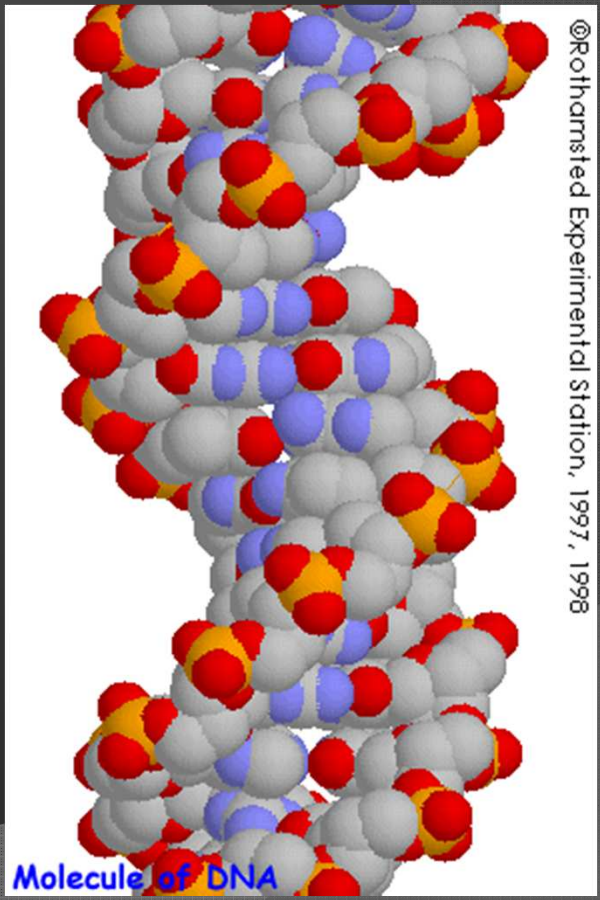
SEMESTER 2 FINAL REVIEW
BIOLOGY 2012



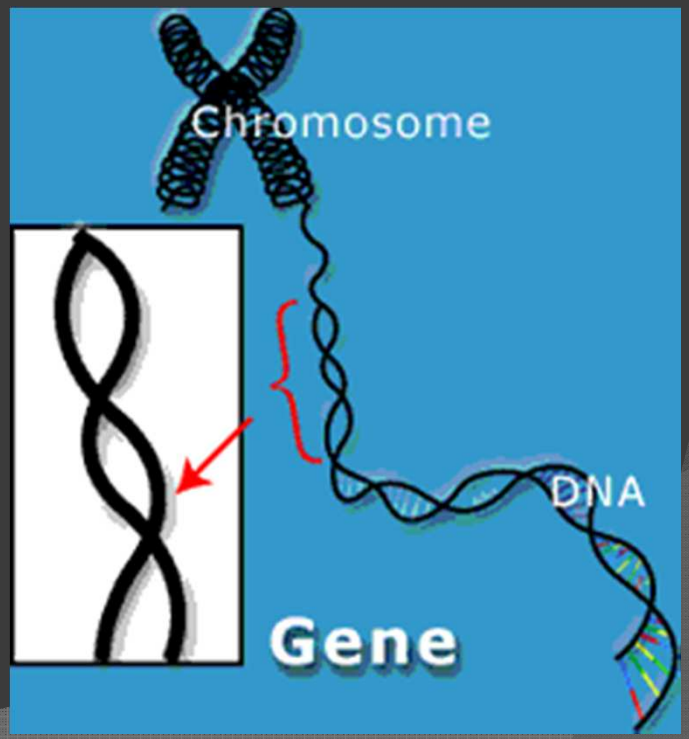
Systems

- All levels of life have systems of related parts.
- A system is an organized group of related parts that interact to form a whole.
- Task: With your tablemate, write down one example of a system and explain why you think it is a system.

DNA

Deoxyribonucleic Acid

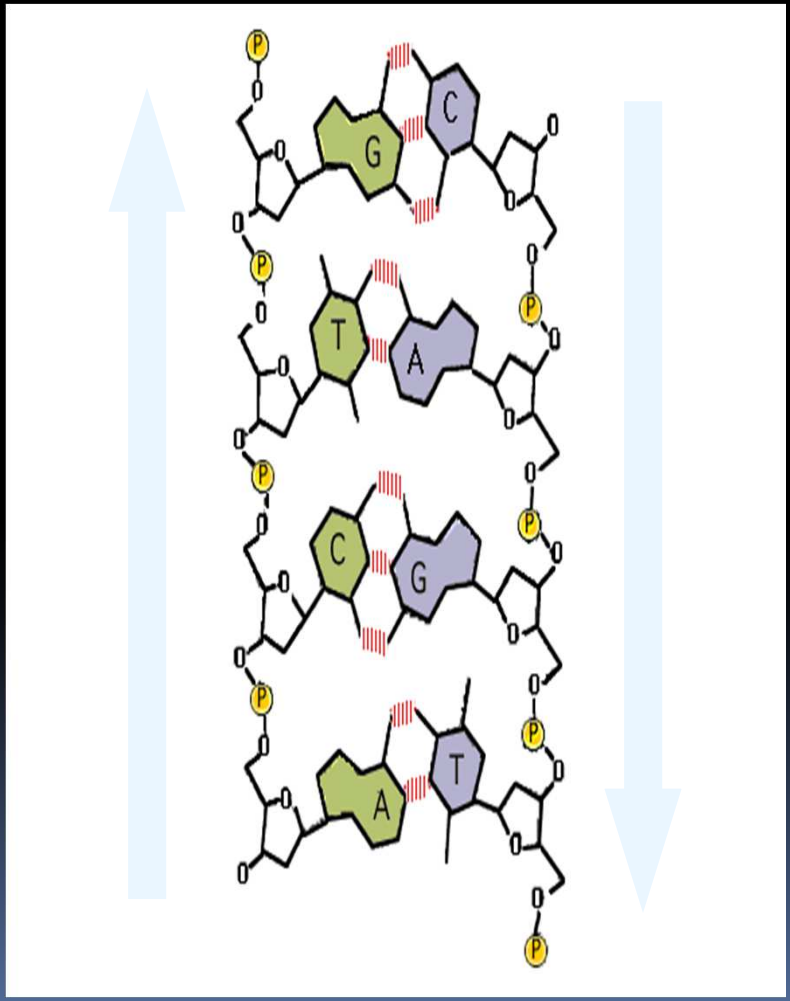
- Stores **hereditary** information in the cell that directs the cell's activities and determines a cell's characteristics.
- Supercoiled into **chromosomes**
  - DNA makes up **GENES**



More on Structure…

- Nitrogen bases make up the rungs of the ladder.

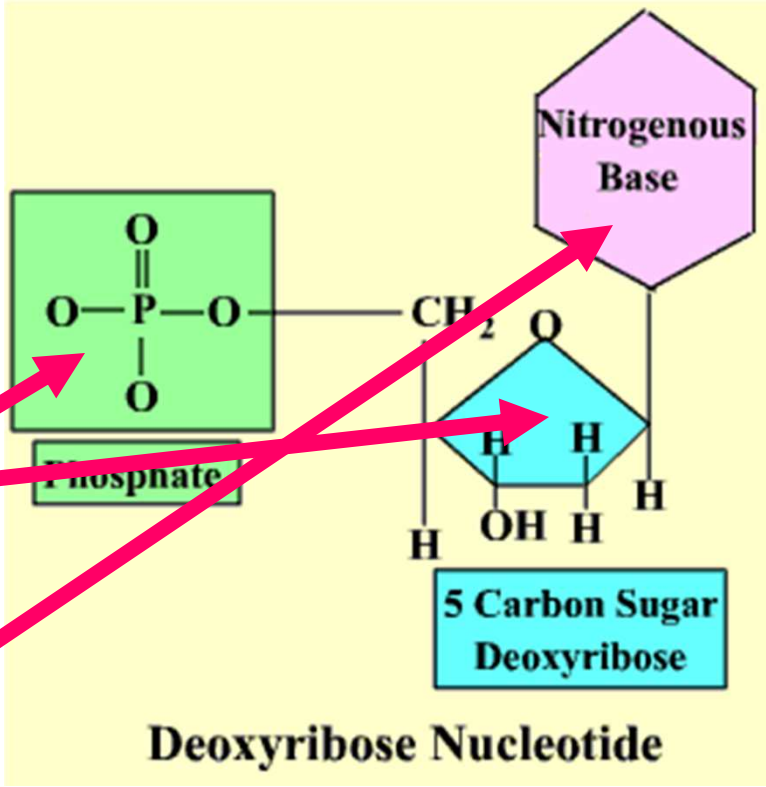
- A bonds to T
- G bonds to C



Structure of Nucleic Acids:

- Definition:
  - small, repeating chain of nucleotides.
- Nucleotide:

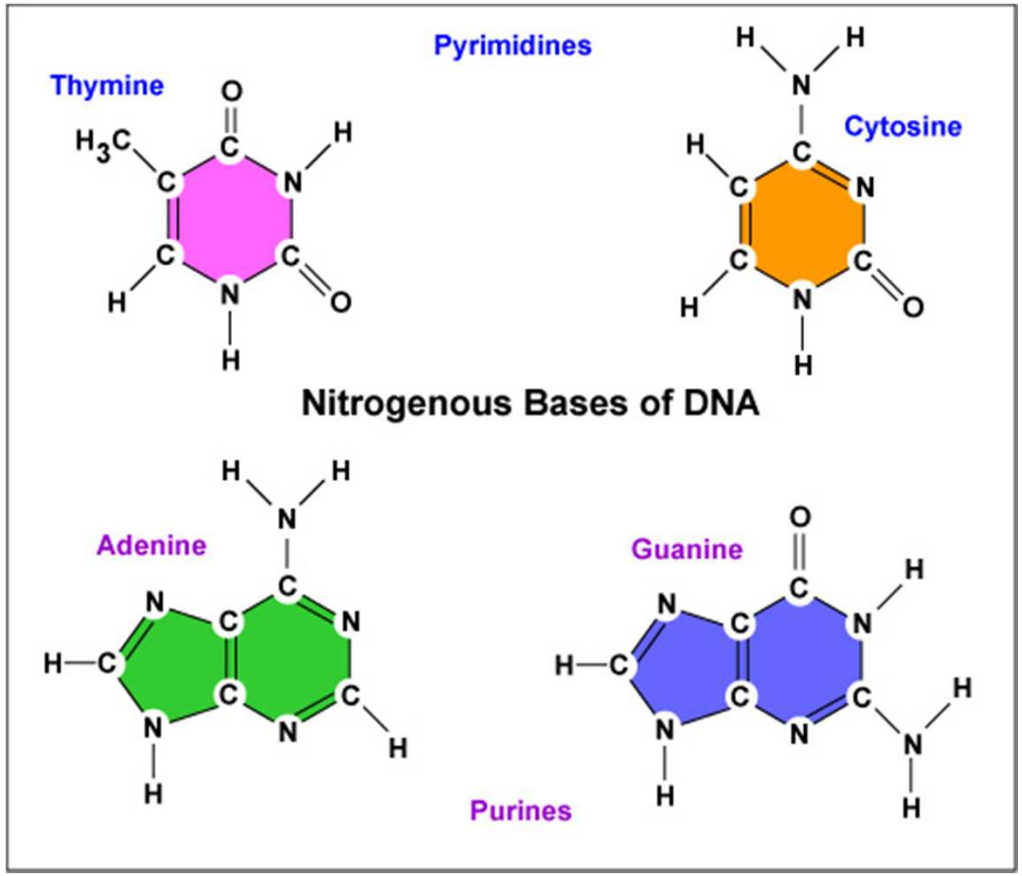
  * 5 carbon sugar
  * phosphate
  * nitrogenous base



DNA Nucleotide Structure: component #3

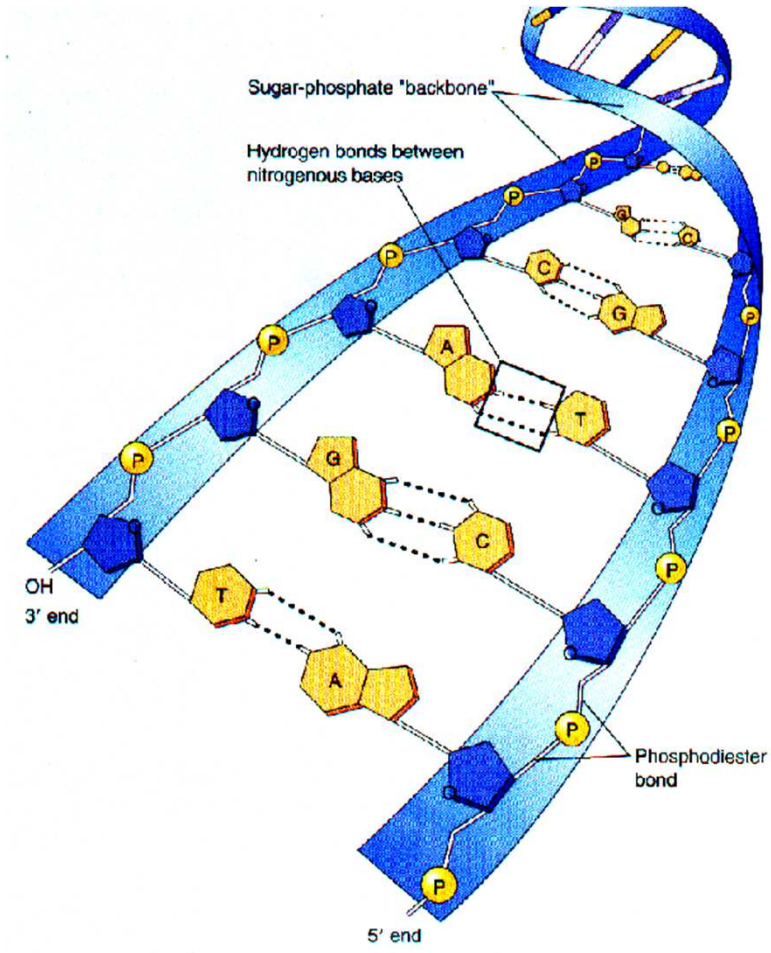
Nitrogenous Base

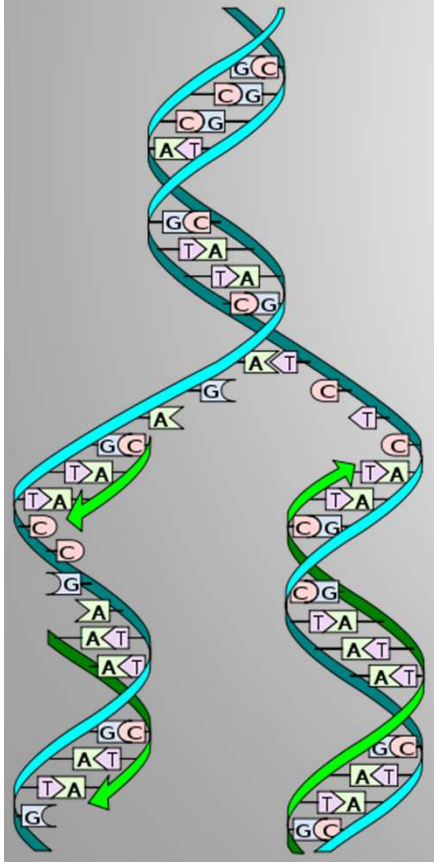
- 2 possible types
  - <u>Purines:</u>
    - Adenine and Guanine
    - Double ringed
  - <u>Pyrimidines:</u>
    - Thymine and Cystosine
    - Single ringed
    - DNA does not contain Uracil



3-D Structure of DNA

- The nucleotides are connected together into two long chains hooked together in the middle to create a ladder.
  - Double Stranded
    - Sides: alternating sugar and phosphate units
    - Rungs: Purine and pyrimidine held together by hydrogen bond.





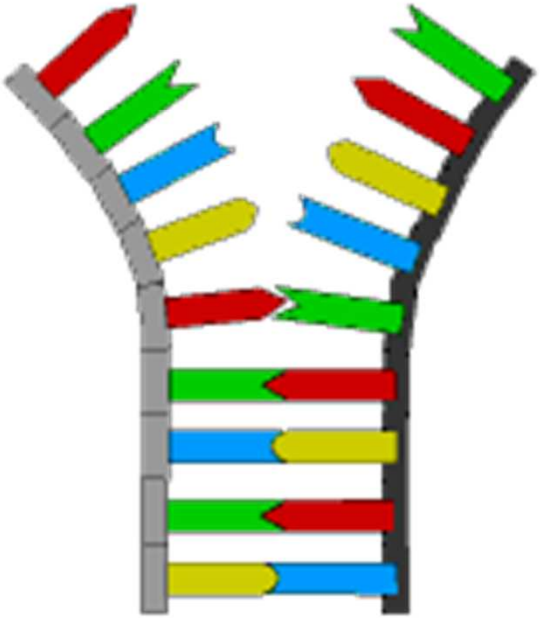
REPLICATION:

How do we get more DNA?

STEPS:

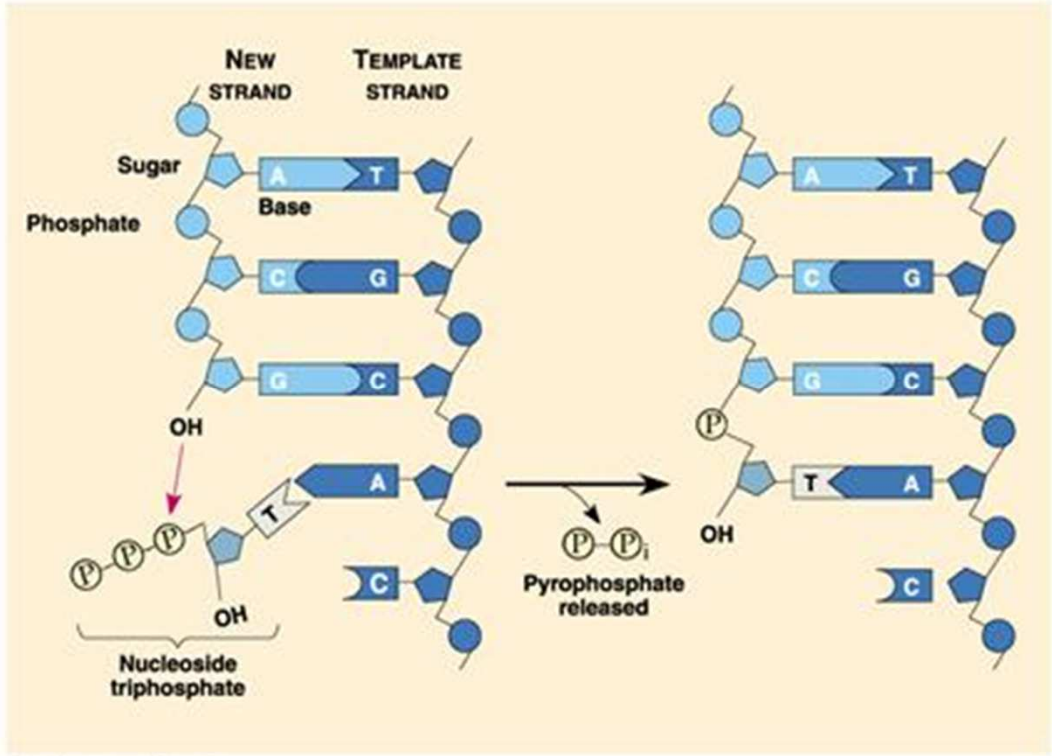
- 1. Double Helix unwinds and unzips. The enzyme is called:
- **helicase**.

enzyme unzips the 2 strands, so that they separate



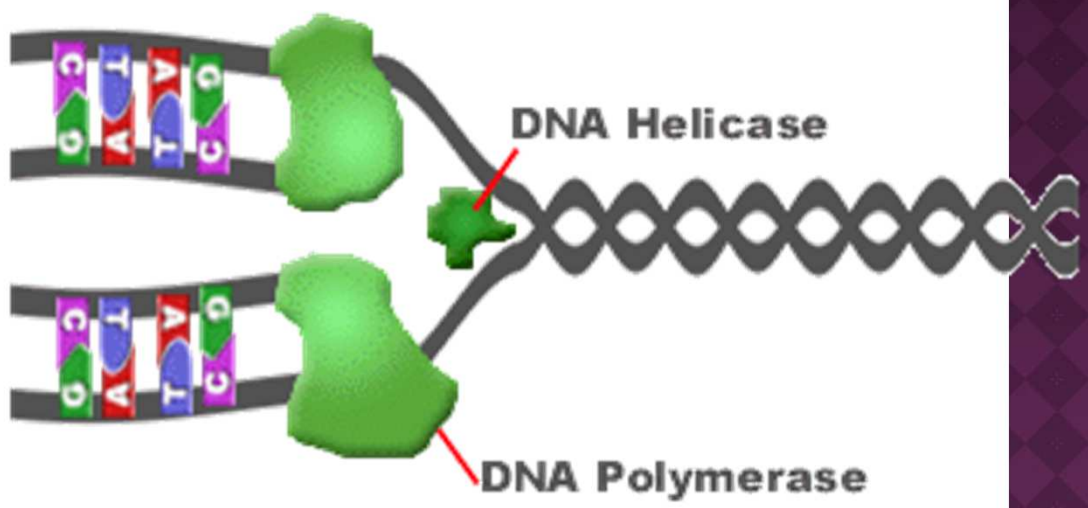
STEPS:

2. Pairing of new nucleotides to old nucleotides



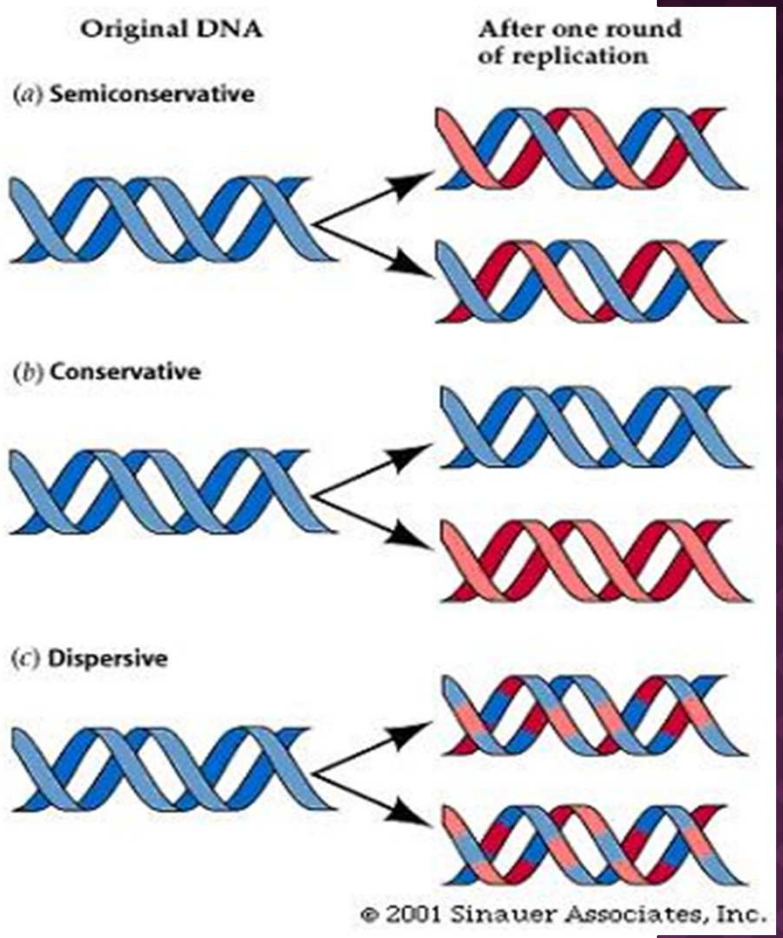
DNA POLYMERASES ARE ENZYMES THAT MOVE ALONG EACH STRAND, ADDING FREE-FLOATING NUCLEOTIDES TO THE EXPOSED BASES ACCORDING TO COMPLIMENTARY MATCHING.

The original DNA strand acts as a **"template"**



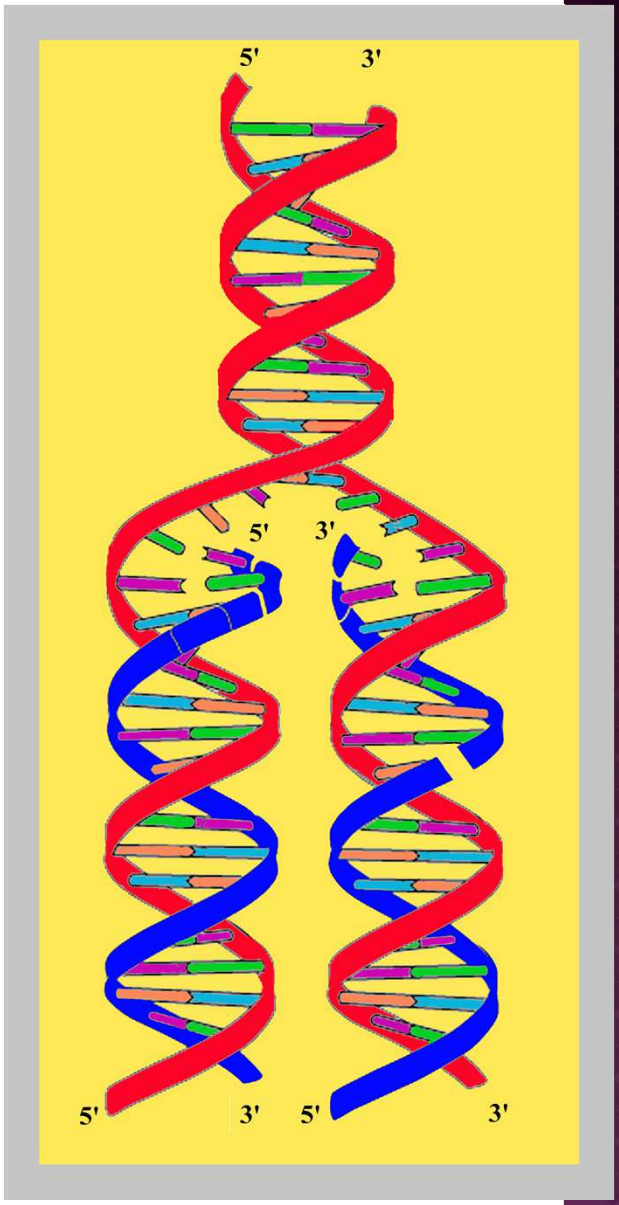
Semi-conservative Replication

Each DNA Molecule contains 1 strand from the old DNA and one strand of the new DNA.



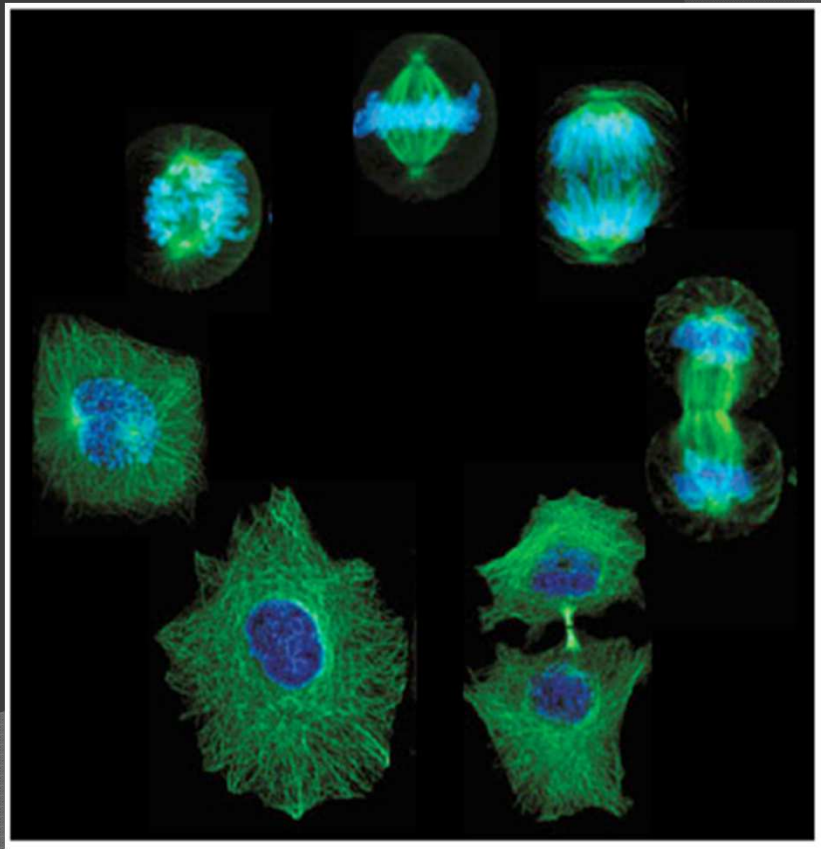
STEPS:

4. After 2 new ladders are formed, each ladder twists to form 2 new double helices.



Cell Reproduction

Binary Fission and The Cell Cycle



Prokaryotes vs Eukaryotes

1. Prokaryotes = Binary Fission
   - Have no nucleus
   - DNA in a simple loop
2. Eukaryotes = The Cell Cycle
   - Cells with a nucleus
   - Linear DNA (has beginning and end)

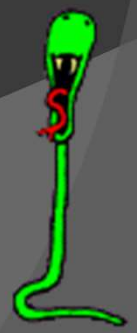
Binary Fission-2 Steps:

1. Circular DNA unzips and copies itself
2. Cell splits

Cell Cycle (Eukaryotes)

Definition:

- The repeated sequence of growth and division required to strategically maneuver the nucleus, chromosomes and organelles before the cell can properly divide.



CHROMOSOMES

Definition:
SUPERCOILED DNA

Structure: a single coiled DNA molecule

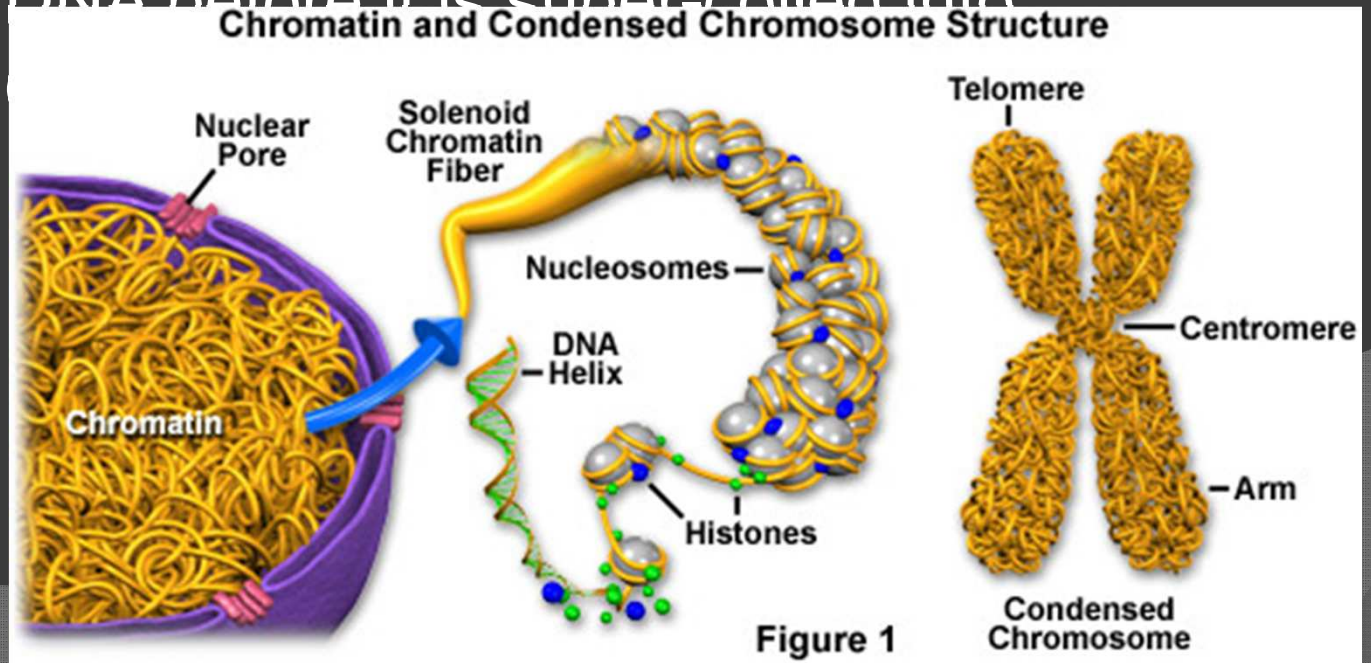
OR

after replication, it may be two coiled DNA molecules held together at the center.

The area it is held together is called "**centromere**"

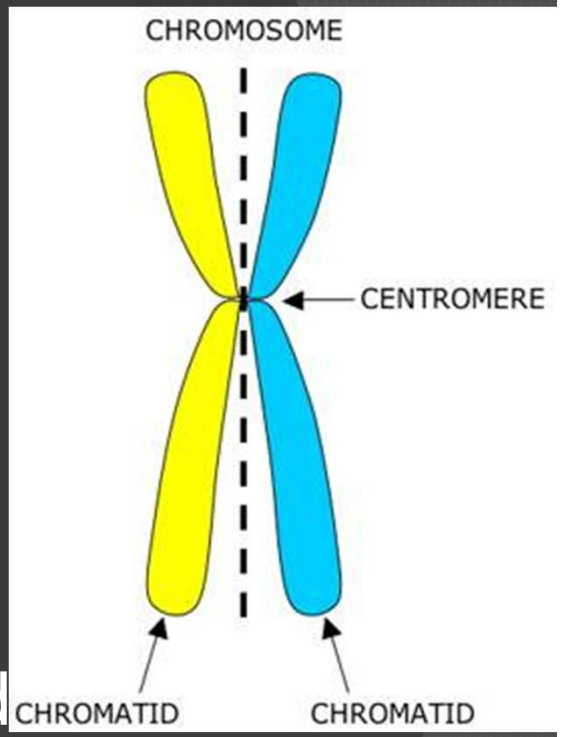
Chromatin:

- Chromatin:
  - Nuclear DNA in a loose, “spaghetti-like” structure
    - during Interphase of the cell cycle.
  - DNA before it is super-coiled into



Chromatid:

- Each DNA molecule in the chromosome …therefore, each replicated chromosome has 2 chromatids.

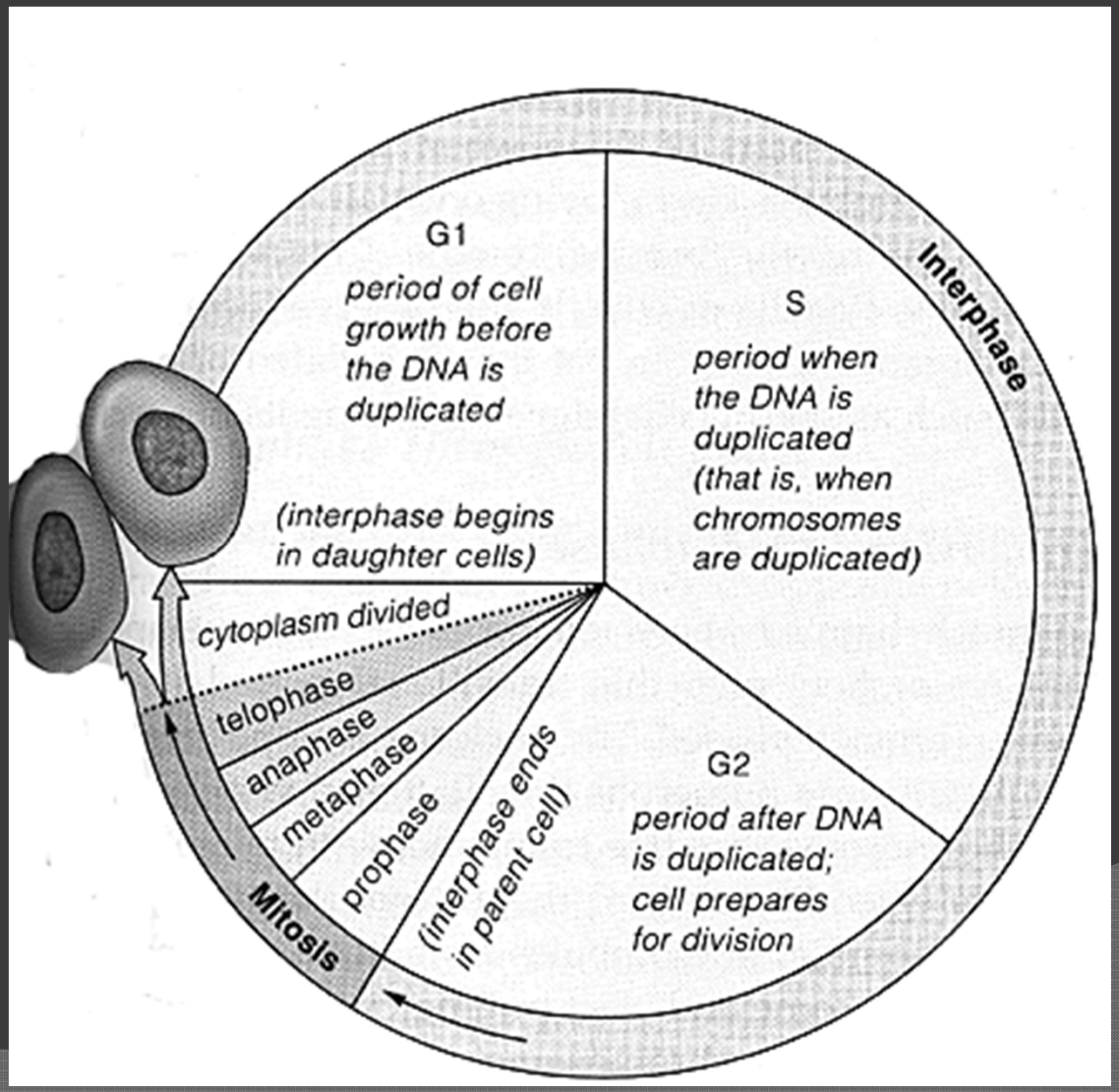


- NOTE: Chromosomes, Chromatin and Chromatids are all made of the same DNA, it's just different shapes at different times of the cell cycle.

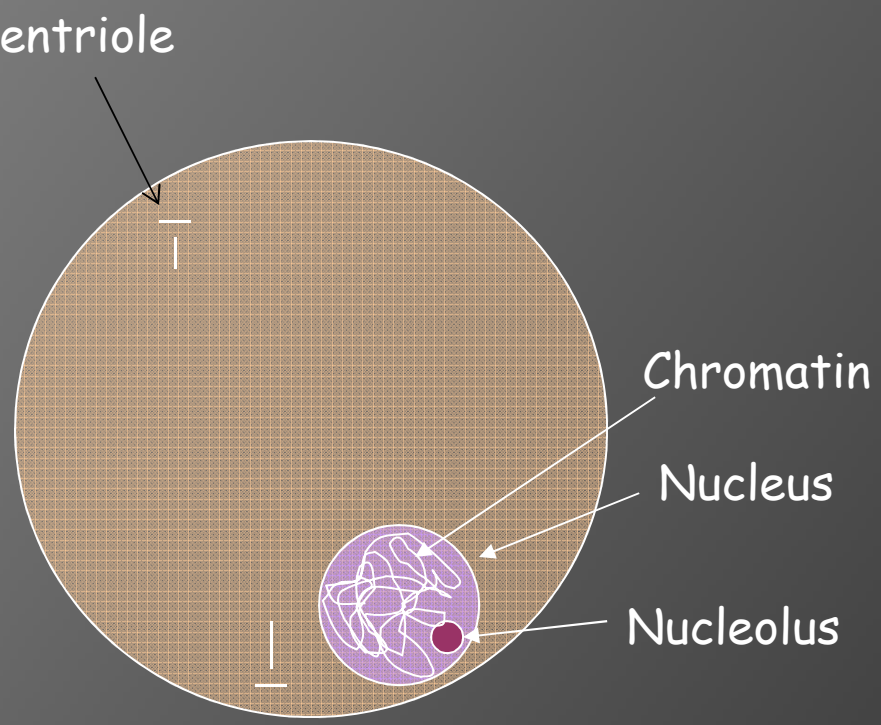
Phases of the Cell Cycle

- **G1 (Gap 1 or Growth 1):**
  - Cell growth
    →All routine functions of the cell
- **S (Synthesis):**
  - DNA Copied
    - Individual chromosomes consist of 2 chromatids attached at the centromere
- **G2 (Gap 2 or Growth 2):**
  - Growth and Preparation for Mitosis
    - Organelles replicate, microtubules are reassembled
- **M Mitosis:**
  - Nucleus divides into 2 nuclei
- **C Cytokinesis:**
  - Cytoplasm divides into 2 cells

Phases of the Cell Cycle



INTERPHASE



The time spent between cell divisions

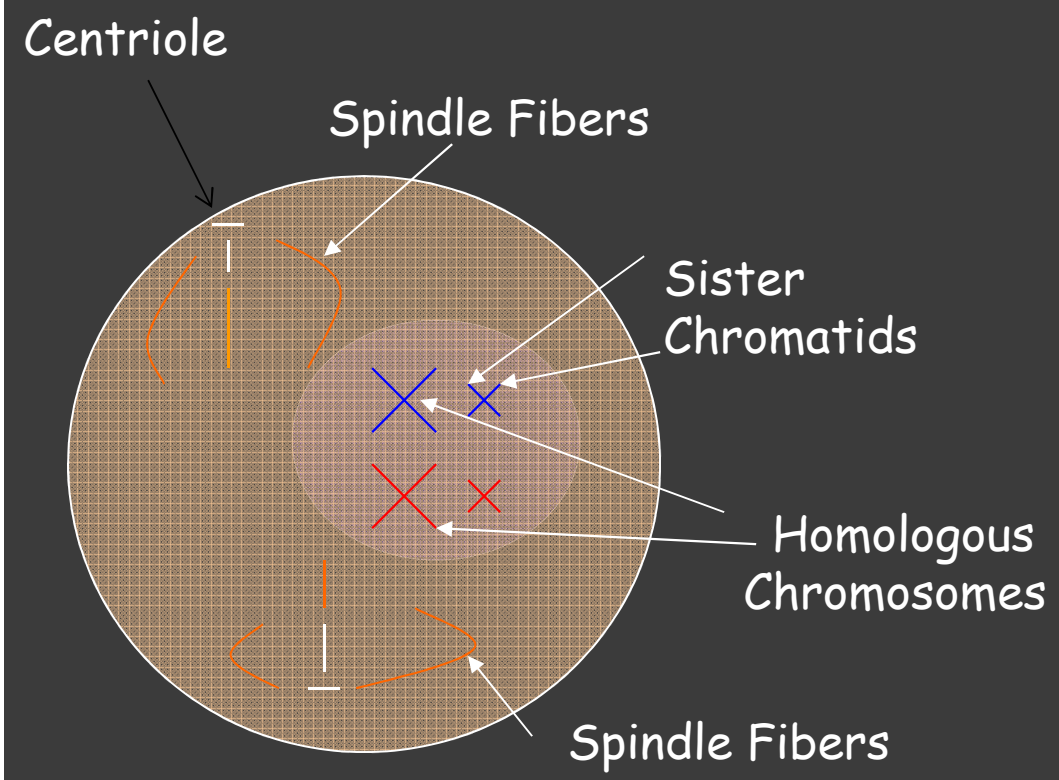
Cell is doing what it normally does, carrying out life functions

Cell spends most of its life between cell divisions

DNA is in the form of chromatin - a net of loosely coiled DNA

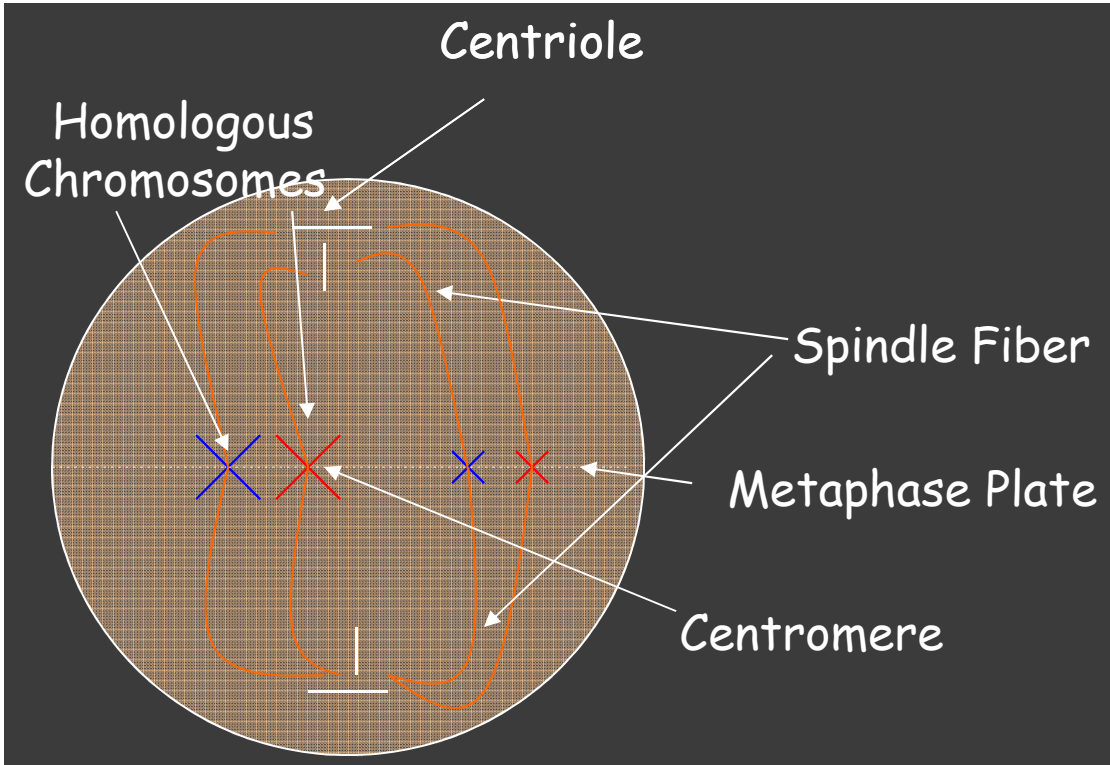
Three parts: G1, S and G2

Prophase



- **Chromosomes are seen as 2 distinct chromatids.**
- **Spindle fibers begin to form from centrioles.**
- **The longest phase of mitosis, often taking 50-60% of time.**
- **Near the end of prophase, the nucleolus disappears, and the nuclear envelope breaks down.**

Metaphase

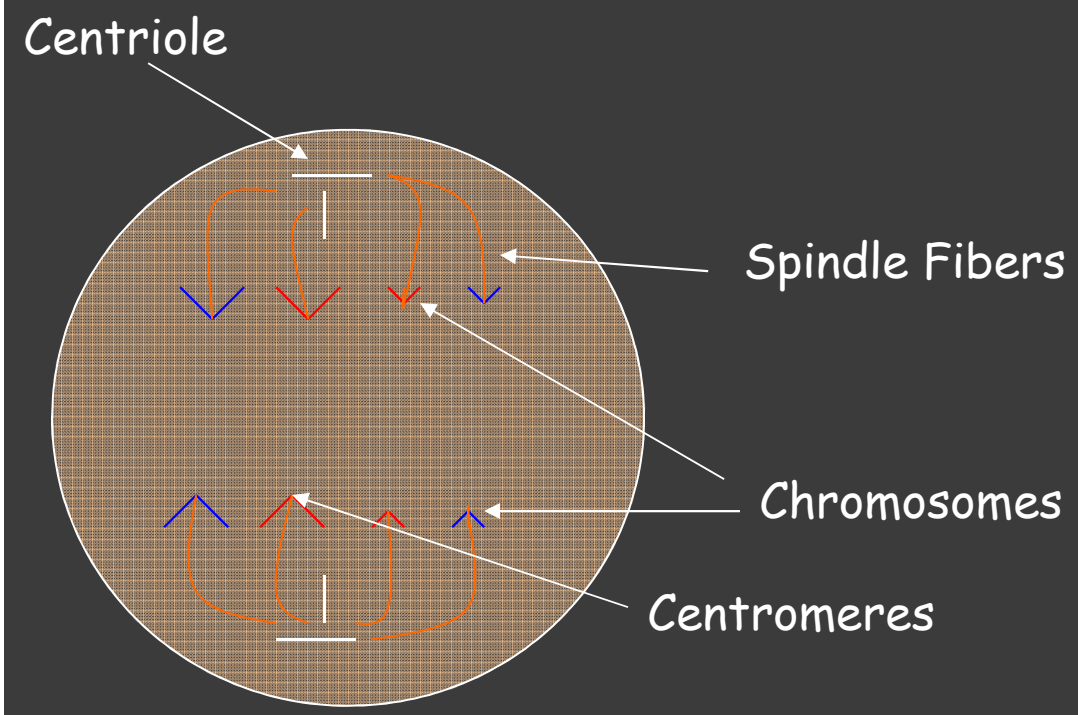


Nuclear membrane disappears.

Centromeres of each double stranded chromosome attached to spindle fibers at equator.

The shortest time of mitosis.

Chromosomes line up on the metaphase plate.



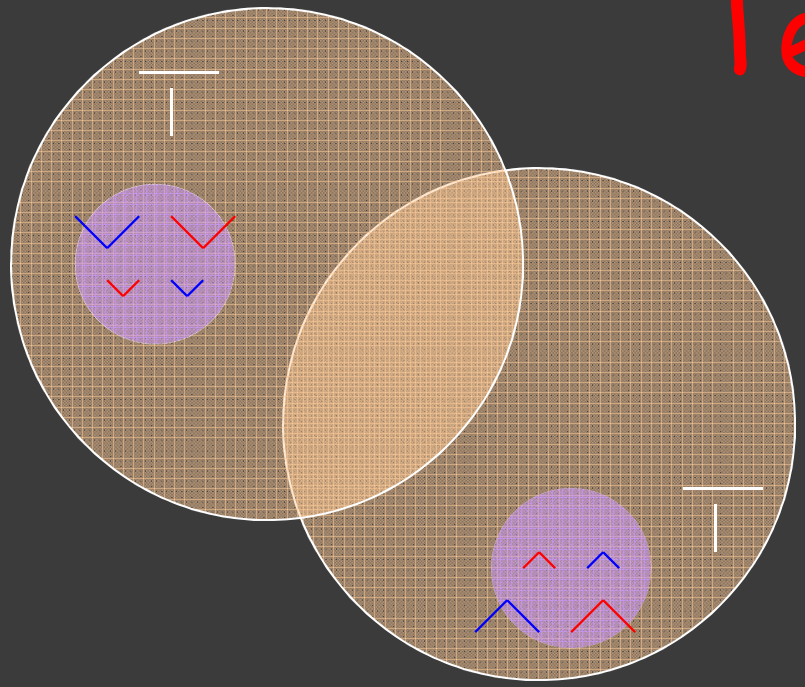
Anaphase

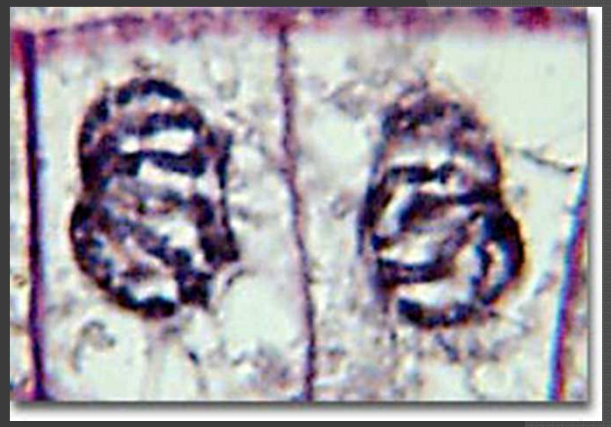
Centromeres that join the chromatids split

Chromosomes begin moving toward opposite poles

No longer sister chromatids

Telophase

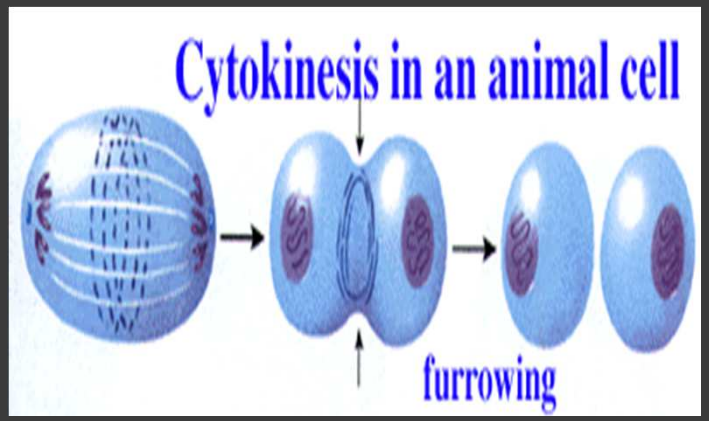




- New *nuclear* membranes form.
- Chromosomes become longer, thinner, and less distinct.
- Spindle fibers break down.
- Cell membrane pinches in.

Cytokinesis- division of cytoplasm

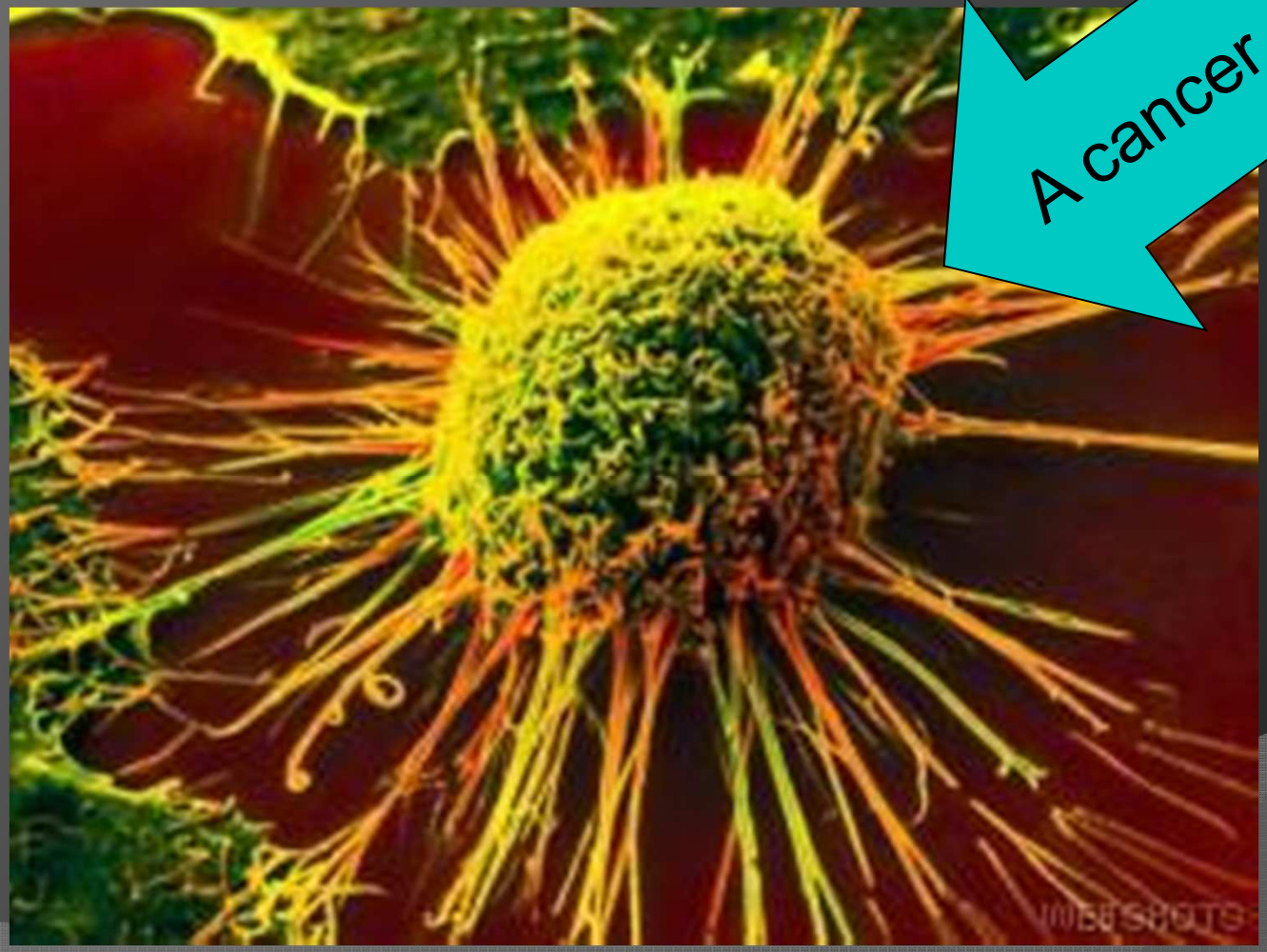
- Cytoplasm divides into 2 cells
- Animal cells: Cell membrane pinches in (constricts) in middle called a “cleavage furrow”
- Plant cells: CELL PLATE forms in middle of dividing cell



Rates of Division

- Cells spend most of their time in interphase.
- The mechanism for cell growth is highly regulated by genes (segments of DNA) in the cell so that you just get the new cells you need.

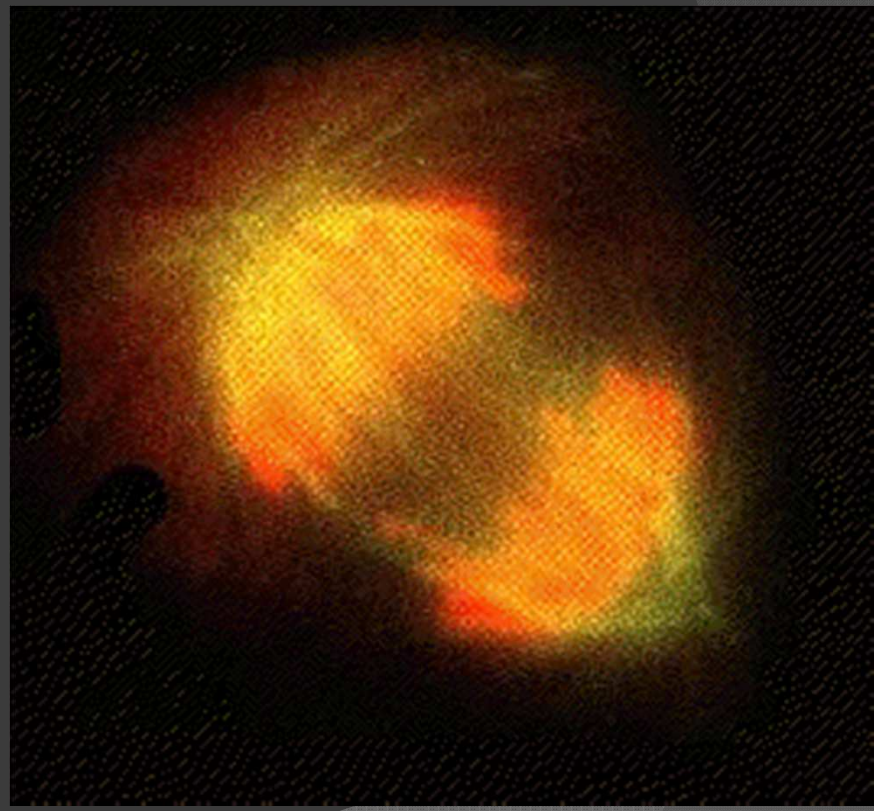
THE CANCER/MITOSIS CONNECTION



A cancer cell

Rates of Division

- If the control mechanism for this process gets messed up, the rate of mitosis in that body tissue increases



Increased Mitosis ...

- Leads to
  - Accumulation of cells in that area known as a **TUMOR**

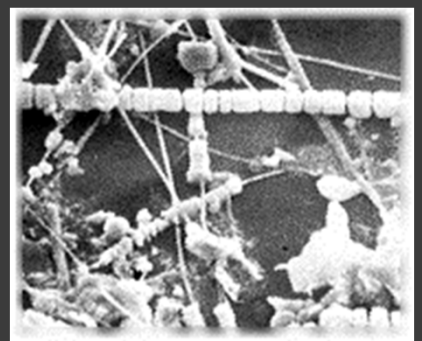
Increased Mitosis …

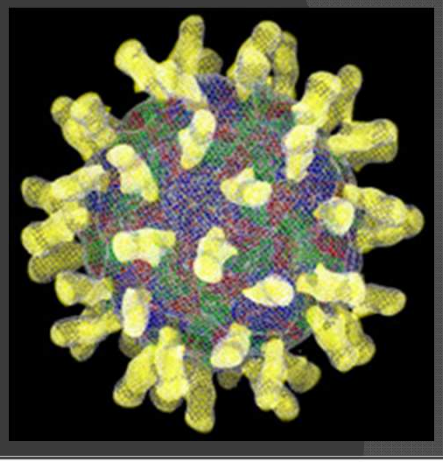
- Leads to
  - **CANCER**
    - A disorder of cells in which the genes which control growth have been **damaged** and the cells have the ability to **spread** throughout the body.

Ovary Cancer Cell

Causes of cancer:

- Viruses
- Chemicals (such as Nicotine, Benzene, Asbestos)
- Ultraviolet radiation



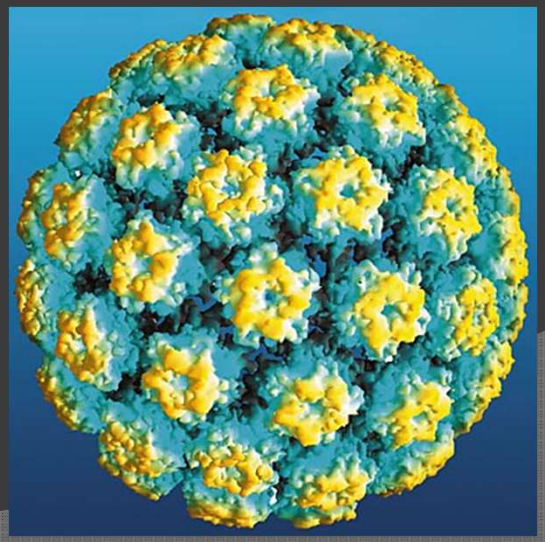


Causes of Cancer:

- These are called **CARCINOGENS**: cancer-causing agents (also called **MUTAGENS)**
  - Attack DNA and **mutate** the genes that controls cell division
  - These "control" genes are called **ONCOGENES**

Kinds of tumors:

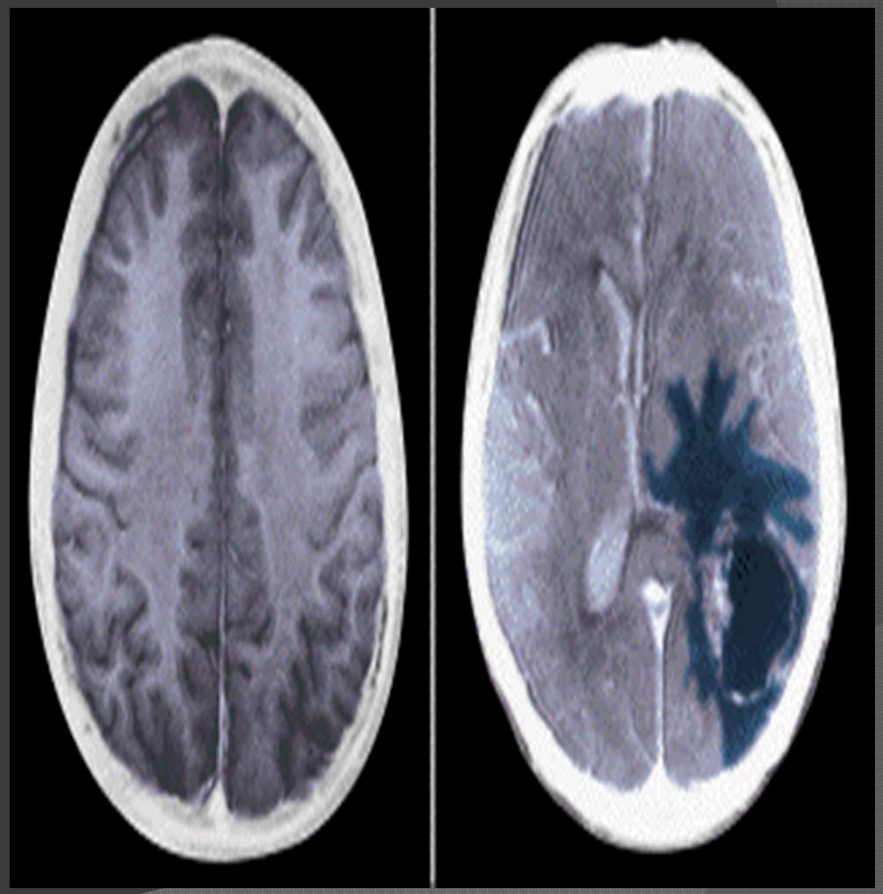
- **BENIGN**: Harmless because do not spread to other tissues of the body
  - Ex. Warts (caused by a virus)



HPV

Kinds of tumors:

- **MALIGNANT**:
  = **CANCER**
  - Very dangerous
  - Spreads to different kinds of tissues (called **METASTISIS)**
  - interferes with organ function



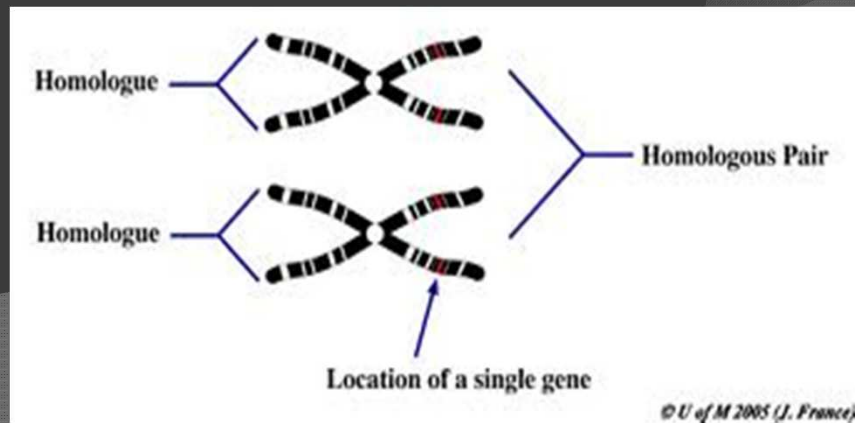
Cancer

- Cancer cells do not carry on normal functions, all their energy goes into dividing.
- They also use up the nutrients for cells so they can't do their job as well.

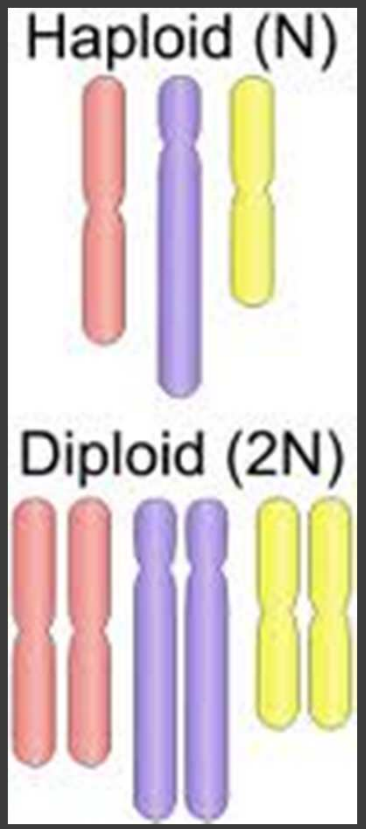
How many chromosomes does a cell have?

- **Homologues**:
  - Homo= Latin for: the same
  - So this means two chromosomes that code for the same genetic traits (ex. eye color, etc)
  - Two options in a cell:
    - 1. Two homologues (diploid)
    - 2. One homologue (haploid)

Most of your cells have two homologues: 1 from your father and 1 from your mother.



Haploid vs Diploid



- Humans have 23 pairs of homologues in all cells except sex cells
  - This is called diploid or 2N
    - *N stands for the number of unique chromosomes*
  - These non–sex cells are called "**somatic cells**"
    - That means human somatic cells have 46 total
- Sex Cells: Haploid or N
  - (think "half").
  - This is how many are in sex cells
  - Sex Cells are called "**gametes**." (ex. egg and sperm)
    - Human Sex Cells have 23 chromosomes in them.

Sex cells (sperm and egg)

- Only have one of each chromosome (either the mom's or the dad's)
  - No homologous pairs
  - Called "HAPLOID" or N (think "half")
  - Sex Cells are called "GAMETES."

Eukaryotic Chromosomes

- A replicated **chromosome** consisting of two strands of identical chromosomal material called **chromatids** (**sister chromatids**) attached at a **centromere**.

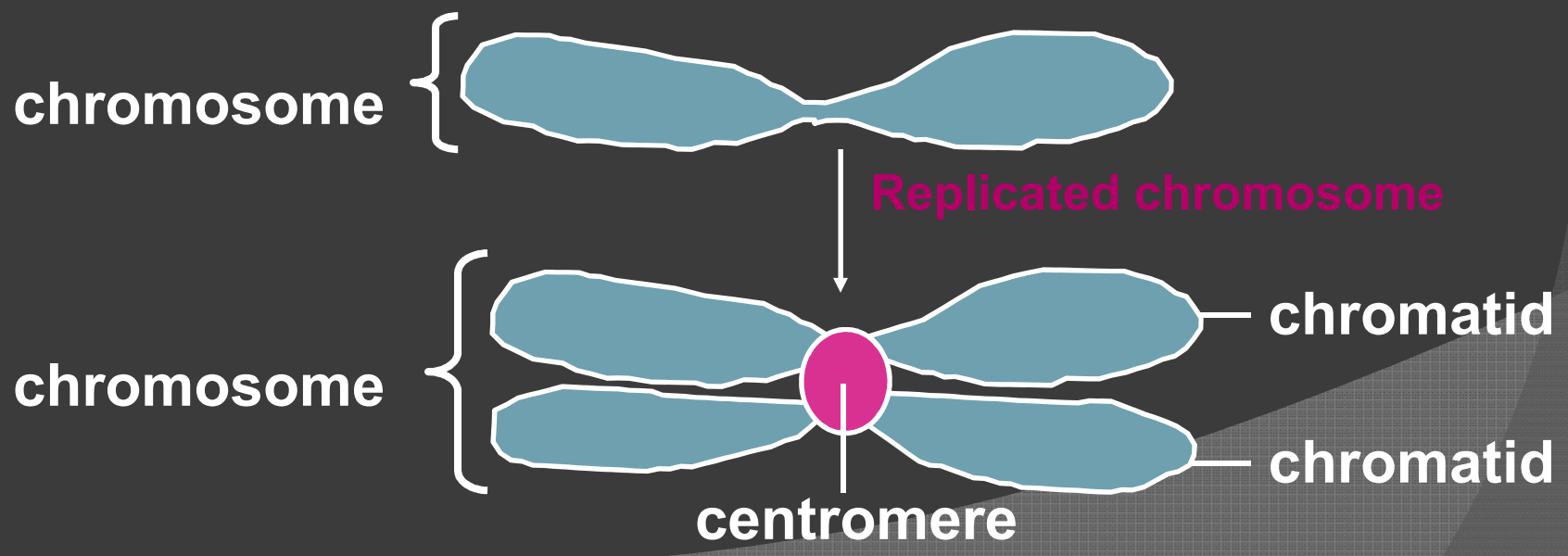
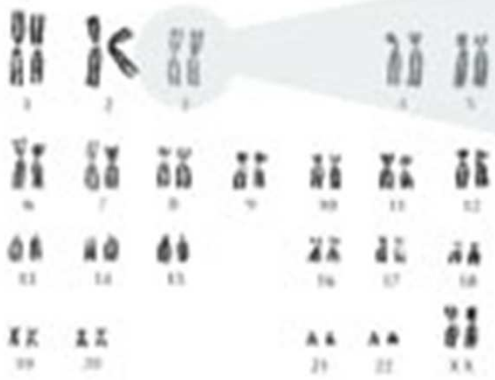
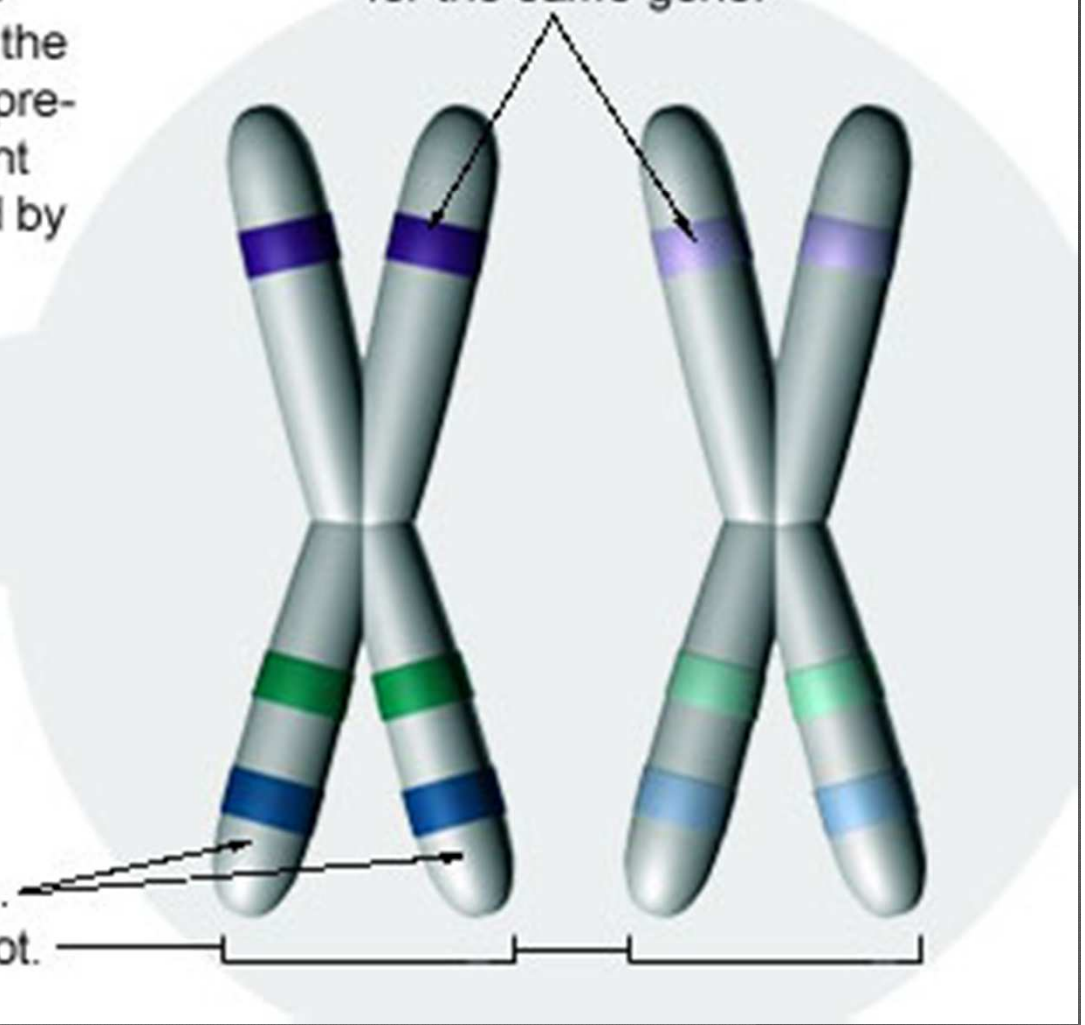


Figure B-11: Homologous Chromosomes

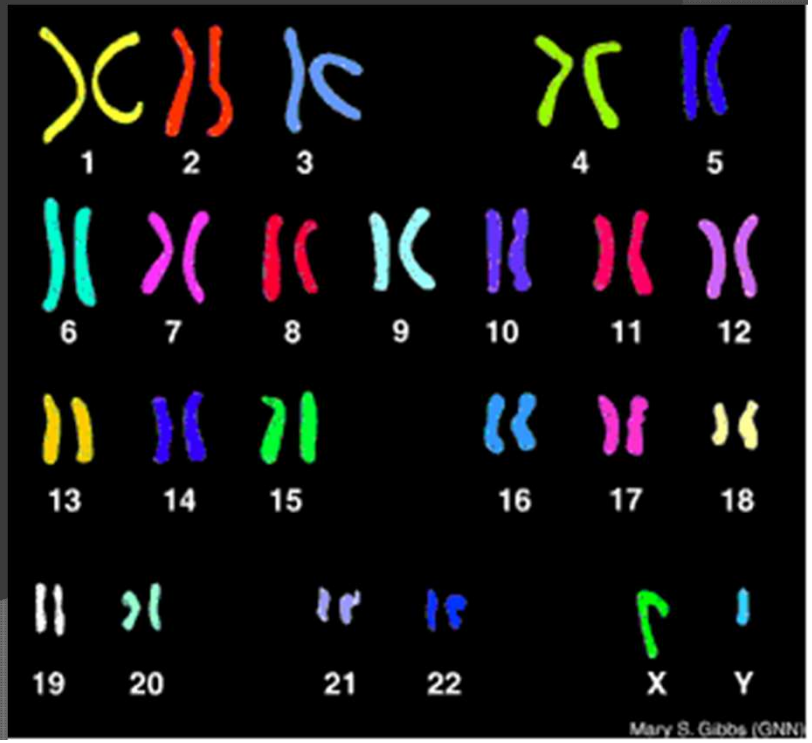
Homologous chromosomes contain DNA that codes for the same genes. In this example, both chromosomes have all the same genes in the same locations (represented with colored strips), but different 'versions' of those genes (represented by the different shades of each color).





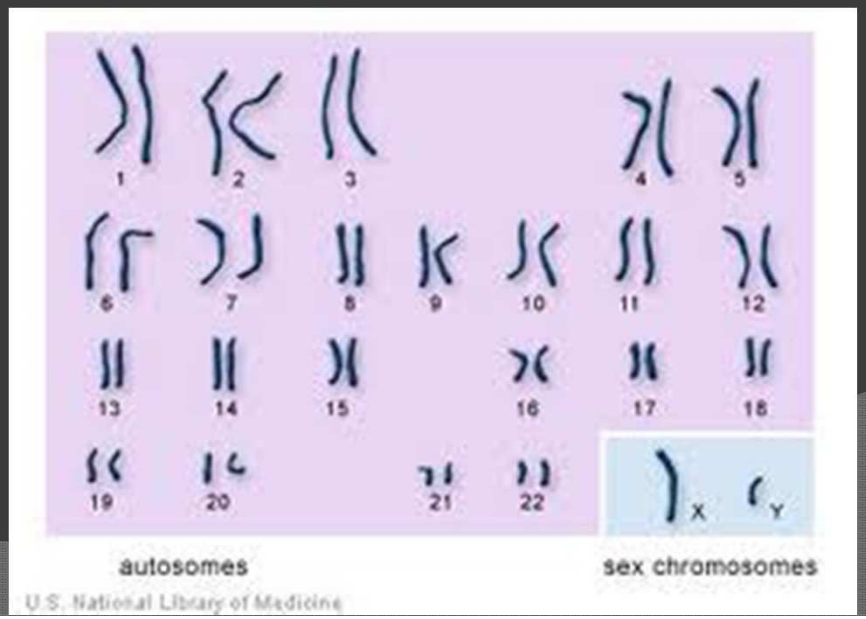
Chromosomes

- Humans have 46 chromosomes
  - 23 chromosomes from Mom
  - 23 chromosomes from Dad



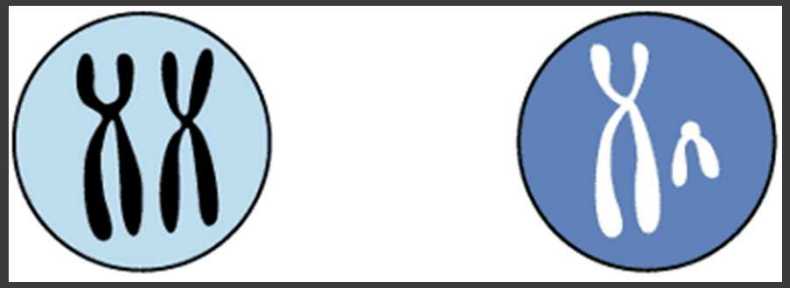
Two Types of Chromosomes:

1. Autosomes
   - ALL chromosomes except the sex chromosomes
   - 22 pairs (Chromosomes #1-22)



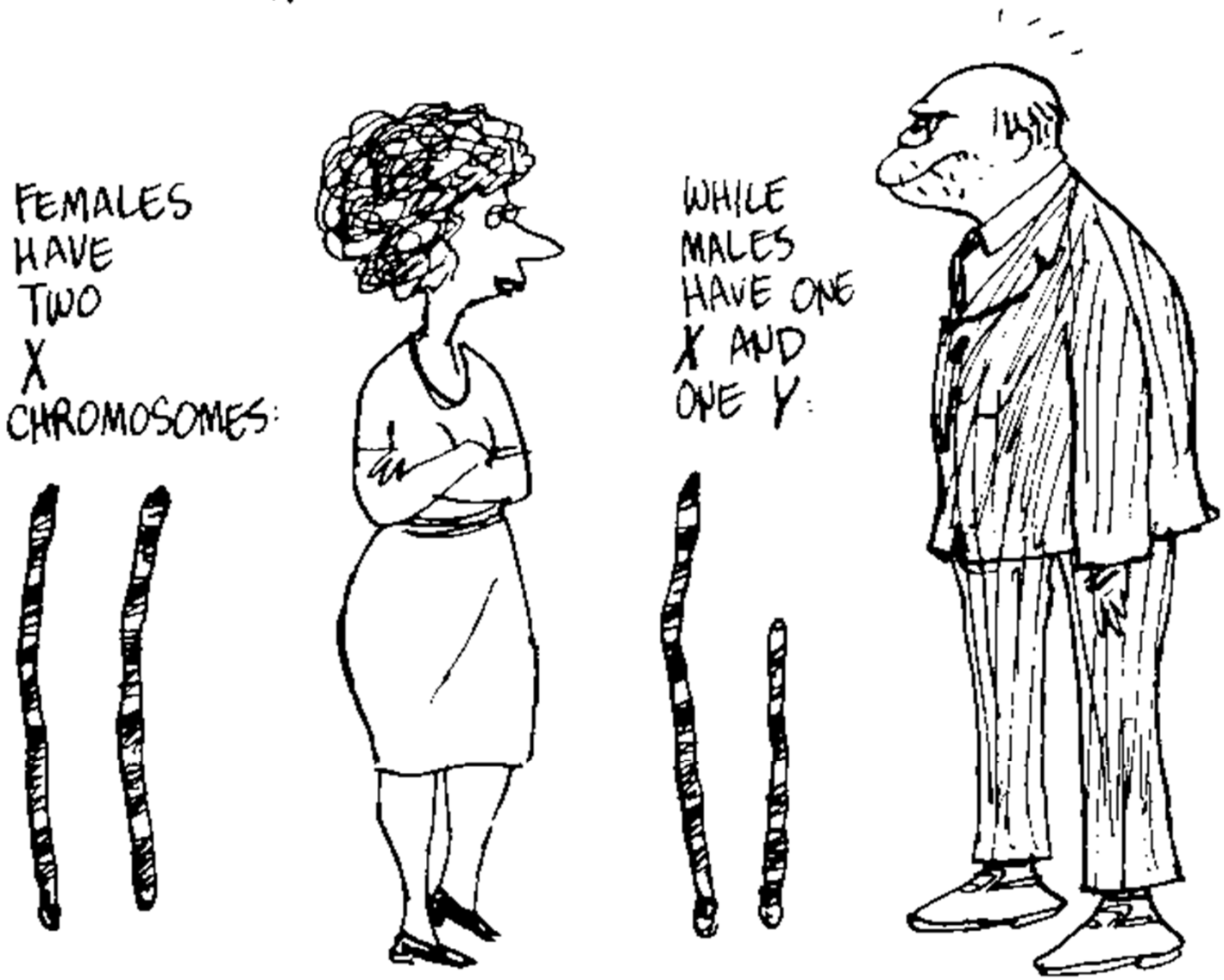
Two Types of Chromosomes:

2. Sex Chromosomes:
   - 1 pair (human chromosome #23)
   - Determine the sex of an organism
     - In mammals & fruit flies XX is female, XY is male



Female **Male**

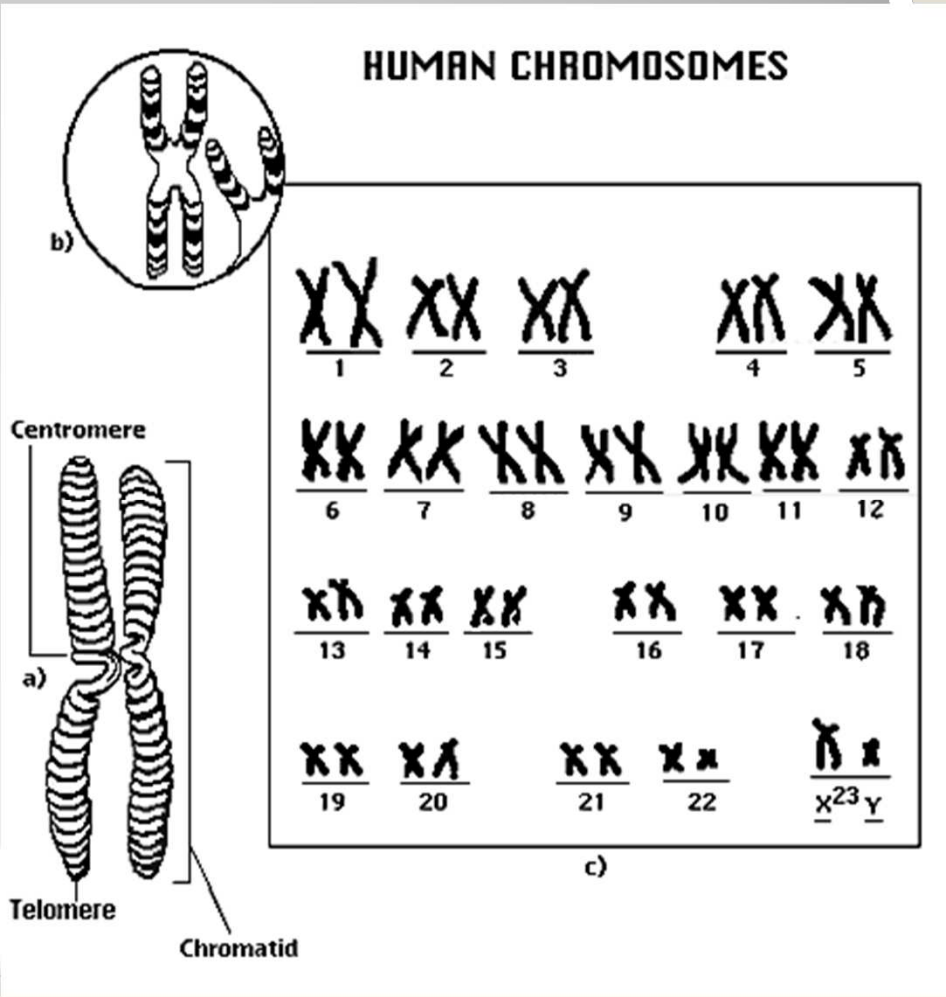
THE ONLY GENETIC DIFFERENCE BETWEEN (HUMAN) MALES AND FEMALES IS THIS:



THE OTHER 22 OTHER PAIRS OF CHROMOSOMES ARE THE SAME.

Karyotypes

- Arranged in order by size from largest pair to smallest pair
- Largest is #1, smallest is #22.
- The sex chromosomes (X and Y) are always the last pair #23, though they are not the smallest.



Karyotypes

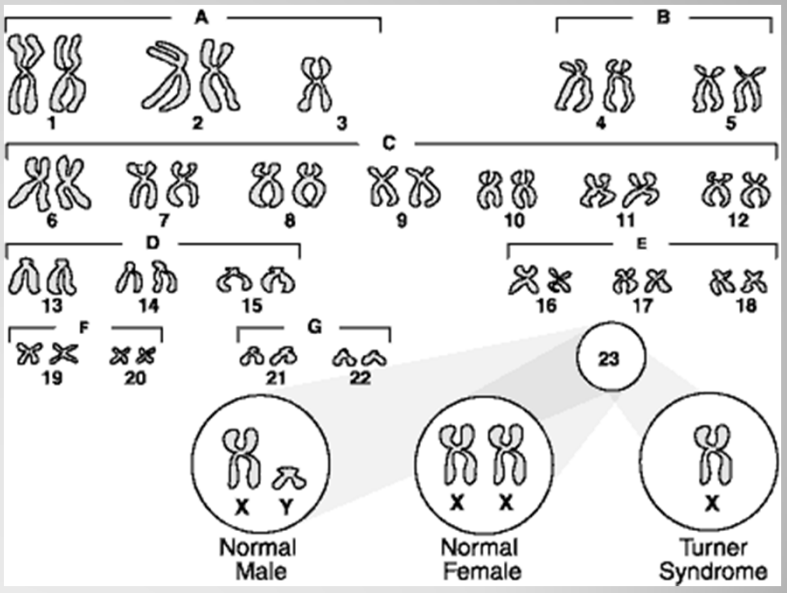
- How are they used?
  - They are used for diagnosis of genetic abnormalities that are based on the number of chromosomes.
  - They are used to determine the sex of an unborn child.

Genetic Disorders

- Normal:
  - Have 2 matching chromosomes for each of the 23 pairs
- Aneuploidy:
  - Having one **more** or one **less** of one of the chromosomes of the 23 pairs.

Genetic Disorders

- Monosomy: Missing one chromosome of one of the pairs
  - Turner's syndrome = Monosomy of #23
    - Missing one of the X chromosomes
    - Female who is X0 instead of XX

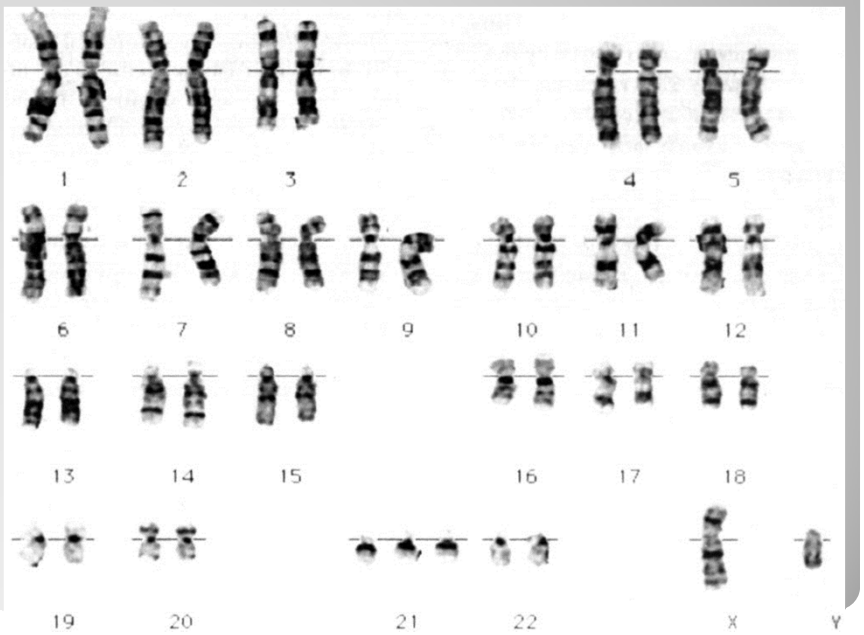


Genetic Disorders

- Trisomy: An extra chromosome of one the pairs

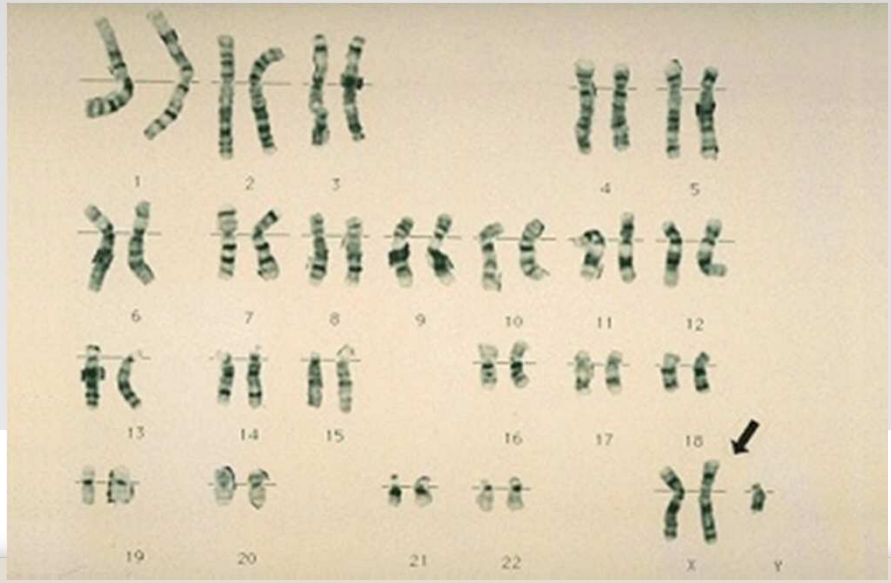
Downs syndrome = Trisomy 21

Extra chromosome #21 (so, there are 3 chromosome #21)



Genetic Disorders

- Kleinfelter's Syndrome= Trisomy 23
  - Extra sex chromosome
  - Male who is XXY instead of XY
  - The most common sex chromosome abnormality in males

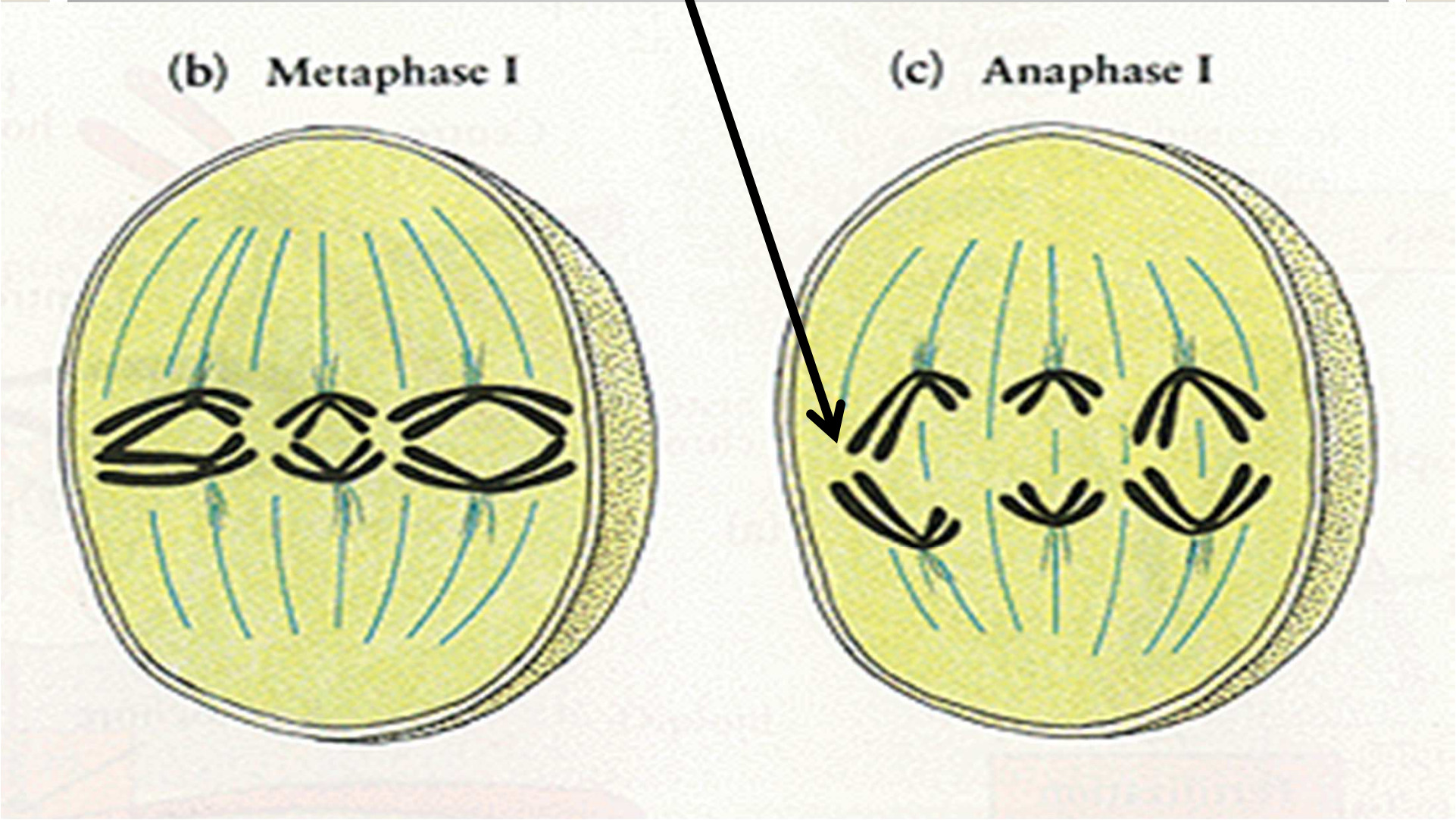


Disjunction

How do chromosome abnormalities occur?

- Seperation of Chromosomes in Anaphase of Meiosis is called <u>Disjunction</u>.
  - Replication of DNA during "S"
  - Mitosis begins with formation of tetrads in Prophase I.
  - Normal Anaphase results in disjunction (seperation of chromosomes)

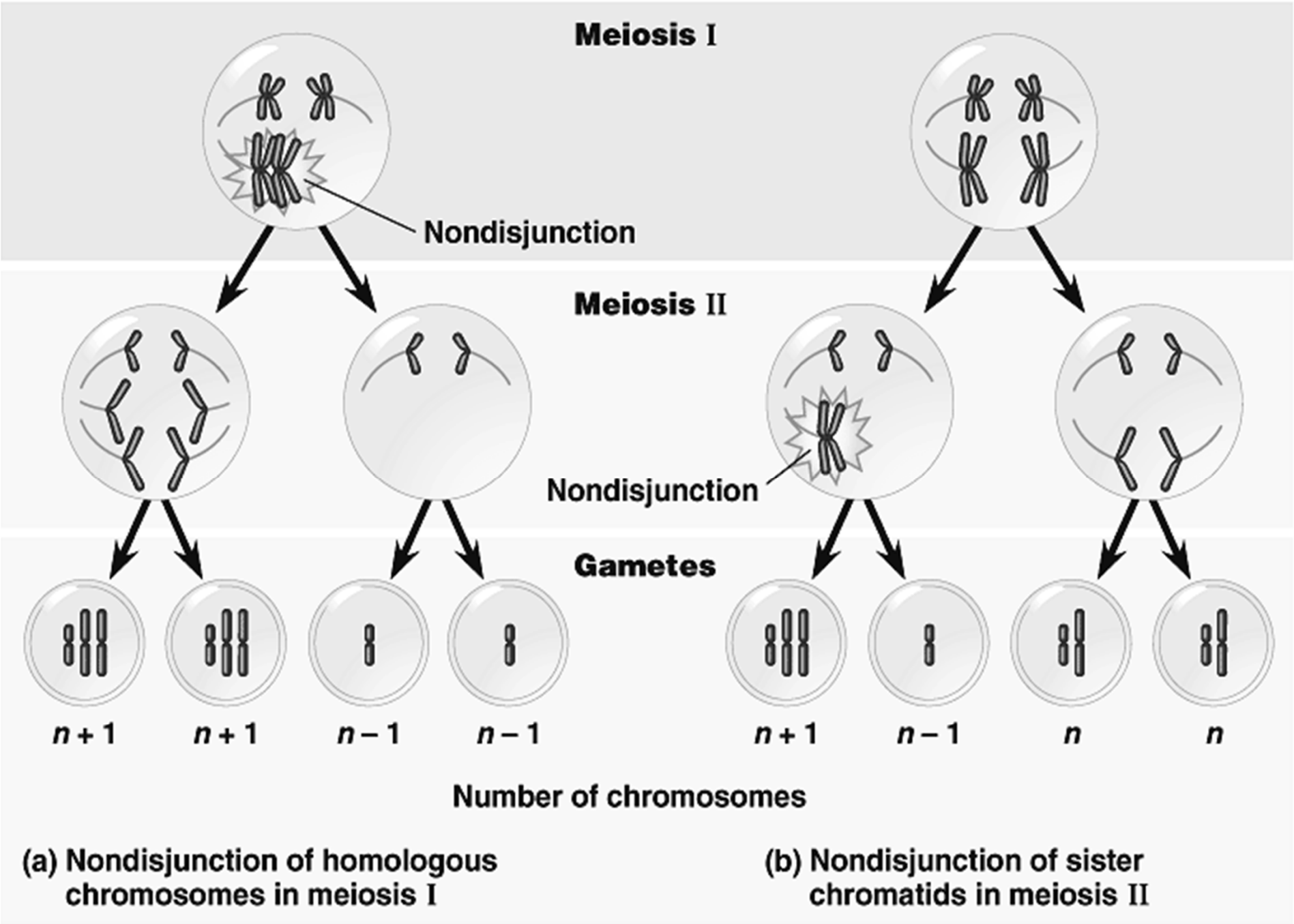
Disjunction: Chromosome Separation



Non-disjunction

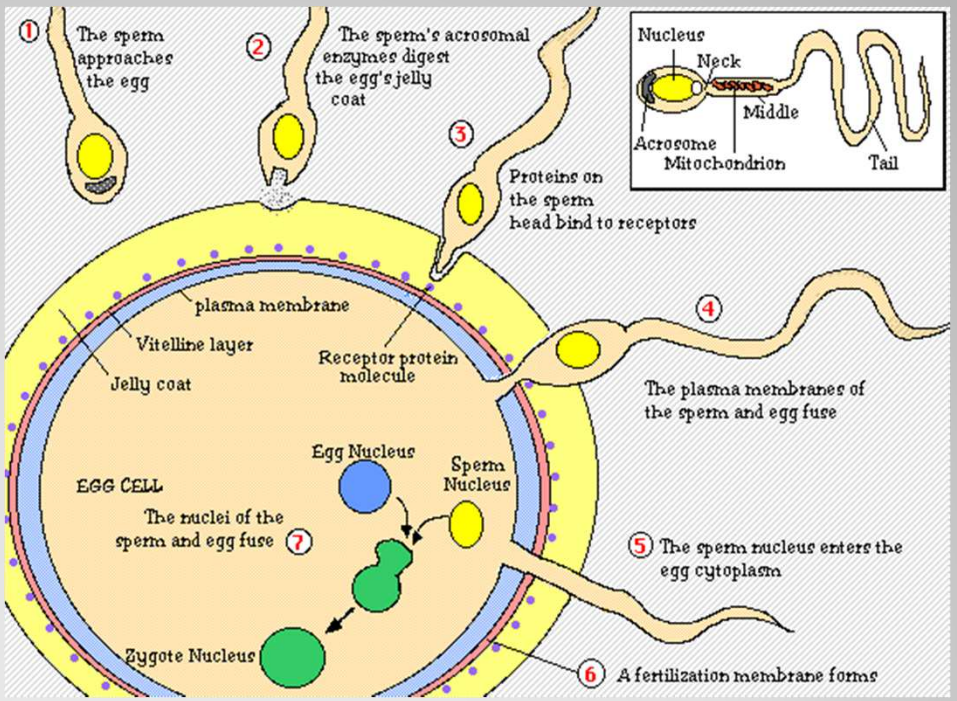
When chromosomes fail to separate during **anaphase** we call it non-disjunction.

- Chromosomes which should split end up moving to the same pole.
- This can happen in Meiosis I or Meiosis II.
- Result: Aneuploidy- gametes are produced with either one chromosome too many or one too few.



Fertilization

Is when two haploid gametes (egg and sperm) join with each other to produce a diploid zygote.



- Only 1 sperm can enter the egg.
- In plants the fertilized ovul is called a "seed".
- In animals the fertilized egg is called a zygote.

Zygote

The zygote is the diploid fertilized egg.

- In this photo you can see the two nuclei that are about to fuse.

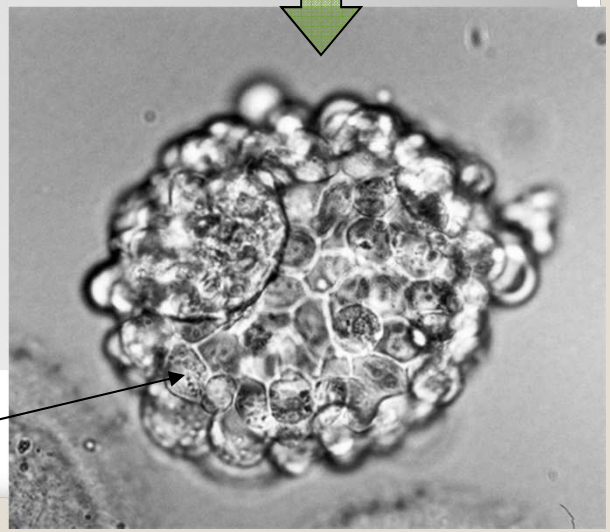
- The egg nucleus has 23 chromosomes from Mom.

- The other nucleus from the sperm, has the 23 chromosomes from Dad.

- The result will be 2N, for a total of 46 chromosomes.

Embryo

- The embryo is the new, developing diploid individual.
- 1 cell develops into 2, both 2n.
- Here the embryo has undergone **mitosis** again and is now in the 4 cell stage.
- All 4 cells are identical, 2n.

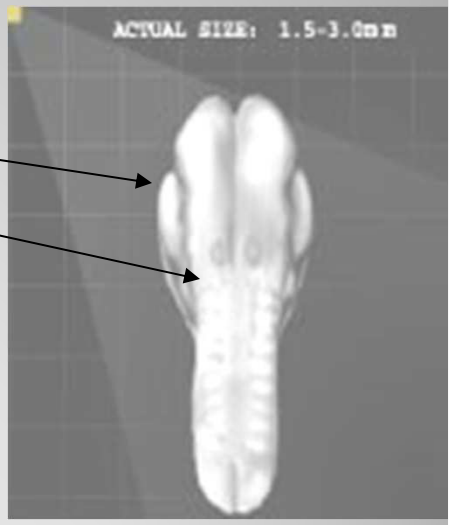


After day five: 70-100 cells (Blastocyst)

Differentiation

The process by which cells are directed to specialize into various different tissues.

- Differentiation allows organisms to reach their adult form and function.
- Here the developing spinal cord and brain are visible in the embryo.
- Cells become more specialized in their structure and function to be more efficient.
- Each cell has the same genetic information.
- The cell uses only the genetic information it needs to follow its specific pathway of development.
- (All cells have the same genes, because they have the same chromosomes. Genes can be "turned on" or "turned off" to make each type of cell specific for its function.)
- This is called Gene Expression!



Fetus

When the individual has developed all the major organs and structures of an adult, we call it a **fetus.**

For humans this is the start of the 9th week after fertilization till birth.

Meiosis

- The form of **cell division** by which **gametes,** with **half** the number of **chromosomes,** are produced.
- **Diploid (2n)** $\rightarrow$**haploid (n)**
- Involves **two divisions** (**meiosis I** and **meiosis II**).

Meiosis

- **Sex cells** divide to produce **gametes (sperm or egg)**.
- **Gametes** have **half** the # of **chromosomes**.
- **Occurs only in gonads (testes or ovaries).**

  Male: spermatogenesis
  Female: oogenesis

- **Meiosis** is similar to **mitosis** with some chromosomal differences.

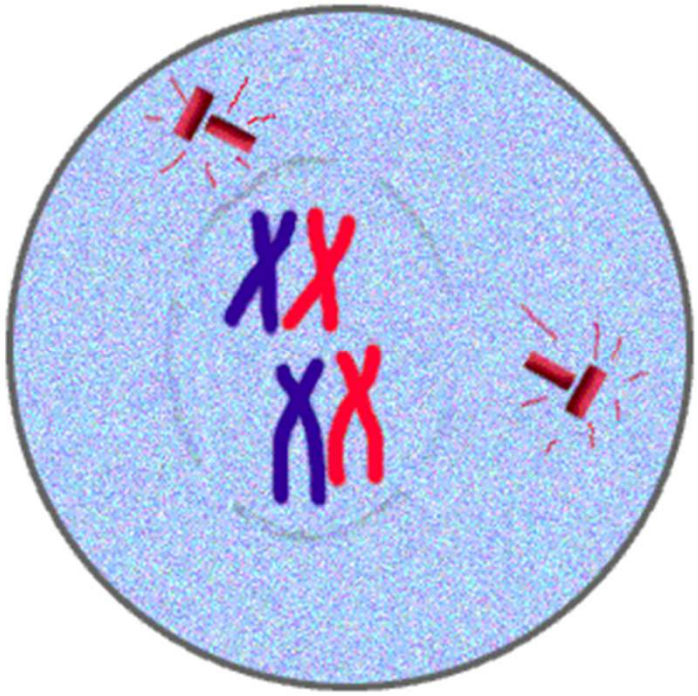
Meiosis I (four phases)

- four phases:
  a. prophase I
  b. metaphase I
  c. anaphase I
  d. telophase I

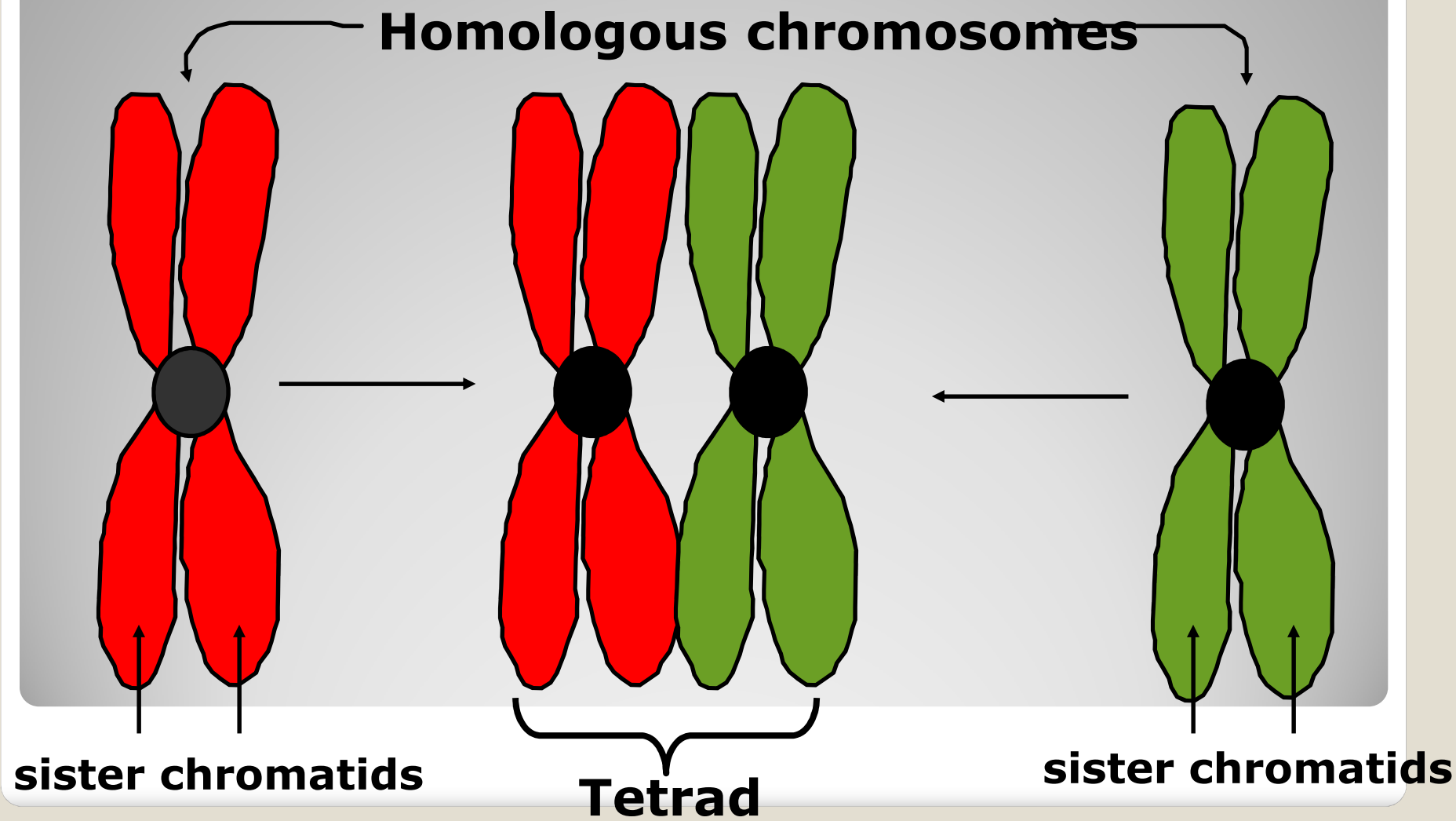
Same order and properties in each phase as Mitosis. Easy right?!?

Prophase I

- **Longest and most complex phase (90%).**
- **Homologous chromosomes** come together to form a **tetrad**.
- **Tetrad** is two **chromosomes** or four **chromatids**.

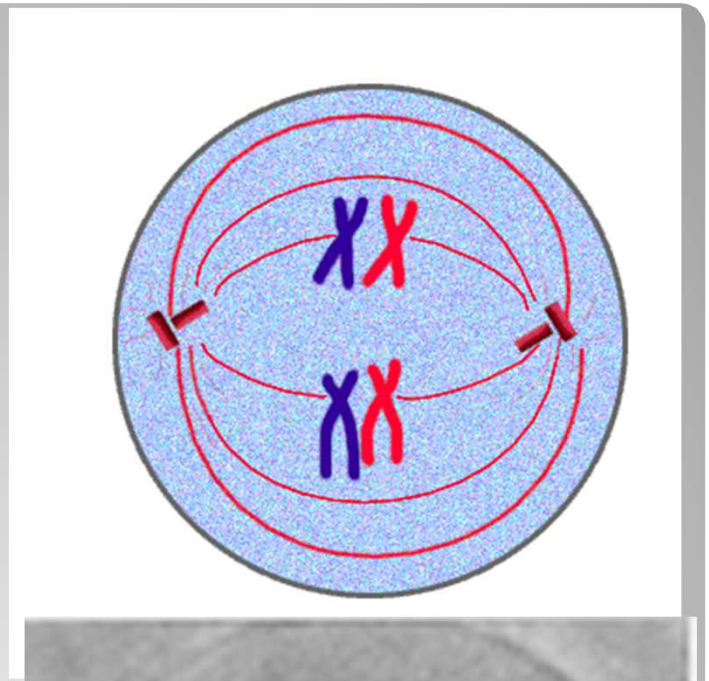


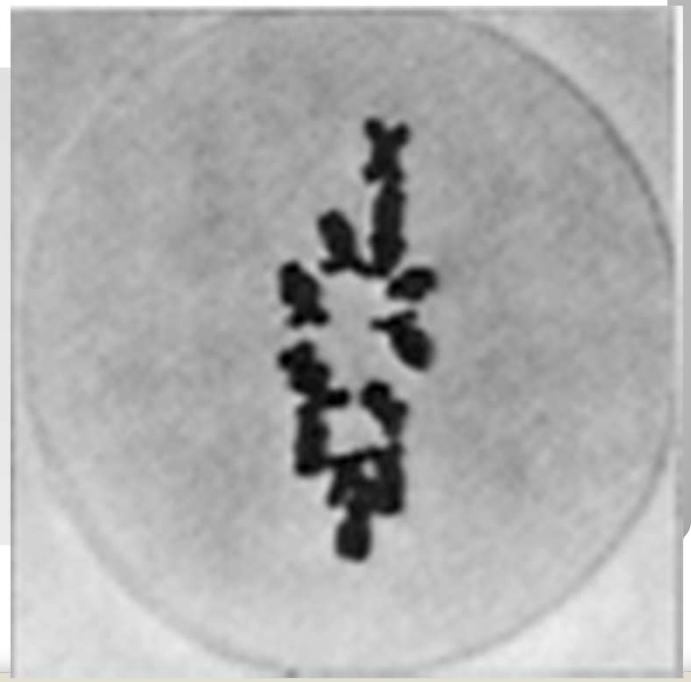
Prophase I


Homologous chromosomes
sister chromatids
Tetrad
sister chromatids

Metaphase I

- **Shortest phase**
- **Tetrads** align on the **equator**. They straddle the equator



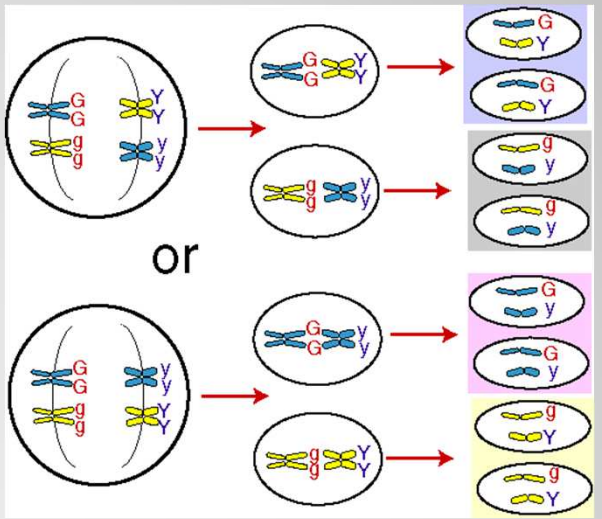


Metaphase I

INDEPENDENT ASSORTMENT OCCURS:

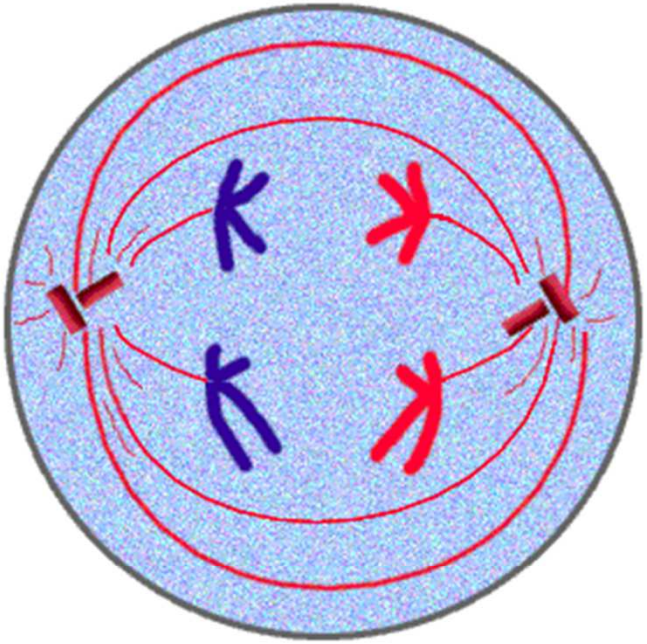
- Orientation of homologous pair to poles is random.

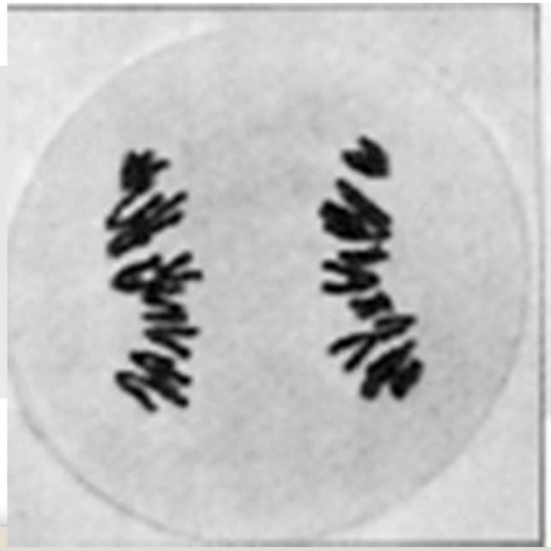
- Leads to Variation



Anaphase I

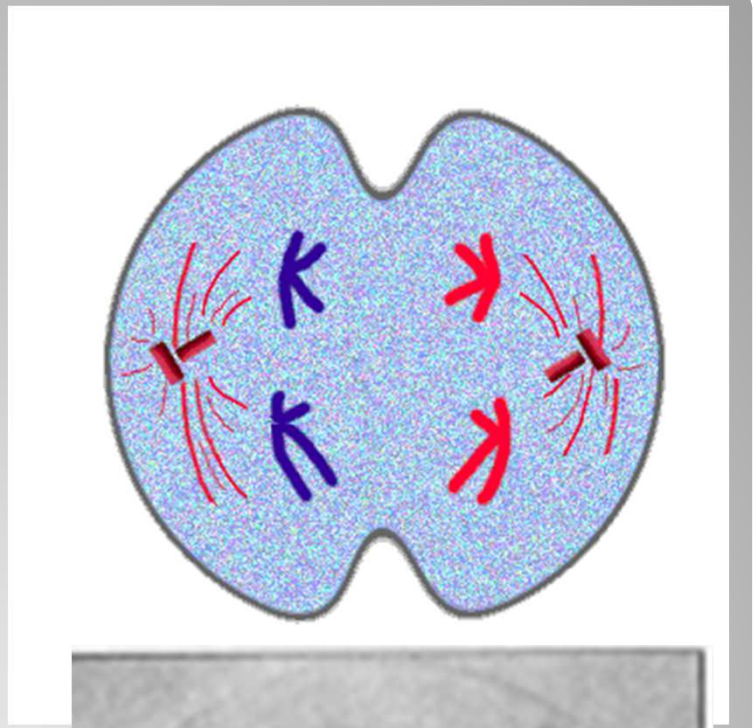
- **Homologous chromosomes** separate and move towards the poles.
- **Sister chromatids** remain attached at their **centromeres**.

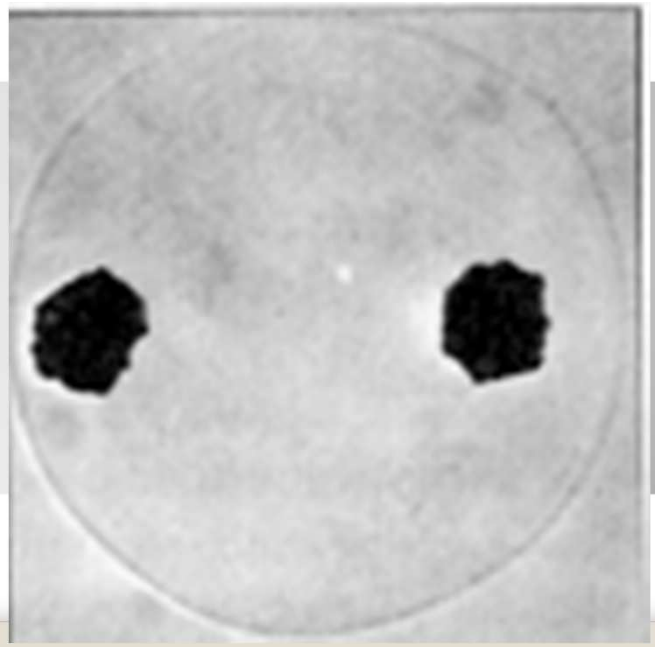




Telophase I

- Each pole now has **haploid** set of replicated **chromosomes**.
- The chromosomes still consist of two chromatids.





Meiosis II

- **Very short interphase II** - no more **DNA replication**
- The next set of cell divisions will separate the chromatids.
- **Meiosis II** is similar to **mitosis**

Meiosis II (four phases)

- **four phases**:
  a. **prophase 2**
  b. **metaphase 2**
  c. **anaphase 2**
  d. **telophase 2**

Question:

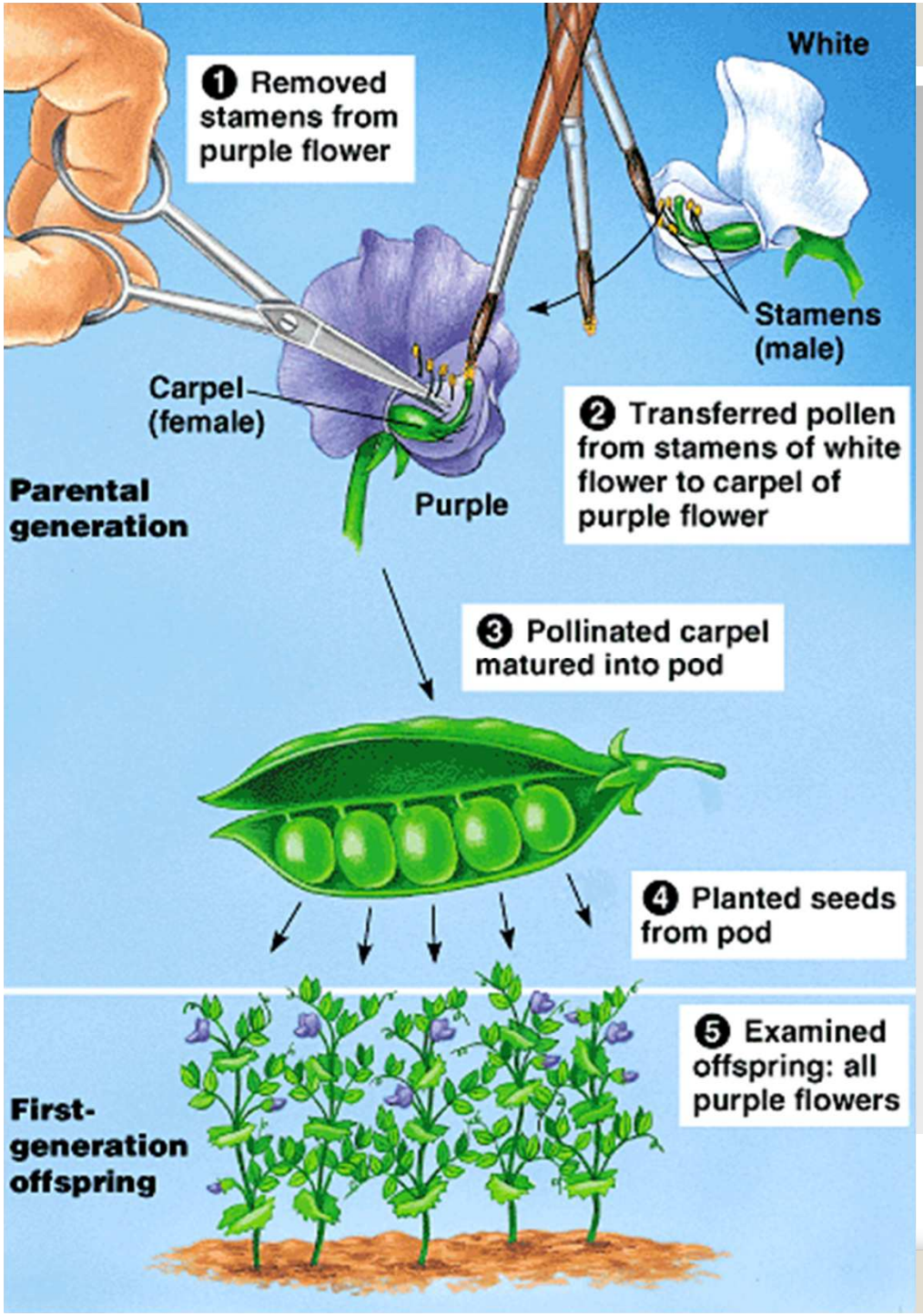
- A cell containing **20 chromosomes (diploid)** at the beginning of meiosis would, at its completion, produce cells containing how many **chromosomes**?

- **10 chromosomes (haploid)**

We've all heard of it, but … What is genetics?

Genetics: **the study of gene structure and action and the patterns of inheritance of traits from parent to offspring.**

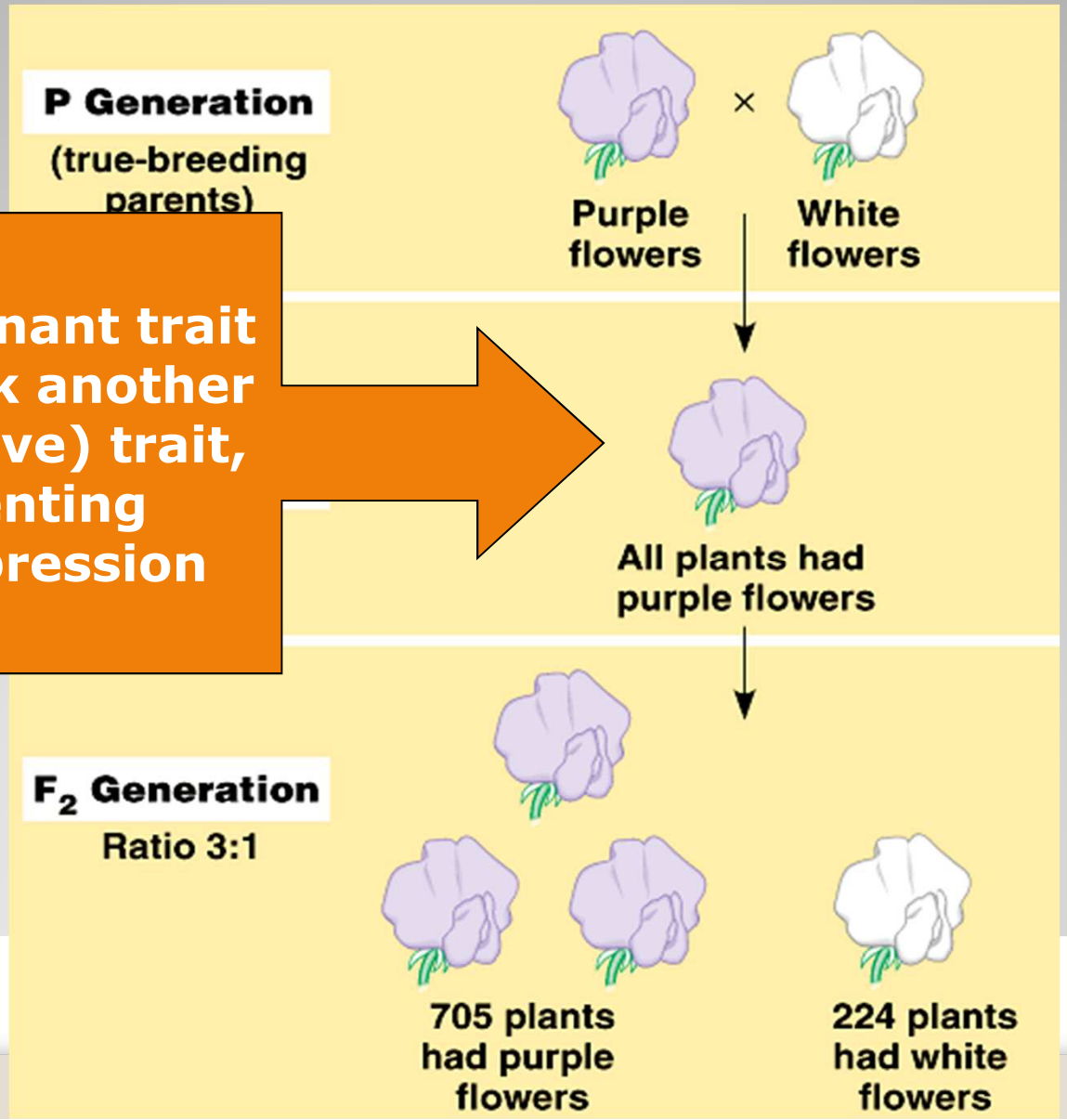
Mendel's experiments



Mendel's Principle Findings

- Dominant and Recessive
  - Certain characteristics are <u>dominant</u> to others
  - The dominant trait will mask another (recessive) trait, preventing it's expression
  - The recessive trait "disappears" for a generation

Cross between varieties



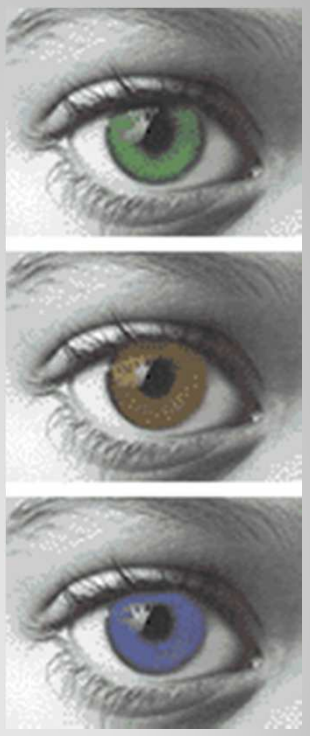
The dominant trait will mask another (recessive) trait, preventing it's expression

Mendel's Principle Findings

- Segregation
  - **For each trait, organisms have 2 genes**
  - Each pea plant got one gene from each parent
  - Genes segregate from each other during egg or sperm formation (meiosis)

Some terms …

- Trait: characteristics of an organism pass from generation to generation.
  - Eye color
  - Hair color and type
  - Height
  - Temperament
  - Symptoms for genetic diseases



Genotype

- Tells you the genetic makeup of the organism
- The genes the organism carries

Genotype

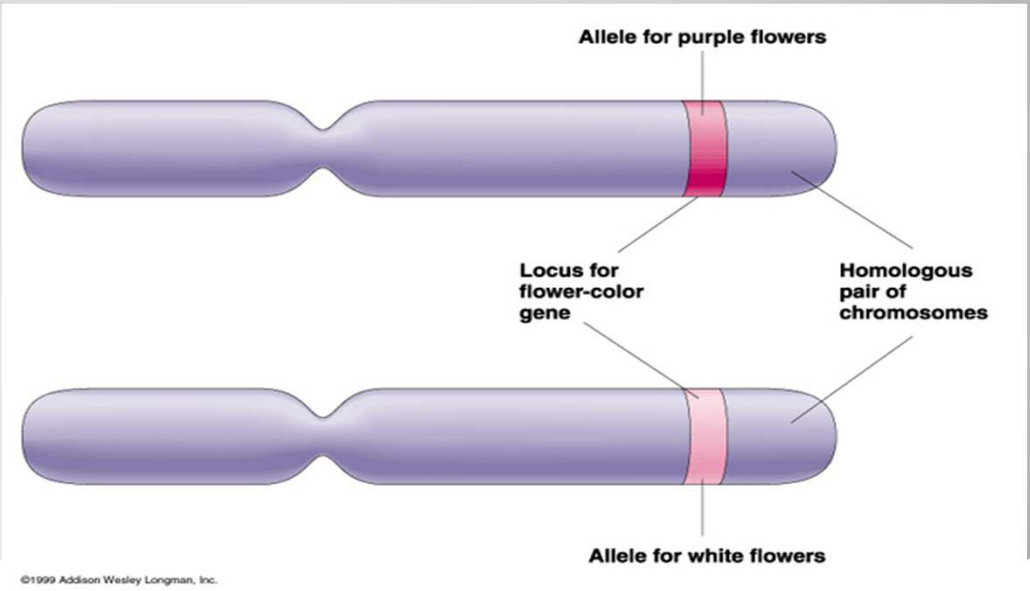
- Written using symbols
  - Each allele is represented by a letter
    - Tall = T dominant
    - Short = t recessive
  - Capital letter designates the dominant trait and lower case letter designates the recessive trait.
  - Capital letter is always written first.

Homozygous

- An individual which contains one allele for a genetic trait
  - TT-- homozygous dominant
  - tt -- homozygous recessive

Heterozygous

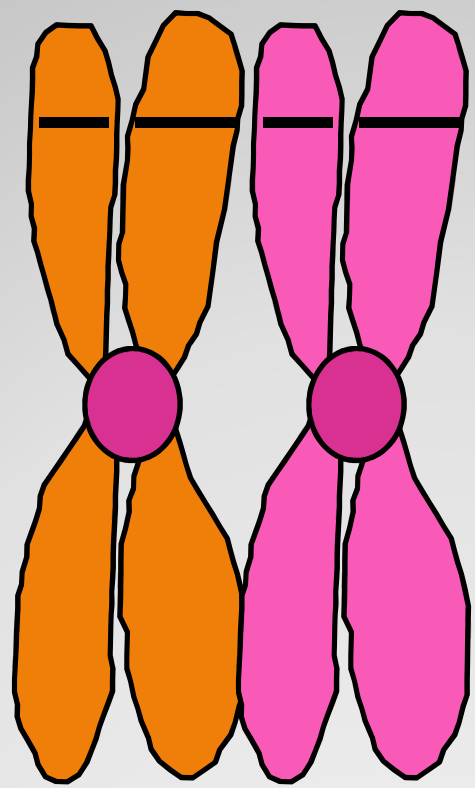
- An individual which contains different alleles for a genetic trait
  - Tt heterozygote



Phenotype

- What the organism looks like
- Controlled by the genotype
  - TT---------- tall
  - Tt---------- tall
  - tt---------- short

eye color gene
Allele B
(brown eyes)



eye color gene
Allele b
(blue eyes)

This person would have brown eyes (Bb)

Example

Paternal Maternal

Punnett squares

- The probability the next generation will exhibit a certain trait can be shown with a punnett square.
  - The genotype of the mother is shown on the top of the square (TT)
  - The genotype of the father is shown on the side of the square (tt)
  - The various combinations of genes (genotypes) are shown in the squares. All of these offspring will be (T) Tall and carry the recessive (t) short allele.

	T	T
t	Tt	Tt
t	Tt	Tt

Punnett squares

- What happens if you cross a heterozygous plant (Tt) with a short plant (tt)?

Two of the four will be Heterozygous (Tall) and the other two will be homozygous recessive (short)

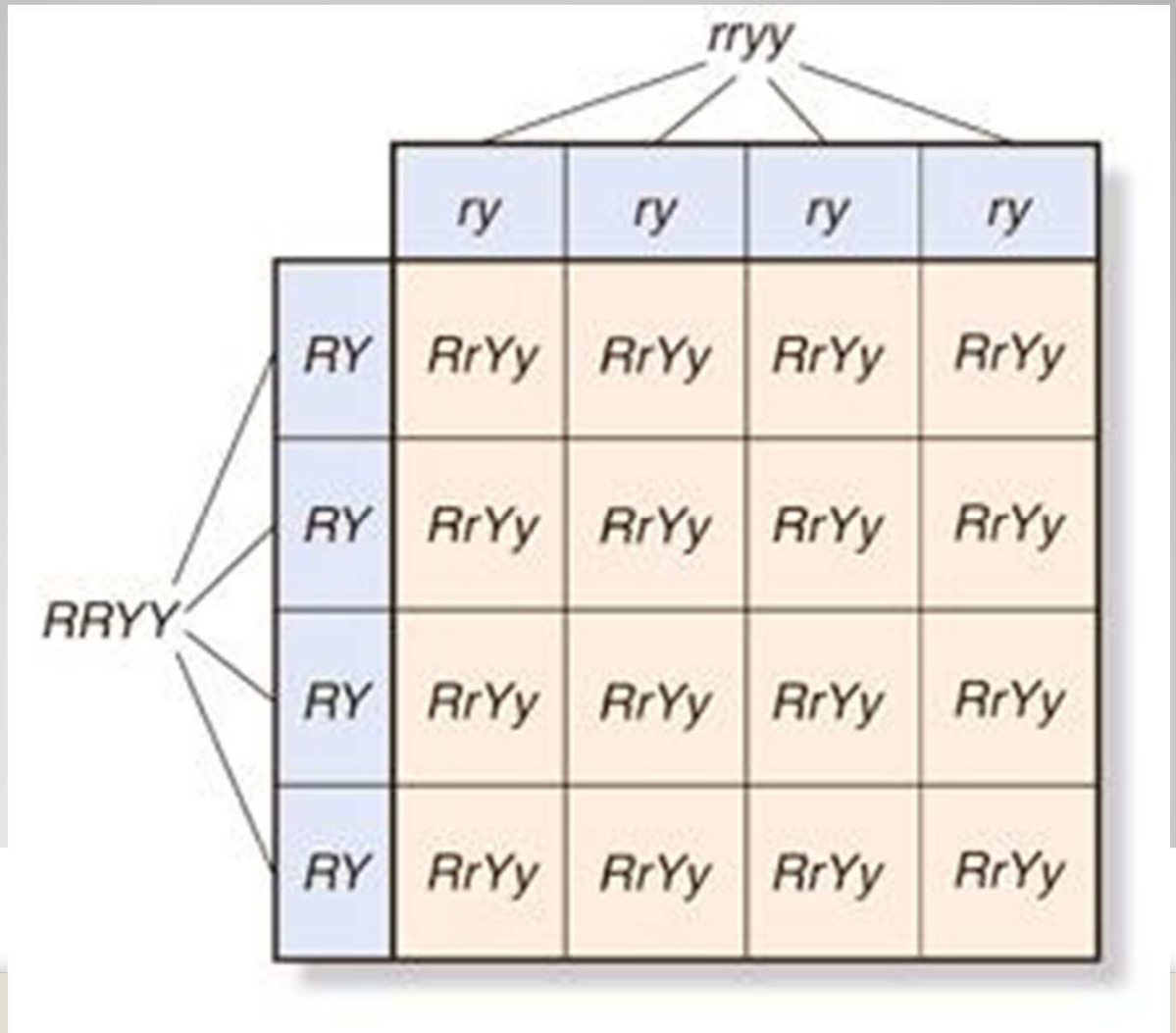
This is a 1:1 ratio

	T	t
t	Tt	tt
t	Tt	tt

Monohybrid vs. Dihybrid

- Monohybrid crosses are crosses that examine the inheritance of only one specific trait.
- Dihybrid crosses are crosses that examine the inheritance of two different traits.

Mendel and Dihybrid Crosses



Mendel and Dihybrid Crosses

The resulting cross looks like this:

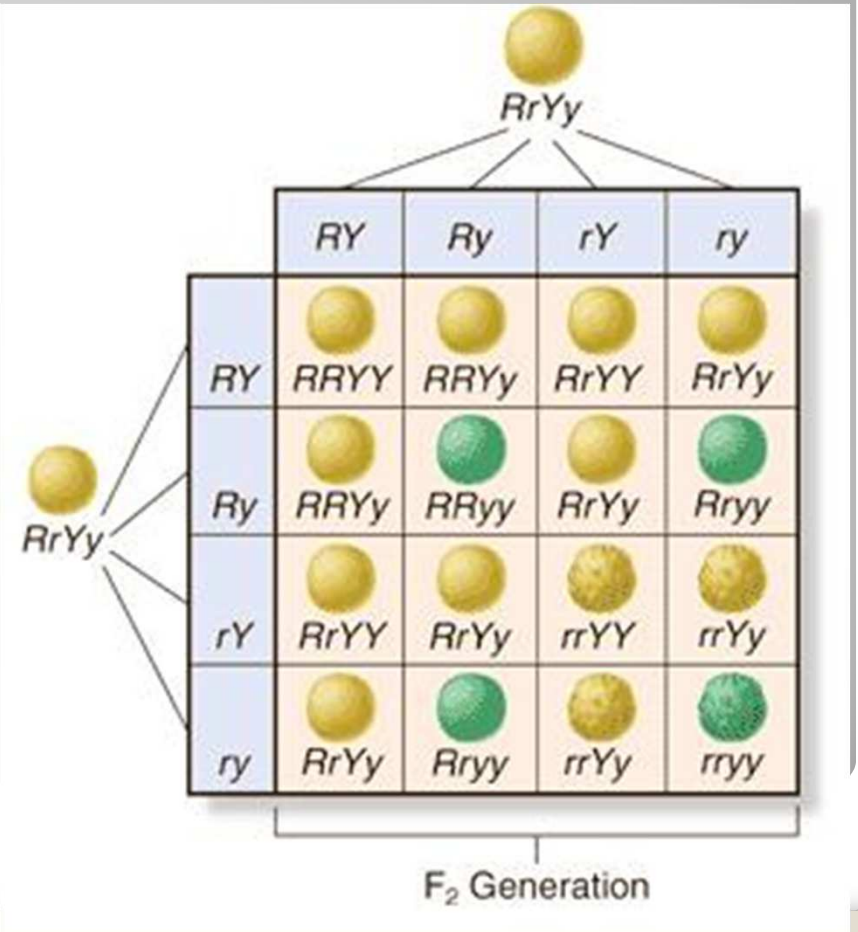
phenotypic ratio--

9:16 yellow and round,

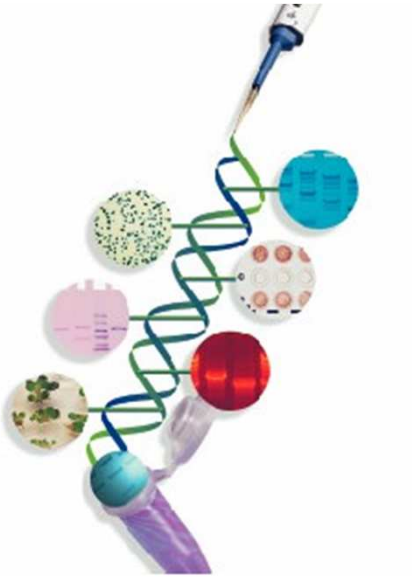
3:16 green and round,

3:16 wrinkled and yellow,

1:16 wrinkled and green.



Biotechnology

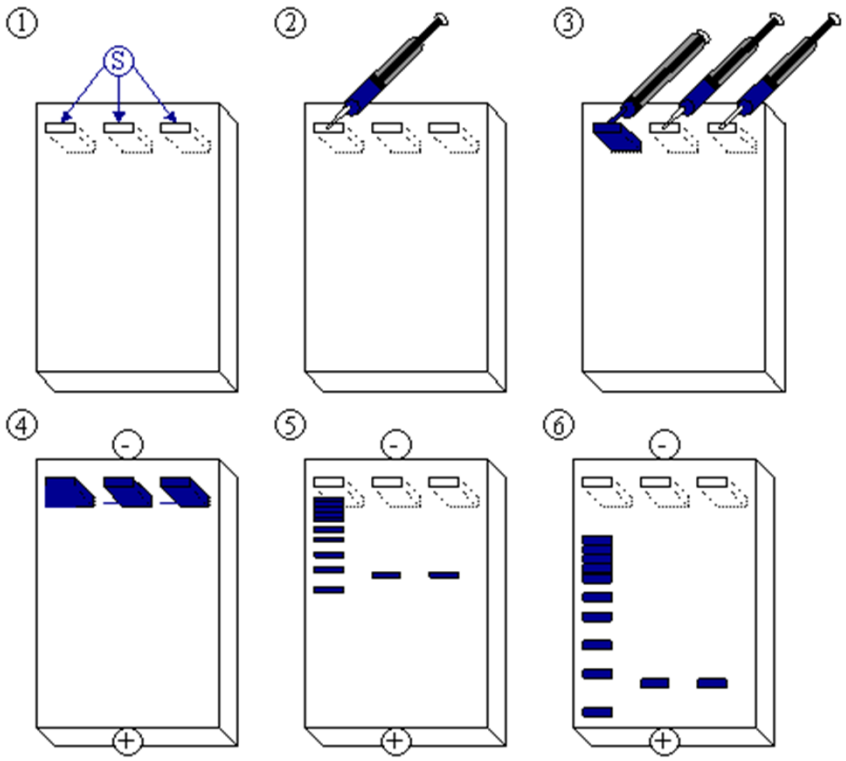


Gel Electrophoresis

- A technique that separates macromolecules
- on the basis of their rate of movement
- through a gel
- under the influence of an electric field.
  - Example of macromolecules
    - nucleic acids or proteins

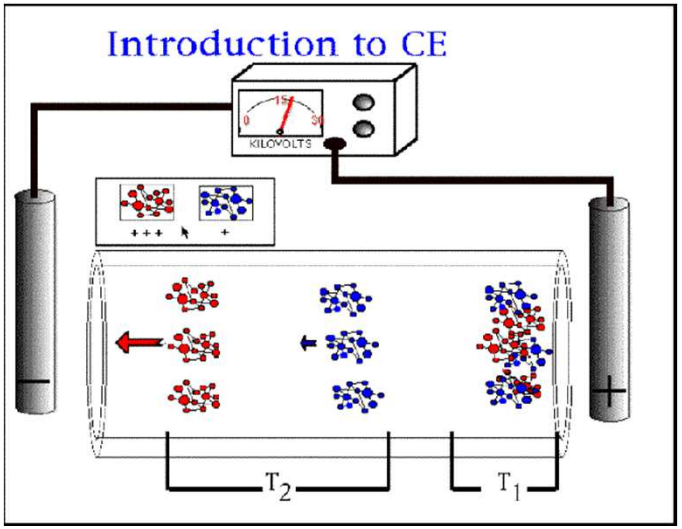
Gel Electrophoresis

- It sorts a mixture of DNA molecules into bands, each band consisting of DNA molecules of the same length.



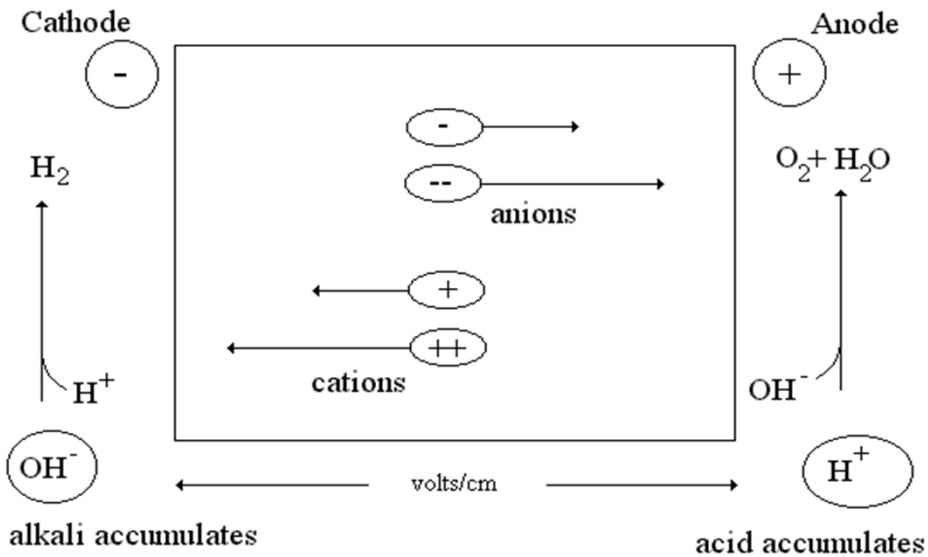
Gel Electrophoresis

- Each macromolecule then migrates toward the electrode of opposite charge at a <u>rate determined</u> mostly by
  - the molecule's <u>charge</u> and <u>size</u>
- How far a molecule travels while the current is on is <u>inversely proportional</u> to <u>molecular size</u>.



Gel Electrophoresis

- Nucleic Acids (DNA and RNA) are negatively charged : "anions"
  - The "-" charge carried on the phosphate groups
  - The "-" charge is proportionate to their lengths.
- They will move toward the "+" electrode- "anode."

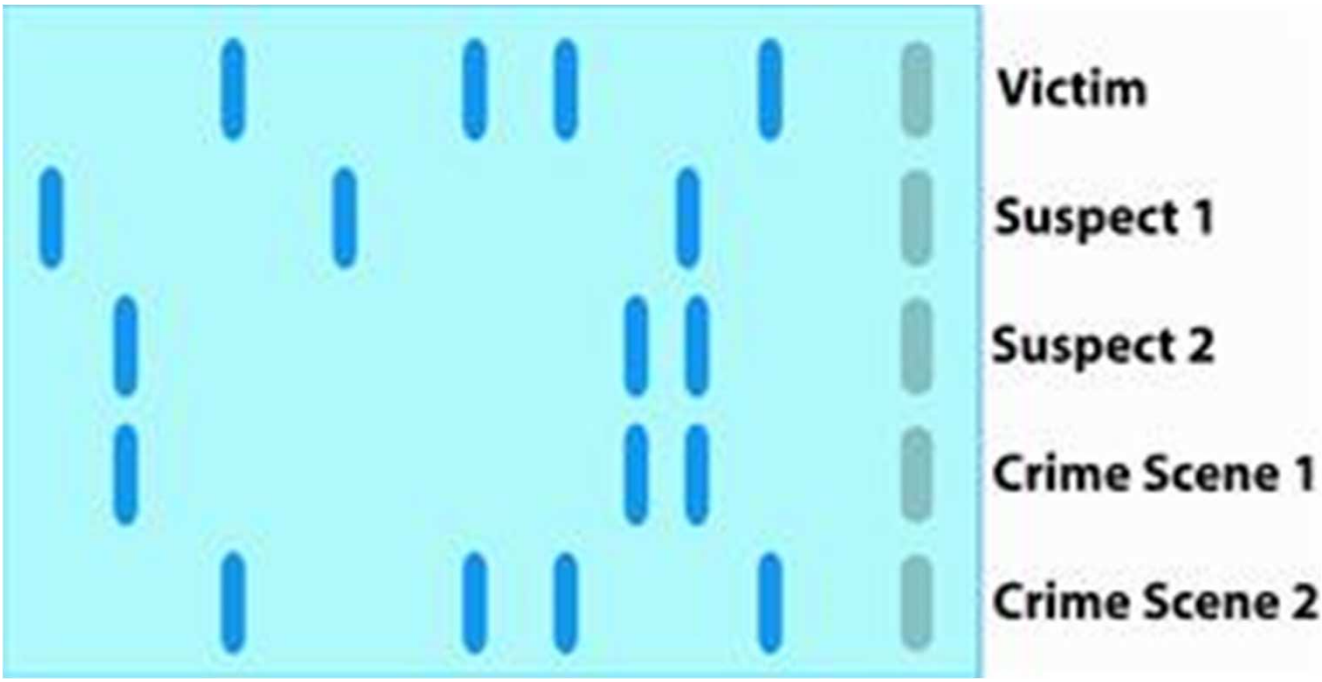


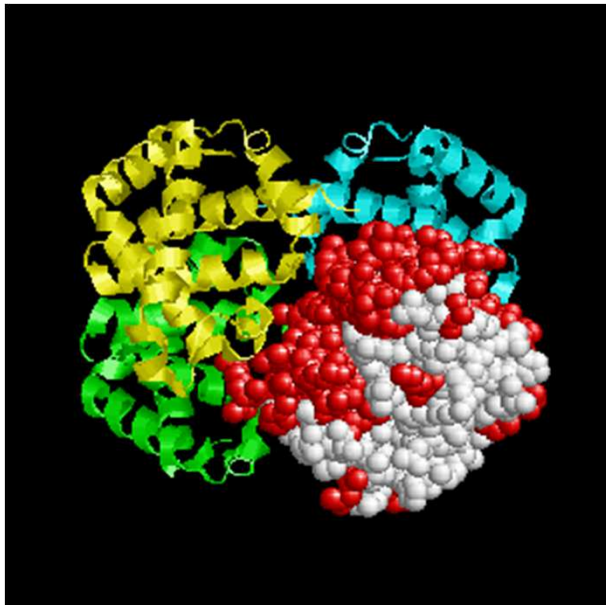
Gel Electrophoresis

- The polysaccharide Agarose is used to make the gel.
  - It is derived from algae.
  - Once poured, it contains microscopic pores which act as molecular sieves.
  - These will influence the rate at which the molecules will migrate.

Gel Electrophoresis

- Smaller molecules will be able to move through the pores more easily than larger ones:
  - The pores in gel impedes the longer fragments more than it does shorter ones.
  - If the fragments are the same size, the one with greater charge will migrate faster.

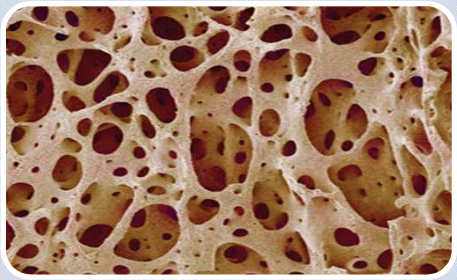

Victim
Suspect 1
Suspect 2
Crime Scene 1
Crime Scene 2



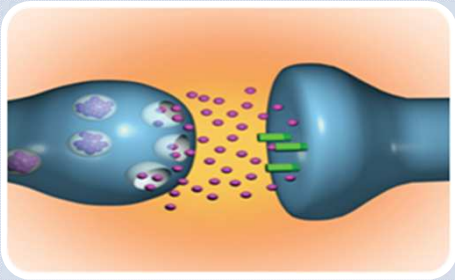
Proteins

Major Types of Proteins

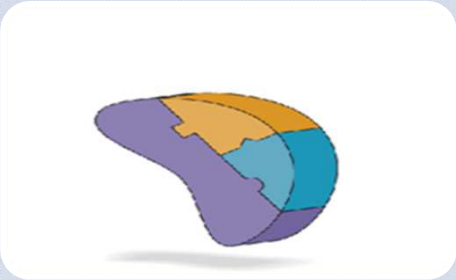
There are many types of proteins.
Most fall into the following 3 major categories:



Structural



Signaling

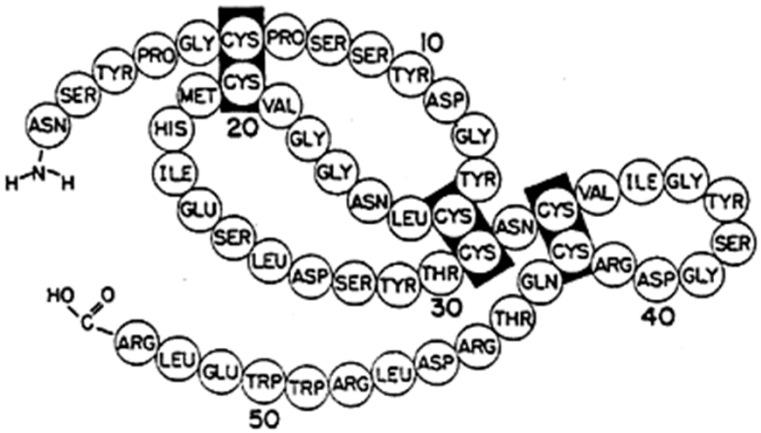


Enzymatic

What is a protein made of?

Like DNA, **Proteins** are made of long strings of **individual building blocks**.

DNA is made of **nucleotides** while proteins are made up of **amino acids**.



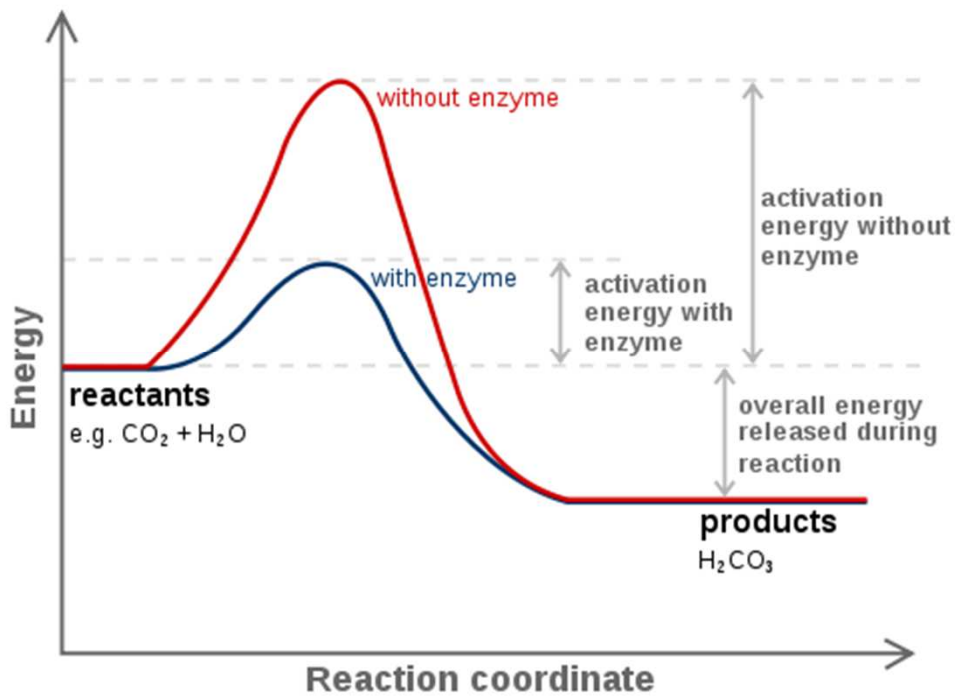
Enzymes control and initiate chemical reactions

Enzymes initiate **synthesis reactions**

Enzyme initiated **lysis or cleavage**

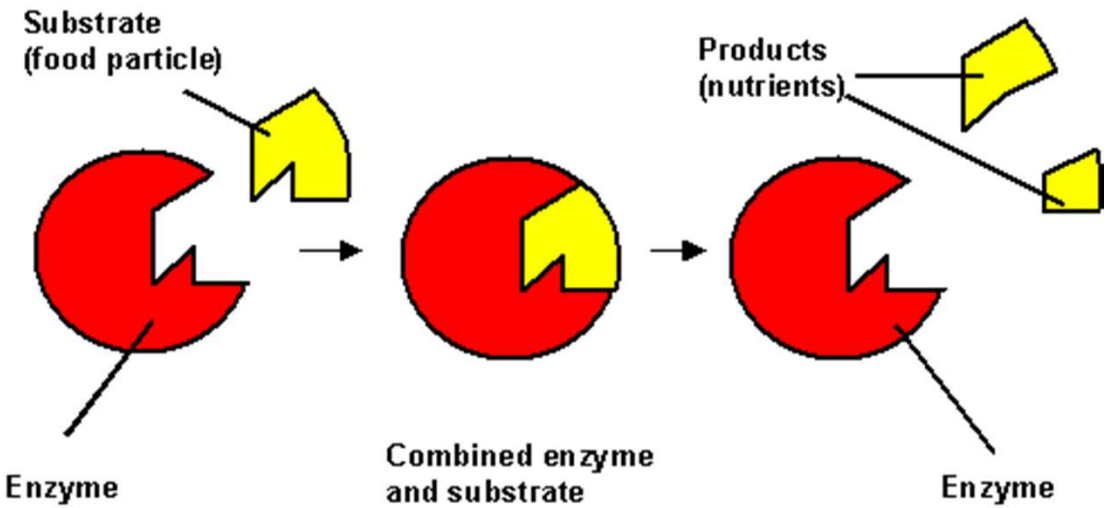
Enzymes **lower activation energy** and promote rapid reactions to occur

Without enzymes, organisms would have to heat to a lethal temp or else life sustaining rxns would occur too slowly.



Some helpful terminology:

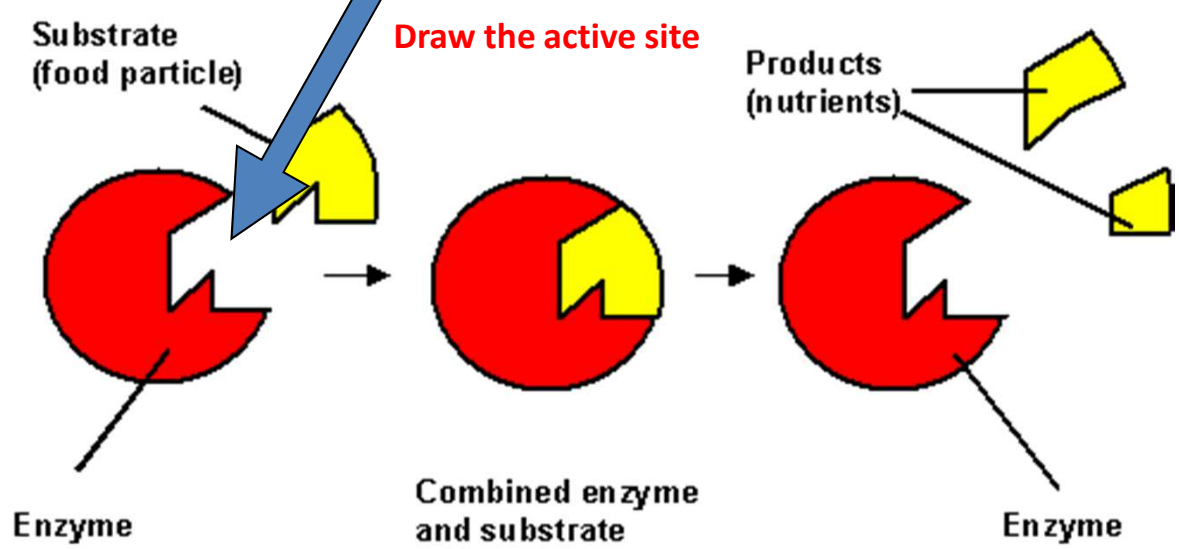
- **<u>SUBSTRATE</u>:** The substance (**reactants**) that an enzyme acts on and makes more reactive. This could be another protein, lipid, carbo. or nucleic acid.
  - Ex. Lactase (enzyme) that acts on lactose (substrate)



How enzymes break down food into nutrients

ACTIVE SITE:

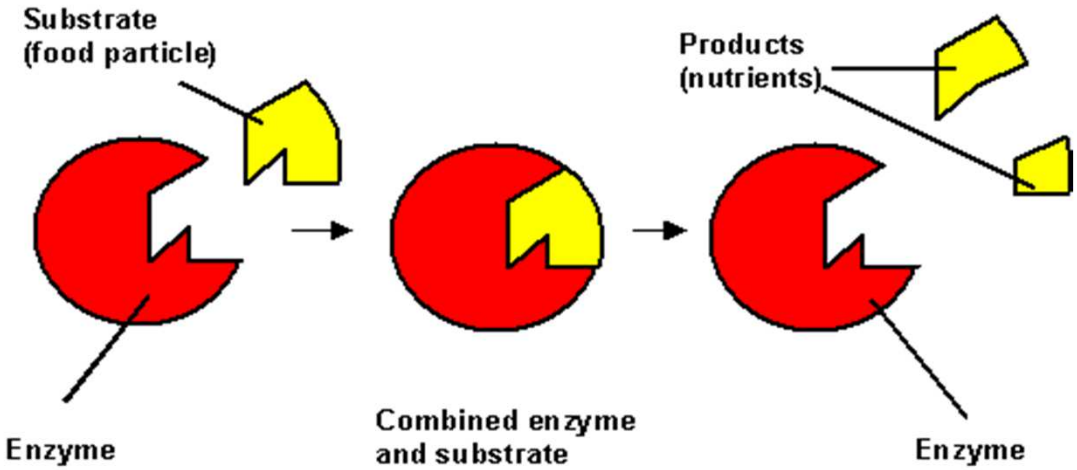
- The **area of an enzyme molecule** which **binds to the substrate**.
  - Groove in enzyme surface, formed with only a few of its amino acids.



How enzymes break down food into nutrients

"Lock and Key"

- Enzyme **specificity** is based on **compatible fit** between shape of active site and shape of substrate.
  - The substrate is the key whose shape is complementary to the enzyme or lock.



How enzymes break down food into nutrients

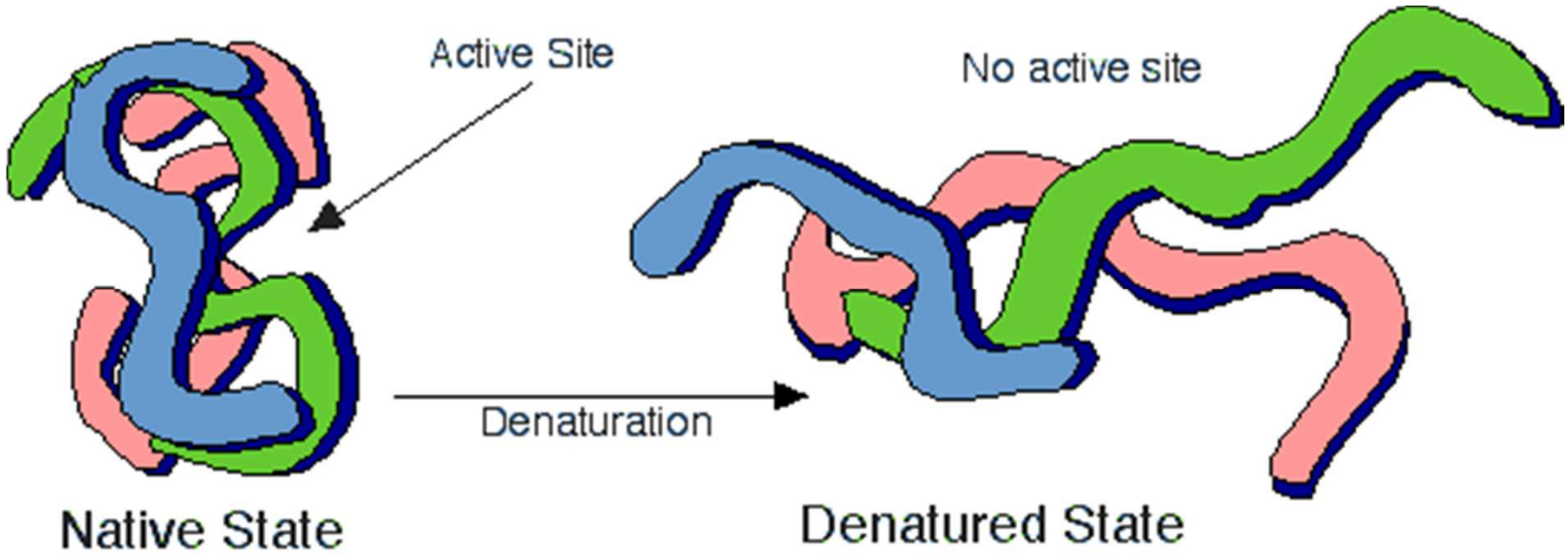
“Lock and Key”…Specificity

- A **different** substrate would need a different “Lock” …enzyme!
    - This is called

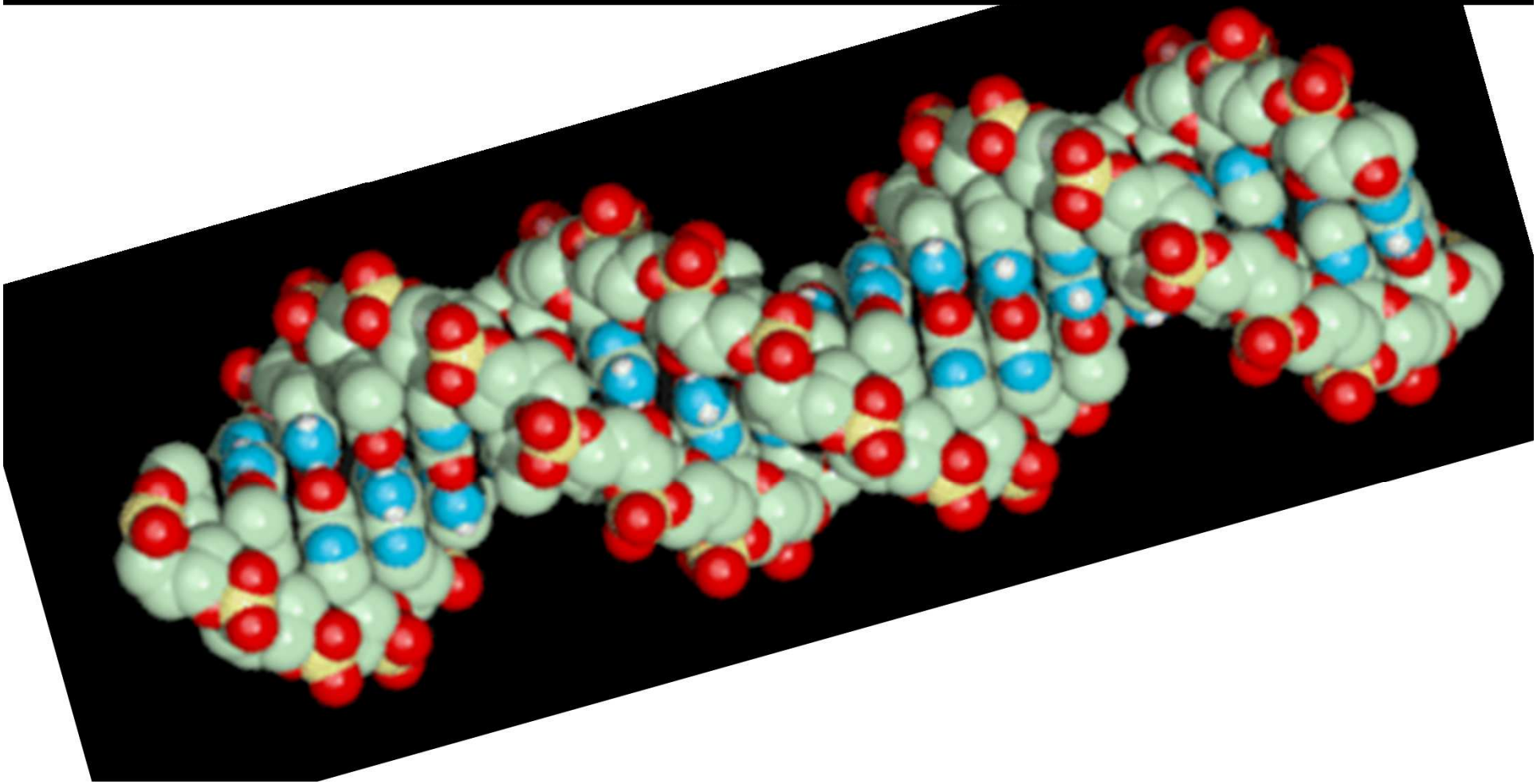
SPECIFICITY!

Denaturation:

- Loss of the 3-D shape of a protein (it unravels).
  - This destroys the active site
  - Caused by: Heat, Cold, Chemical agents, pH change (too acidic or basic)
    - This is why a temp. of over 104° F is dangerous and person should go to the hospital.



DNA codes for Proteins



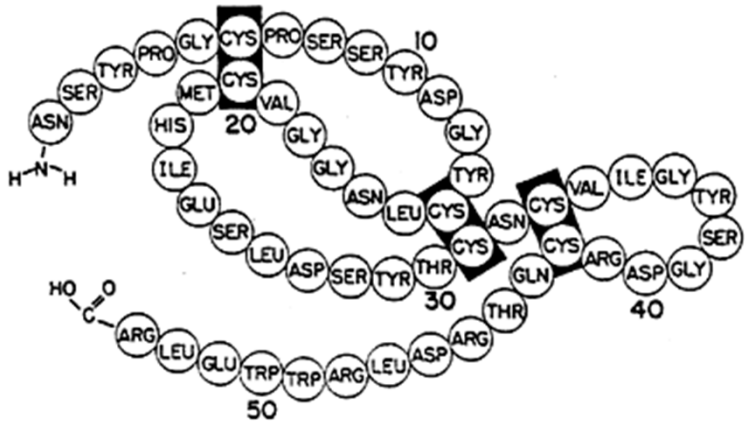
DNA codes for Proteins

- Proteins do the nitty-gritty jobs of every living cell.

- The importance of DNA is that it contains the information that is used to make all of the proteins on which life depends.

Part I: WHAT IS A PROTEIN?

- Proteins are made of long strings of <u>individual building blocks</u> known as AMINO ACIDS.

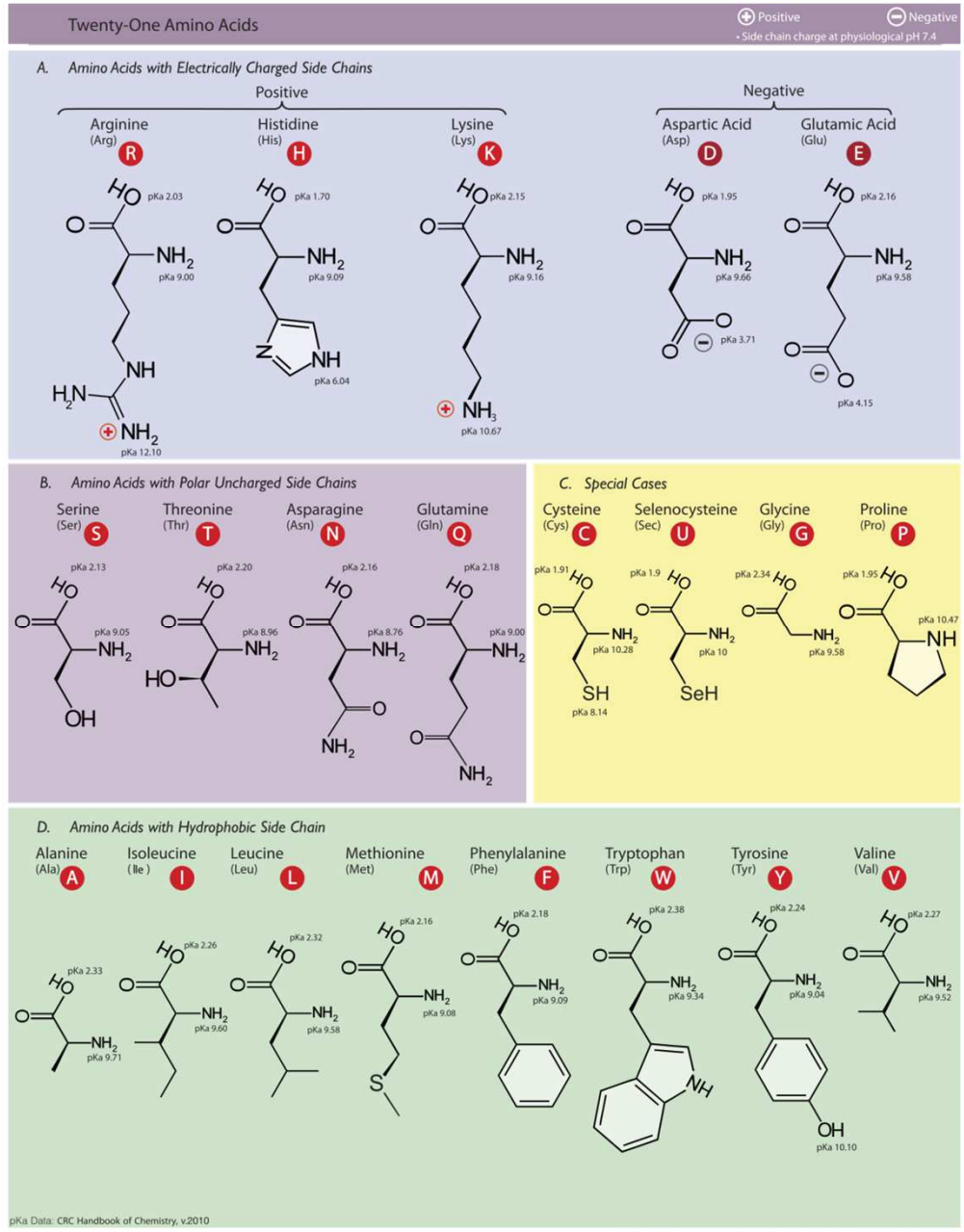


What is an amino acid?

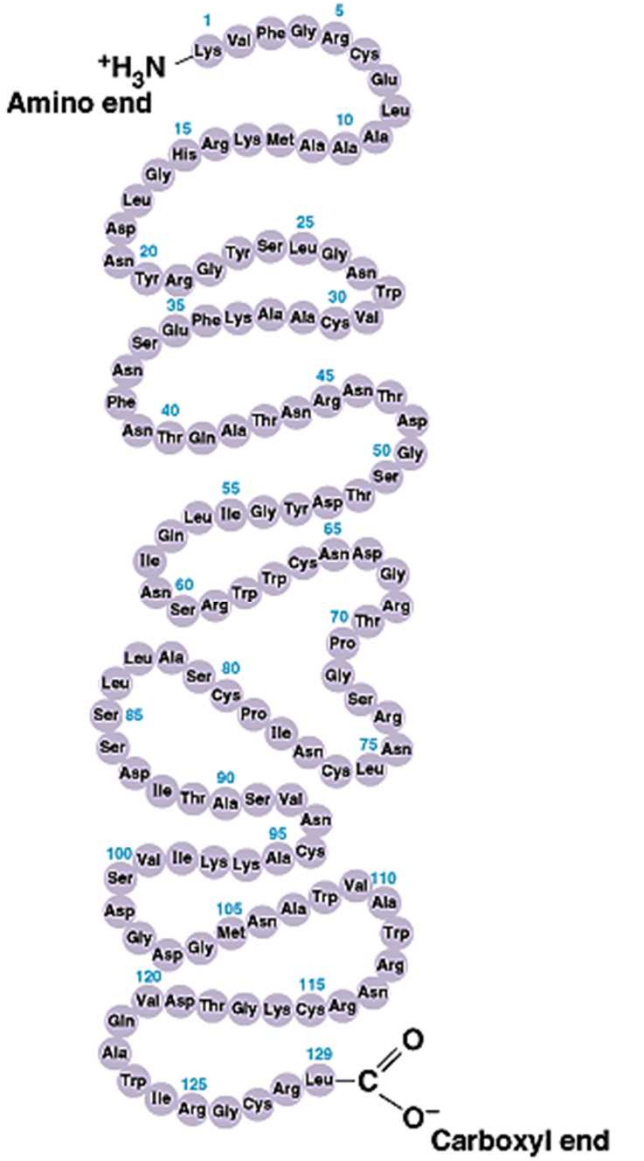
Amino acids are **organic molecules**

They come in **20** different types that are all slightly **different from one another**

These structural differences **give rise to their different properties**



BACK TO PROTEINS



A protein is **a chain** of amino acids (aa):
…aa-aa-aa-aa-aa…

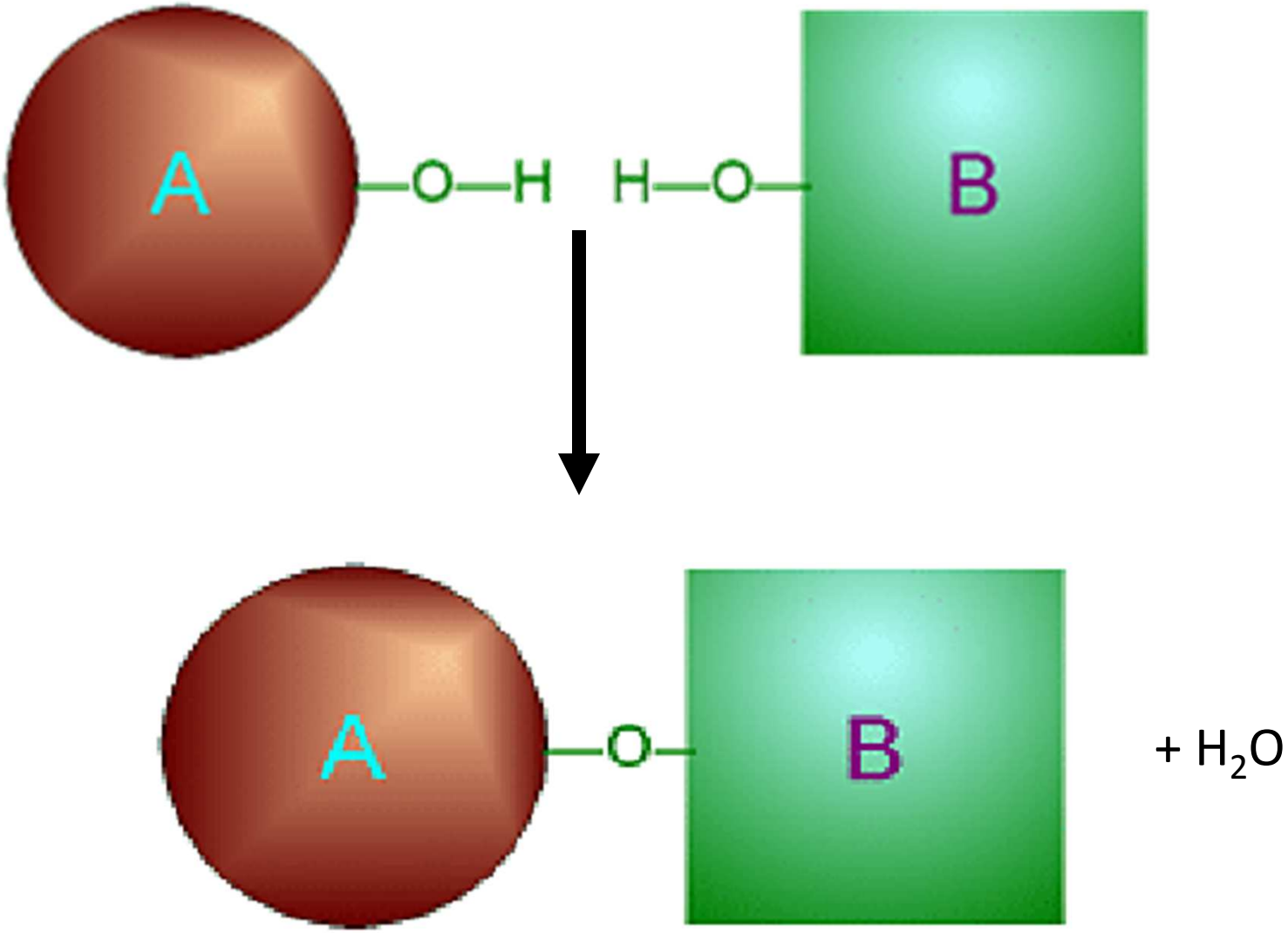
Think of a beaded **necklace** where the different colored beads are **the different amino acids**

Individual amino acids are held together by **peptide bonds**

These are formed through a **dehydration synthesis** reaction

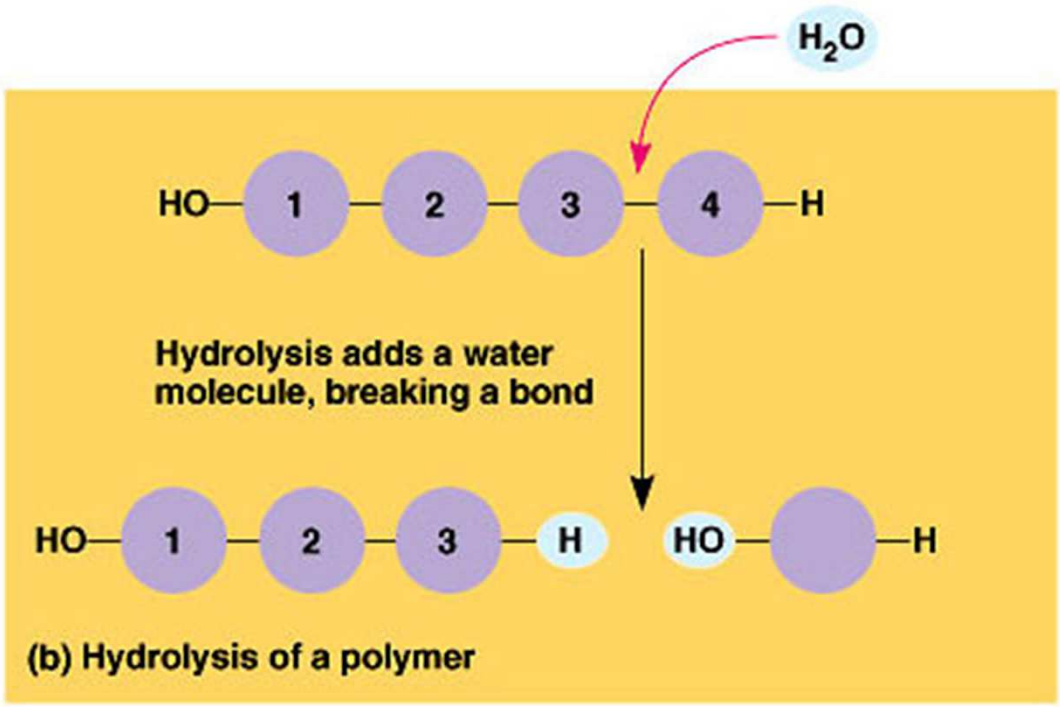
More than two amino acids joined together are called a **polypeptide**

Condensation



Hydrolysis:

- Hydro-
  - water (H_2O)
- Lysis-
  - to split



HYDROLYSIS...

the splitting of a polymer by adding water to a covalent bond;

catalyzed by a hydrolyase enzyme.

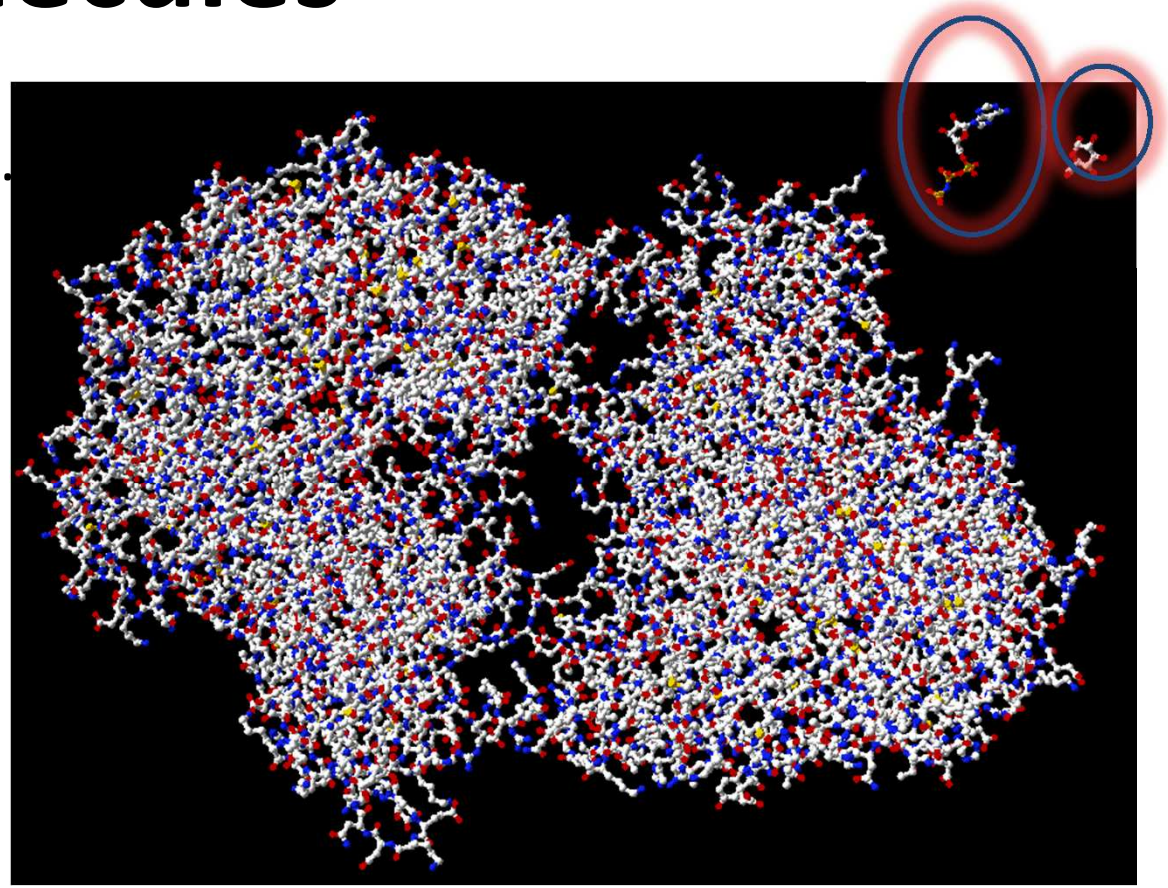
Proteins are organic macromolecules

A protein might contain **many hundred amino acids**.

Ex: the enzyme hexokinase. To scale in the corner its substrates:

ATP

and **glucose**.



If just one of these amino acids is changed, the **function** of the protein might **change drastically**

DNA codes for Proteins

- **Enzymes** do the nitty-gritty jobs of every living cell.

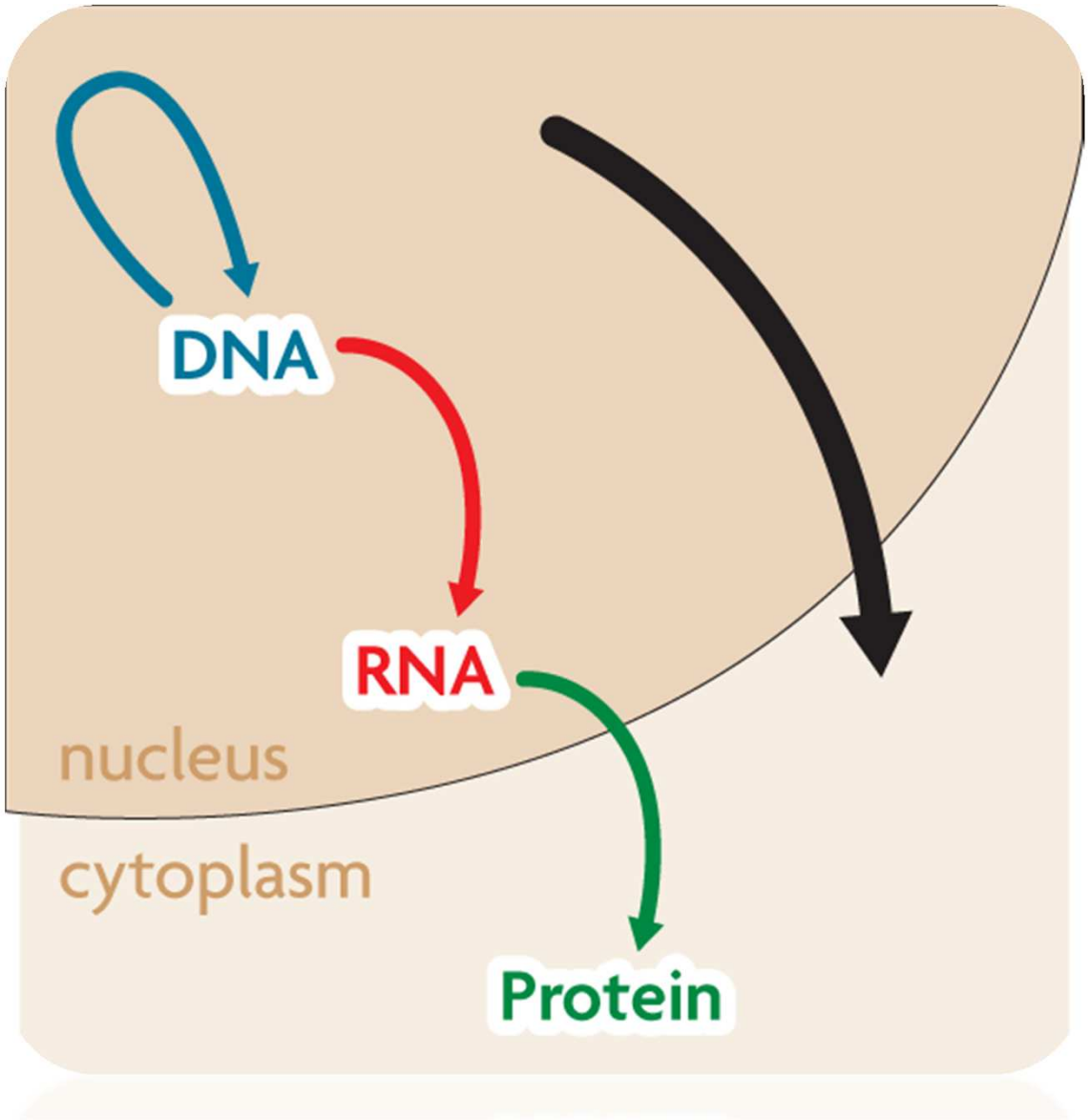
- The importance of **DNA** is that it contains the information that is used to make all of the proteins on which life depends.

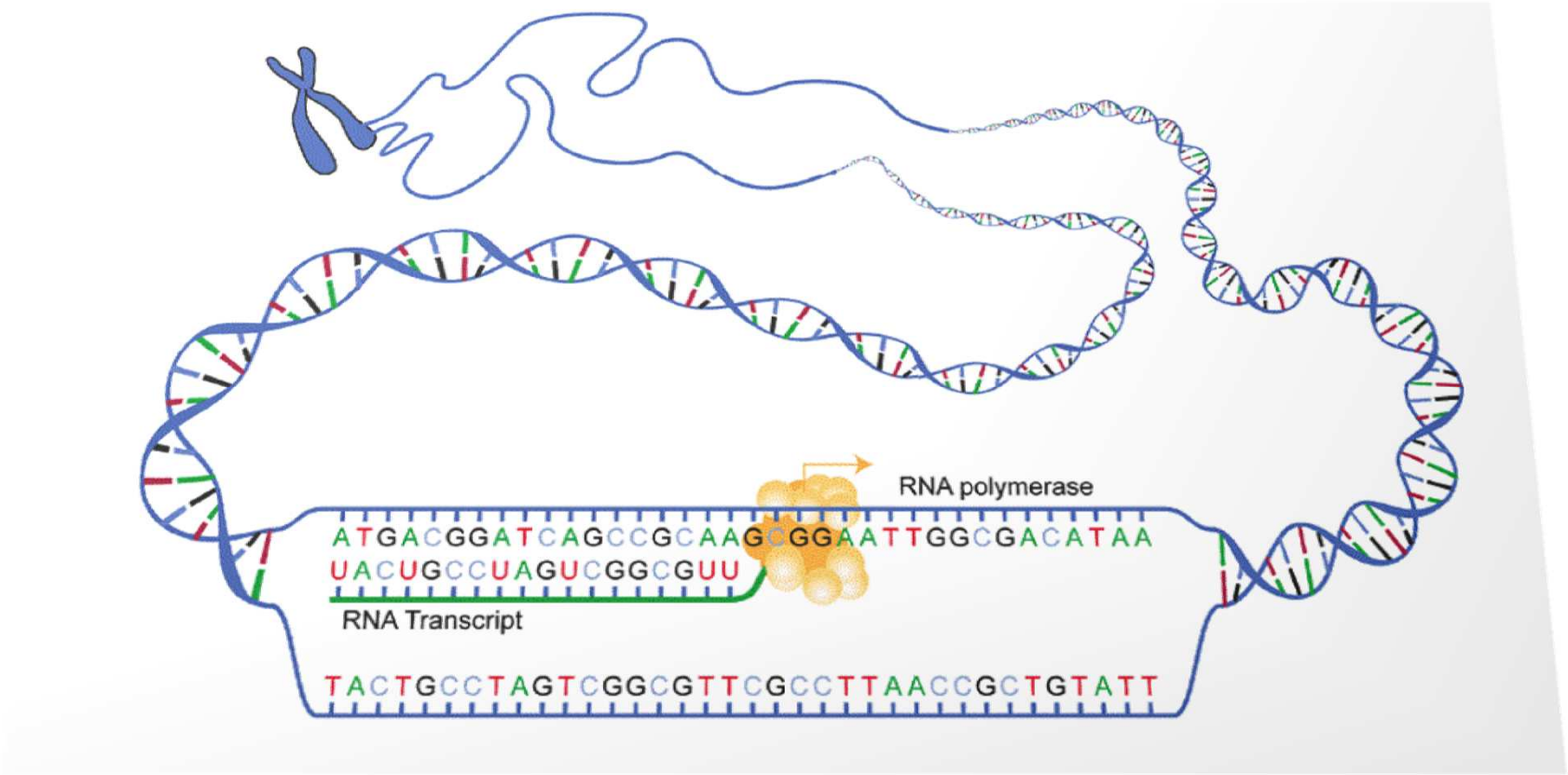
- DNA is the **blueprint**
- Proteins are **the product**

GENES STORE INFORMATION

The Central Dogma

The central dogma states that information flows in **one direction** from **DNA to RNA to proteins**.





Transcription

Converting a gene from the DNA blueprint into a complimentary single-stranded RNA sequence

RNA is very similar to DNA

However, it differs in 3 major ways:

- RNA has a **ribose sugar.**
- RNA has **uracil** instead of thymine.
- RNA is a **single-stranded** structure.

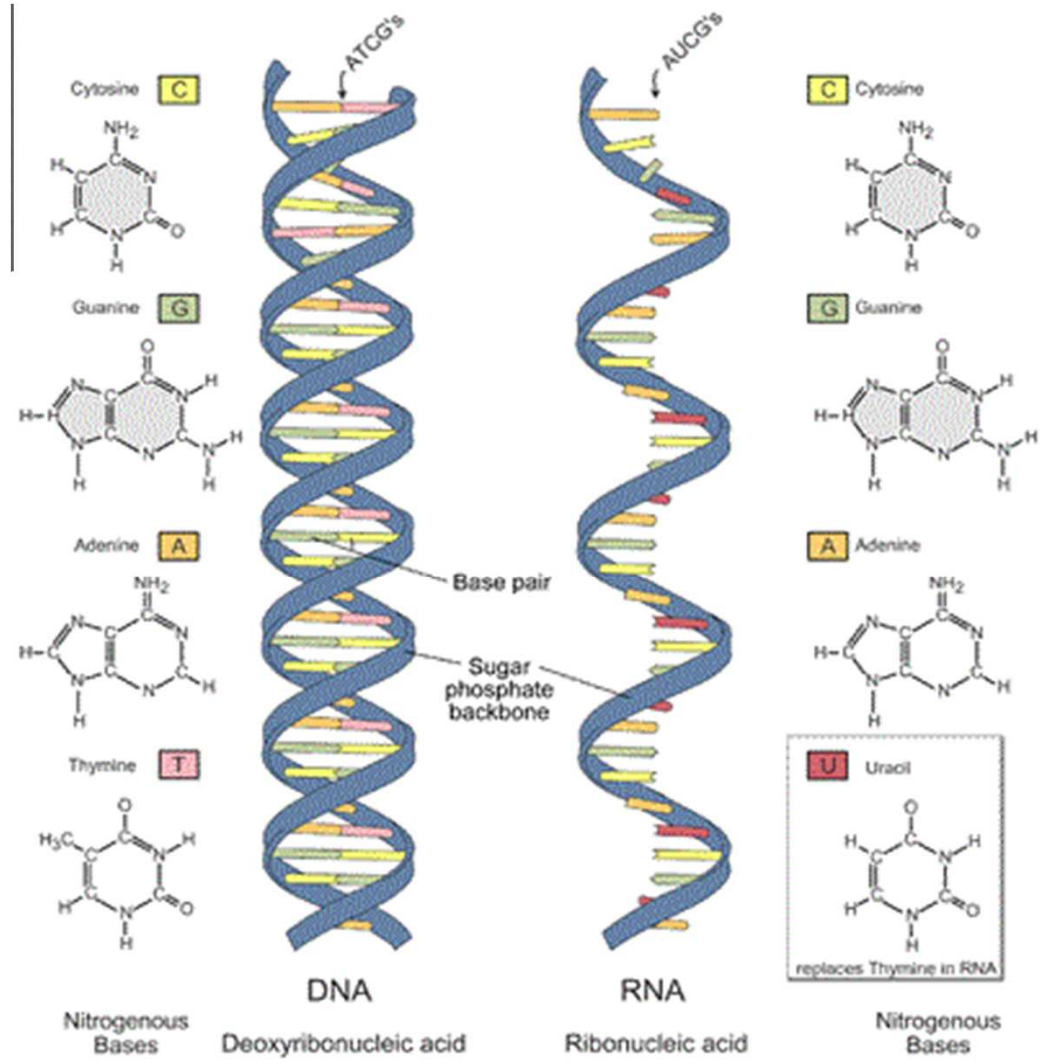
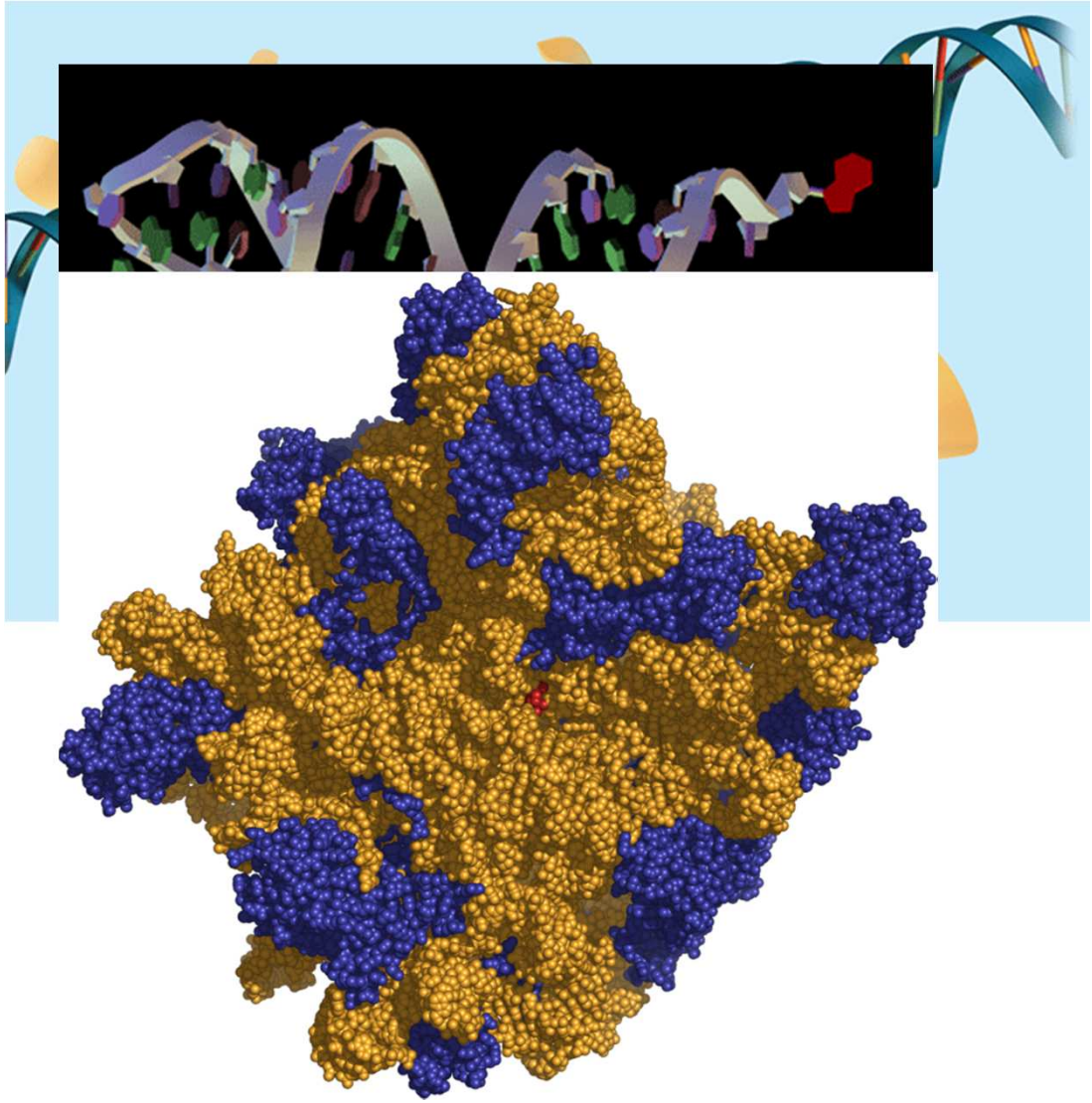


Image adapted from: National Human Genome Research Institute.

Protein Synthesis uses 3 types of RNA

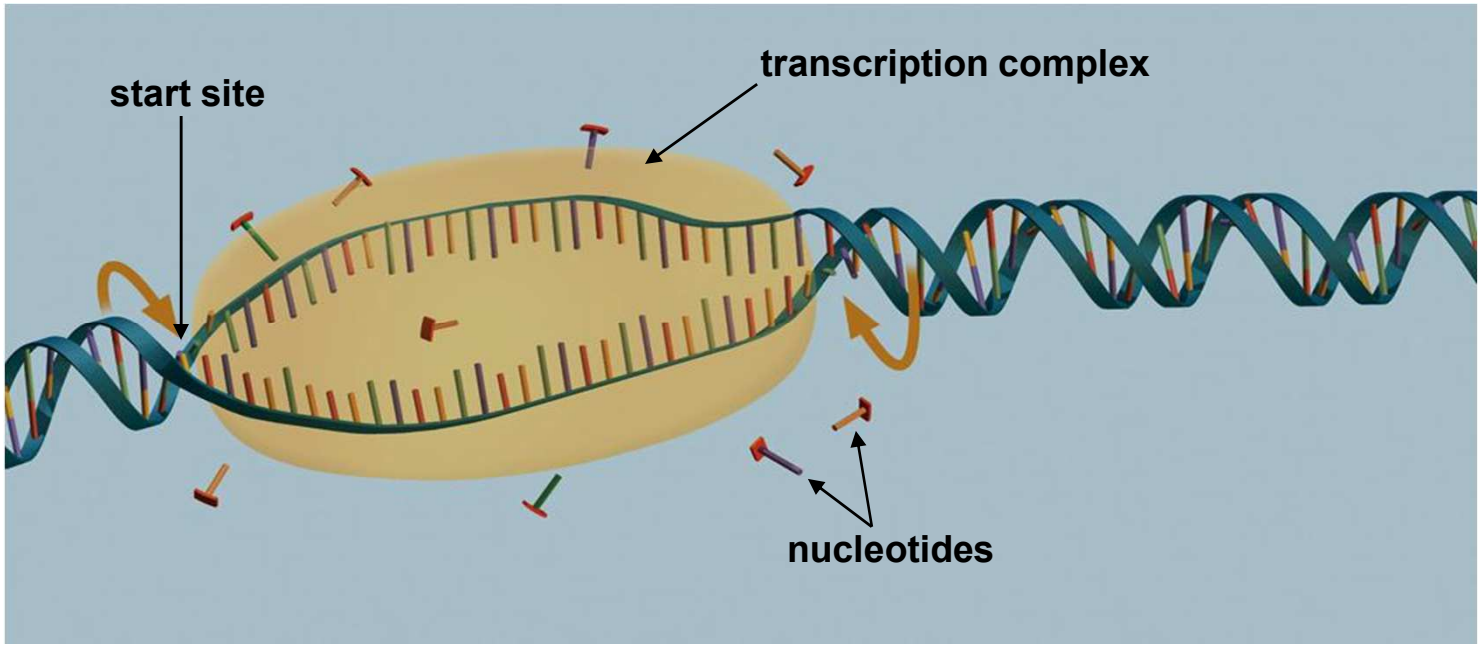
Three forms of RNA involved in protein synthesis

1. mRNA (messenger): **copies instructions from DNA and carries these to the ribosome.**
2. tRNA (transfer): **carries amino acids from the cytoplasm to the ribosome.**
3. rRNA (ribosomal): **composes parts of the ribosome, which is the site of protein synthesis**



How Transcription Occurs

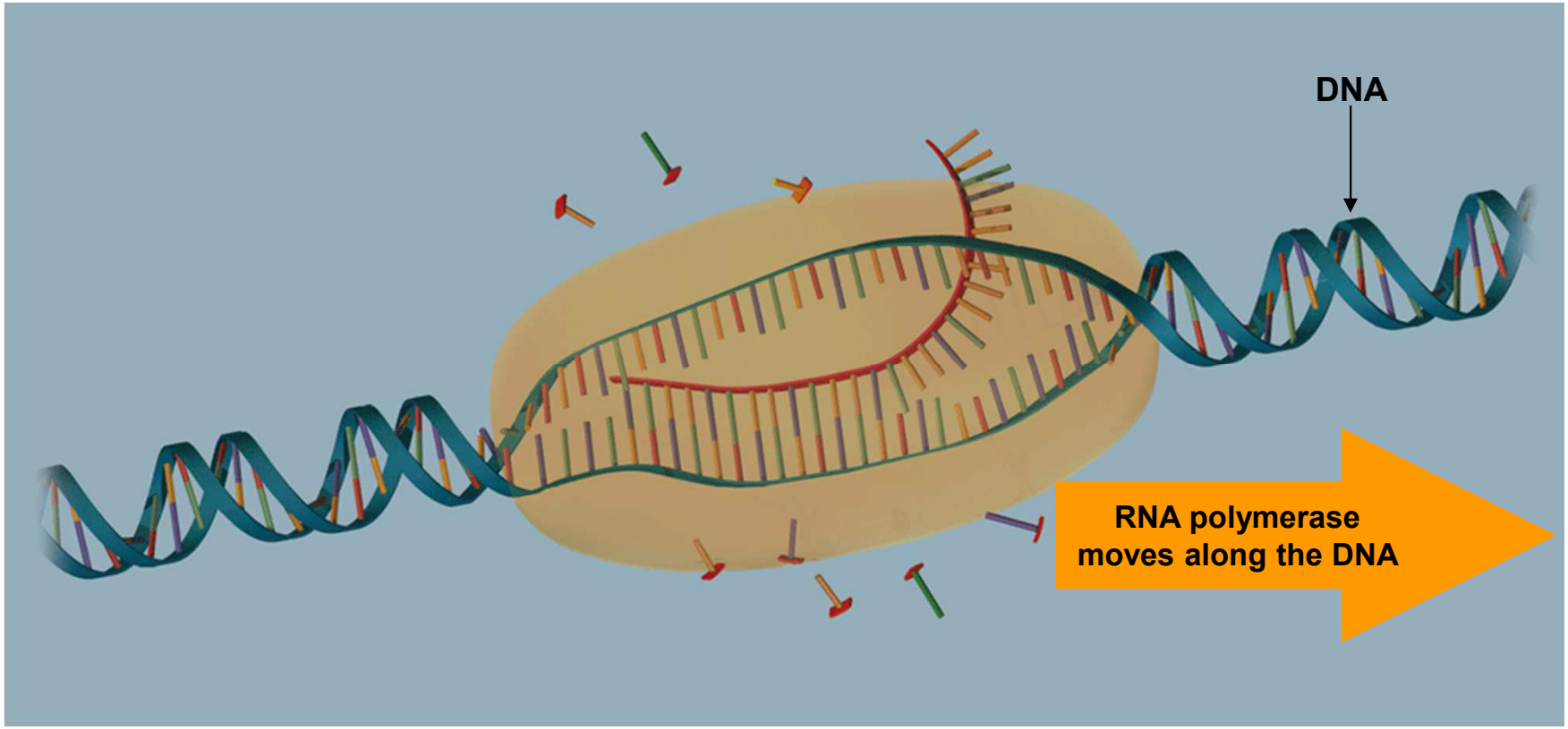
1. **RNA polymerase** untwists and unzips a section of the DNA (usually a single gene).



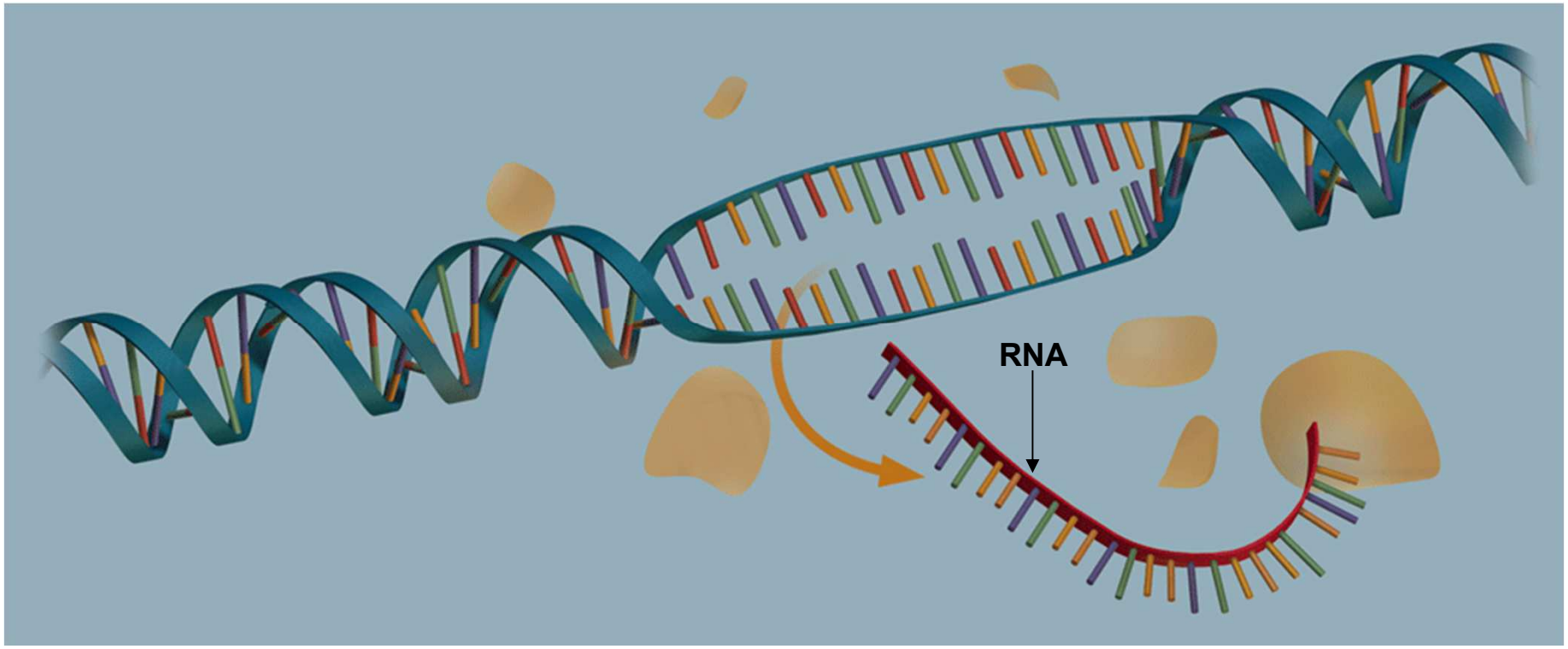
2. RNA polymerase **pairs free RNA nucleotides** to the exposed bases of one of the DNA strands following **base pair rules**.

Uracil replaces thymine

3. The DNA helix winds again as the gene is transcribed.



4. The RNA strand **detaches from** the DNA once the gene is transcribed.
5. The mRNA strand, with instructions for building a protein, **leaves the nucleus and enters the cytoplasm**



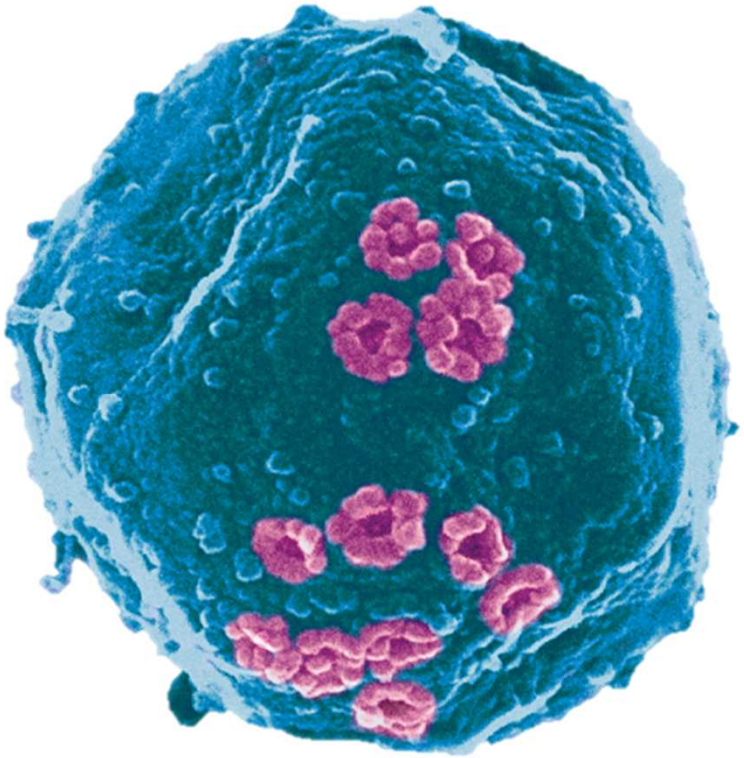
TRANSCRIPTION EXAMPLE

- Transcribe the following DNA Sequence into mRNA

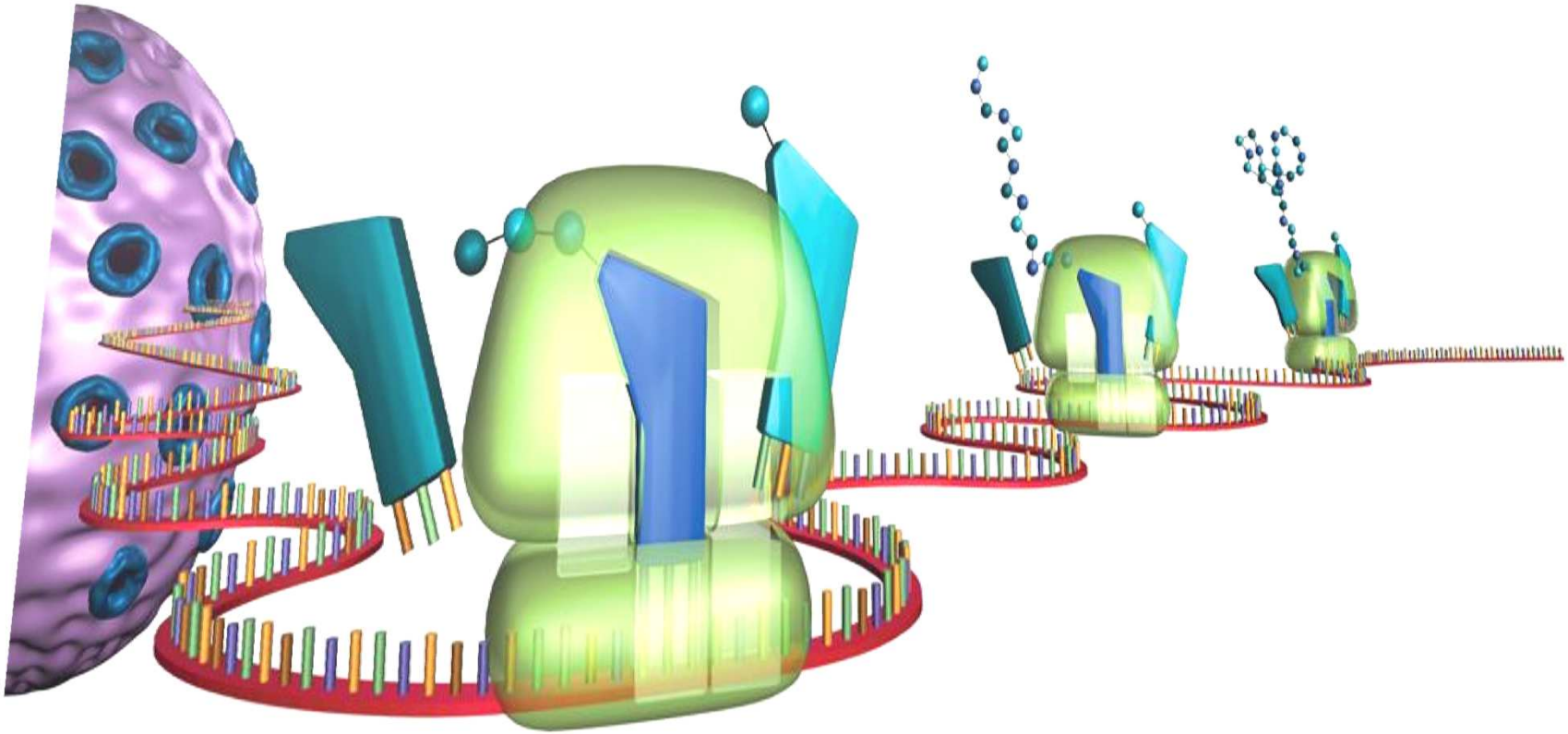
Template DNA: TAC CGG ATG CTA GGA TCA

AUG GCC UAC GAU CCU AGU

Result of Transcription



Completed mRNA template
leaves the nucleus

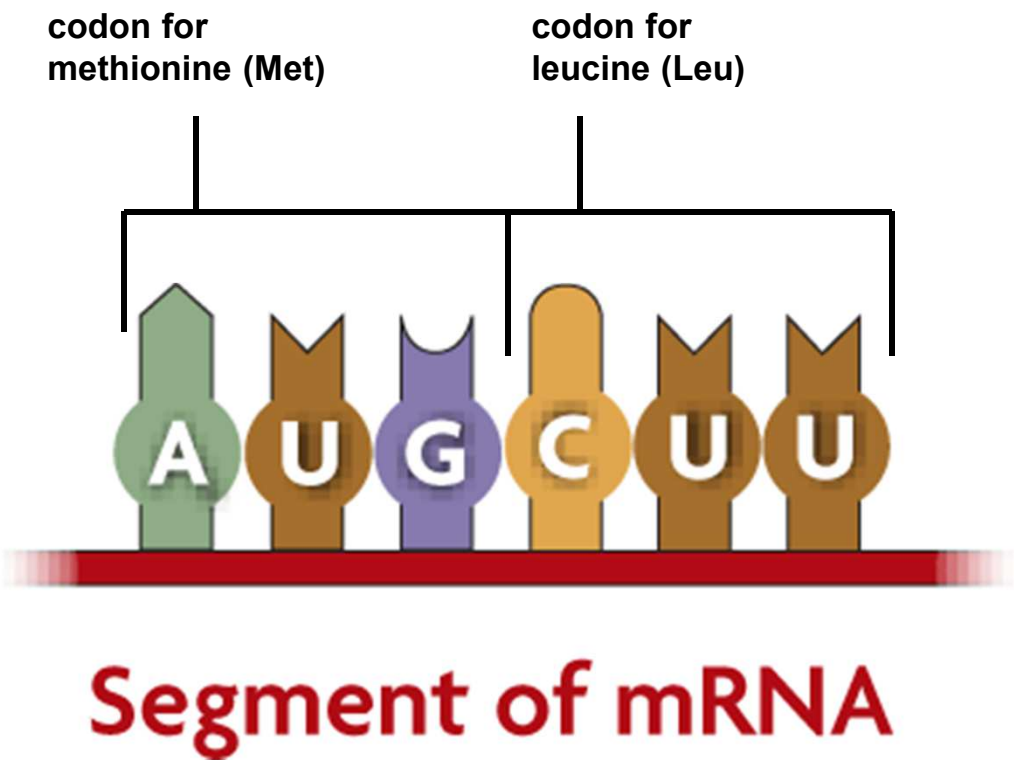


Translation

Instructions in mRNA are decoded to produce a protein

Amino acids are coded by mRNA base sequences

- Translation **converts mRNA messages into proteins**.
- A **codon** is a sequence of **three nucleotides on the mRNA** that code for a specific amino acid.



The genetic code matches each codon to its amino acid or function.

Note: more than one codon can code for a single amino acid

Reading the triplet code chart

1. Find the first base, C, in the left column.
2. Find the second base, A, in the top row. Find the box where these two intersect.
3. Find the third base, U, in the right column. CAU codes for histidine, abbreviated as His.

First base	Second base: U		C		A		G		Third base
U	UUU	phenylalanine (Phe)	UCU	serine (Ser)	UAU	tyrosine (Tyr)	UGU	cysteine (Cys)	U
	UUC		UCC		UAC		UGC		C
	UUA	leucine (Leu)	UCA		UAA	STOP	UGA	STOP	A
	UUG		UCG		UAG	STOP	UGG	tryptophan (Trp)	G
C	CUU	leucine (Leu)	CCU	proline (Pro)	CAU	histidine (His)	CGU	arginine (Arg)	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	glutamine (Gln)	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	isoleucine (Ile)	ACU	threonine (Thr)	AAU	asparagine (Asn)	AGU	serine (Ser)	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	lysine (Lys)	AGA	arginine (Arg)	A
	AUG	methionine (Met)	ACG		AAG		AGG		G
G	GUU	valine (Val)	GCU	alanine (Ala)	GAU	aspartic acid (Asp)	GGU	glycine (Gly)	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	glutamic acid (Glu)	GGA		A
	GUG		GCG		GAG		GGG		G

TRANSLATION EXAMPLE

- Translate the following mRNA sequence into amino acids

Template DNA: TAC CGG ATG CTA GGA TCA

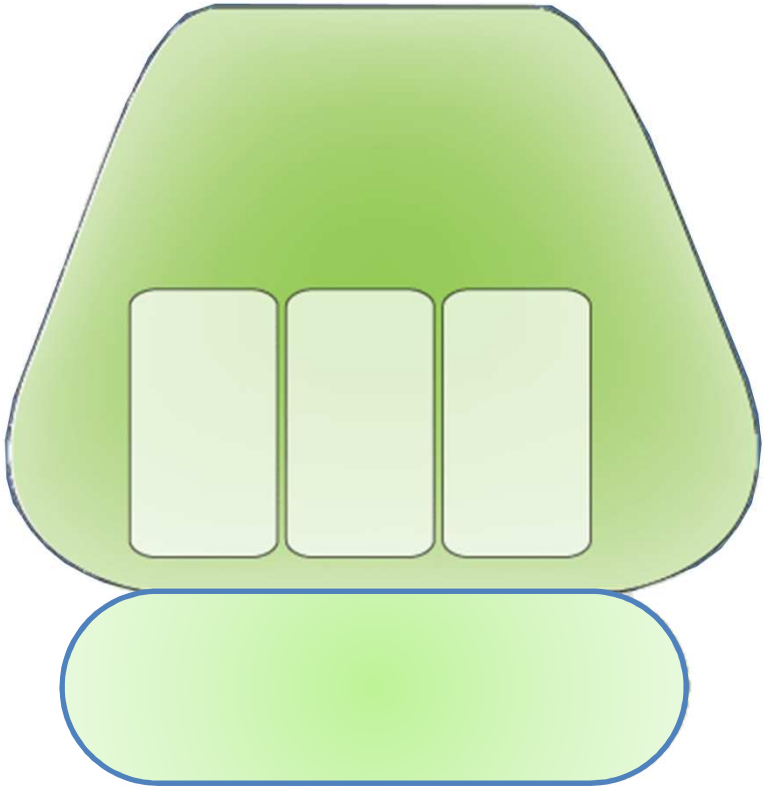
Template mRNA: AUG GCC UAC GAU CCU AGU

Amino Acids: Met Ala Tyr Asp Pro Ser

Ribosomes (aka rRNA) are Protein Factories

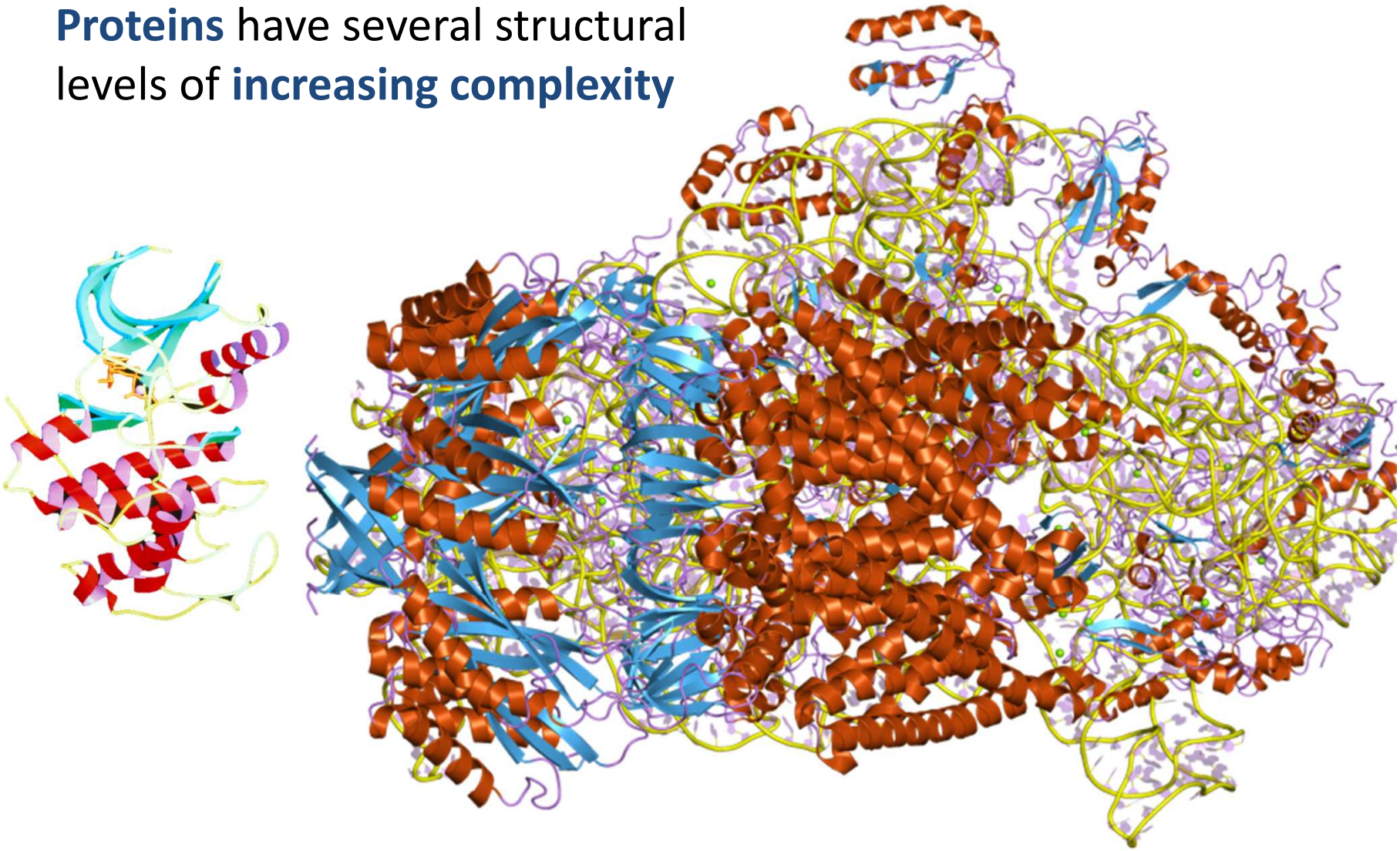
Ribosomes consist of two subunits

- The large subunit has **binding sites for tRNA**.
- The small subunit **binds to mRNA**.

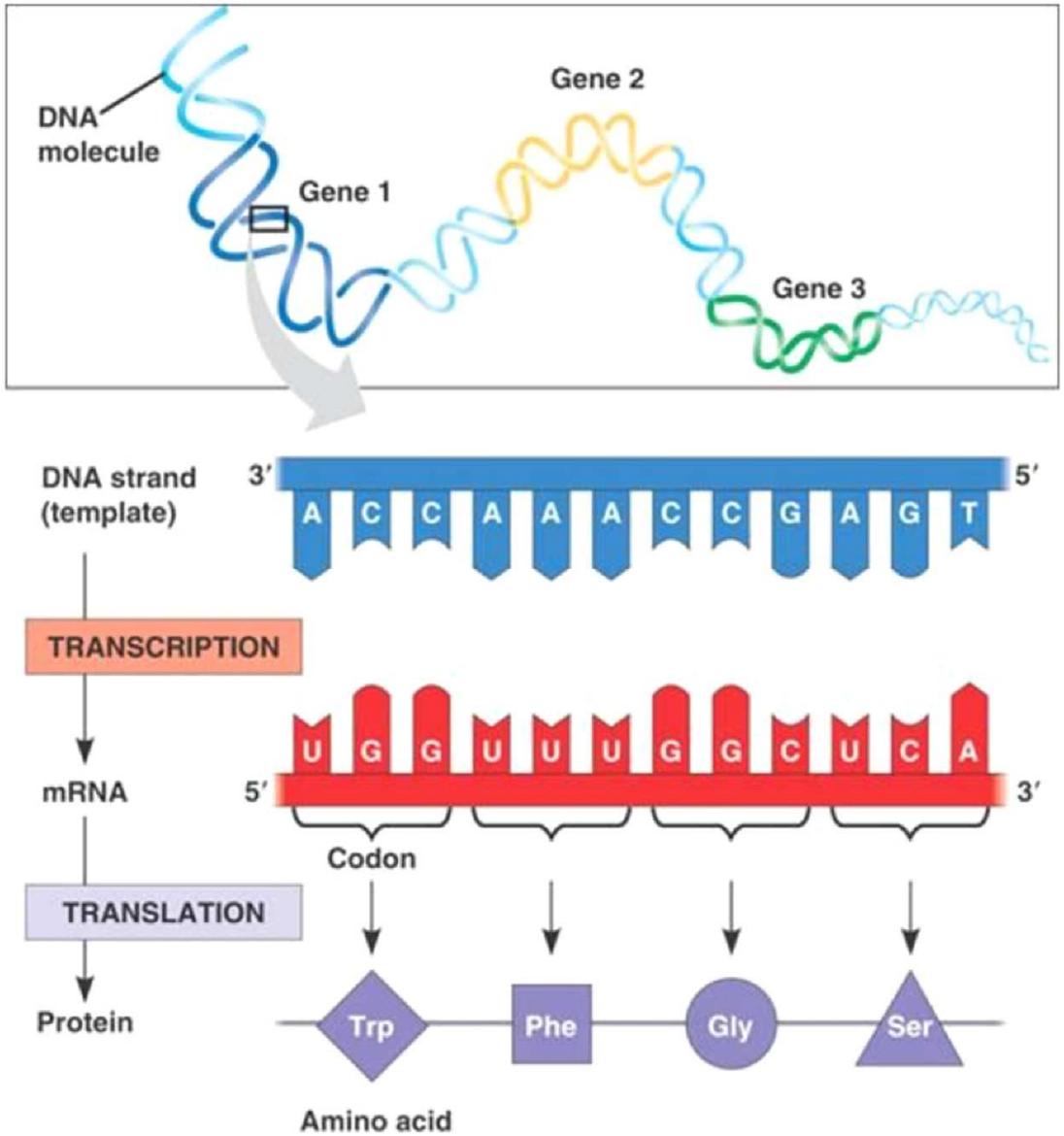


The Result of Translation

Proteins have several structural levels of **increasing complexity**



Protein Synthesis Overview



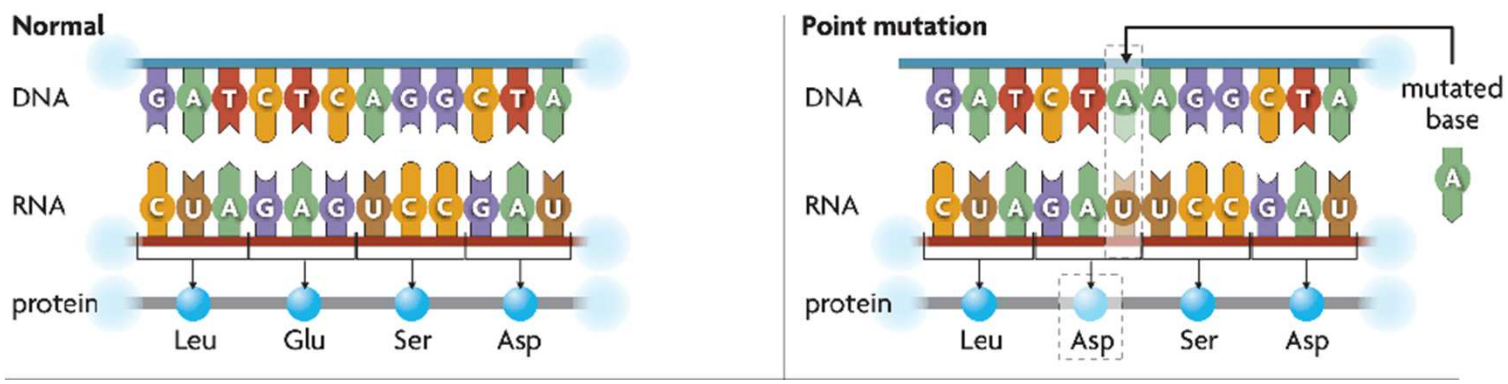
Mutations

A Mutation is a change in **an organism's DNA**

- It can **occur naturally** whenever a base is incorrectly copied, especially during **DNA Replication**.

- It can also occur as a result of DNA damage **from environmental causes**.

Point Mutations



- Many types of mutations can occur
- Point mutations substitute **one nucleotide** for another, resulting in **a new codon**

Point Mutations	Silent
	Missense
	Nonsense

Silent Mutations

- The result is either **the same amino acid** as before or
- An amino acid that does not affect the **shape** of the protein and therefore does not affect its **functioning**.

*We are generally **unaware of these "quiet mutations"***

Serine
- **UCG**

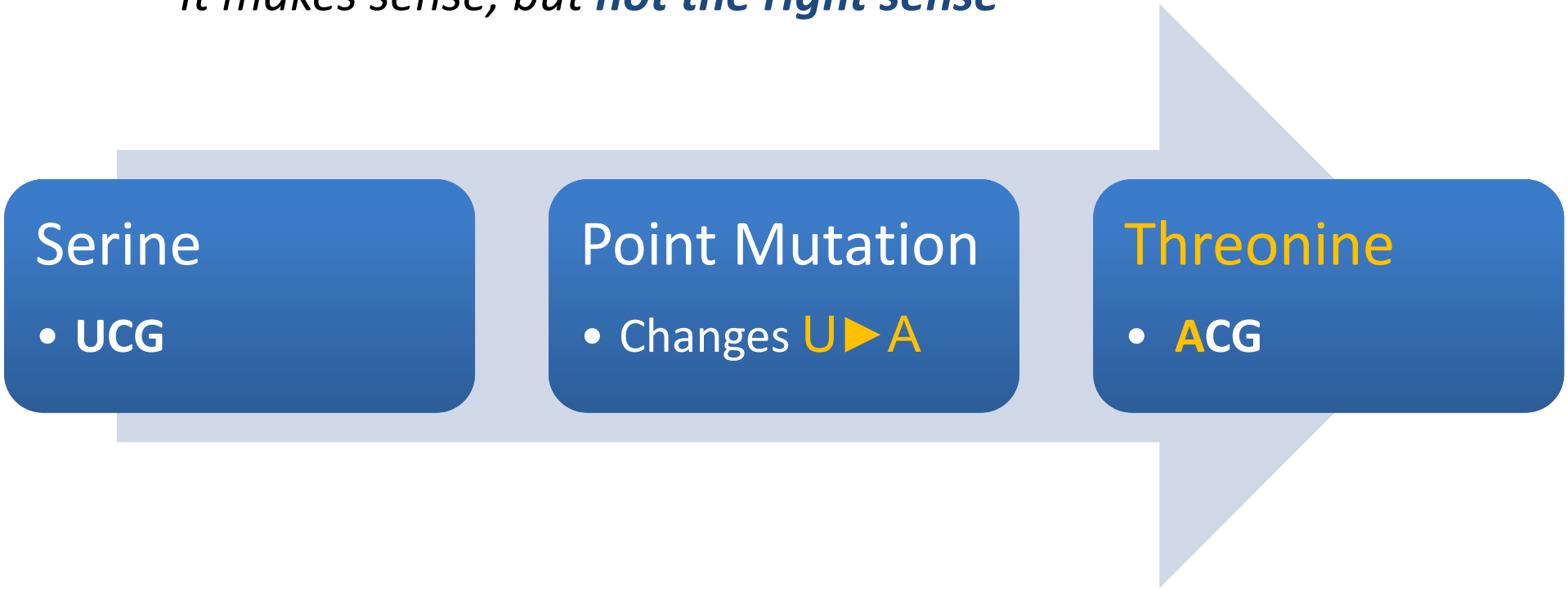
Point Mutation
- Changes G►A

Serine
- **UCA**

Missense Mutations

- The result is that **one amino acid is changed**
- That change will affect just that area of the protein and will likely **affect functioning of the enzyme**

*It makes sense, but **not the right sense***



Nonsense Mutations

- Nonsense mutations generate **a STOP codon**
- This causes coding to **terminate early** and only a fragment will be translated; it is not complete

*After one of these, **the protein is non-functioning***

Serine
- **UCG**

Point Mutation
- Changes C►A

STOP CODON
- **UAG**

What if a missense mutation caused a stop codon to be removed?

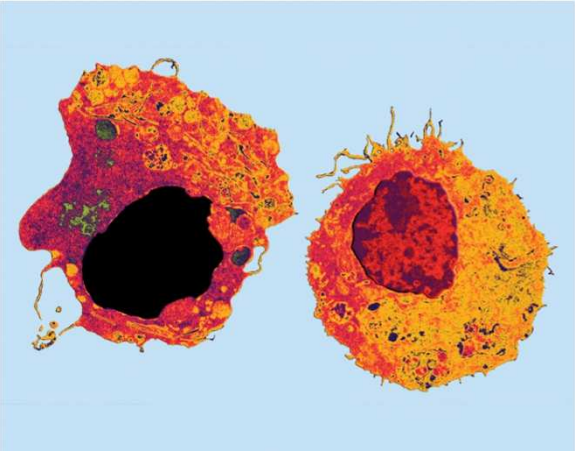
The Heredity of Mutations

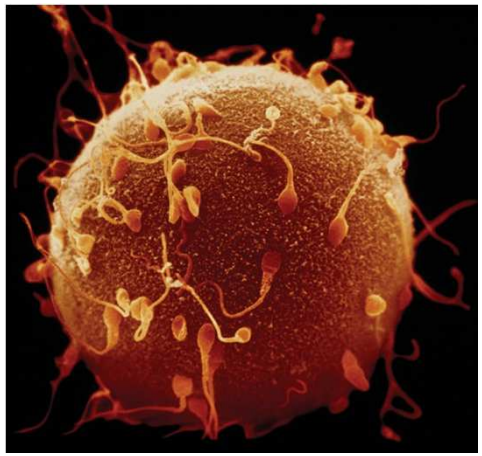
Body Cell Mutations

- If the mutation occurs in **somatic cells**, it will be restricted to the tissues of a single organism, **not passing it to the next generation**

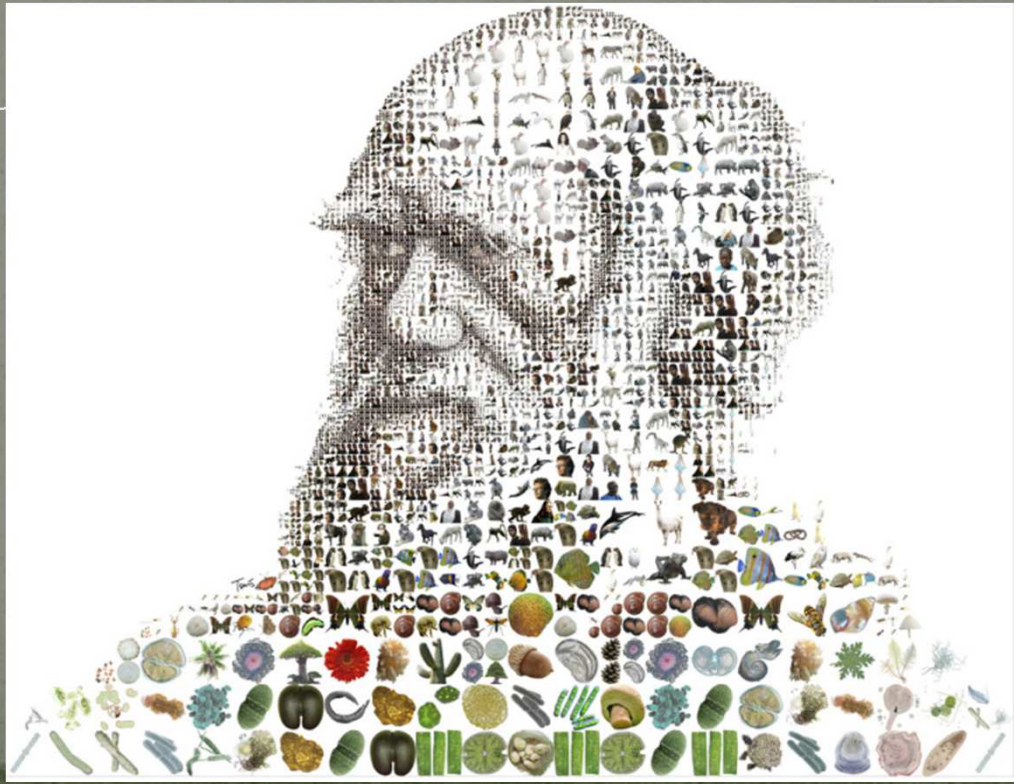
Sex Cell Mutations

- If the mutation occur in the reproductive cells, they may **be transmitted by gametes to the next generation**

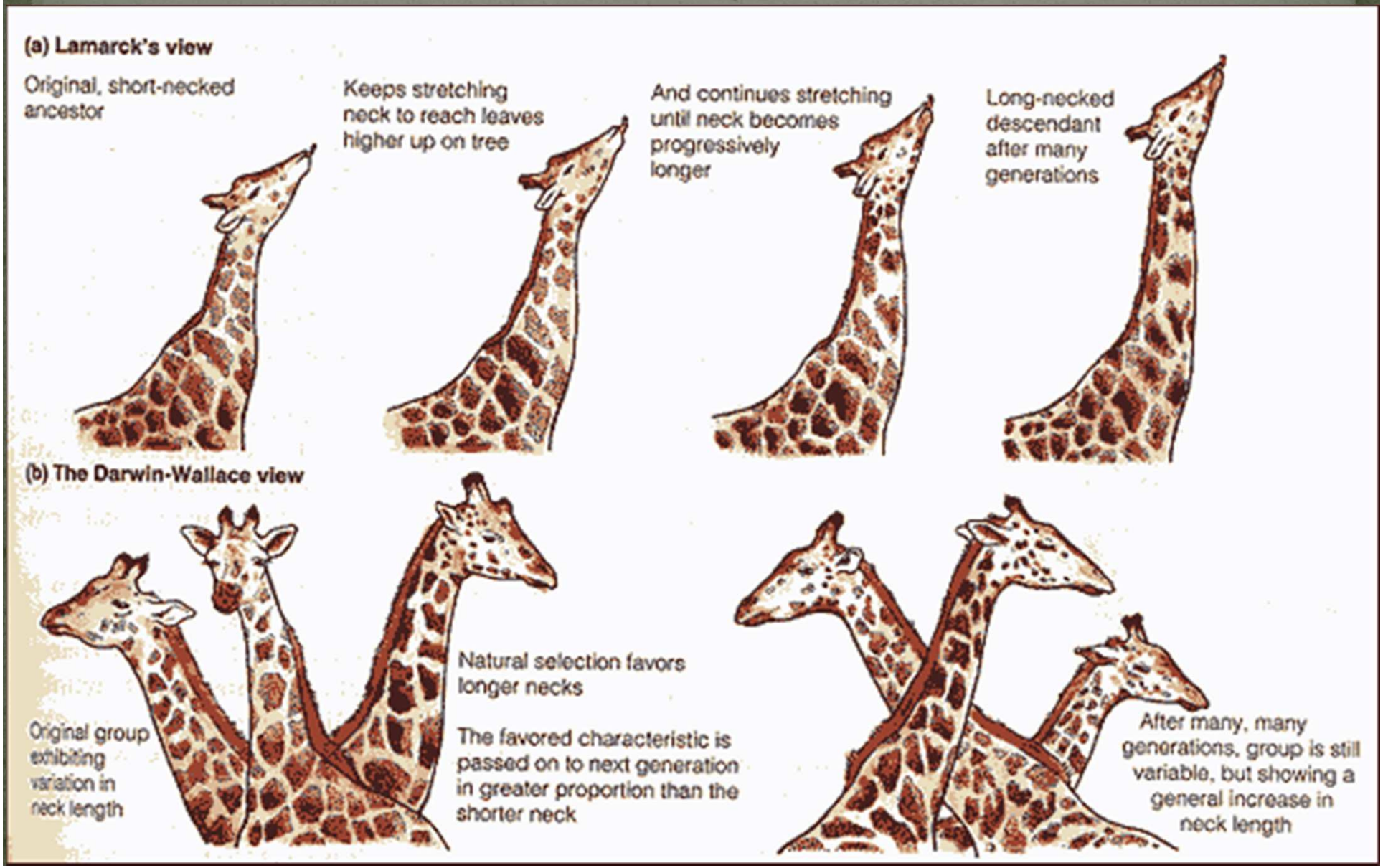




Biological Evolution



Competing Theories

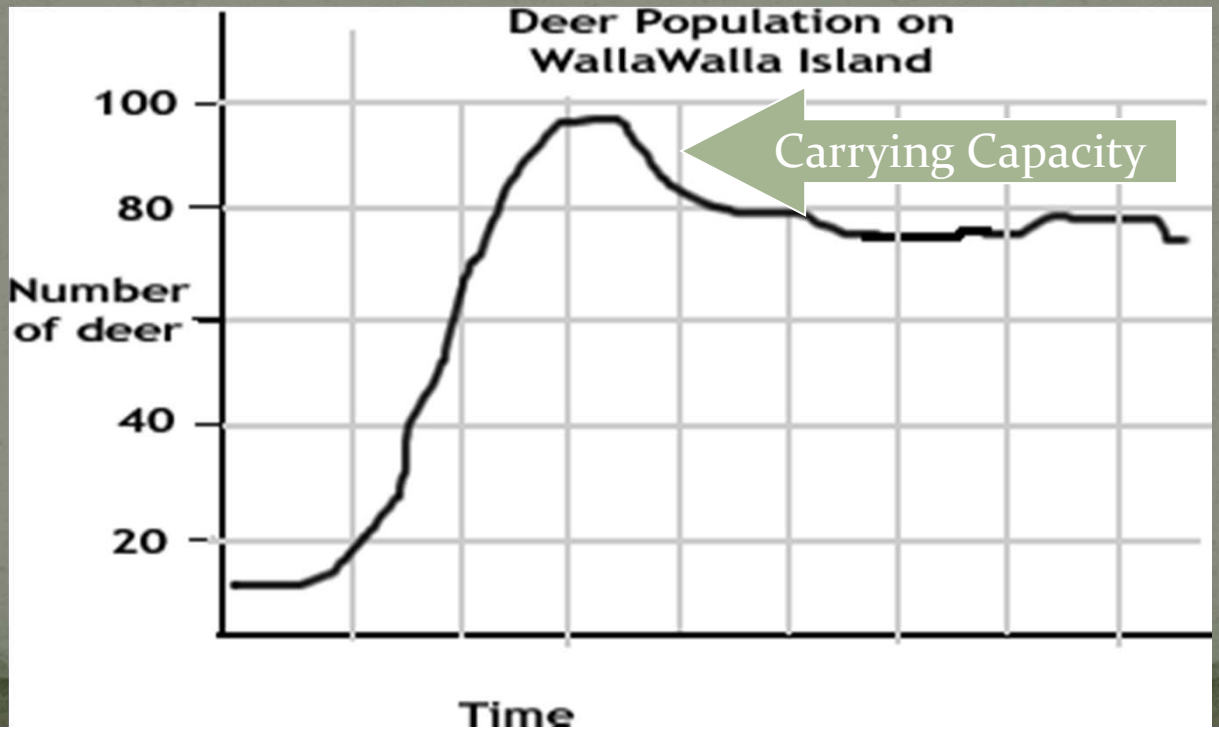


Definition of Evolution:

- The accumulation of <u>changes</u> in the <u>heritable</u> characteristics of a **<u>population</u>**.
- Evolution describes the changes in the various genes of a species over time.

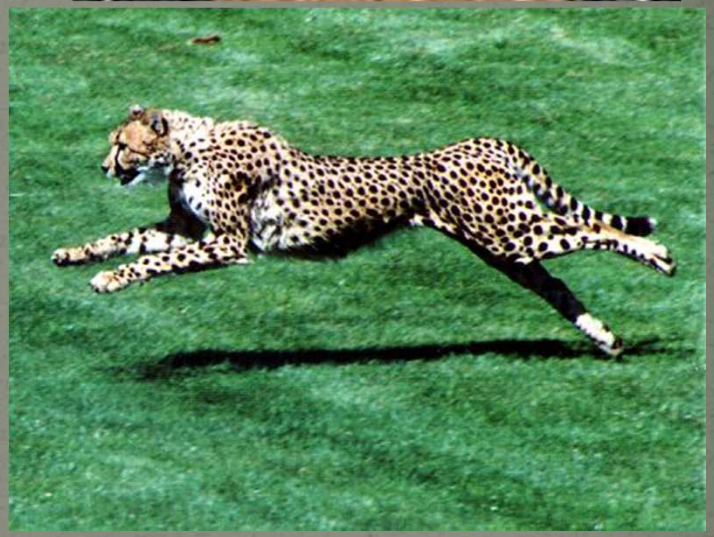
- These changes are the result of:
  - Mutations
  - Natural selection
  - Chance

1. Populations tend to produce more offspring than the environment can support.
   - This leads to a *struggle for existence* in which some individuals survive and some die.



2. Natural Selection

- Definition:
  - The over-production of offspring leads to competition and survival of the individuals best suited to that *particular environment*.
- The better adapted individuals tend to survive and reproduce more than the less well-adapted individuals .



3. The ***variation*** in individuals in a population is controlled by their genes and is therefore ***inheritable***.

- The better ***adapted*** individuals ***pass on their characteristics*** to more offspring than the less well adapted.
- The results of natural selection therefore ***accumulate***.
- As one generation follows another, the ***characteristics of the species gradually change.***

How Variation arises

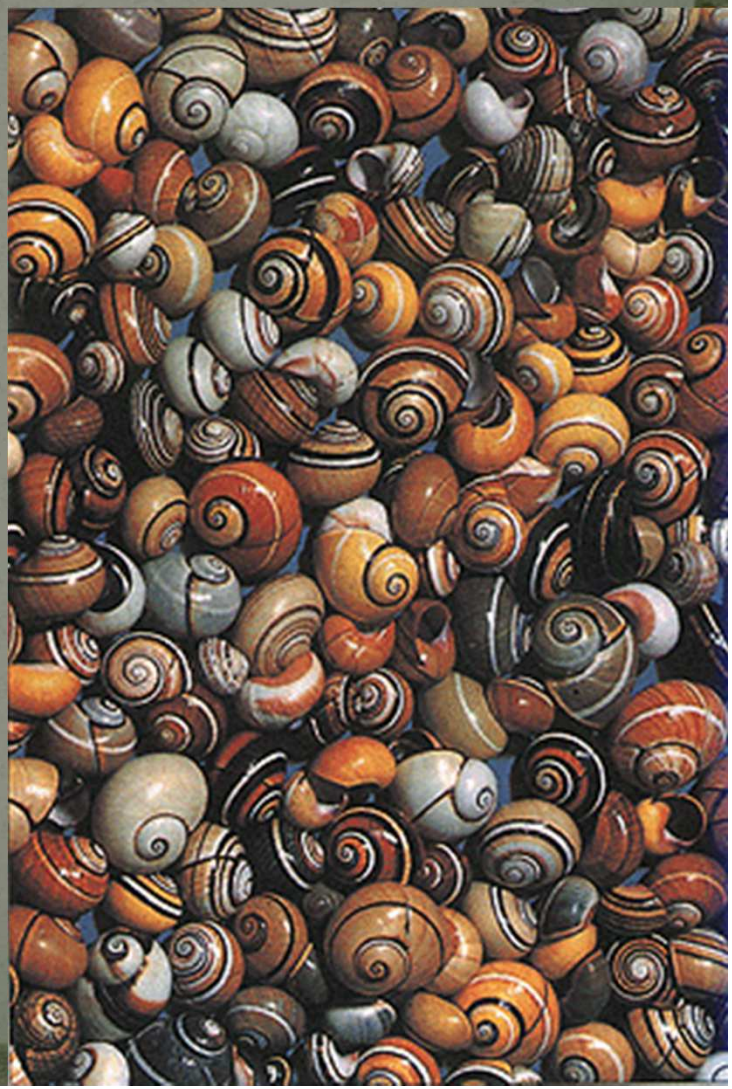
In the DNA:

-Sexual Reproduction

-Mutations

In the Environment:

-Genetic Drift



Populations:

- It is important to know at this point that evolution doesn't work on the level of individuals or species- it works on the level of populations.

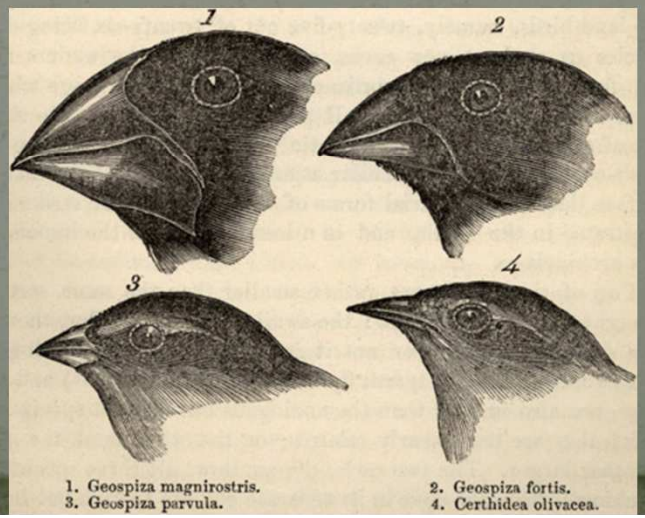
- In other words: individuals do not evolve, populations do.

The Environment can also lead to Speciation

- When two groups of a species are in different environments they cannot interbreed.
- If the selection pressure is different, they will eventually become different species: aka speciation.

- The eastern meadowlark and the western meadowlark have very similar body shapes and coloration.
- Considered different species:
  - Songs are different
  - Behavioral differences that prevent interbreeding.

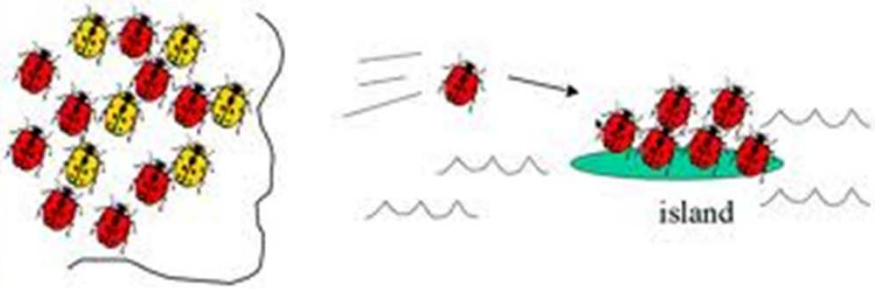
Ex. Many of the finches in the Galapagos islands.



Why are finches different on different islands?

- Islands have different kinds of seeds available which select for different kinds of beaks to eat them.
- In time the birds become so genetically/physically different they cannot interbreed.

- **founder effect**: a few individuals from a population start a new population with a different allele frequency than the original population



Examples of Evolution:

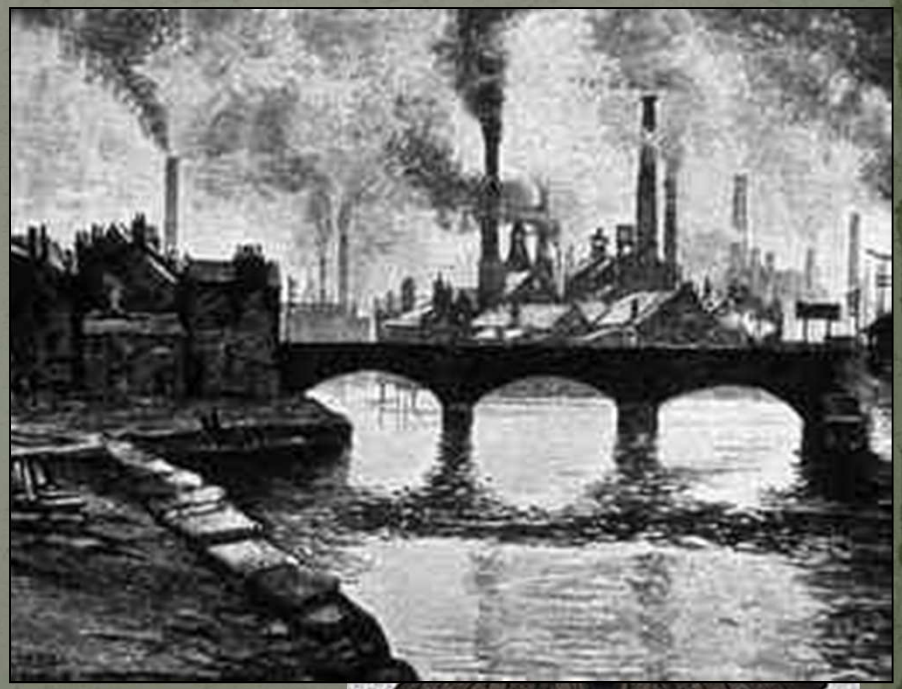
Archeopteryx: A transition fossil between reptiles and birds.

Peppered Moths

- A famous example from England that demonstrates natural selection is the Pepper Moth.
  - ***Two*** different species of moths, one ***light*** colored and one ***dark***.
    - ***Before*** the 1850's the ***dark*** one was very ***rare***, ***after*** the 1850's the ***light*** color became ***rare***.

What happened in the 1850's?

INDUSTRIAL REVOLUTION→
Coal fired plants produced lots of soot that covered the trees and buildings, making everything dark. So where once the ***birds*** preferentially picked off and ate the dark moths, they now saw and ate the light ones instead.



Resistance of Bacteria to Antibiotics Through Exposure

- As the use of antibiotics have become widespread
  - many disease-causing bacteria have developed resistance against known antibiotics.
  - Only the resistant bacteria will survive and reproduce

Example #3: Artificial Selection

- There are numerous examples of humans performing their own type of selection (hence: artificial) on desired, *heritable* traits belonging to a variety of organisms, such as domesticated animals and modern agriculture.

Scientific Evidence for Evolution

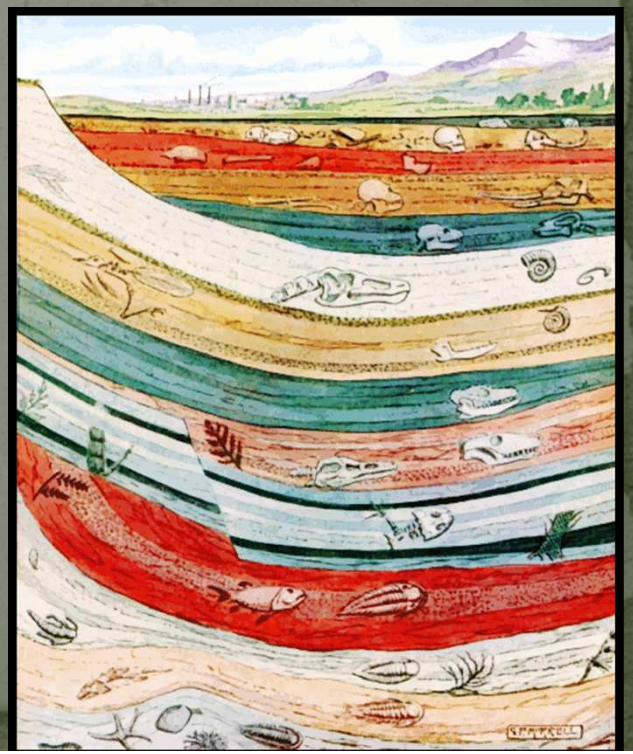
Fossils!

Fossils do show intermediate stages, despite their rarity.

For example, there are now at least eight intermediate fossil stages identified in the evolution of whales.

And geological strata consistently reveal the same sequence of fossils!

A quick and simple way to debunk the theory of evolution would be to find a fossil horse in the same stratum as a trilobite.

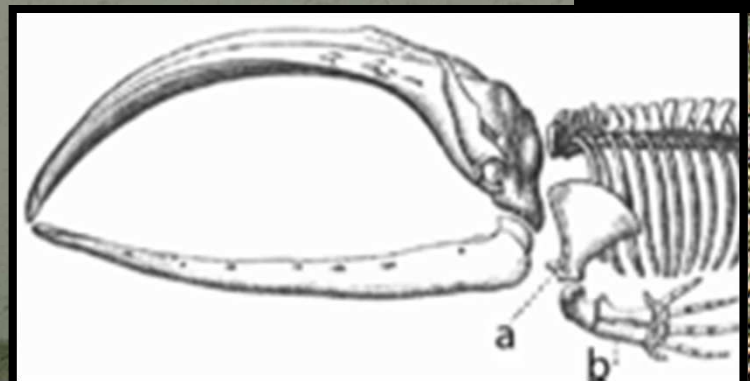


Vestigial Structures

- An organ present in the organism but either reduced in size or has no use.

  Ex.

  - Femur in some whales
  - Dewclaw in dogs
  - Eyes in blind mole rats
  - Fake sex in virgin Whiptail lizard
  - Wings on flightless birds

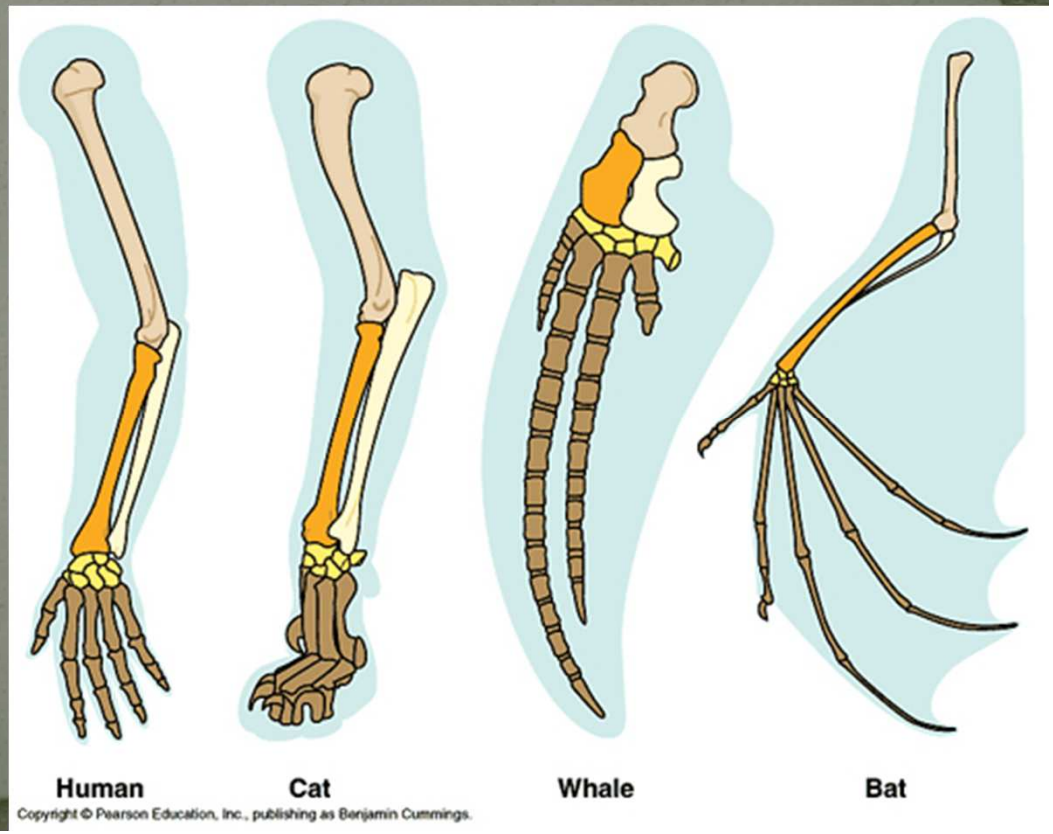


Scientific Evidence

- Homologous Structures
  - Similar structures in very different organisms is evidence of a common ancestor.

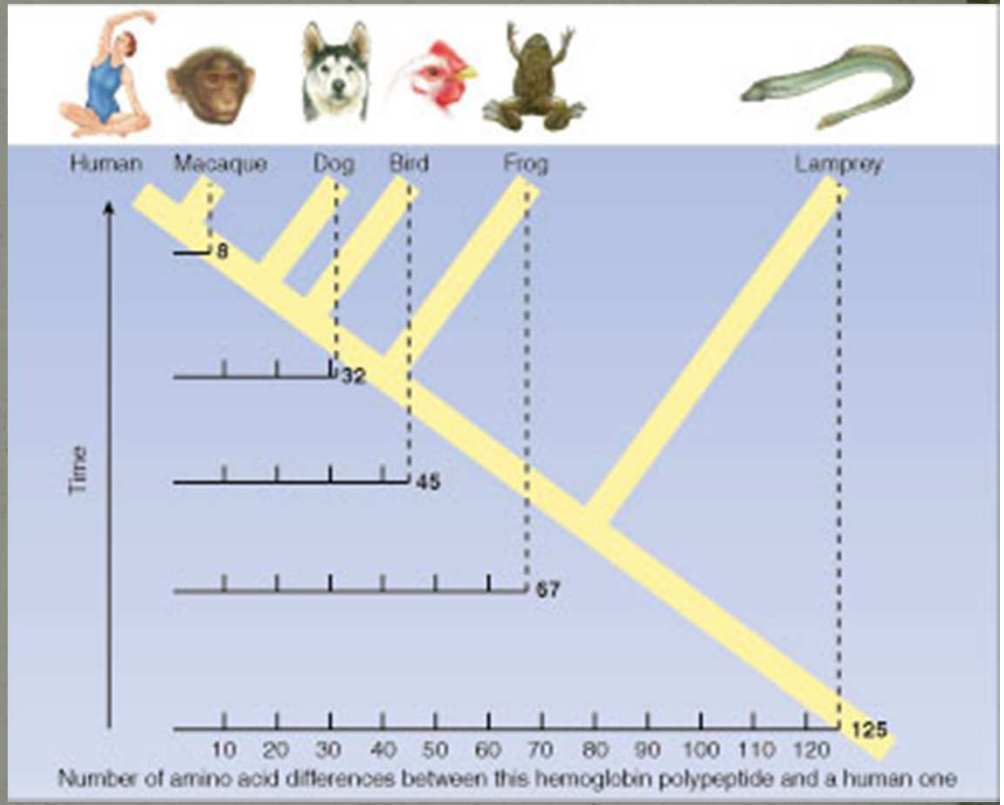
An example of this is the similarity of the skeleton between all mammals.

Every bone in a bat has is its own identifiable counterpart in a human. Identifiable, because of the order in which they join up. Only the proportions are different.

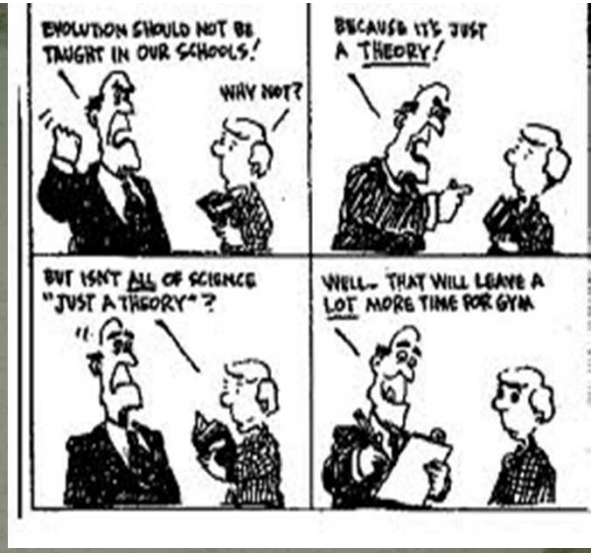


Scientific Evidence

- Similarity of Genetic Code (DNA)
  - All organisms share the same genetic code, based on the series of bases, A, T, G, and C.
  - The more similar the species the closer the sequence of bases in the DNA.



#1:
Isn't evolution just a theory that even scientists can't agree on?



First we need to look at what the word theory means. The *Oxford English Dictionary* gives two meanings:

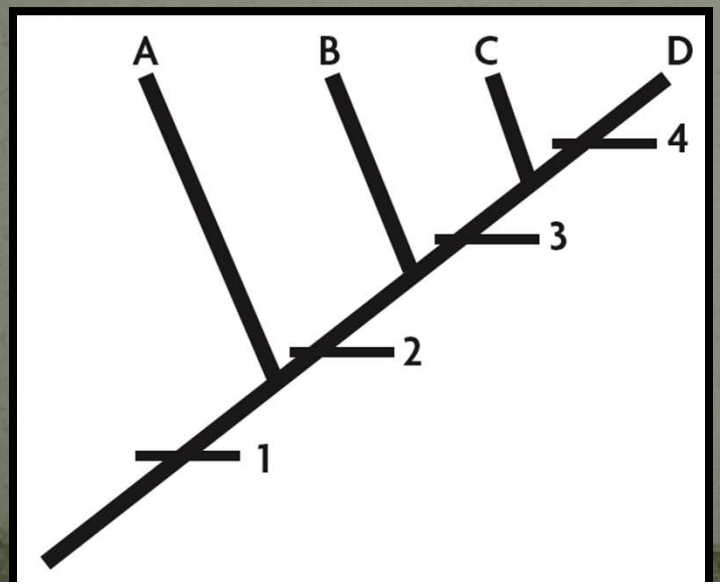
Theory, Definition 1: A scheme or system of ideas or statements held as an explanation or account of a group of facts or phenomena; a hypothesis that has been confirmed or established by observation or experiment, and is propounded or accepted as accounting for the known facts; a statement of what are held to be the general laws, principles, or causes of something known or observed.

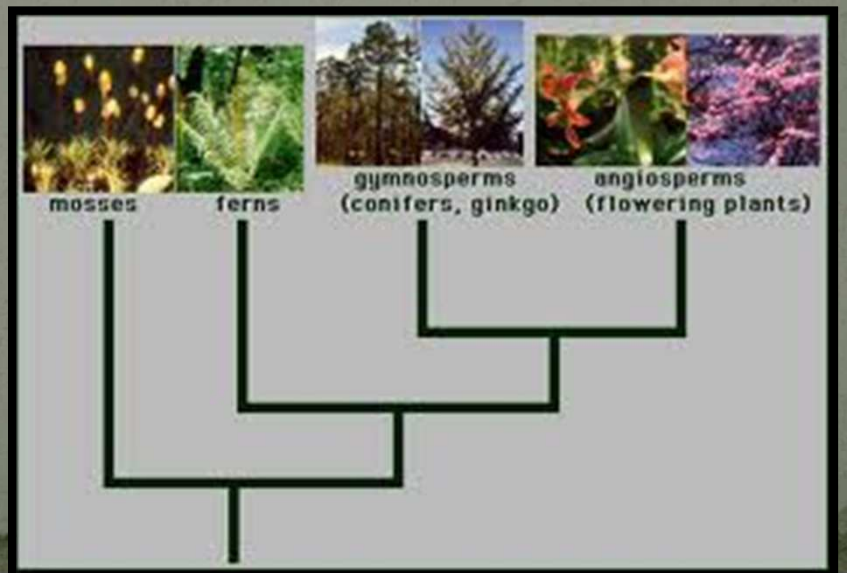
Theory, Definition 2: A hypothesis proposed as an explanation; hence, a mere hypothesis, speculation, conjecture; an idea or set of ideas about something; an individual view or notion.

Scientists use this one!

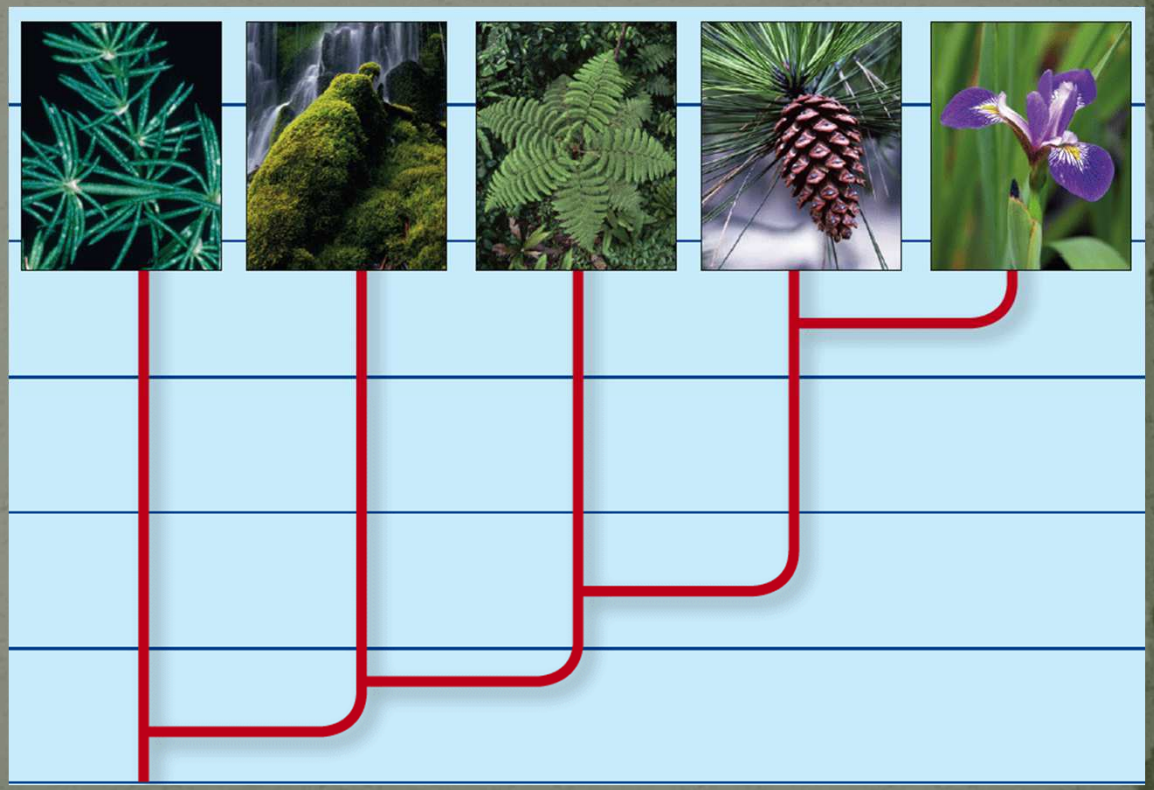
Cladistics is classification based on common ancestry.

- Phylogeny is the evolutionary history for a group of species.
  - evidence from living species, fossil record, and molecular data
  - shown with branching tree diagrams

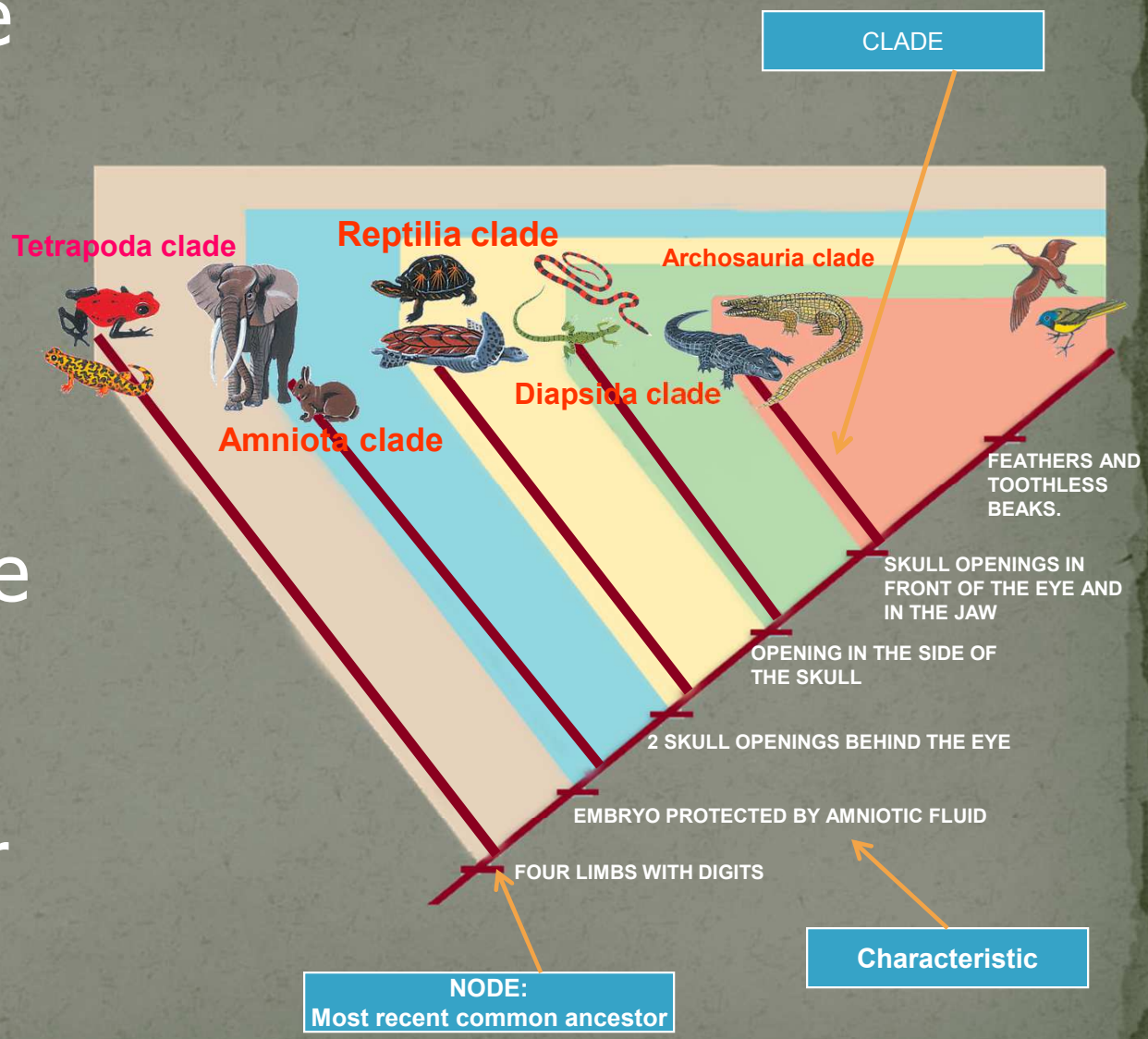




- A cladogram is an evolutionary tree made using cladistics.
  - A clade is a group of species that shares a common ancestor.
    - Each species in a clade shares some traits with the ancestor.
    - Each species in a clade has traits that have changed.

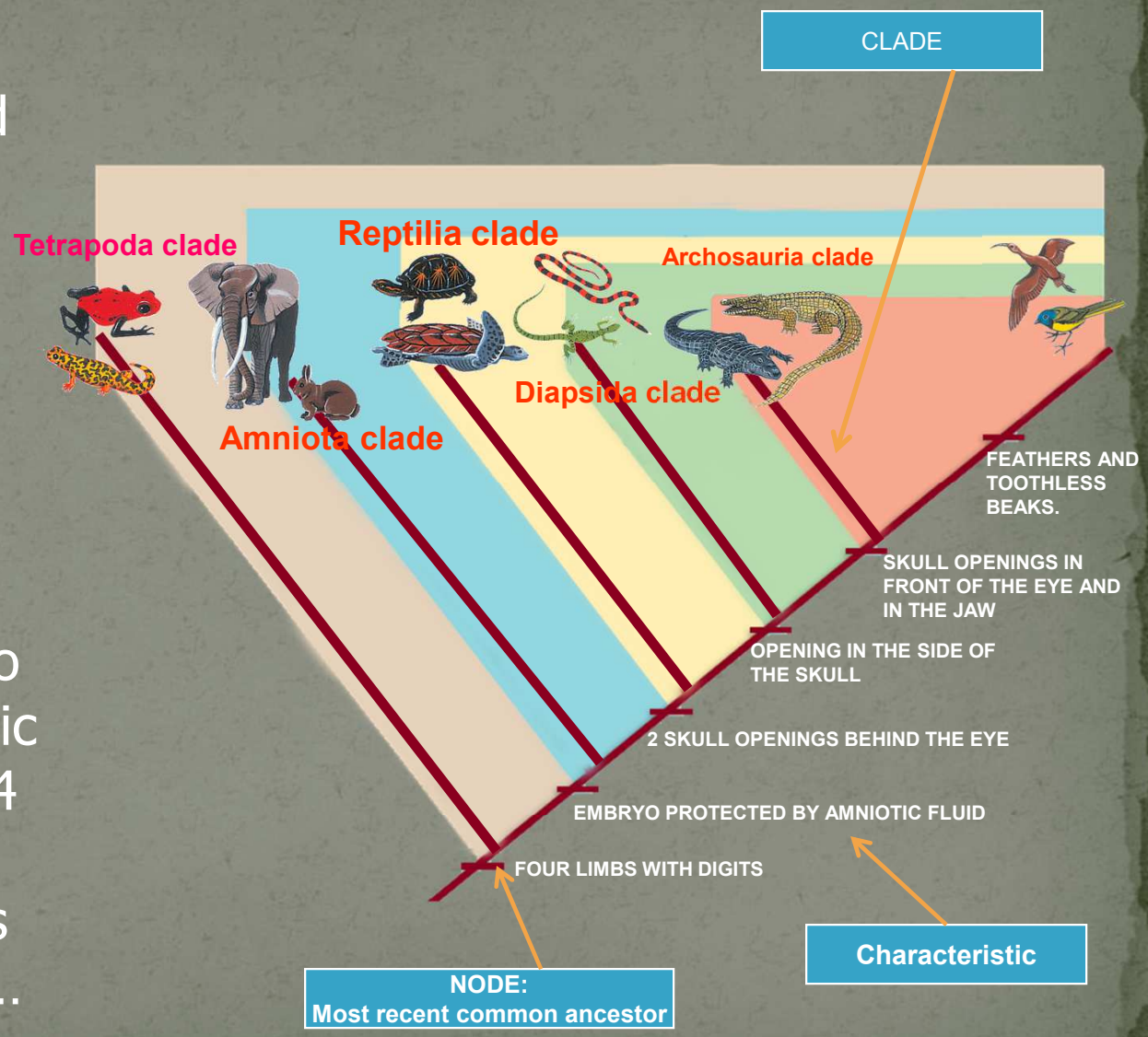


- Nodes represent the most recent common ancestor of a clade.
- Clades can be identified by snipping a branch under a node.



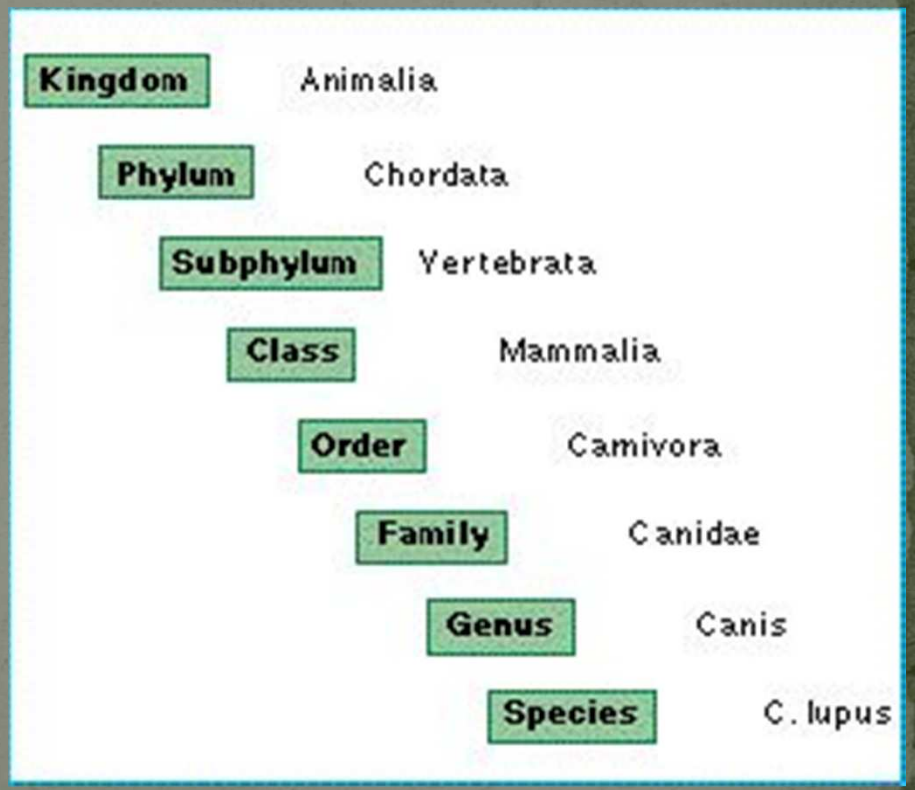
- As you move up a cladogram, you are building upon the characteristics found before it. You are becoming <u>more specific</u>.

- Ex: Tetrapoda only has 4 limbs. Amniotes have 4 limbs and an embryo protected by amniotic fluid. Reptiles have 4 limbs, amniotic fluid and 2 skull openings behind the eye, etc…



Taxonomy:

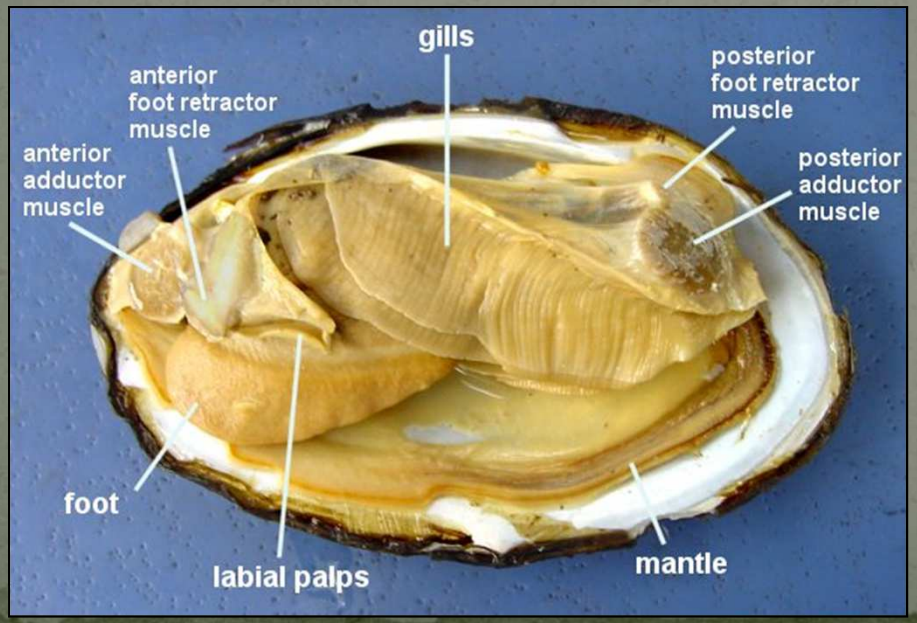
- The science of naming and classifying organisms
  - This scheme consists of different levels of classification, each more comprehensive than the one below it.

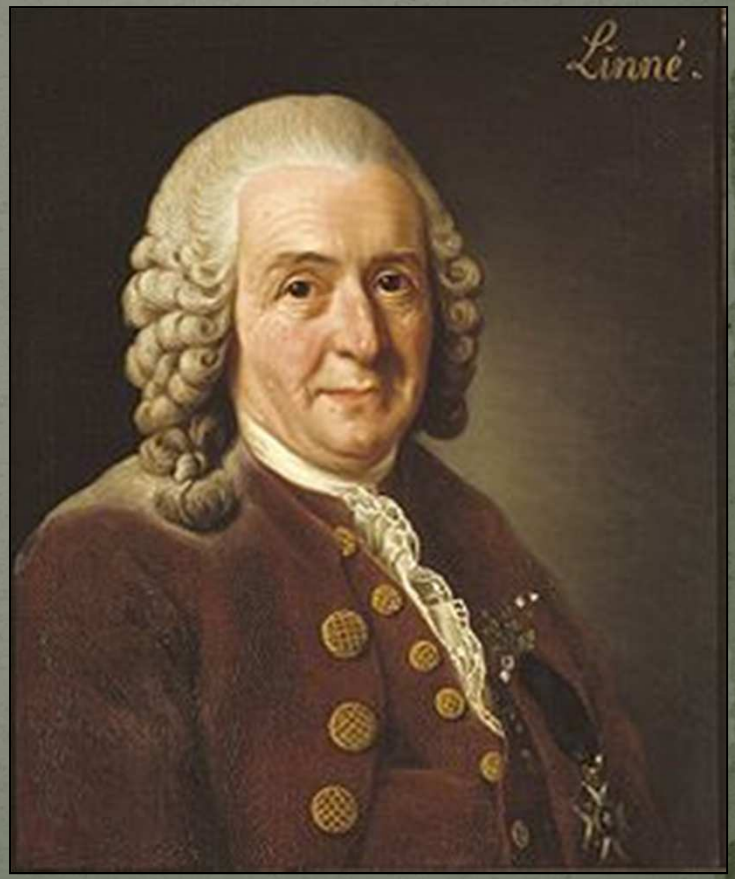


Taxonomy:

Carl Linnaeus-

Swedish botanist, physician and zoologist. Father of Modern Taxonomy.





Why Classify Organisms?

- To make diversity less overwhelming.
- To reflect phylogeny (evolutionary history).
- To avoid ambiguity, so there is one name everyone can use for identification.
- Relationships among organisms are evident in their names

The "6" Kingdoms:

Prokaryotes

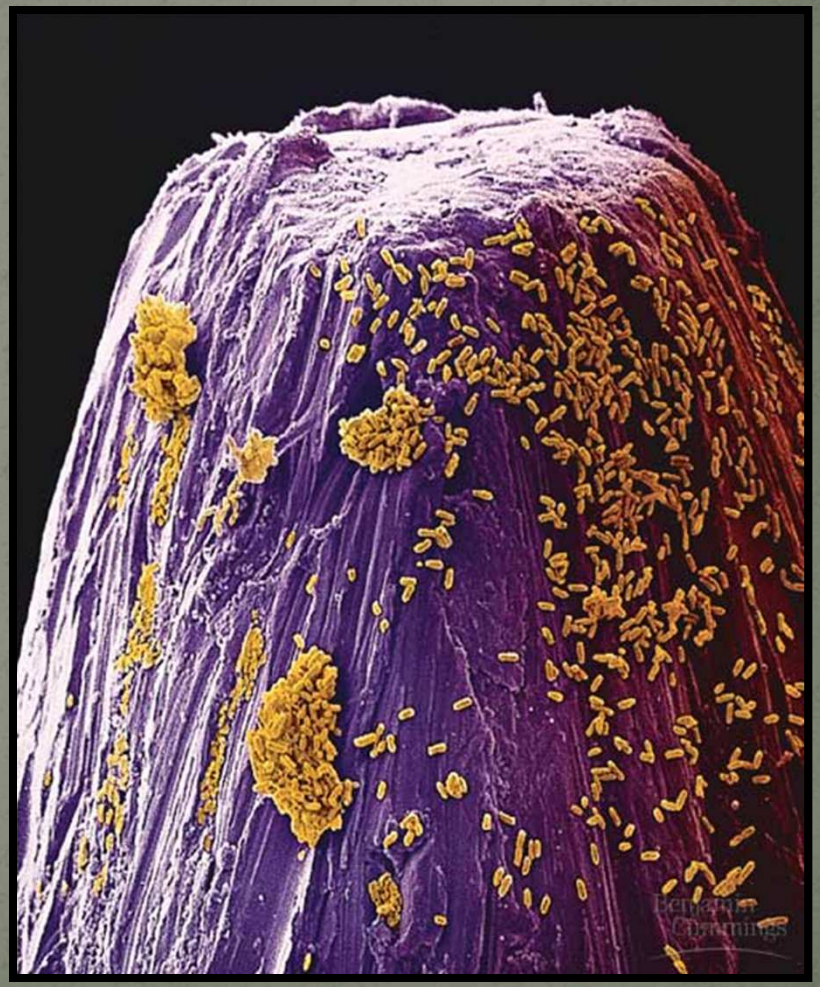
1. *Eubacteria*
2. *Archeabacteria*

Eukaryotes

3. *Protista*
4. *Fungi*
5. *Plantae*
6. *Animalia*

Prokaryotes:

- No true nucleus
- Unicellular
- Can either:
  - Eat other things
  - Photosynthetic
    - "Blue-green bacteria"
- 2 types: Eubacteria and Archeobacteria



Prokaryotes:

Eubacteria:

- "true bacteria"
- Very diverse

Prokaryotes:

Archeabacteria

- Name means "ancient."
- May be ancestors to eukaryotes
- Look almost identical to eubacteria, but genetically are as different as animals and plants.
- Inhabit extreme environments such as hot springs and salt ponds

Protista:

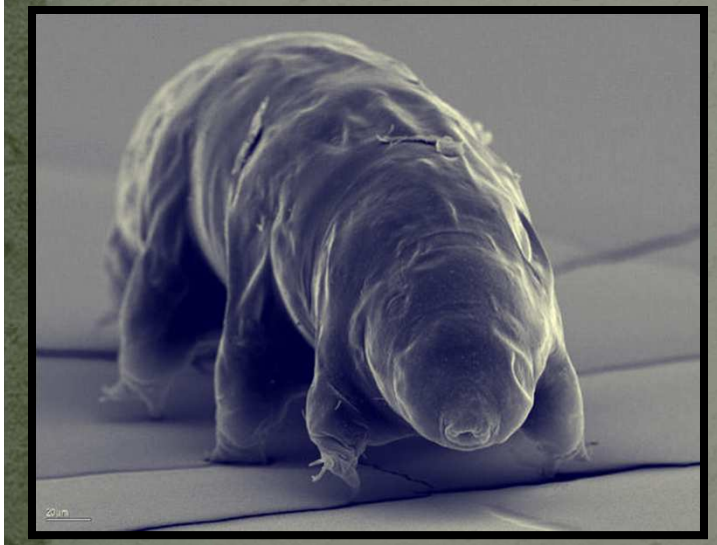
- Eukaryotic (have a nucleus)
- Most are unicellular but some are colonial and even multicellular
- Found almost anywhere there is H_20

Protista:

- There are a wide range of protista, including:
  - Algae: unicellular, photosynthetic
    - plant-like

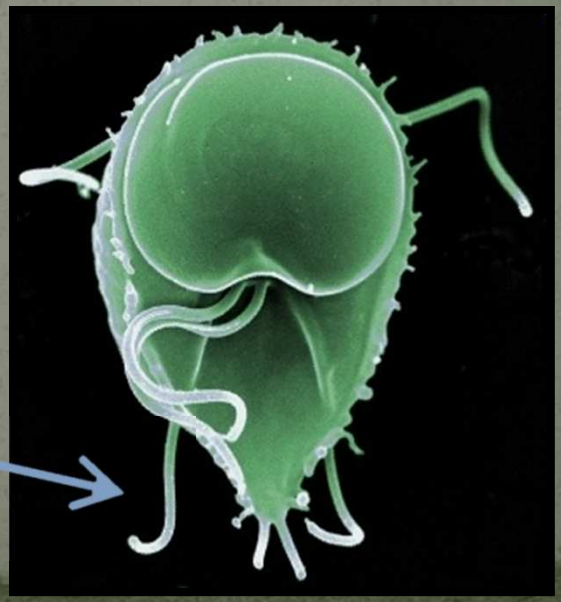
Protista:

- **Protozoans are:**
  - animal like
  - mobile
  - ingest food



Tardigrade or "water bear"

Giardia Lamblia



Fungi:

- Get nutrients from other things
- Digest externally and absorb nutrients
  - Examples are yeast and mushrooms

Plantae:

- Multicellular
- Make their food by photosynthesis
- 4 Types:
  - Non-vascular
  - Vascular without seeds
  - Seeded vascular- Gymnosperms
  - Flowering Plants- Angiosperms

Nonvascular Plants

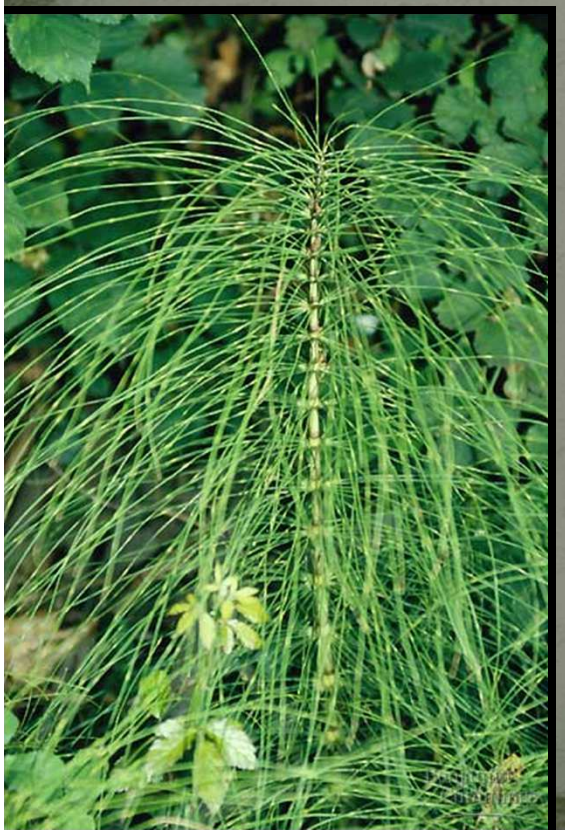
Mosses and liverworts

- Lack vascular tissue (tubes for water flow)
- That's why they only grow close to the ground in wet areas!!

Vascular Plants

Seedless vascular plants:

- Have tubes for water flow in stems.



Horsetail

Ferns

Vascular Seed plants

Gymnosperms = "Naked-Seed":

- Conifers, such as pines, fir and ginkgo trees and other plants with cones.

Vascular Seed Plants

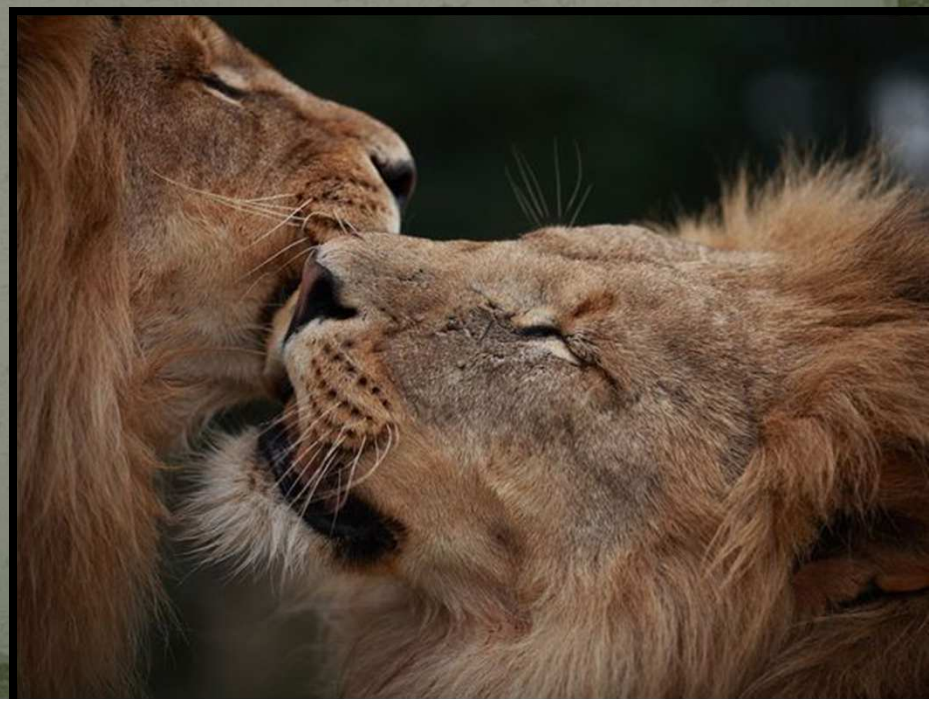
- Likely evolved as Earth's climate changed from warm and moist to hot and dry between 410 and 360 million years ago
- Evolutionally, have a number advantages over non-seed plants
  - Can reproduce without free-standing water
    - Pollination occurs when pollen is carried between plants of the same species by wind or insects; fertilization follows
  - Seeds feed and protect developing plant embryos
  - Seeds allow plants to colonize new places
    - Often carried by wind, water, or animals

Flowering plants

- Angiosperm-"Clothed Seed"
- Seed is found within a protective chamber called a fruit- which is the ripened ovary of the flower.
  - (in contrast with bearing naked seeds in conifers)

Animalia:

- Ingest food and digest it within specialized cavities
- Multicellular **and** Eukaryotic
- Reproduce sexually



Phylum Chordata

Chordates

At some point in their life cycle have:

- A Nerve Cord (thus the name)
- Gill Slits
- A Tail

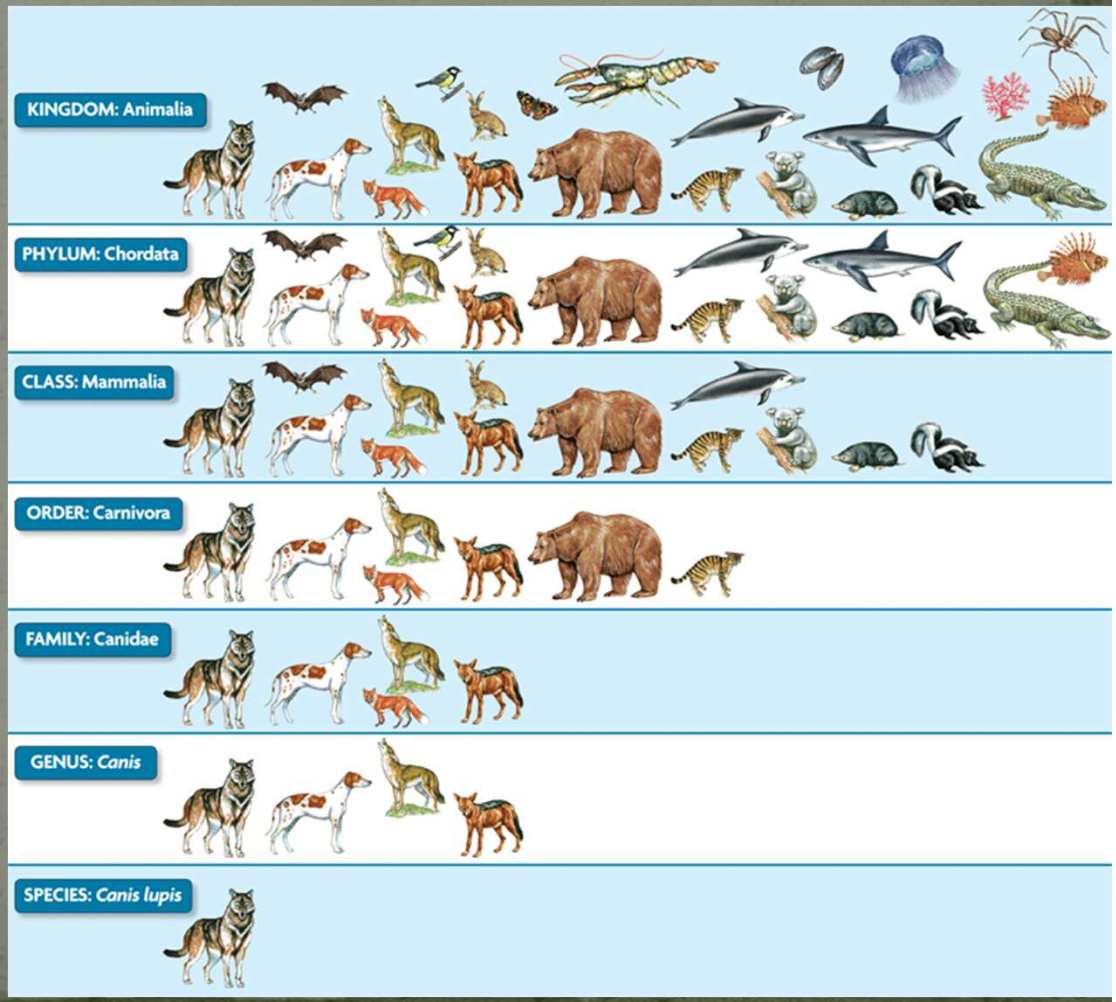
The 7 levels in the hierarchy of taxonomy:

- **Kingdom**
- **Phylum**
- **Class**
- **Order**
- **Family**
- **Genus**
- **Species**

Linnaeus' classification system has seven levels.

- Each level is included in the level above it.

- Levels get increasingly specific from kingdom to species.



What is a species?

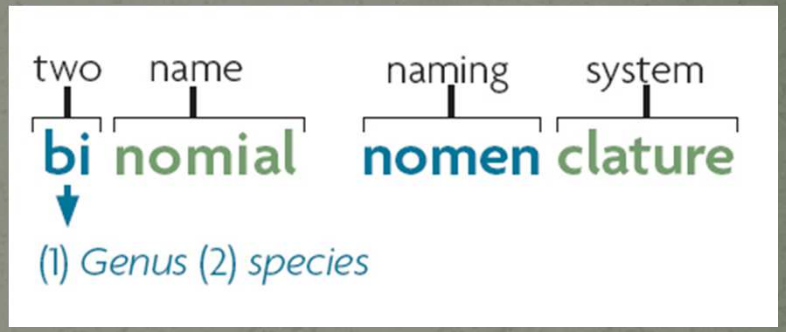
- A distinct form of life
  - A group of *populations* whose individuals:
    - have the potential to interbreed
    - produce viable, fertile offspring in nature

A Liger

The binomial system of nomenclature.

- "Two Name Naming"
- genus (capitalize 1st letter) and species (lower case 1st letter)
  - both italicized or underlined
    - *Homo sapiens*

      or
    - <u>Homo sapiens</u>



This is considered an organism or species' scientific name.