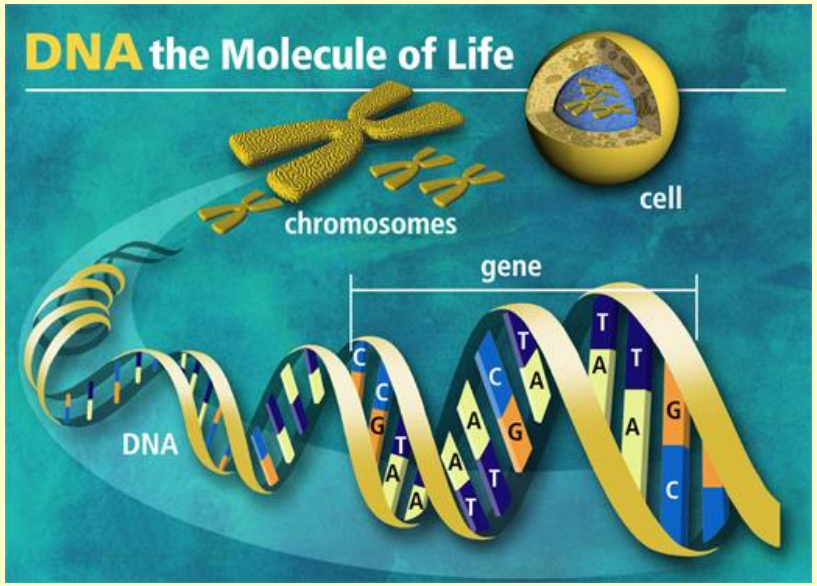
DNA molecule in bacteria is:

SINGLE

CIRCULAR

Found in CYTOPLASM **(NO nucleus)**

DNA in EUKARYOTES is packaged into chromosomes



Humans have approximately 3 billion base pairs (1 m long)
60,000 to 100,000 genes

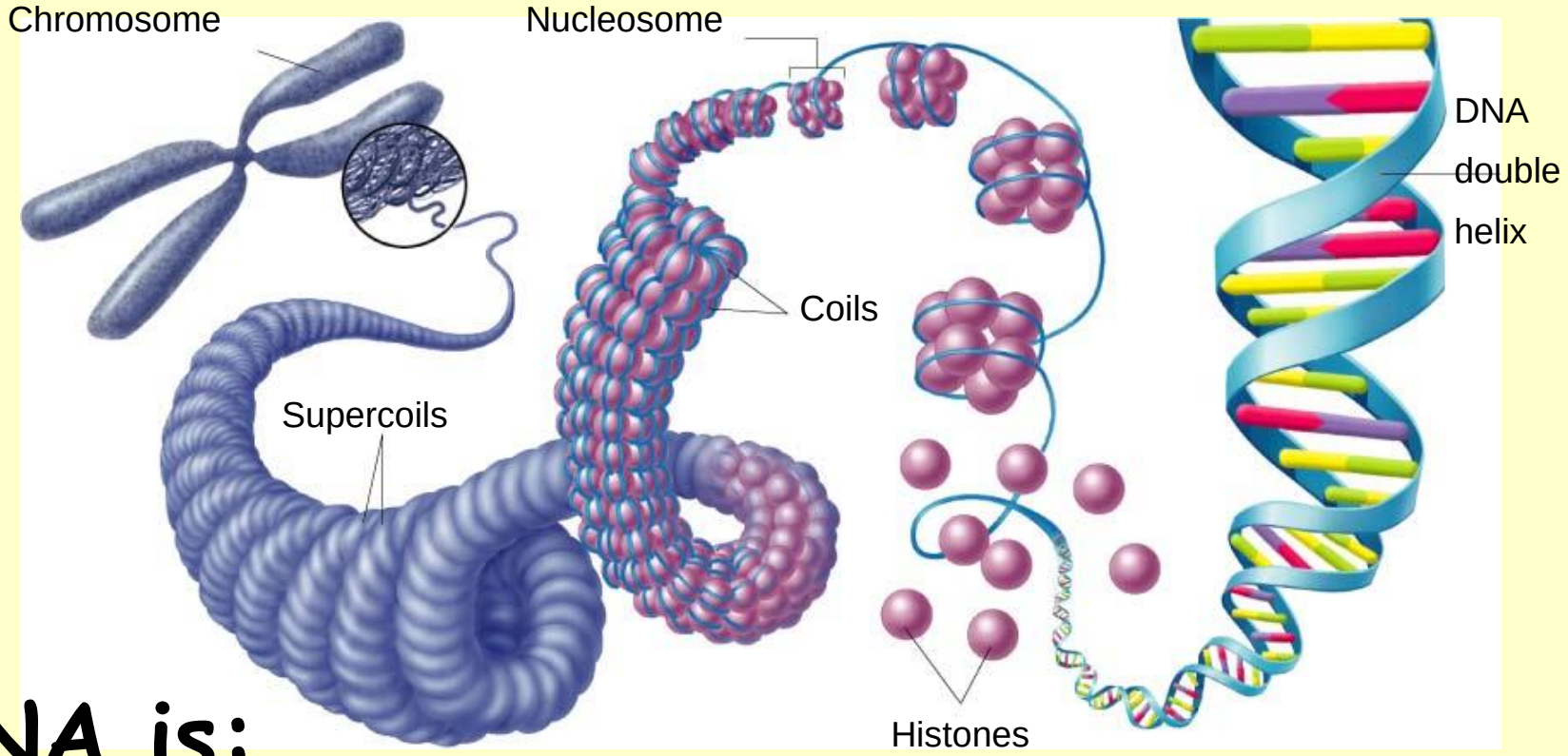
If the diameter of the DNA (2 nanometers) was as wide as a fishing line (0.5 millimeters) it might stretch as far as 21.2 km (or 13.6 miles) in length which would all have to be packed into a nucleus, the equivalent size of 25 cm in diameter.

That is some packaging!

THINK ABOUT IT

How could you get this piece of string into the container?

Chromosome Structure of Eukaryotes



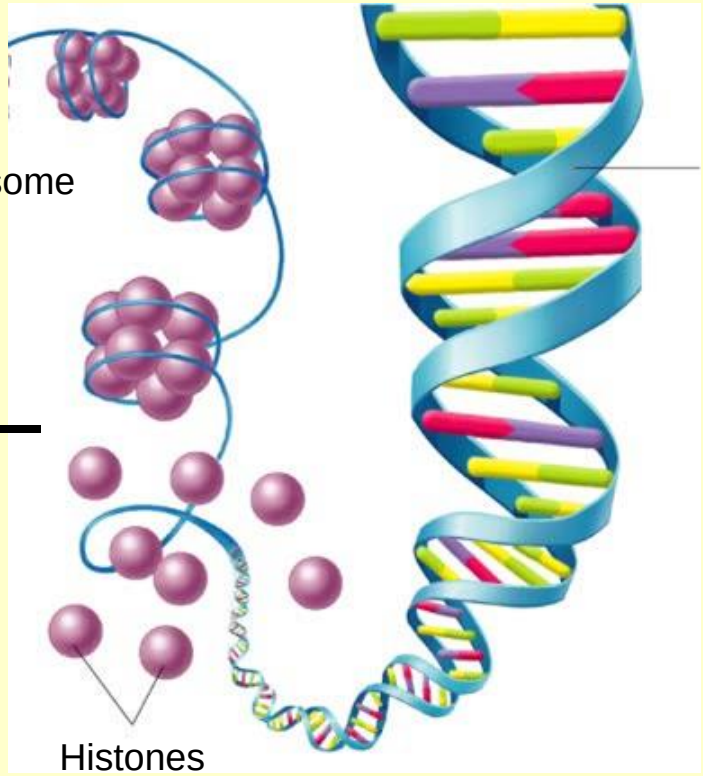
DNA is:

in multiple chromosome bundles

Found in nucleus

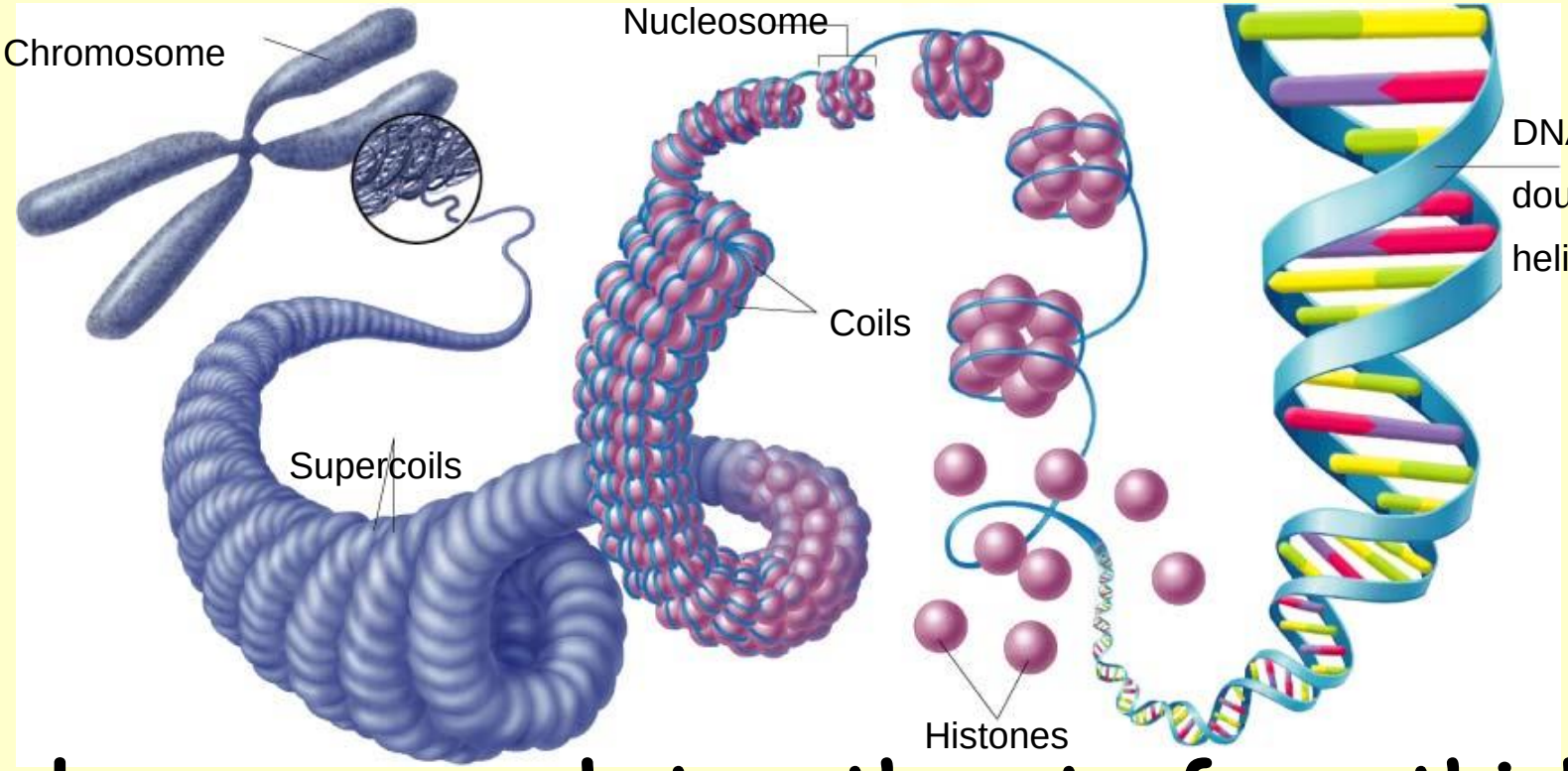
Chromosome Structure of Eukaryotes

Eukaryotic chromosomes are made of DNA & PROTEINS called HISTONES



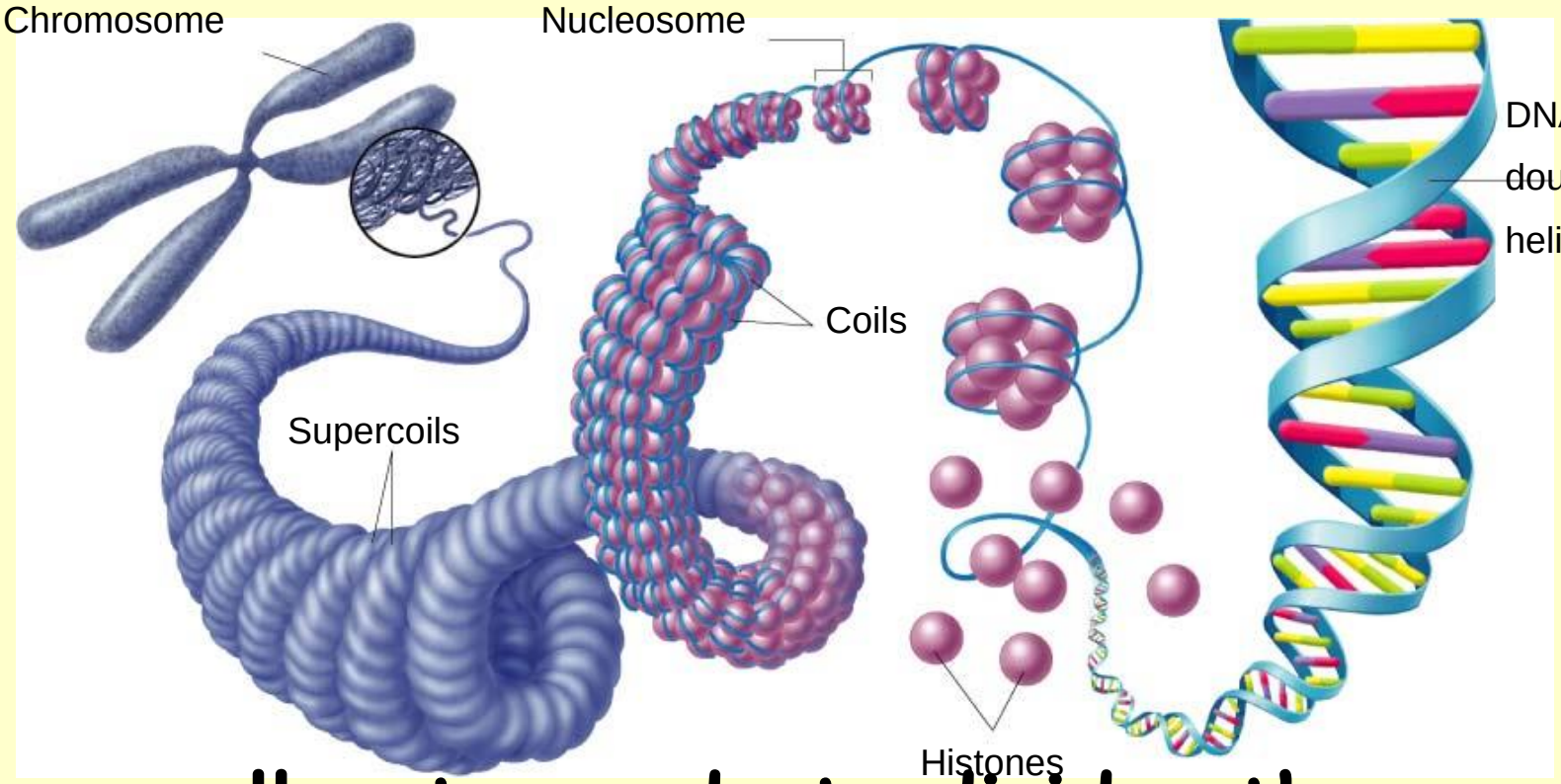
Together the DNA & histone proteins forms a bead-like structure called a NUCLEOSOME

Chromosome Structure of Eukaryotes



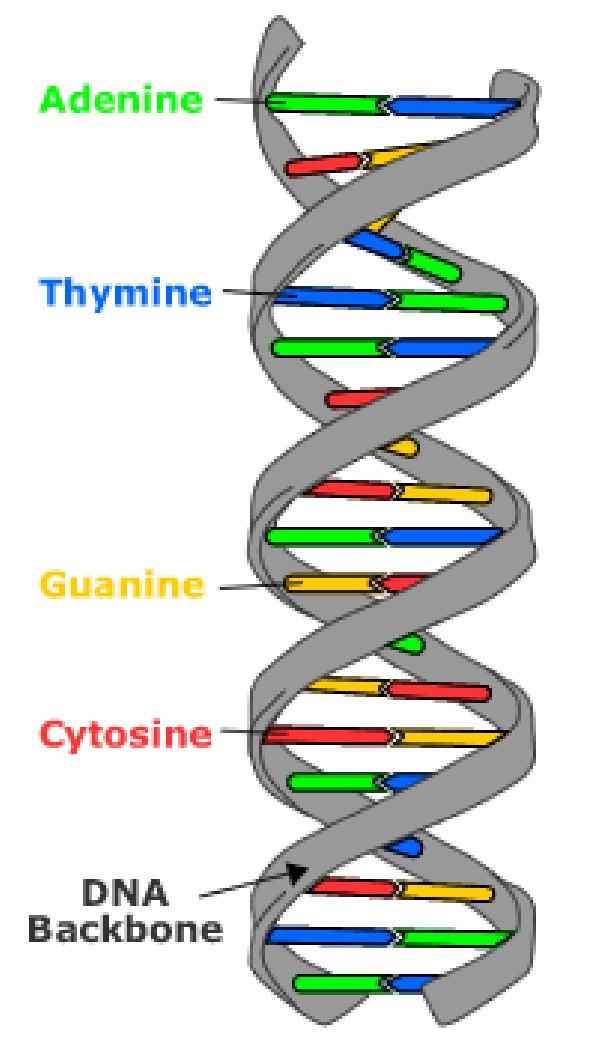
Nucleosomes pack together to form thick coiled fibers. When cell is NOT dividing, these fibers are spread out in nucleus as CHROMATIN. (Allows reading of code)

Chromosome Structure of Eukaryotes



When cell gets ready to divide, the fibers pack even more tightly to form chromosomes.(Makes it easier to move DNA during mitosis)

HOW IS DNA COPIED?



The structure of DNA explains how it can be copied.

Each strand has all the info needed to construct the _____ other half.

matching

If strands are separated, _____ rules allow you to fill in the complementary bases.

base-pairing

Duplicating DNA

- Before a cell divides, it duplicates its DNA in a copying process called **replication**.
- Each resulting cell will have a complete set of DNA molecules.
- During DNA replication, the DNA molecule separates into two strands.
- then produces two new complementary strands following the rules of base pairing.
- Each strand of the double helix of DNA serves as a template, or model, for the new strand.

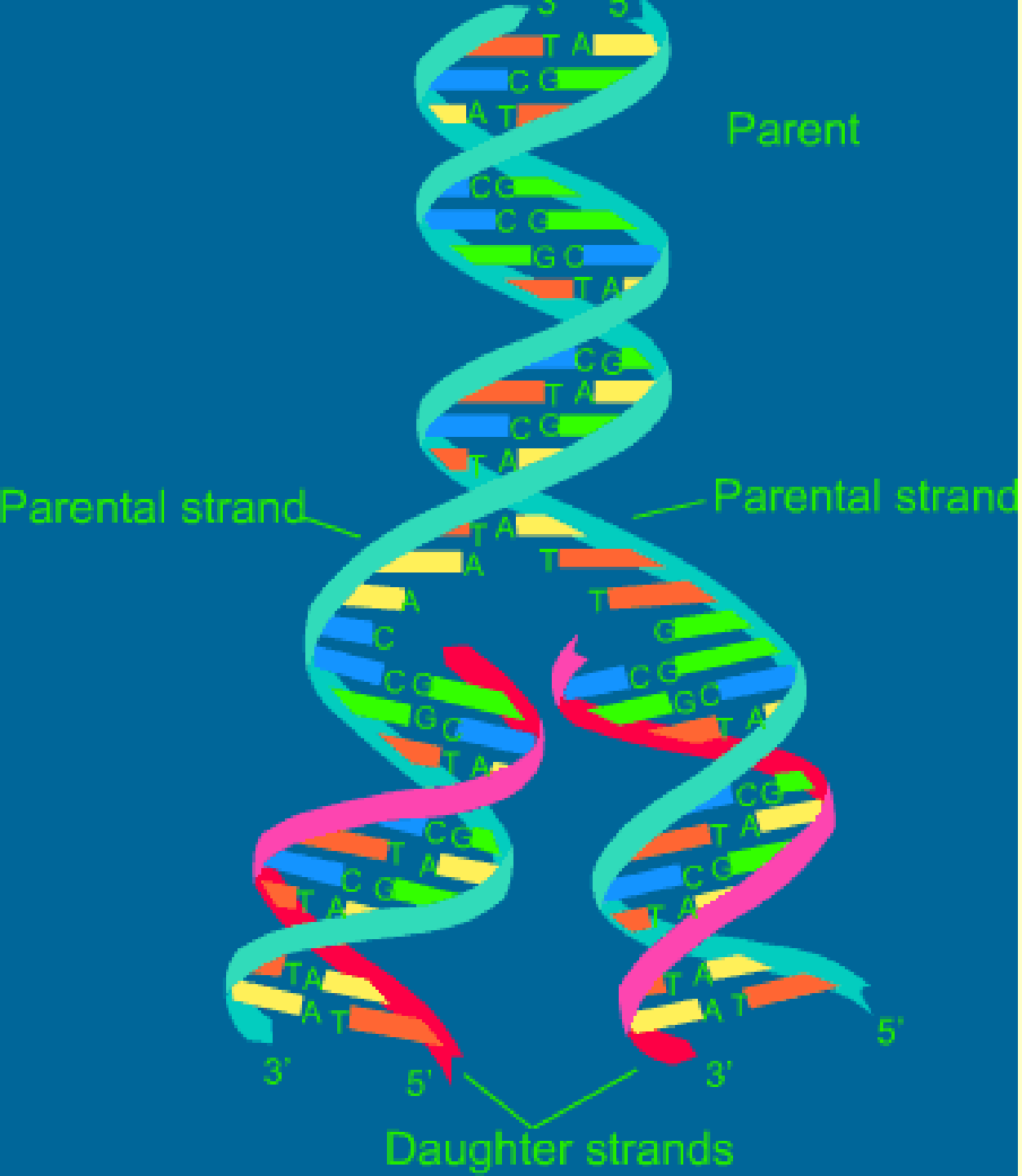
- For example, a strand that has the bases TACGTT produces a strand with the complementary bases ATGCAA.

- The result is two DNA molecules identical to each other and to the original molecule.

- Note that each DNA molecule resulting from replication has one original strand and one new strand.

Enzymes in Replication

- Helicase = unwinds and unzips the DNA
- DNA replication enzyme is called **DNA polymerase** because it joins individual nucleotides to produce a DNA molecule, a polymer.
- DNA polymerase also "**proofreads**" each new DNA strand, helping to maximize the odds that each molecule is a **perfect copy** of the original DNA.
- Ligase = binds the okazaki fragments together on the lagging strand of new DNA


Parent
Parental strand
Parental strand
3'
5'
3'
5'
5'
Daughter strands

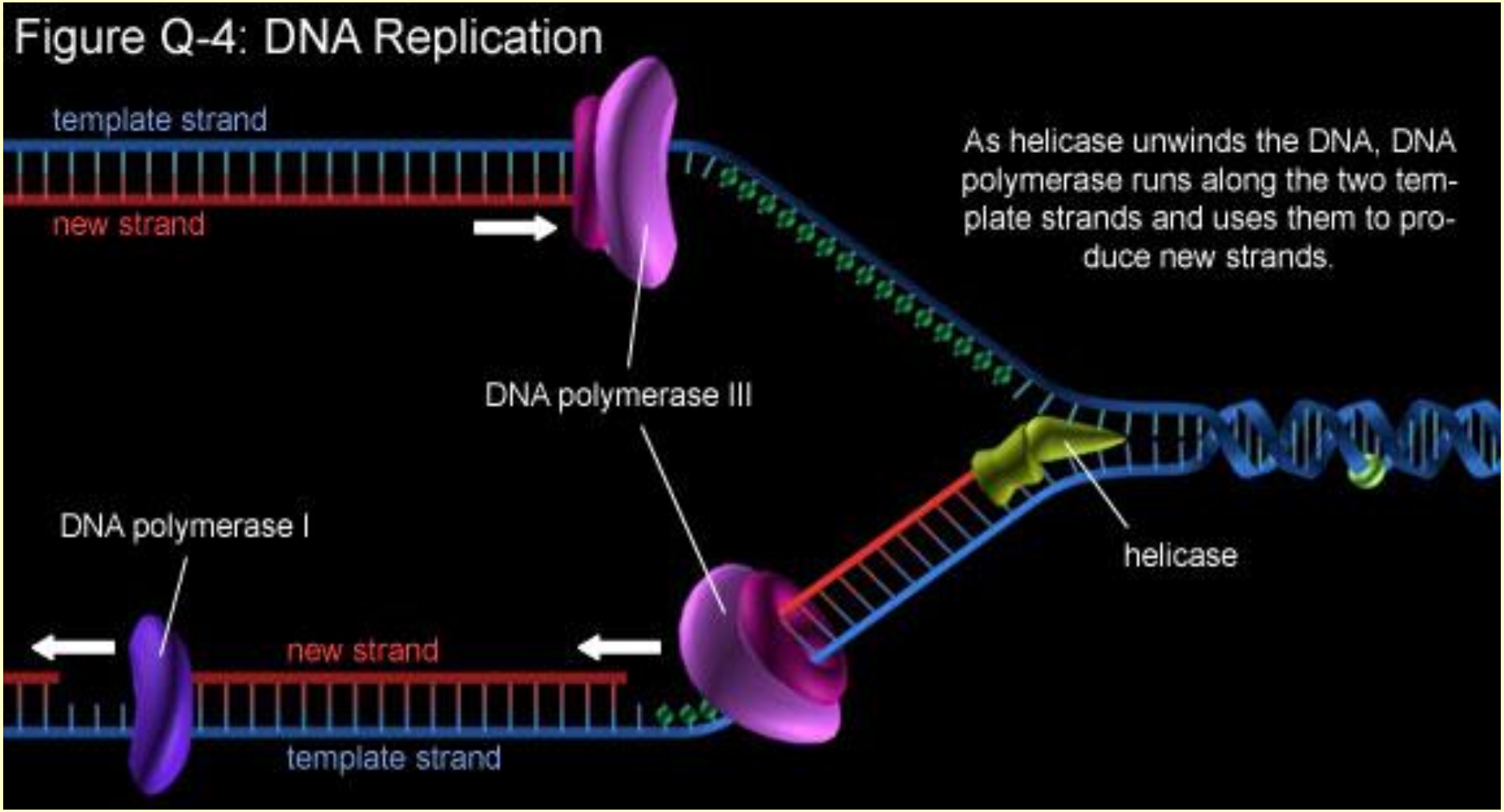


Figure Q-4: DNA Replication
template strand
new strand
As helicase unwinds the DNA, DNA polymerase runs along the two template strands and uses them to produce new strands.
DNA polymerase III
DNA polymerase I
helicase
new strand
template strand

REPLICATION STEPS

1. DNA replication is carried out by a series of enzymes
2. Enzymes "unzip" molecule by breaking Hydrogen bonds that hold the strands together and unwind it.

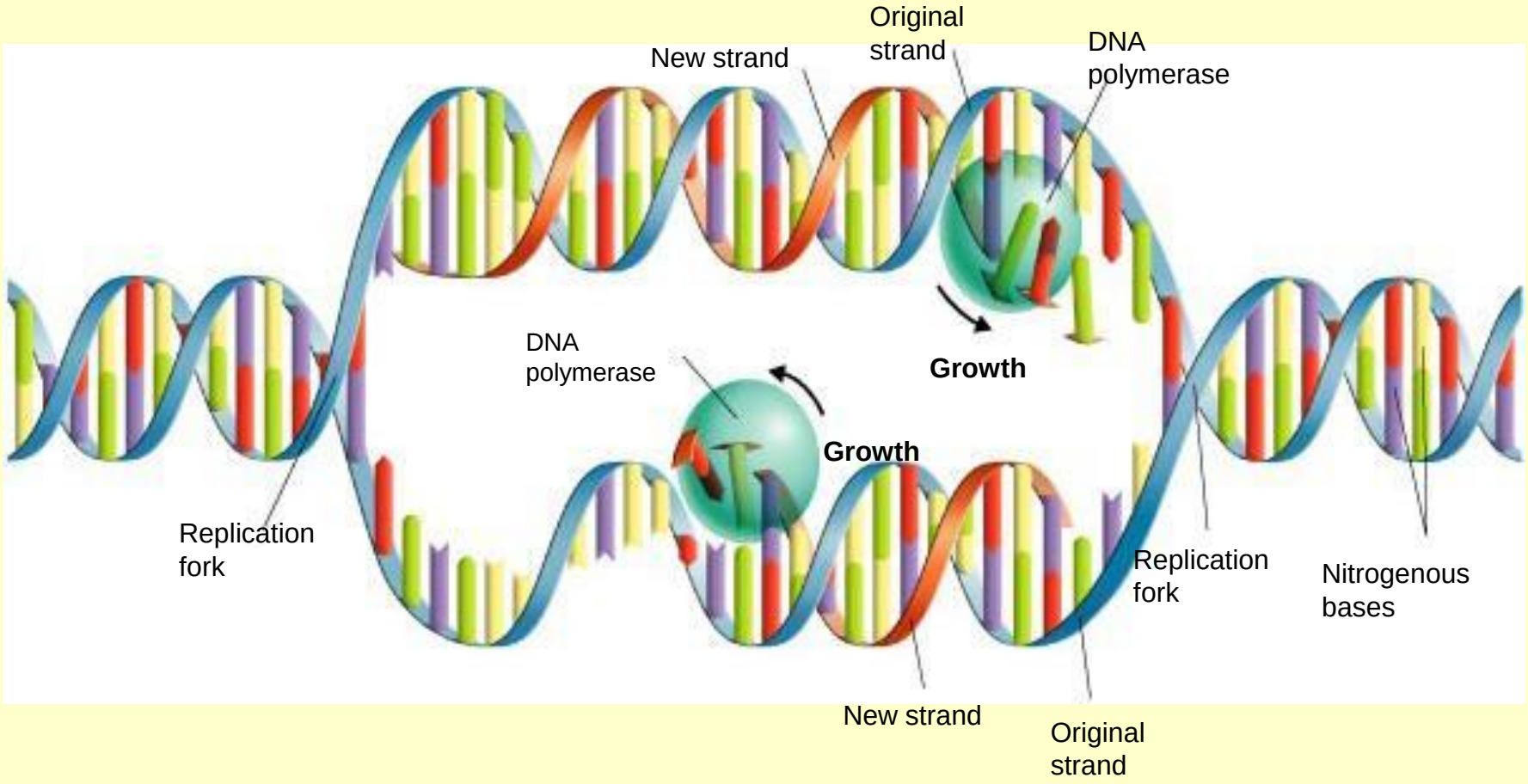
2. DNA polymerase joins nucleotides using original strand as template and spell checks for errors. DNA polymerase is an enzyme* remember enzymes are highly specific to what they do (lock and key) so its' name comes from forming DNA which is a polymer

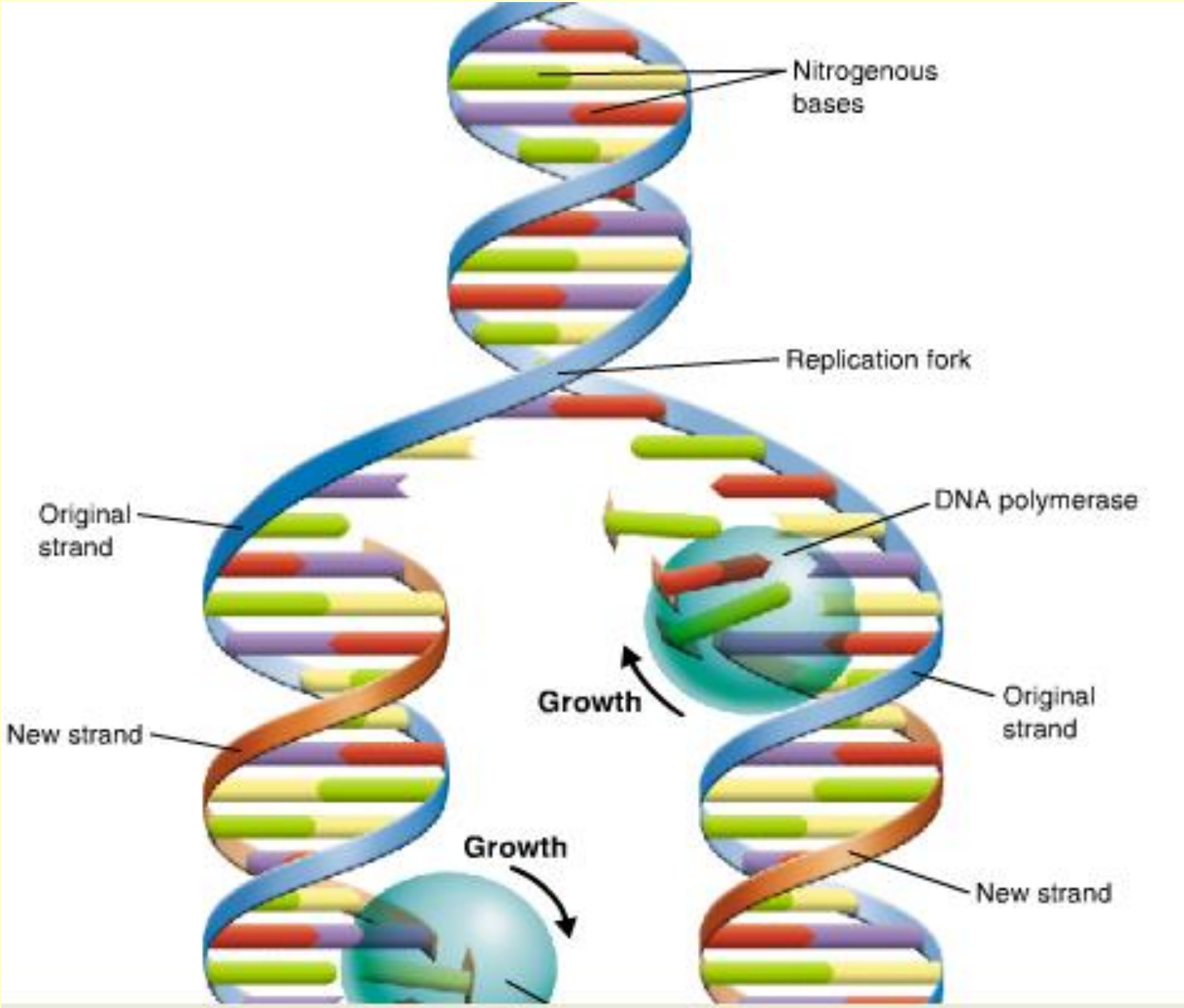
3. Copying happens in _opposite__ directions along the two strands & in _multiple places at once.
4. Each strand serves as a template for the attachment of complementary bases

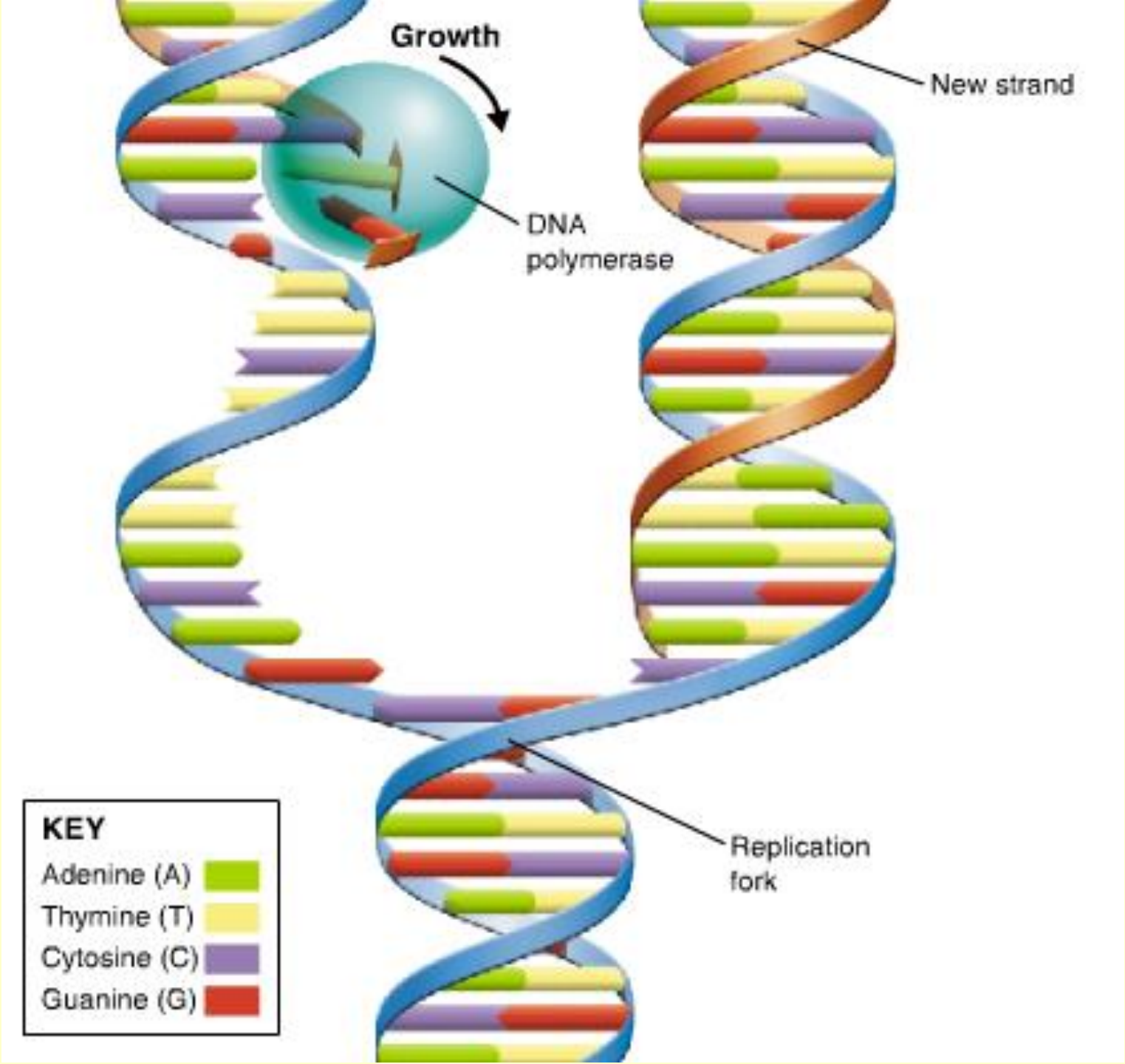
- DNA to DNA animation

Sites where strand separation and replication occur are called replication forks

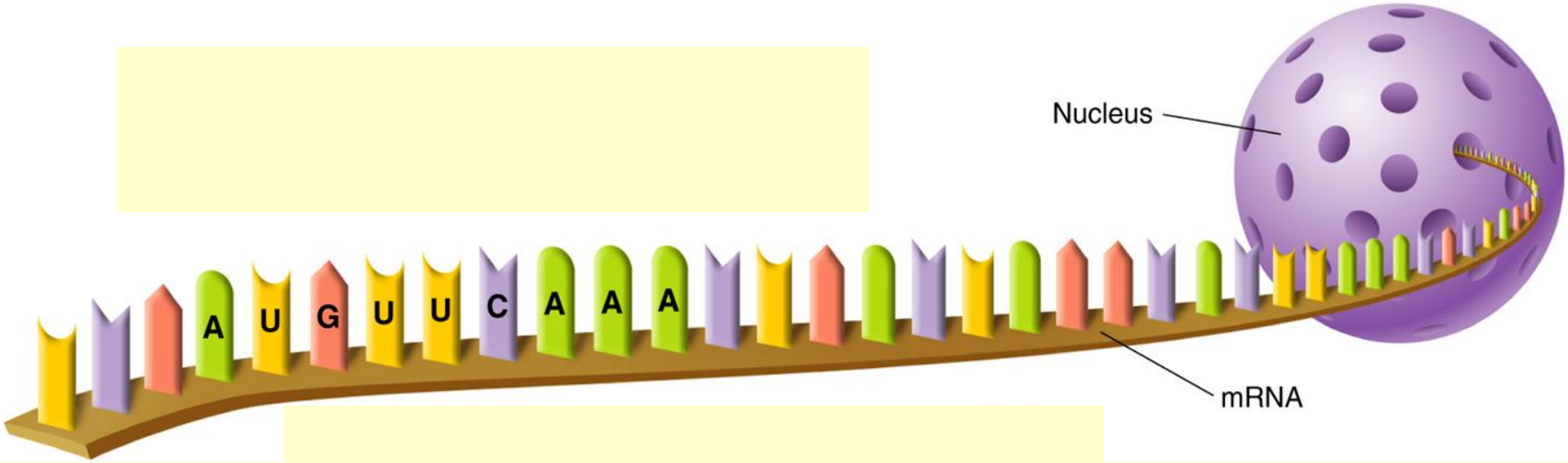
Section 12-2


New strand
Original strand
DNA polymerase
DNA polymerase
Growth
Growth
Replication fork
Replication fork
Nitrogenous bases
New strand
Original strand


Nitrogenous bases
Replication fork
Original strand
DNA polymerase
Growth
Original strand
New strand
Growth
New strand


Growth
New strand
DNA
polymerase
Replication
fork
KEY
Adenine (A)
Thymine (T)
Cytosine (C)
Guanine (G)

RNA and PROTEIN SYNTHESIS 12-3



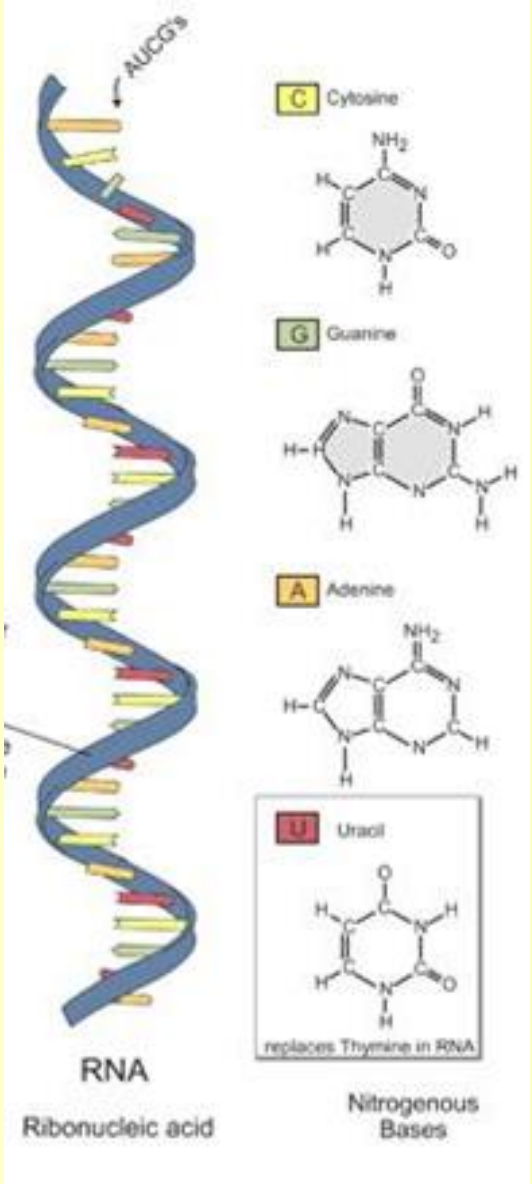
RNA- the Other Nucleic Acid

Also made of NUCLEOTIDES

Sugar is RIBOSE instead of deoxyribose.

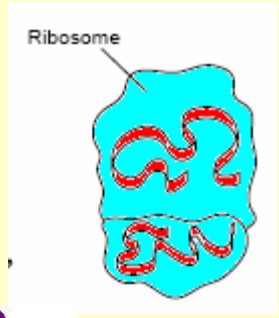
RNA is SINGLE stranded

Contains URACIL instead of thymine.

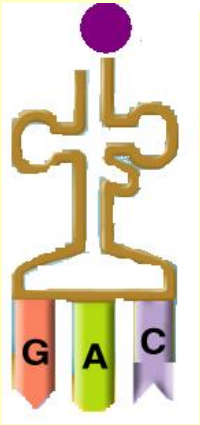


3 KINDS OF RNA HELP WITH INFO TRANSFER FOR PROTEIN SYNTHESIS

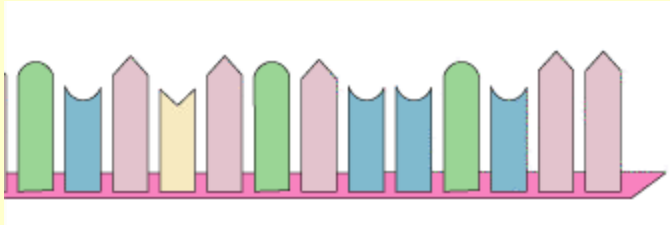
RIBOSOMAL RNA (rRNA)
Combines with proteins to form ribosomes



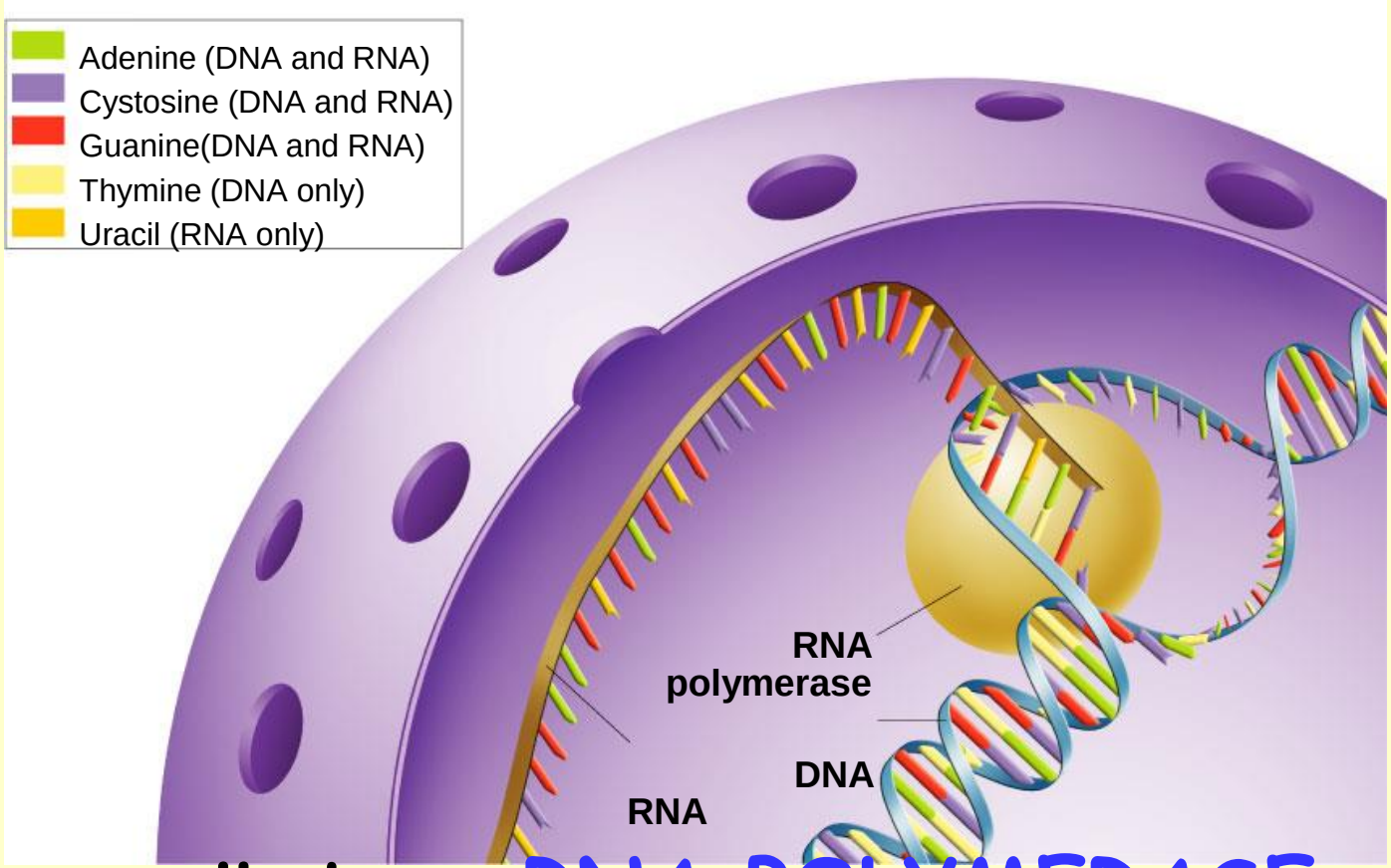
TRANSFER RNA (tRNA)
Matches m-RNA codon to add correct amino acids during protein synthesis



MESSENGER RNA (mRNA)
carries code from DNA to ribosomes



Transcription



Enzyme called RNA POLYMERASE separates DNA strands, then uses one strand as a template to assemble an RNA copy.

How does RNA POLYMERASE know where a gene starts and stops?

Enzyme binds to places with specific DNA sequences called PROMOTERS.

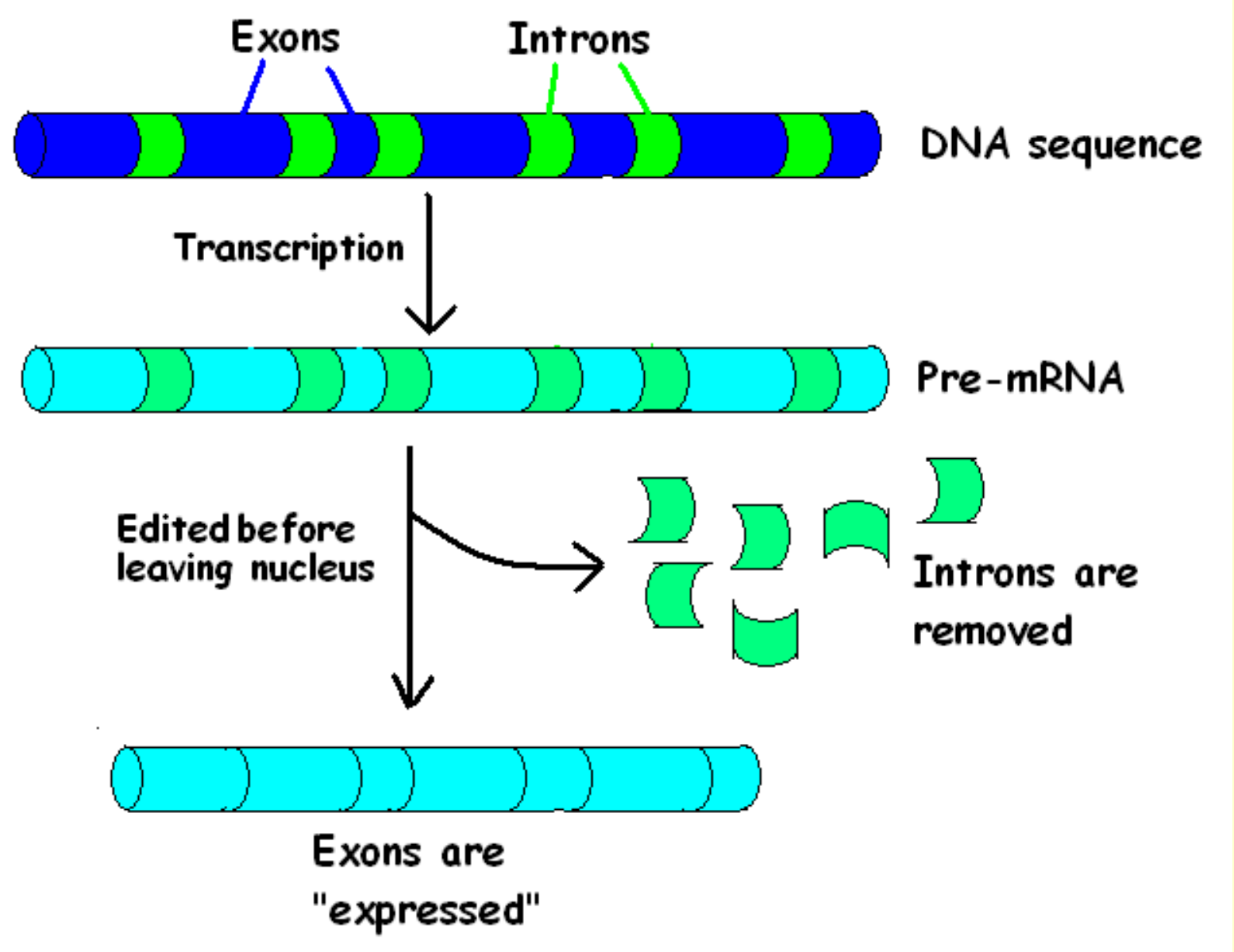
PROMOTERS tell RNA POLYMERASE where to start.

Signals at the end of the gene code cause transcription to stop.

RNA's require EDITING before use

Many RNA molecules from eukaryotic genes have sections, called _introns_ edited out of them, because they are not needed to produce a protein, before they become functional. The remaining DNA sequences that code for proteins , called, _exons_ are spliced together.

RNA's require EDITING before use



WHY WASTE IT?

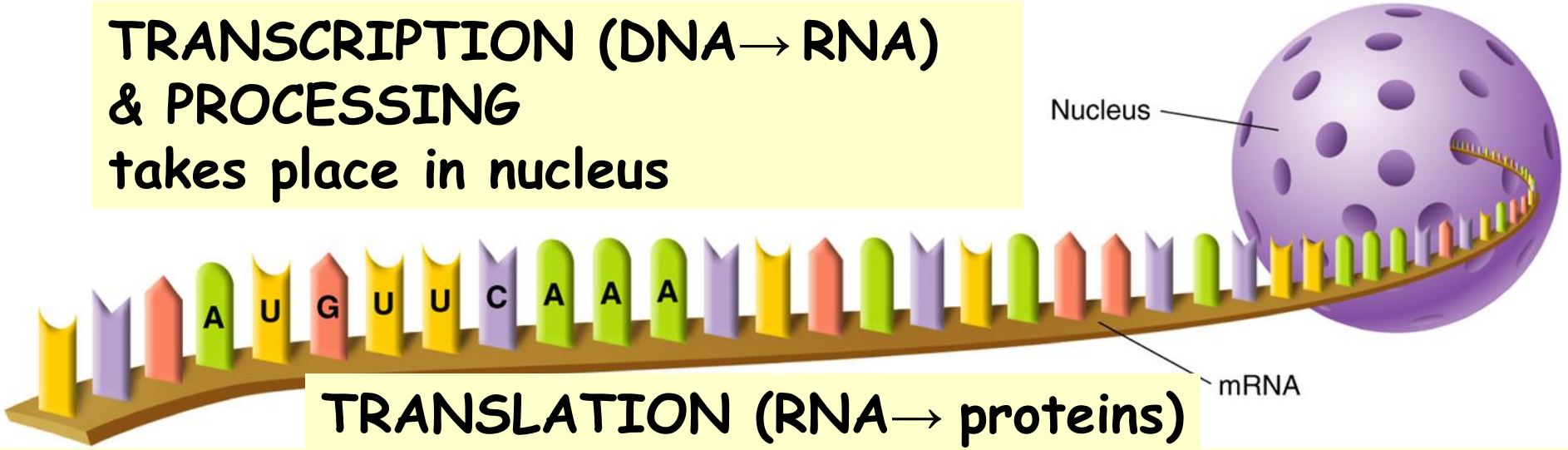
Why spend energy making a large RNA and then throw parts away?

It makes it possible for a single gene to produce several different forms of RNA.

May have a role in evolution… allows small changes in DNA to have a big effect.

MASTER PLAN
DNA stays safe in nucleus

TRANSCRIPTION (DNA→ RNA)
& PROCESSING
takes place in nucleus



TRANSLATION (RNA→ proteins)
takes place on ribosomes
in cytoplasm

"Blueprints" of master plan are carried to building site

The Genetic Code

The genetic code is the "language" of mRNA instructions.

The code is written using four "letters" (the bases: A, U, C, and G).

HOW CAN JUST 4 BASES GIVE DIRECTIONS TO MAKE 20 AMINO ACIDS?

Message is read in groups of 3 = CODON

UCGCACGGU

UCG-CAC-GGU

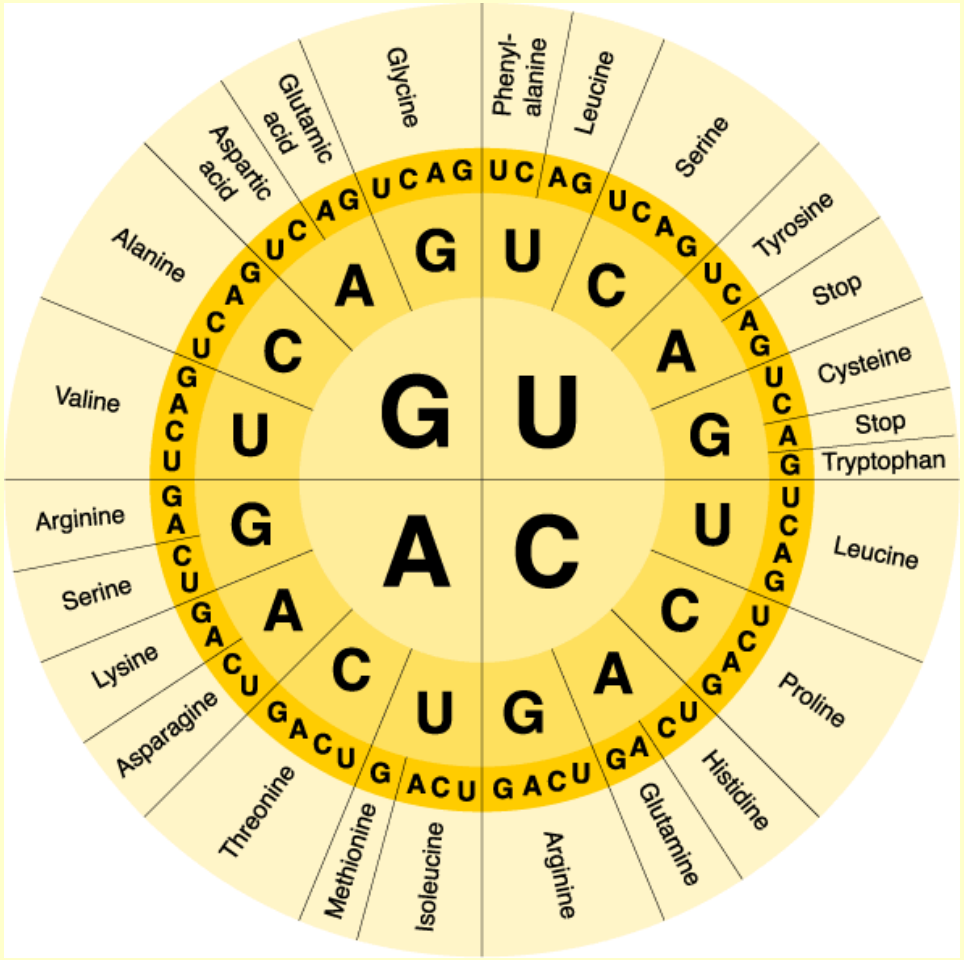
Serine - Histidine - Glycine

Codons are groups of three nucleotides on messenger RNA that specify a particular amino acids

The m-RNA Code

Section 12-3

64 possible codons



Some amino acids have more than one codon.

START= _____

AUG

3 codons for _____

STOP

ANTICODON

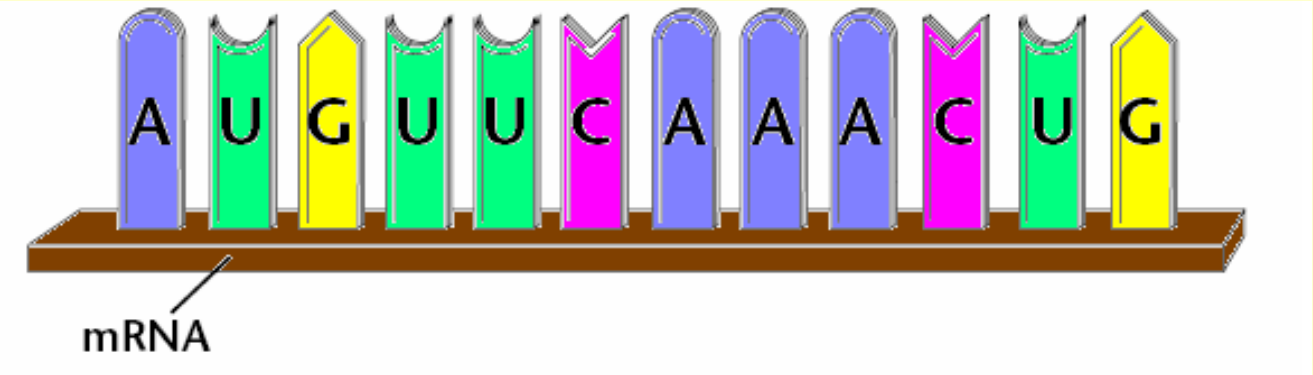
on tRNA

EACH tRNA carries only one kind of amino acid

matches up with

CODON

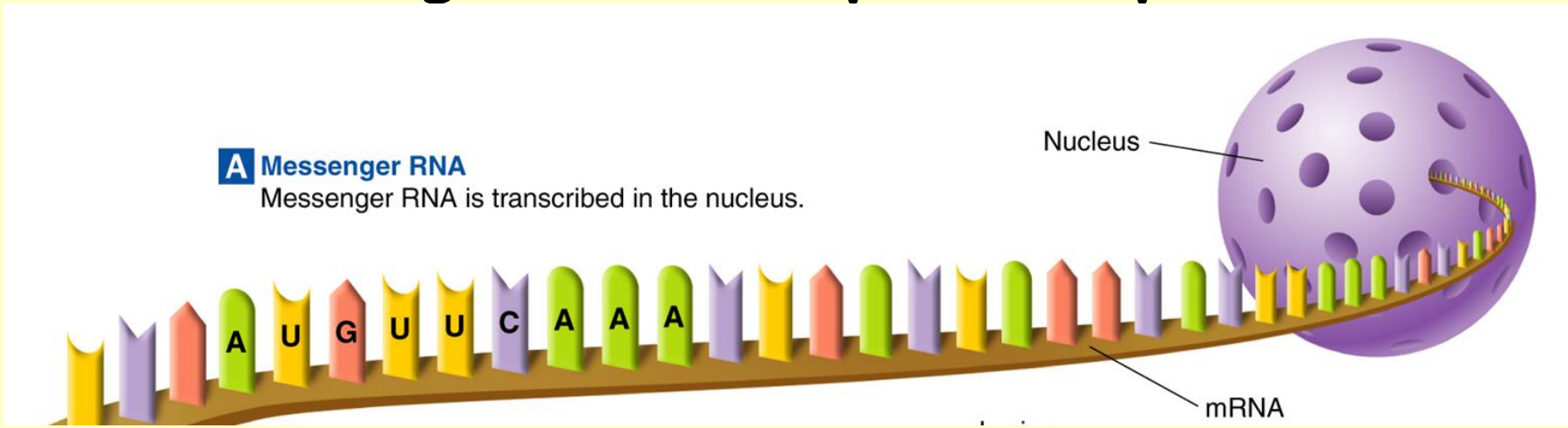
on mRNA



Translation

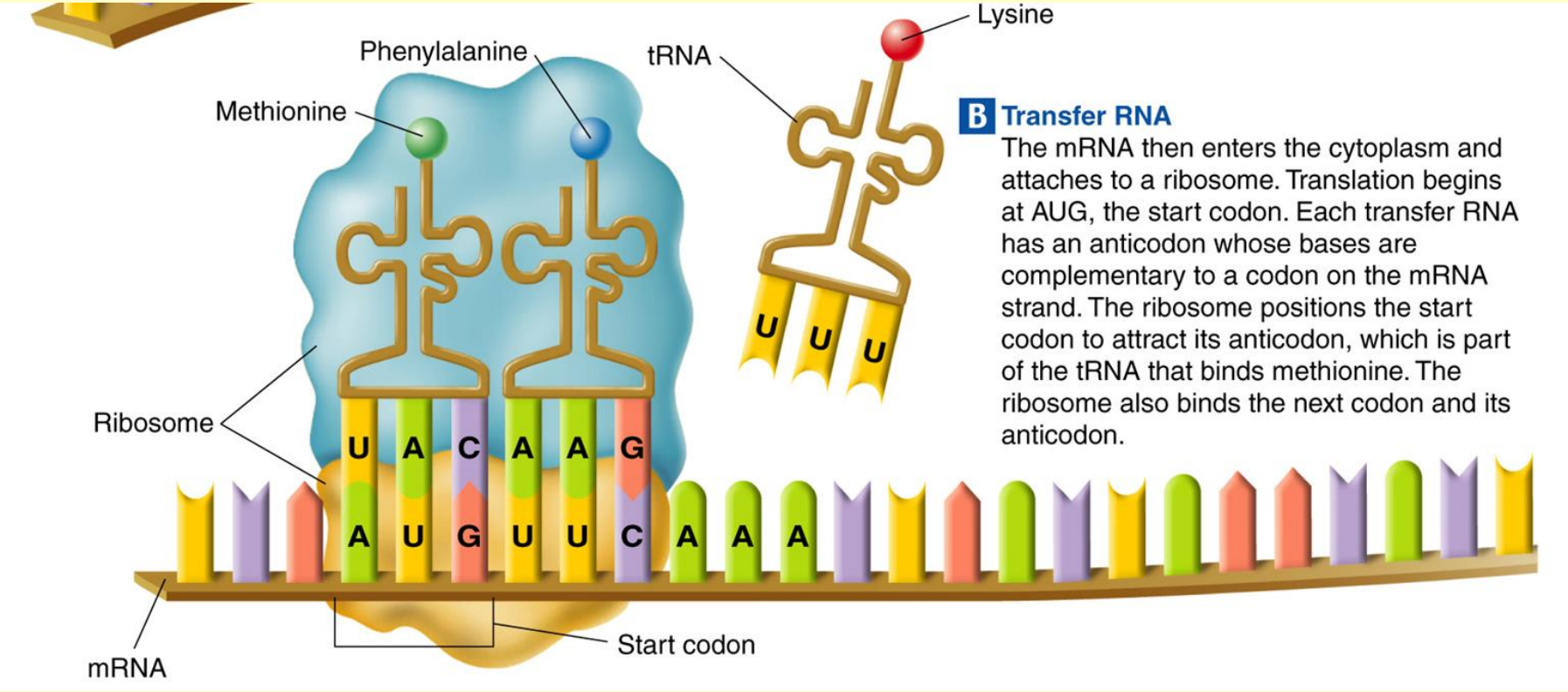
Translation is the decoding of an mRNA message into a polypeptide chain (protein).Translation takes place on ribosomes. The cell uses all three forms of RNA during this process.

During translation, the cell uses information from messenger RNA to produce proteins.

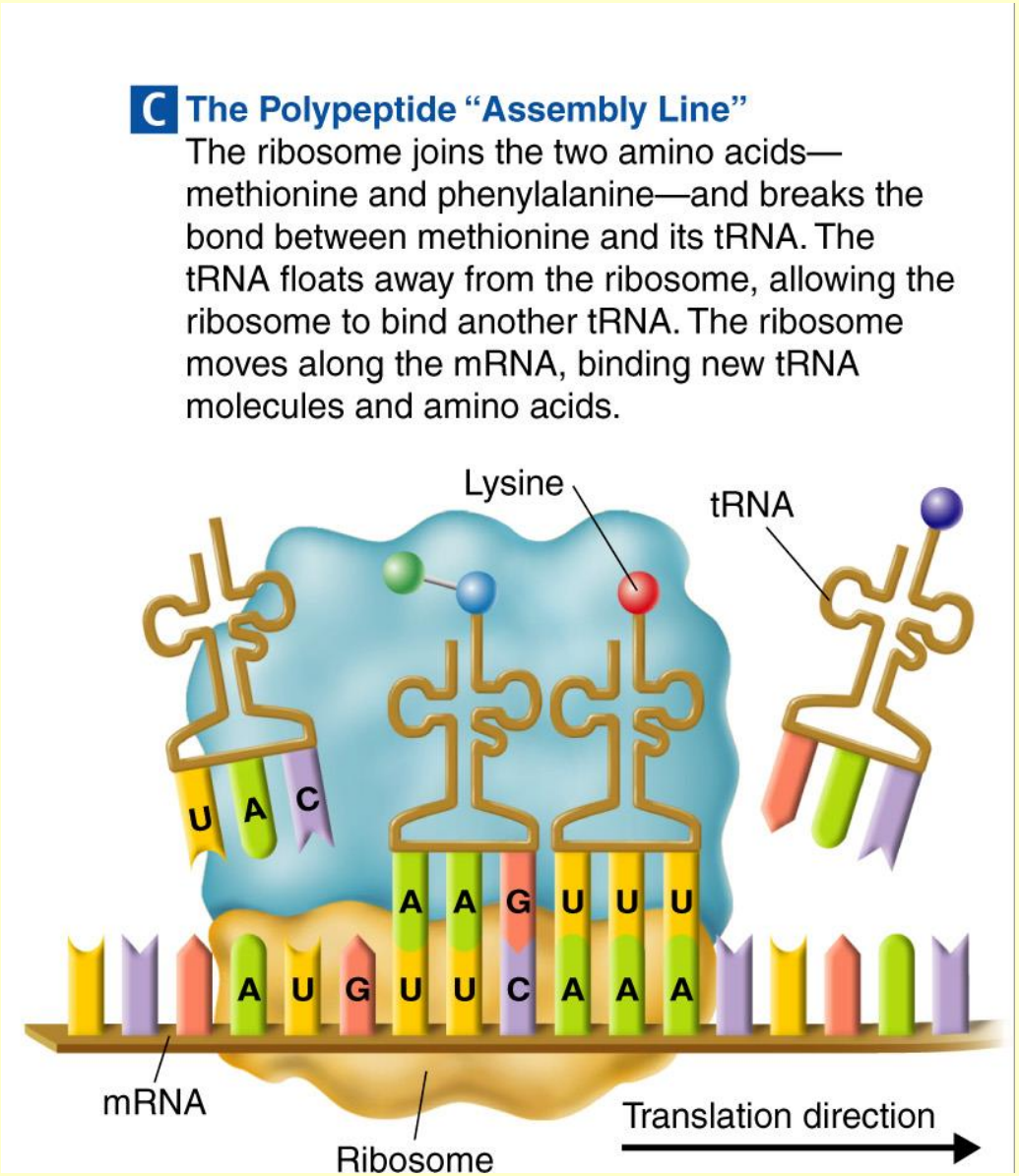


Translation

The ribosome binds new tRNA molecules and amino acids as it moves along the mRNA



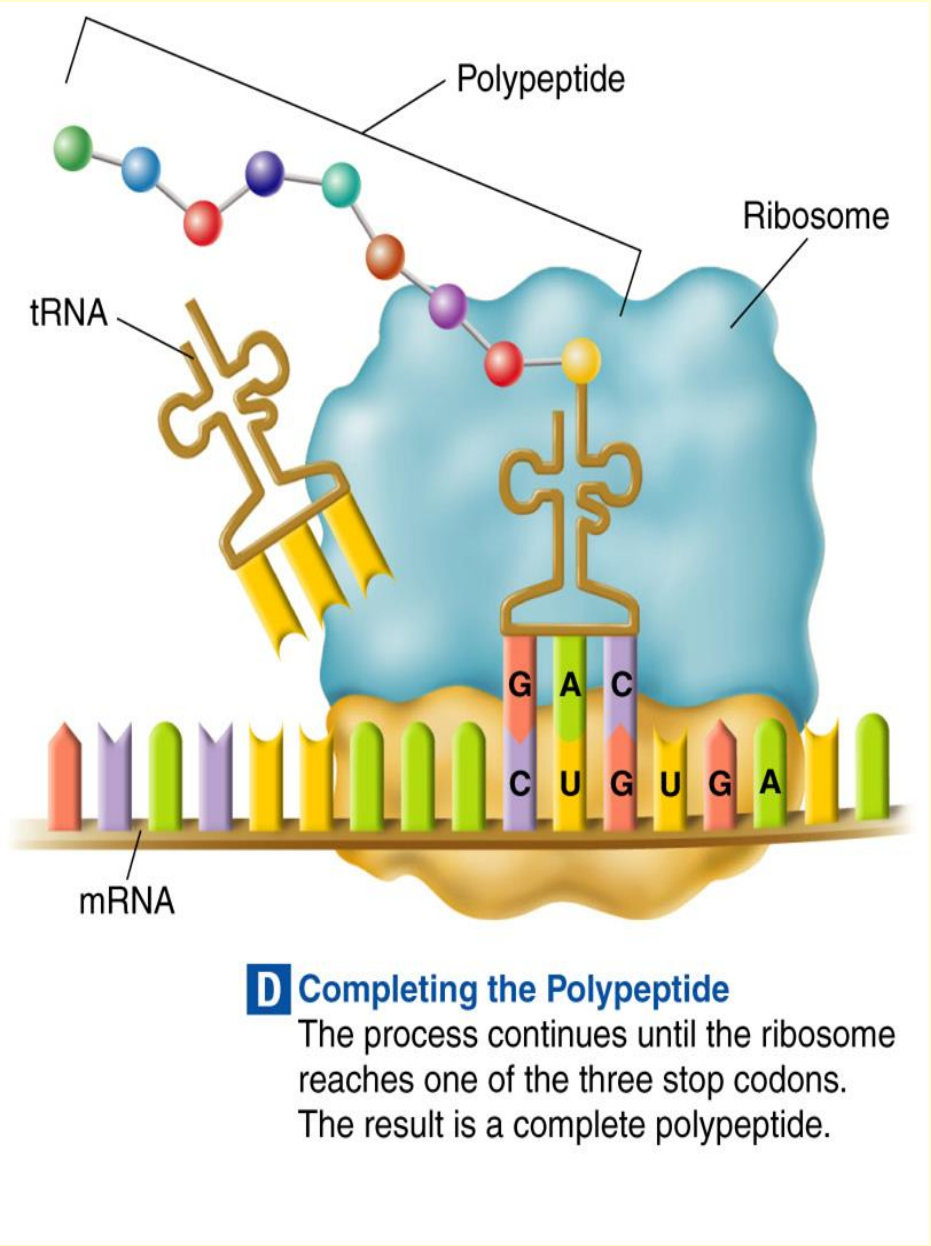
Translation



The ribosome will continue to bind new tRNA molecules and amino acids

Translation

The process continues until the ribosome reaches a stop codon



D Completing the Polypeptide
The process continues until the ribosome reaches one of the three stop codons. The result is a complete polypeptide.

Genes and Proteins

DNA

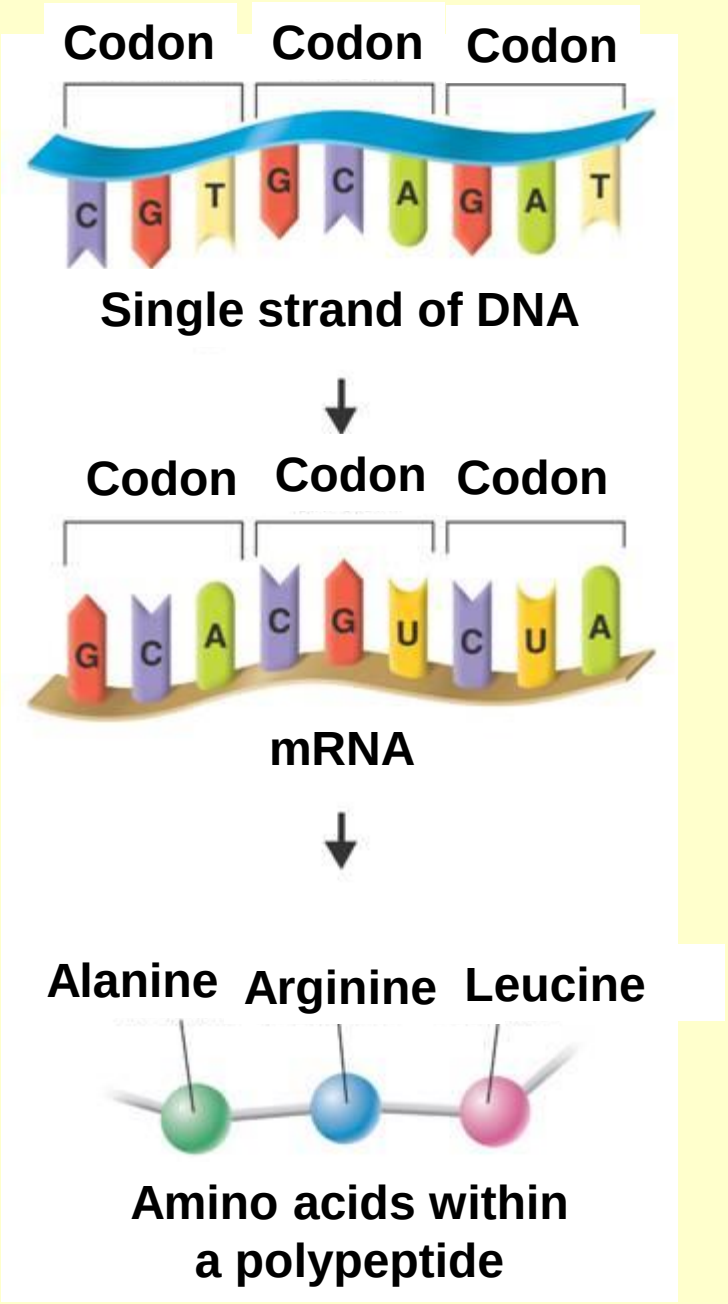
↓

mRNA

↓

Protein

This diagram illustrates how information for specifying the traits of an organism is carried in DNA. The sequence of bases in DNA is used as a template for mRNA. The codons of mRNA specify the sequence of amino acids in a protein, and proteins play a key role in producing an organism's traits.



DNA → DNA REPLICATION

DNA → RNA TRANSCRIPTION

RNA → Protein TRANSLATION

CENTRAL DOGMA OF BIOLOGY

How is information passed?

DNA → RNA → PROTEIN

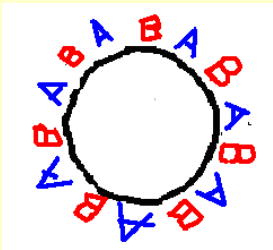
Then the protein "DOES SOMETHING" that shows up as a trait

GENES & PROTEINS

Proteins are the connection between the gene code in the DNA and how that gene is expressed.

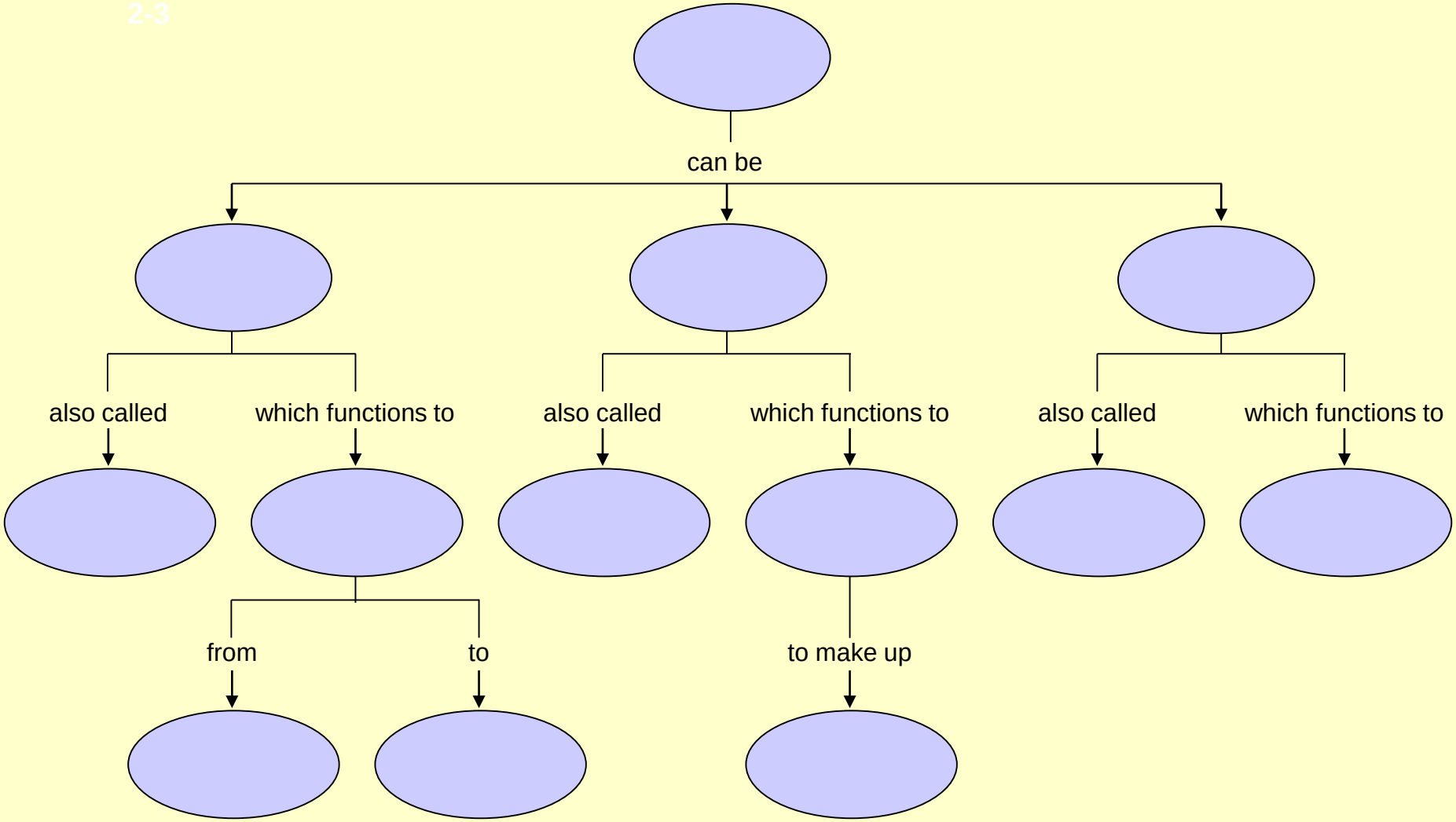
A gene that codes for an enzyme (protein) to make a pigment can control the color of a flower.

A gene that codes for an enzyme (protein) adds carbohydrates to glycoproteins to produce your blood type.

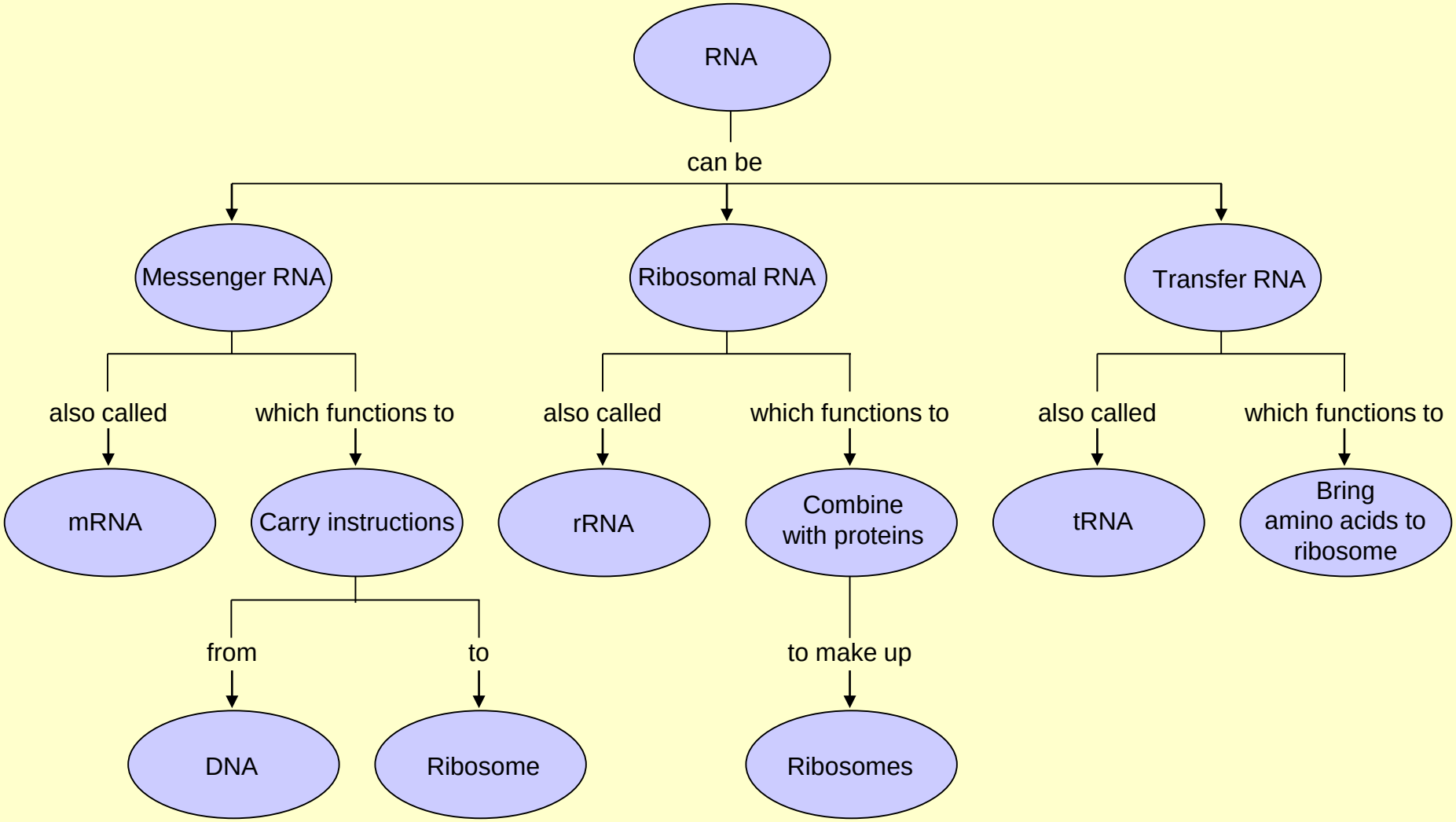


Enzymes catalyze and regulate chemical reactions so proteins build and operate all cell components.

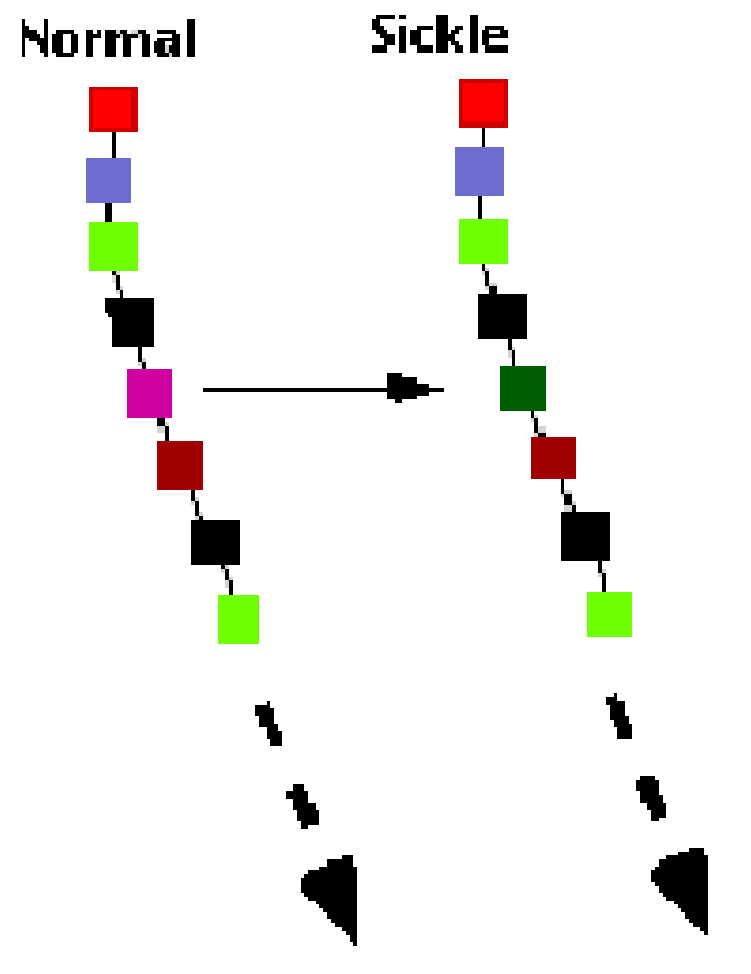
Concept Map


can be
also called
which functions to
also called
which functions to
also called
which functions to
from
to
to make up

Concept Map


RNA
can be
Messenger RNA
Ribosomal RNA
Transfer RNA
also called
which functions to
also called
which functions to
also called
which functions to
mRNA
Carry instructions
rRNA
Combine with proteins
tRNA
Bring amino acids to ribosome
from
to
to make up
DNA
Ribosome
Ribosomes

MUTATIONS
12-4



REMEMBER!

MUTATIONS are changes in the genetic material.

Mutations can happen when cells make mistakes in copying their own DNA or be caused by radiation or chemicals in the environment.

KINDS OF MUTATIONS

Mutations that produce changes in a single gene = GENE MUTATIONS

Mutations that produce changes in whole chromosomes = CHROMOSOMAL MUTATIONS

GENE MUTATIONS

Mutations involving One or a few nucleotides = Point mutation because they occur at a single point in the DNA sequence.

TYPES OF POINT MUTATIONS:

- substitutions
- deletions
- insertions

SUBSTITUTION

Changes one base for another

A T T C G A G C T

A T T C T A G C T

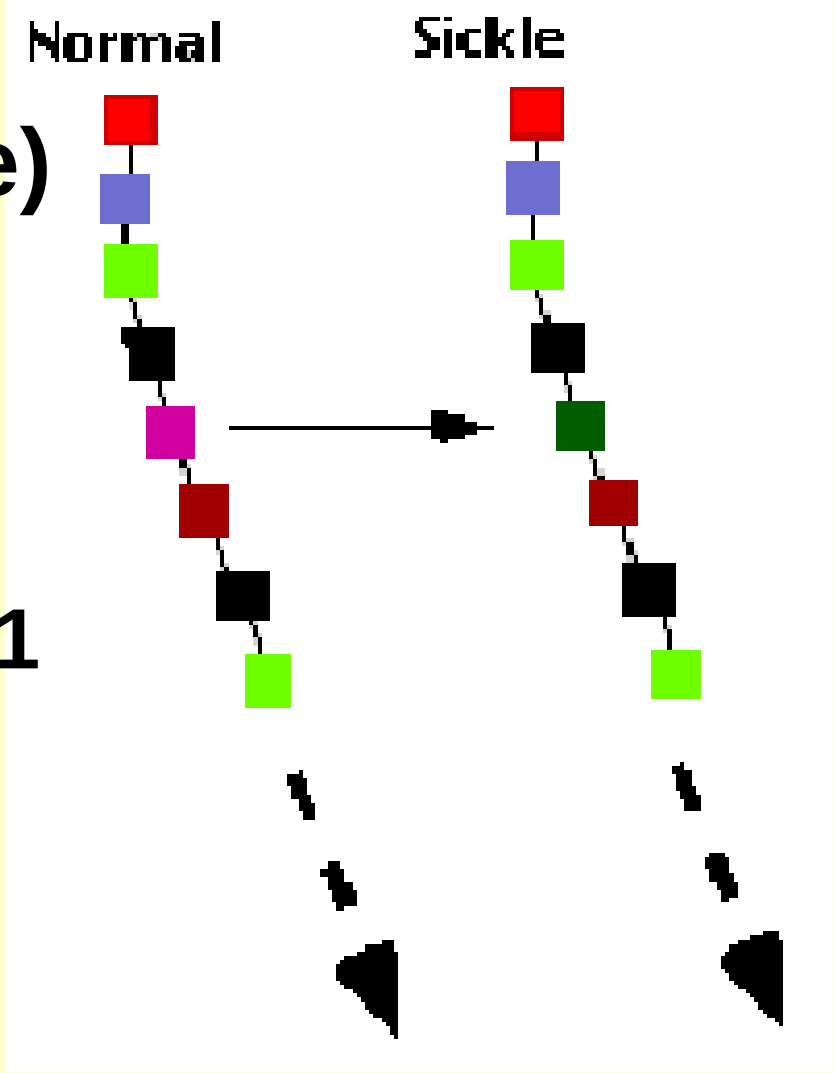
SICKLE CELL ANEMIA

CAUSE:

(autosomal recessive)

A changed to T

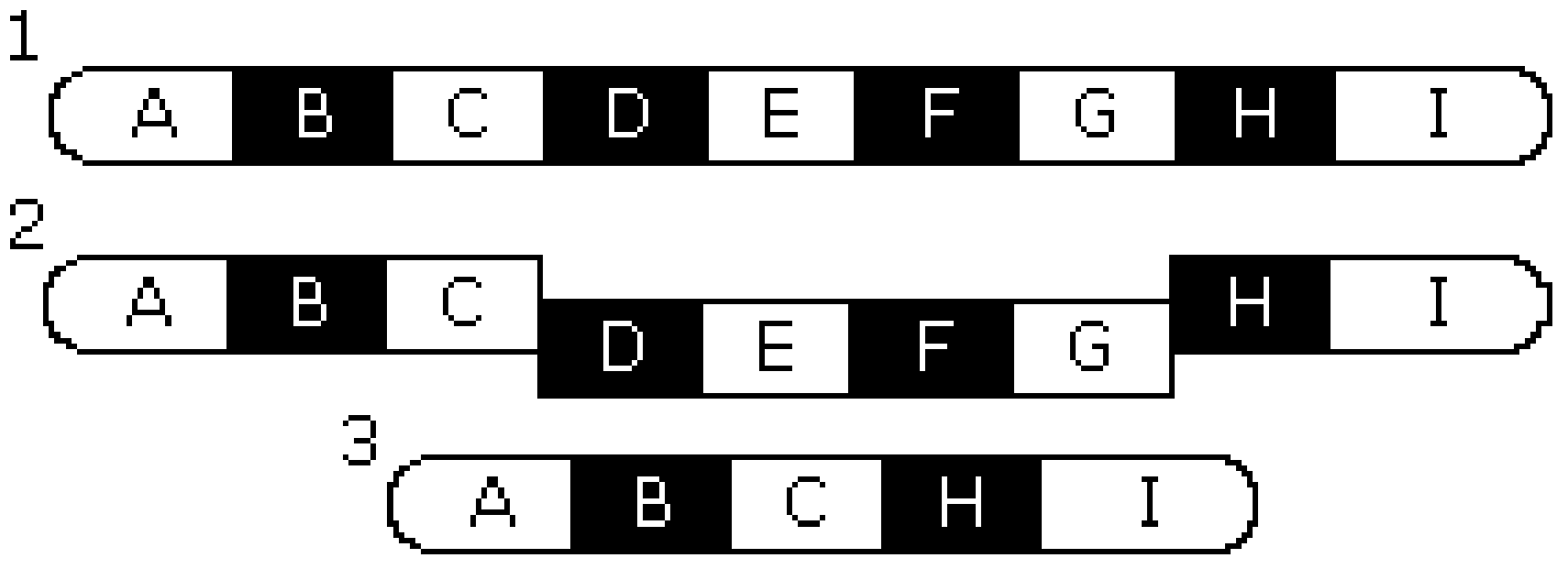
(glu to val)



gene on chromosome #11 that codes for part of hemoglobin protein (carries oxygen in blood)

DELETION

Piece of DNA code for one gene is lost



Duchenne Muscular Dystrophy

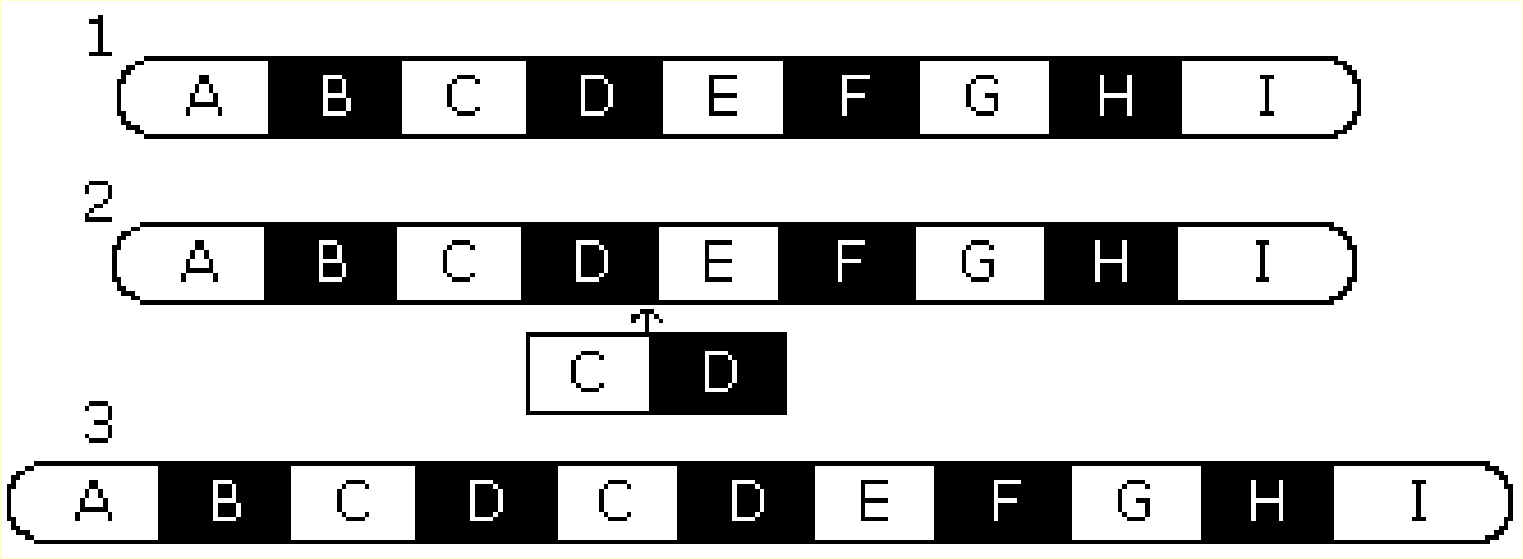
<u>CAUSE</u>:

(X linked recessive)

DELETION in gene that codes for a muscle protein

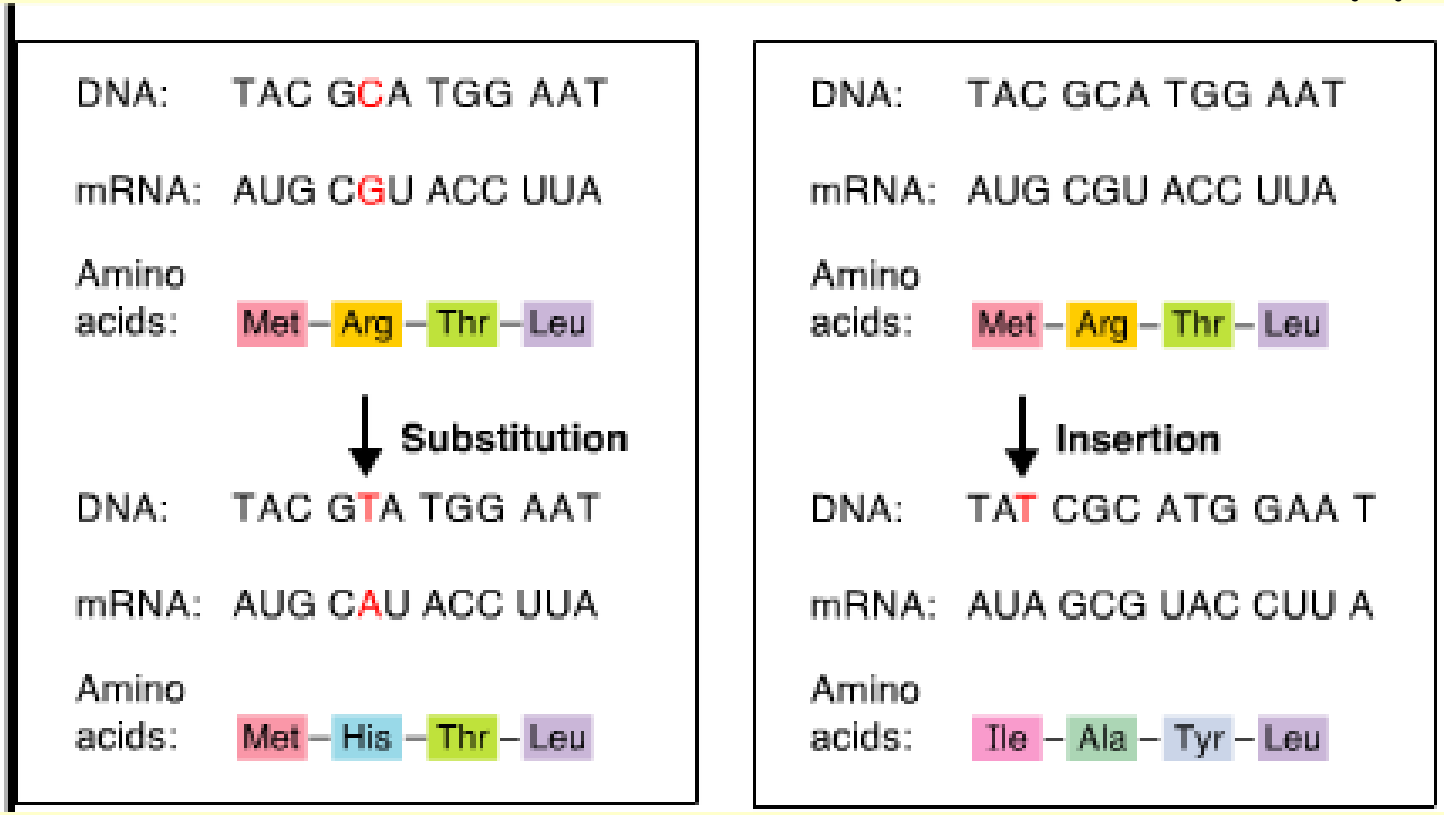
INSERTION

Piece of DNA is copied too many times



GENE MUTATIONS

Substitutions usually affect no more than a single ___Amino acid___, but deletions and insertions can have a more dramatic effect.



FRAME SHIFT MUTATIONS

Change multiple bases in code

thefatcatatetherat

the fat cat ate the rat

INSERTION

thefatcatateateateatetherat

the fat cat ate ate ate ate the rat

DELETION

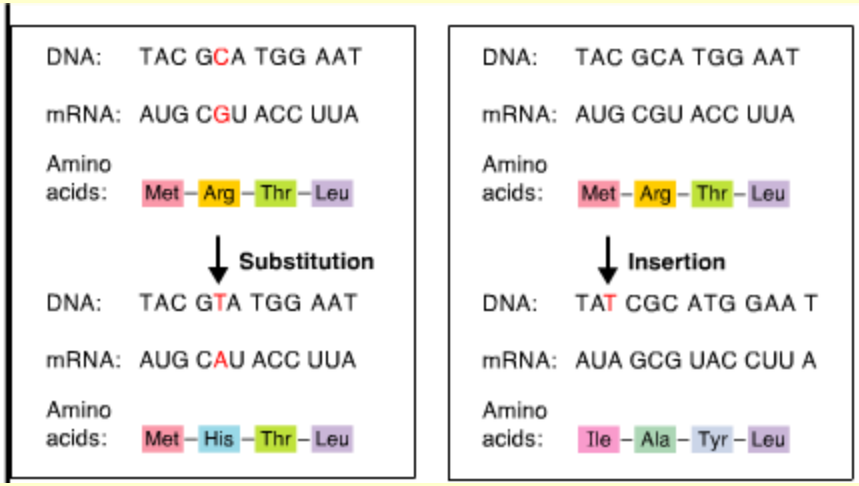
thefatcatatetherat

the fat ata tet her at

FRAME SHIFTS

Frame shift mutations change every Amino acid in the protein that follows the shift.

Frame shifts can alter a protein so much it is unable to function



Location of the shift is important!

AT BEGINNING

the fat cat ate the rat

the fac ata tet her at

AT END

the fat cat ate the rat

the fat cat ate thr at

MUTATIONS AT BEGINNING OF GENE DAMAGE MORE OF THE CODE!

CHROMOSOMAL MUTATIONS

Mutations involving changes in the

Number or structure

of whole chromosomes

TYPES OF CHROMOSOMAL MUTATIONS:

deletions

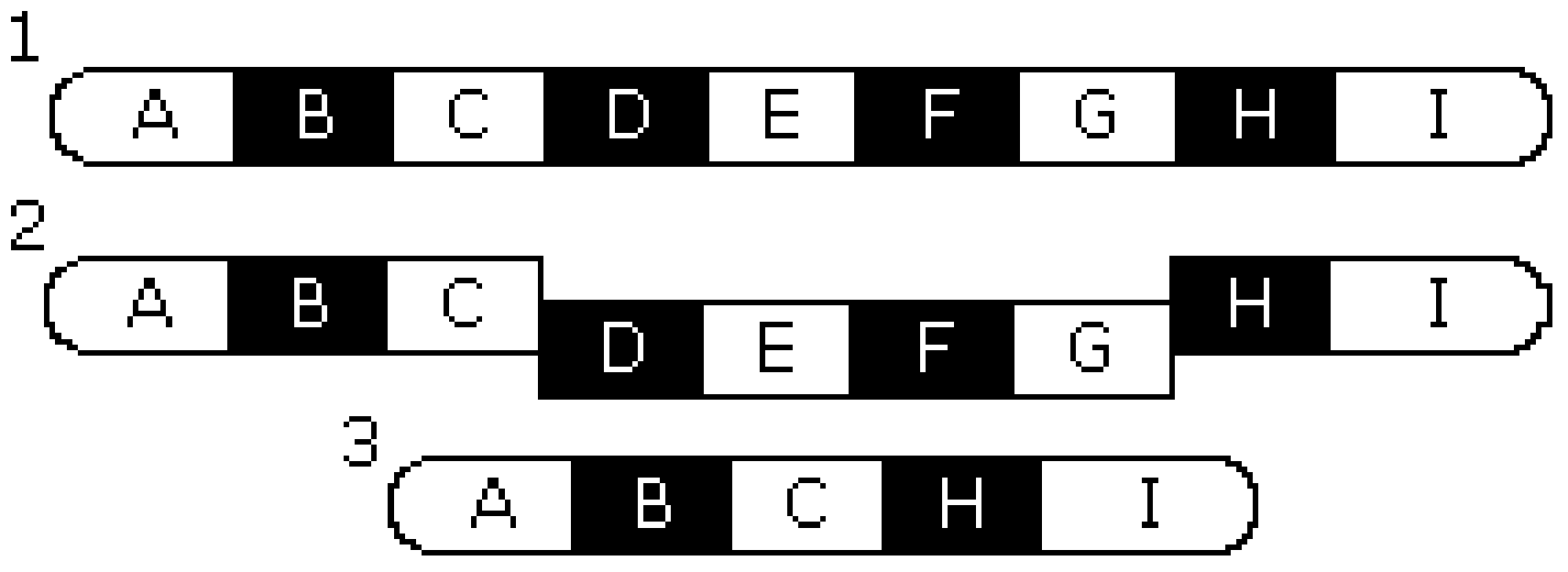
duplications

inversions

translocations

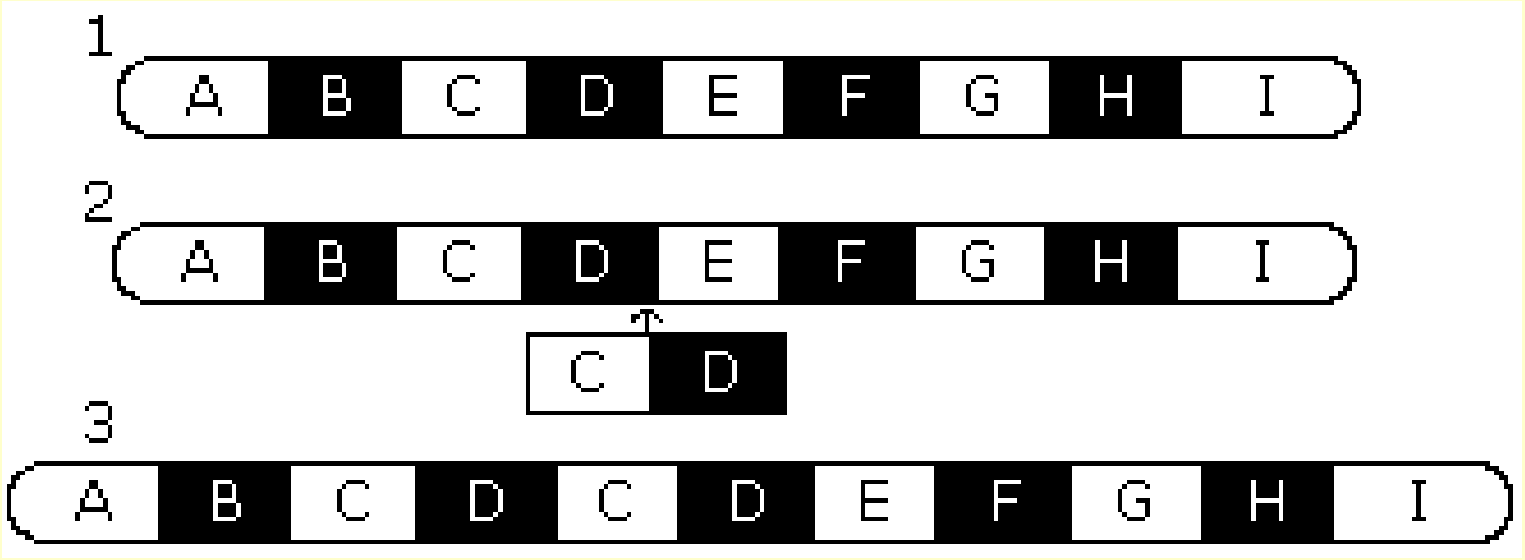
DELETION

Piece of chromosome is lost



DUPLICATION

Piece of DNA is copied too many times



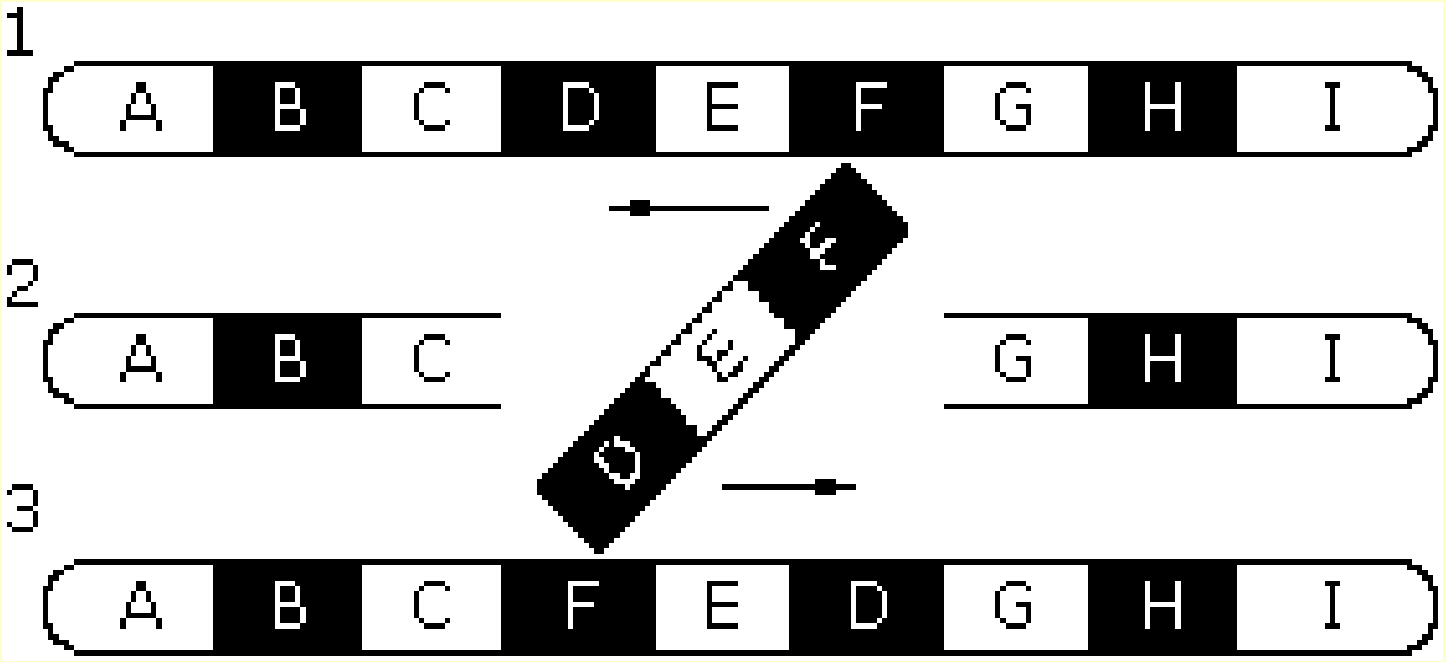
HUNTINGTON'S

- **Degenerative brain disorder**
- **Symptoms appear**

  age 30-40
- **Lose ability to walk, think, talk, reason**
- **Cause = ADDITION of extra CAG repeats**

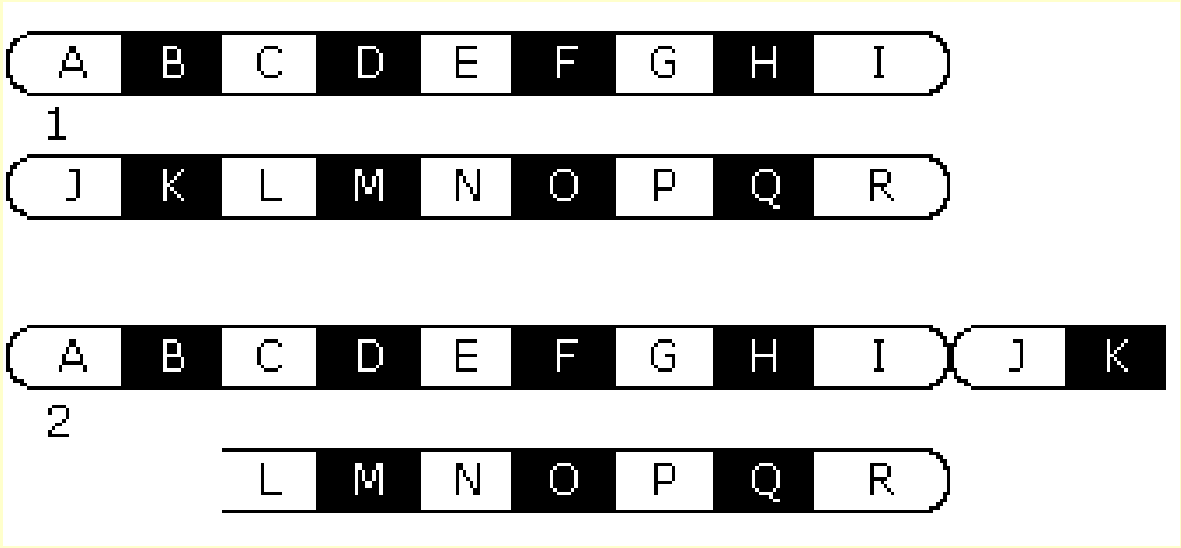
INVERSION

Segment flips and reads



TRANSLOCATION

Segment breaks off and joins a different non-homologous chromosome



MUTATIONS

Most mutations are neutral meaning they have little or no effect on gene function.

Mutations that cause defective proteins are usually HARMFUL

Harmful mutations are associated with many genetic disorders and can cause cancer

MUTATIONS

Mutations are also a source of Genetic variability and can be beneficial

Can help an organism Survive and reproduce

Provide variation in population for natural selection to act upon

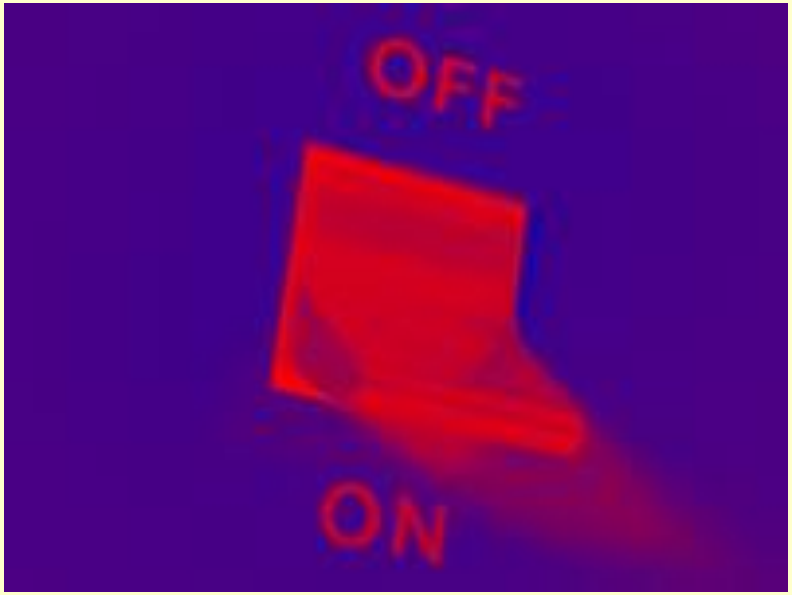
POLYPLOIDY

Condition in which an organism has extra sets of chromosomes
= POLYPLOIDY

LETHAL in humans, but beneficial in some plants.

Triploid (3N) or tetraploid (4N) plants are often larger and stronger than diploid plants.

GENE REGULATION
12-5



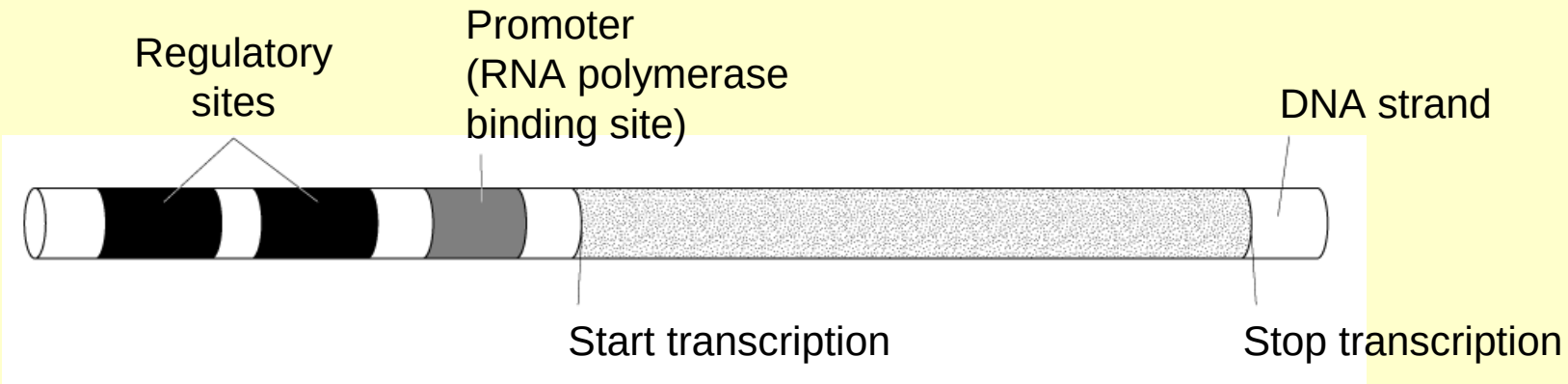
Only a fraction of genes in a cell are expressed (made into RNA) at any given time.

How does the cell decide which will be turned on and which will stay "silent"?

You already know about PROMOTER regions that show RNA polymerase where to start.

There are other REGULATORY SITES that control whether a gene is ON or OFF.

Typical Gene Structure



GAATTCTAATCTCCCTCTCAACCCTACAGTCACCCATTTGGTATATTAAAGATGTGTT
GTCTACTGTCTAGTATCCCTCAAGTAGTGTCAGGAATTAGTCATTTAAATAGTCTGCA
AGCCAGGAGTGGTGGCTCATGTCTGTAATTCCAGCACTGGAGAGGTAGAAGTGGG
AGGACTGCTTGAGCTCAAGAGTTTGATATTATCCTGGACAACATAGCAAGACCTCG
TCTCTACTTAAAAAAAAAAAAATTAGCCAGGCATGTGATGTACACCTGTAGTCCCAG
CTACTCAGGAGGCCGAAATGGGAGGATCCCTTGAGCTCAGGAGGTCAAGGCTGC
AGTGAGACATGATCTTGCCACTGCACTCCAGCCTGGACAGCAGAGTGAAACCTTG
CCTCACGAAACAGAATACAAAAACAAACAAACAAAAAACTGCTCCGCAATGCGCTT
CCTTGATGCTCTACCACATAGGTCTGGGTACTTT

Prokaryote Gene Regulation:lac Operon

- What is an Operon?
  - Group of Genes That Operate Together
- For Example:
  - E. coli ferments lactose
    - To Do That It Needs Three Enzymes (Proteins), It Makes Them All At Once!
      - 3 Genes Turned On & Off Together. This is known as the lac Operon (lactose Operon)

Gene Regulation: lac Operon

The lac Operon

- Regulates Lactose Metabolism
- It Turns On Only When Lactose Is Present & Glucose is Absent.

Lactose is a Disaccharide

- A Combination of Galactose & Glucose

To Ferment Lactose E. coli Must:

1. Transport Lactose Across Cell Membrane
2. Separate The Two Sugars

Gene Regulation: lac Operon

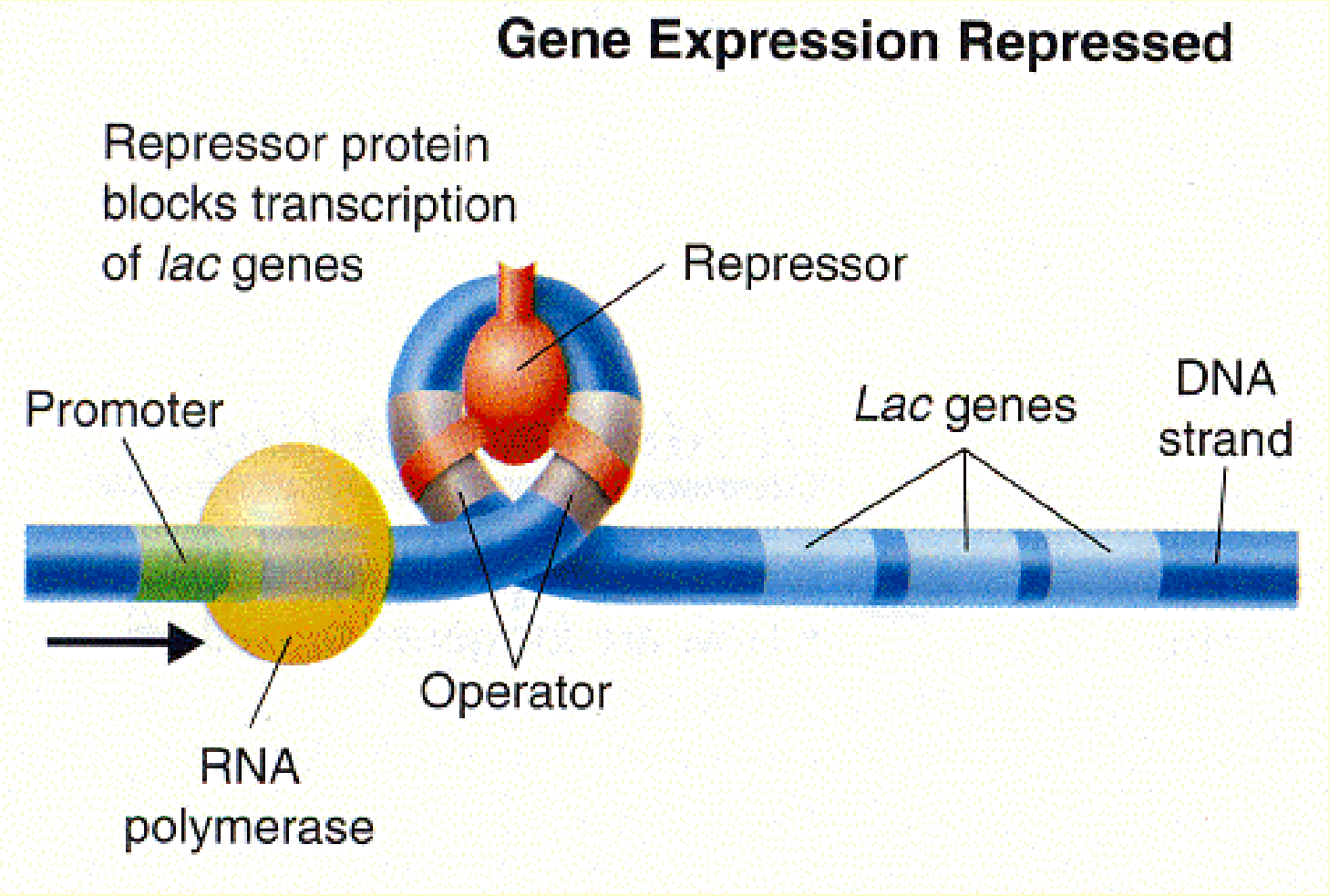
Each Task Requires A Specific Protein

but Proteins Not Needed If Glucose Present (why waste energy if you already have food?)

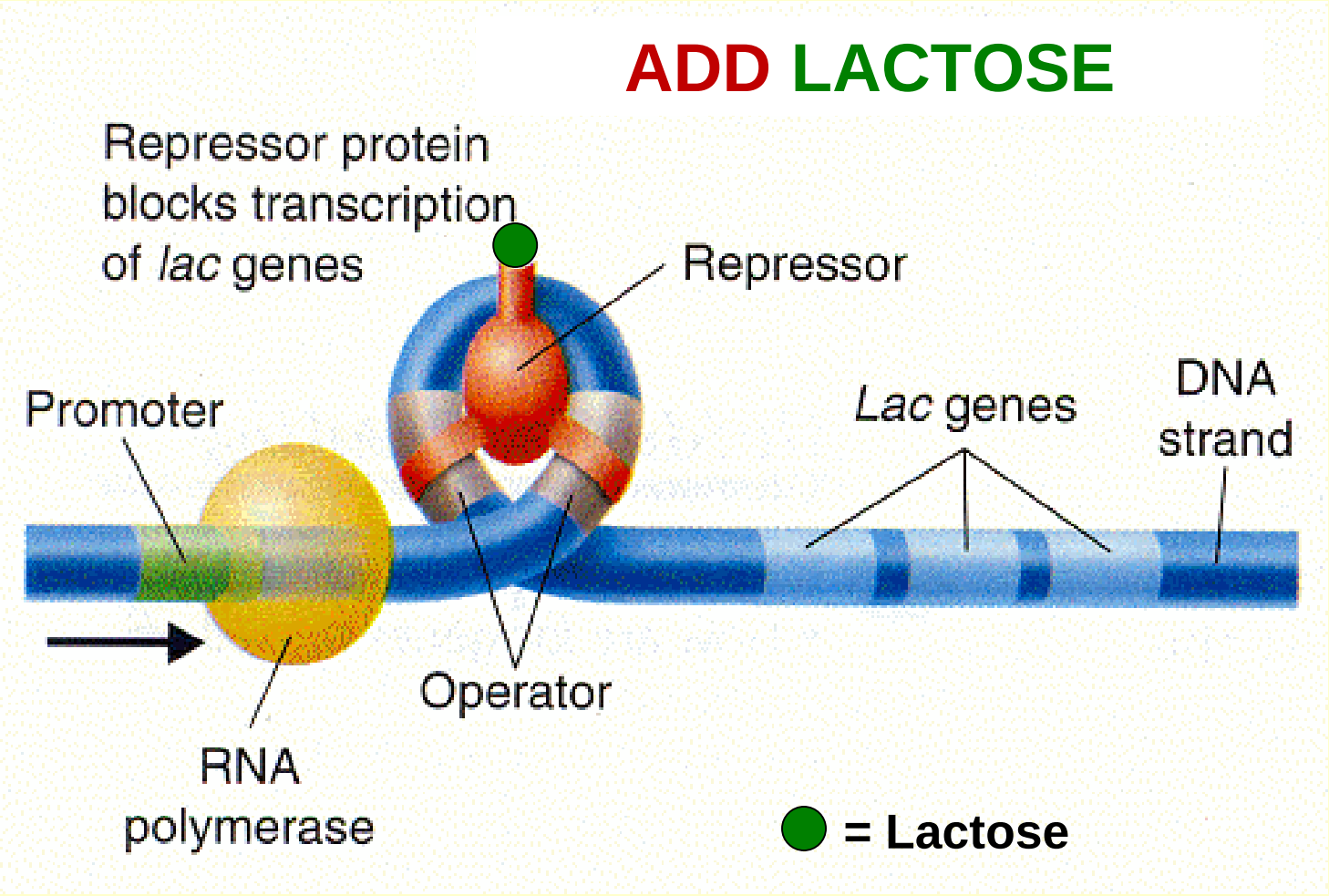
so

Genes Coding For Proteins Expressed Only When There Is No Glucose Present But Lactose Is Present

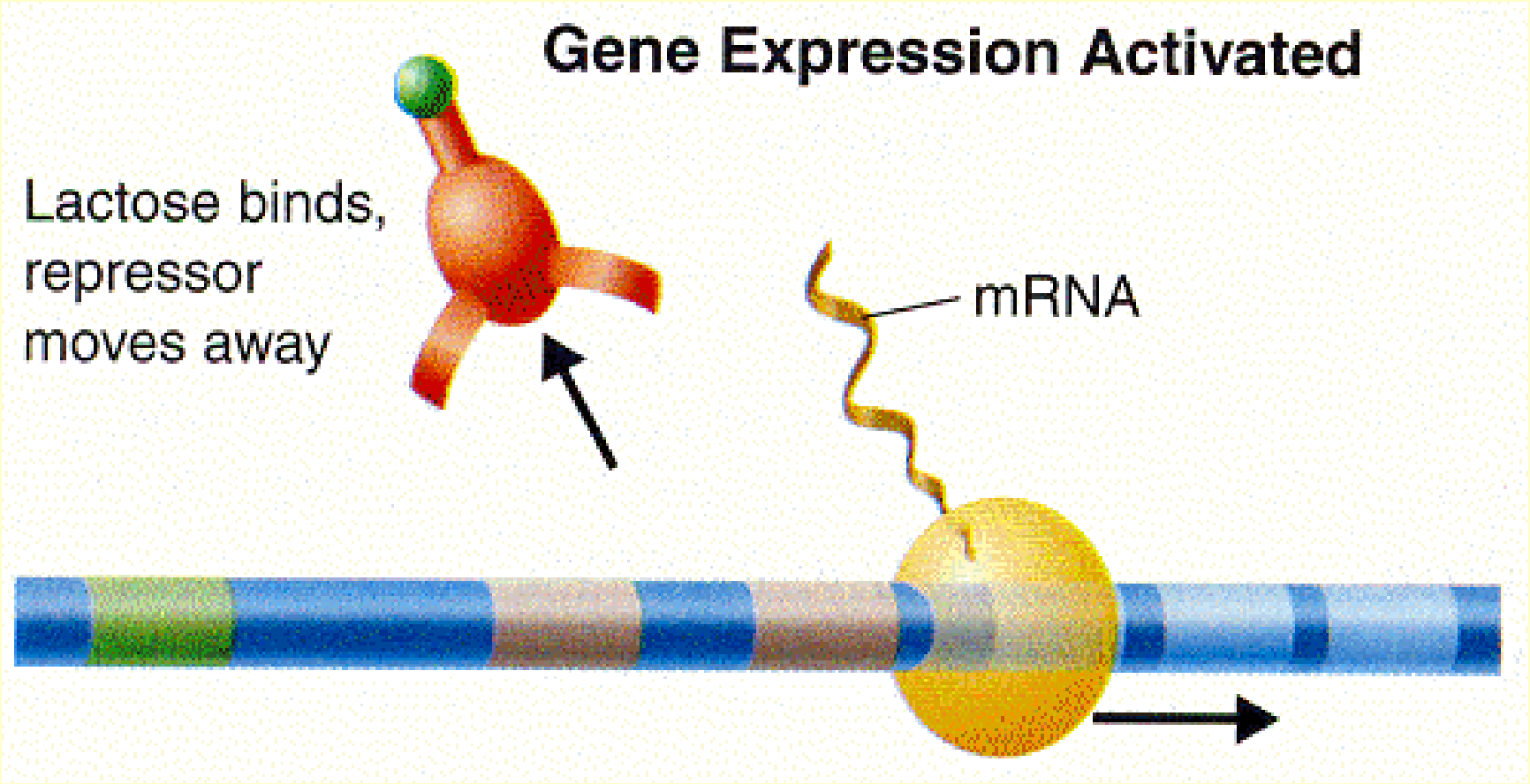
Gene Regulation: lac Operon



Gene Regulation: lac Operon



Gene Regulation: lac Operon



Gene Regulation: lac Operon

Key Concept:

The lac Genes Are:

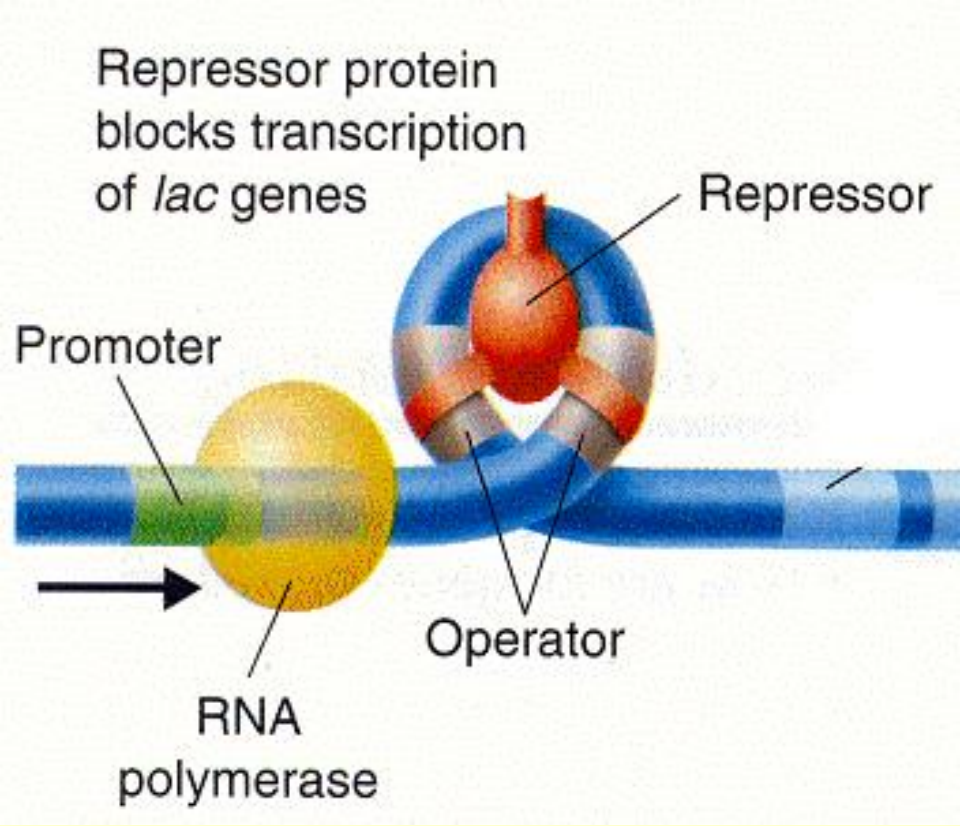
Turned Off By Repressors

And

Turned On By The Presence Of Lactose

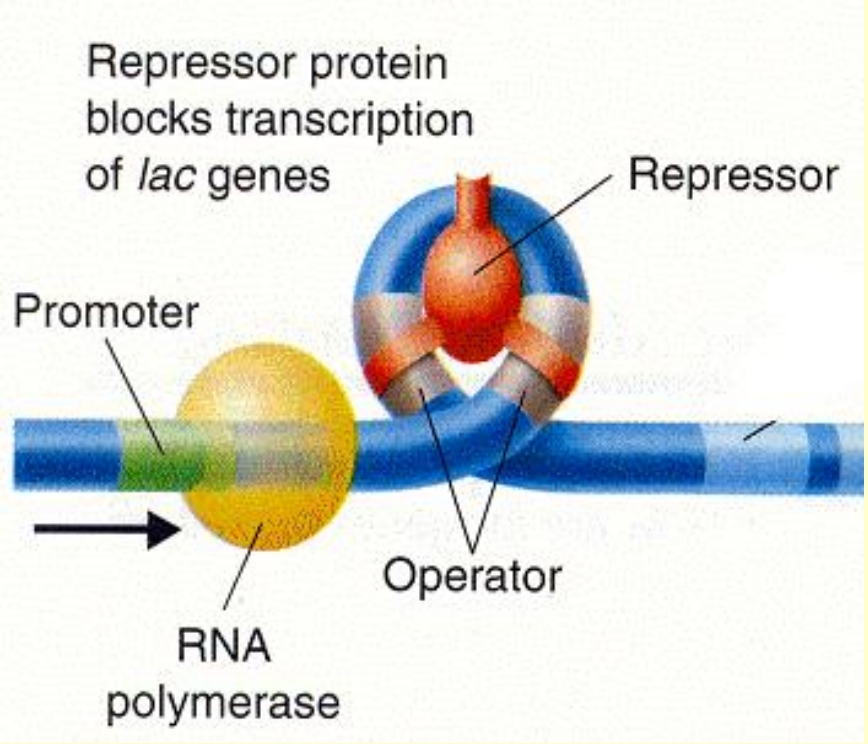
Gene Regulation: lac Operon

- Operon Has 2 Regulatory Regions
  - Promoter (RNA Polymerase Binding)
  - Operator (O region) Bound To A lac Repressor



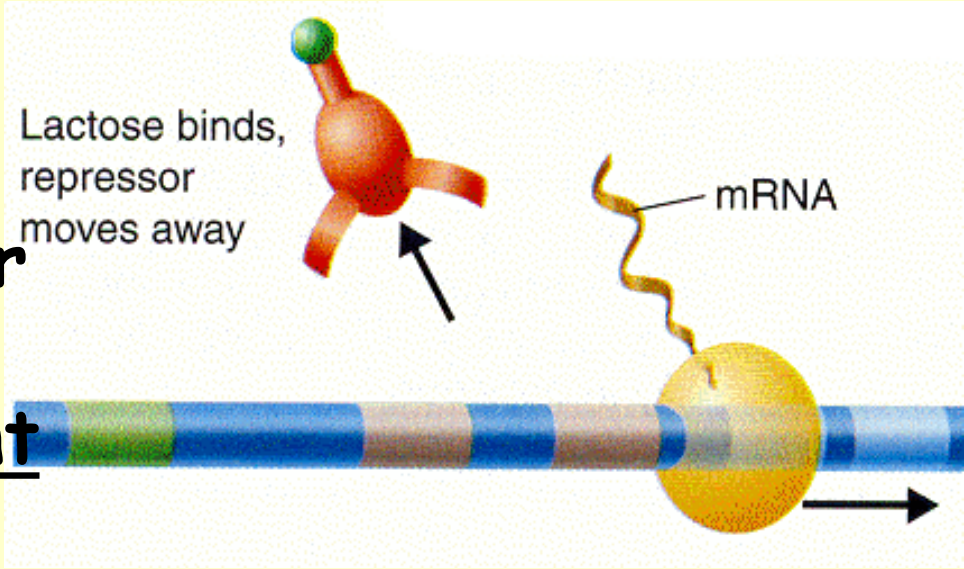
Gene Regulation: lac Operon

- lac Repressor
  - When Bound To O Region : Prevents Binding of RNA Polymerase To Promoter
  - Turns The Operon "OFF"



Gene Regulation: lac Operon

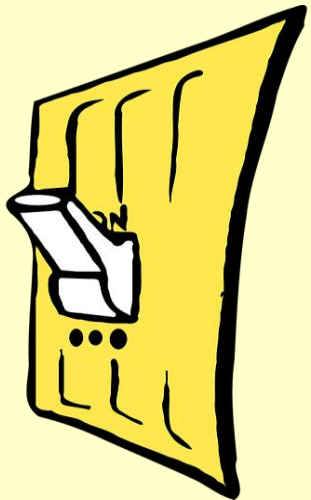
- lac Repressor Also Binds To Lactose
  - Higher Affinity For Lactose
- When Lactose Present lac Repressor Is Released From O Region
  - Allows Transcription of All Three Genes



Cells turn genes ON & OFF as needed

Many genes are regulated by ___REPRESSOR___ proteins that keep them turned off until needed.

Others use proteins that speed up ___transcription___ or affect ___protein synthesis___



Eukaryotic Gene Regulation

Operons Usually
NOT Found In Eukaryotes

Key Concept:

Most Eukaryotic Genes Are Controlled Individually And Have Regulatory Sequences That Are Much More Complex Than Prokaryotic Gene Regulation

EUKARYOTES are more COMPLEX

Additional regulatory sequences:

1. ENHANCER regions
   - upstream from promoters
   - bind many different regulatory proteins

Enhancer Sequences

- Series of Short DNA Sequences
- Many Types

Enormous Number Of Proteins Can Bind To Enhancer Sequences

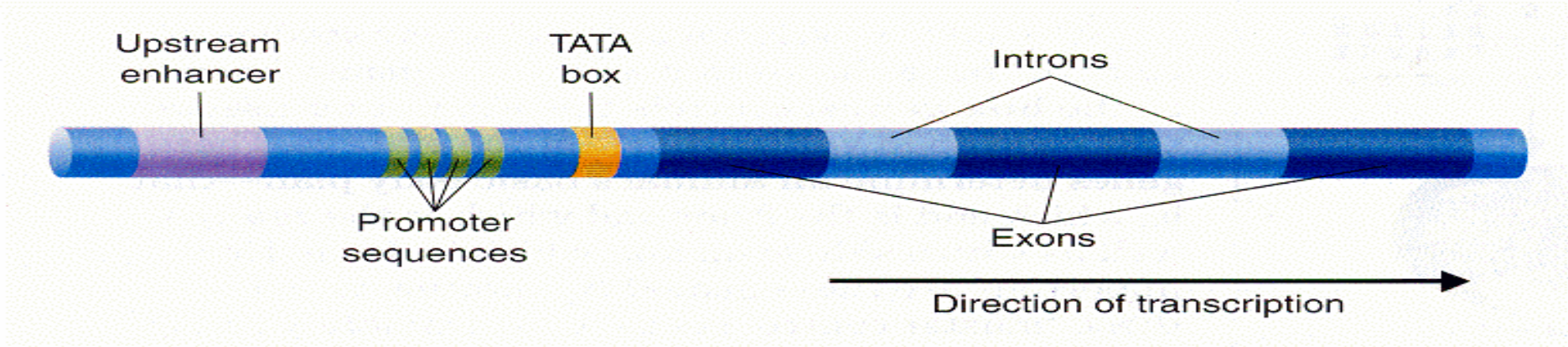
- Makes Eukaryote Enhancement Very Complex

Eukaryotic Promotors

- Some Enhance Transcription By Opening Up Packed Chromatin
- Others Attract RNA Polymerase
- Some Block Access To Genes
- Key To Cell Specialization
  - All Cells Have Same Chromosomes
  - Some Liver, Skin, Muscle, etc.

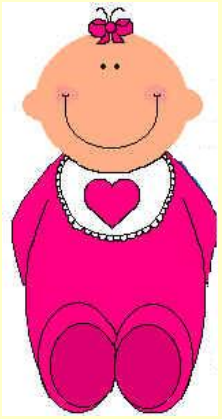
Eukaryotic Gene Regulation

2. _TATA box__(TATATA or TATAAA) helps position RNA POLYMERASE
   - About 30 Base Pairs Long
   - Found Before Most Genes
   - Usually TATATA or TATAAA
   - Promoters Usually Occur Just Before The TATA Box



DEVELOPMENT & DIFFERENTIATION

Gene regulation is also important in shaping way organisms develop

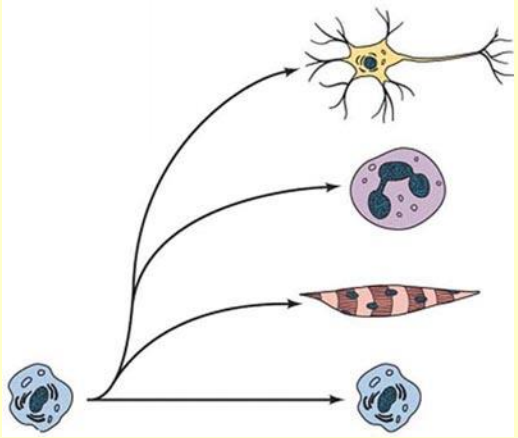


How does a zygote become a multi-cellular organism?

How does it know what kind of cell to be?

DEVELOPMENT & DIFFERENTIATION

Cells DIFFERENTIATE by turning different genes on and off.



BUT…

How does a cell know where it is in the body?

and what genes it should turn on?

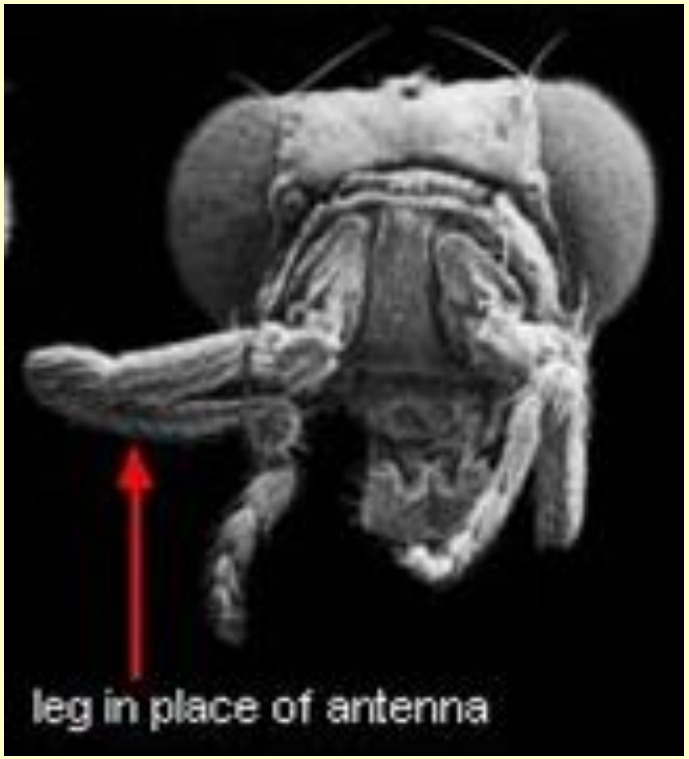
and when?

In the 1980s, researchers discovered a series of genes in fruit flies called

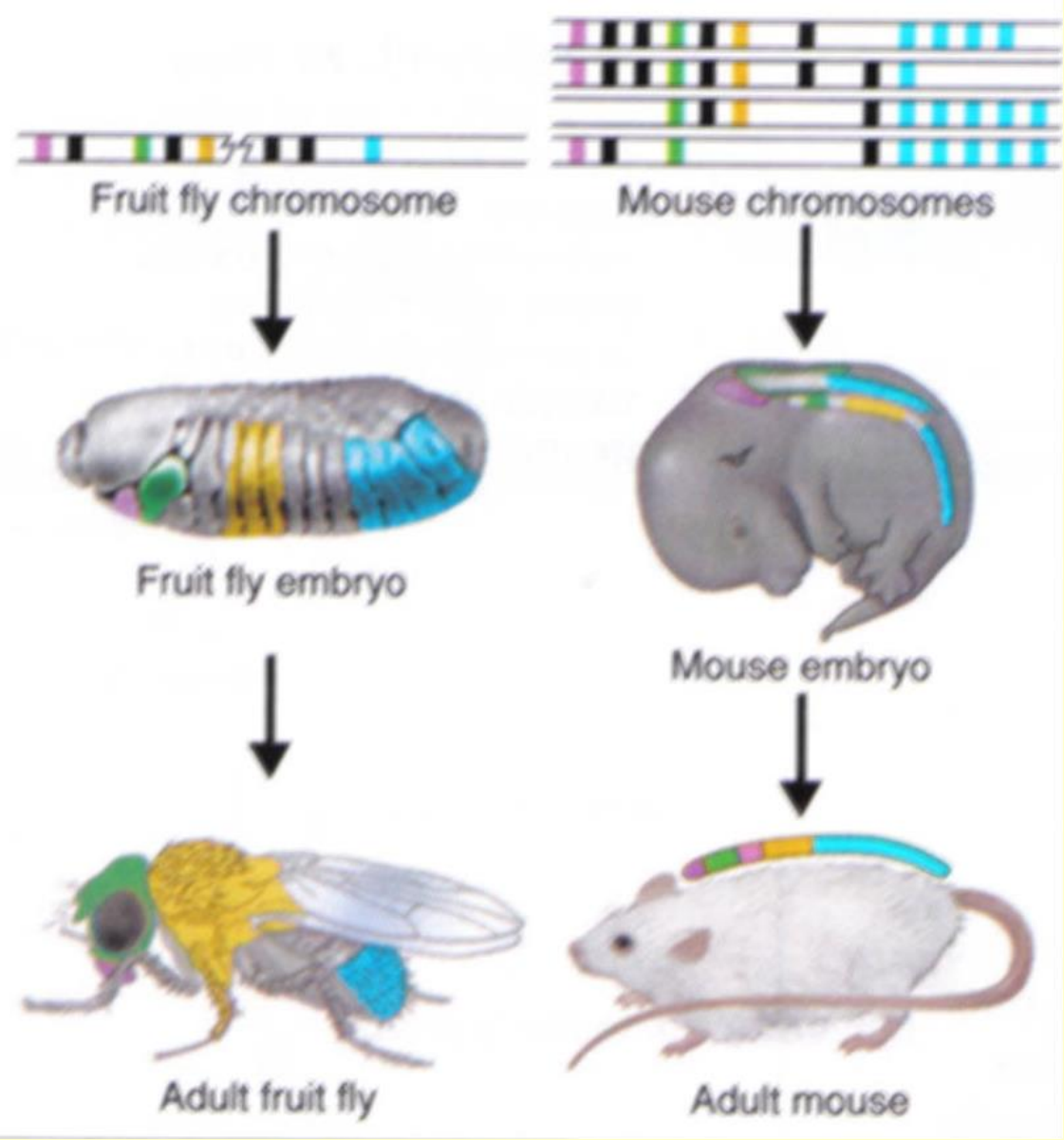
Hox genes

These genes control the organization of the developing embryo and tell parts where to grow and when.

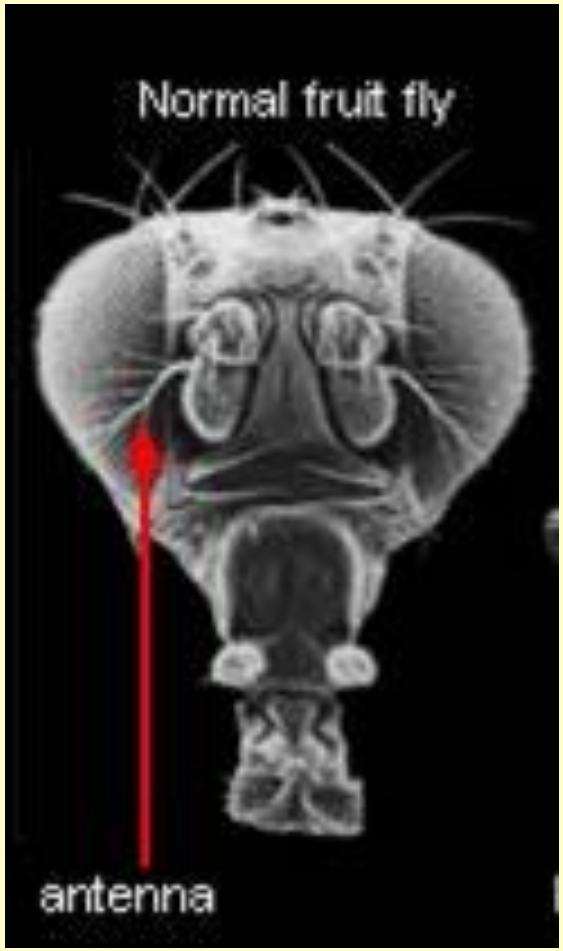
Mutations to *Hox* genes can cause a leg to grow where an antenna should sprout.



Since that time, HOX genes with almost identical sequences have been found in a variety of organisms including HUMANS



HOX GENES

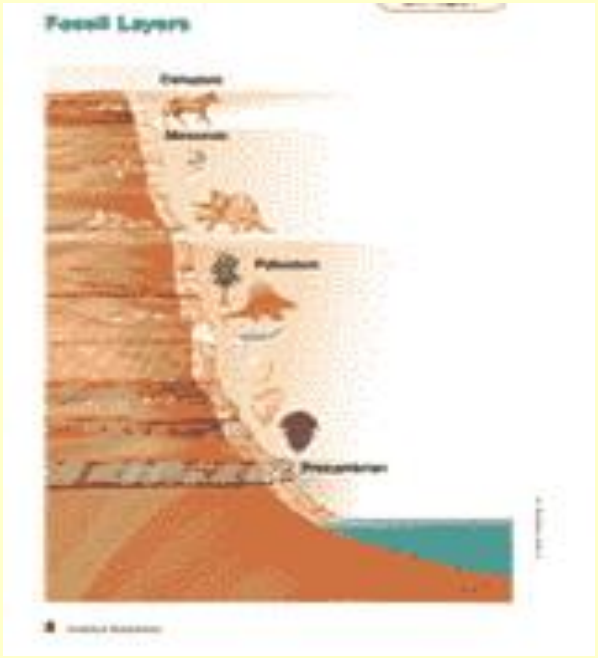


Similar genes controlling the eyes of insects and our own eyes have also been discovered.

Our version of the gene can be inserted in a fly and still trigger the building of an insect eye!

Pax 6 hox gene

- Controls eye growth in Drosophila, Mice & Man
- Pax 6 from Mouse Placed In Knee Development Sequence Of Drosophila Developed Into Eye Tissue.



SO WHAT?

The similarities between HOX gene sequences in very different organisms and the ability of these genes to trade places and still function in different species suggests that these organisms share a common ancestor