Cell Reproduction & Genetics

Vocabulary

Allele
Cell cycle
Chromosomes
Cloning
Co-dominance
Crossing over
Cytokinesis
DNA replication
Dominant inheritance
Gamete
Gene
Gene splicing
Gene therapy
Gene recombination
Genetic engineering
Genetics
Incomplete dominance
Inheritance
Interphase
Meiosis
Mitosis
Multiple alleles
Nondisjunction
Polygenic trait
Recessive inheritance
Semiconservative replication
Sex-linked trait
Genetically modified organism
genotype
phenotype

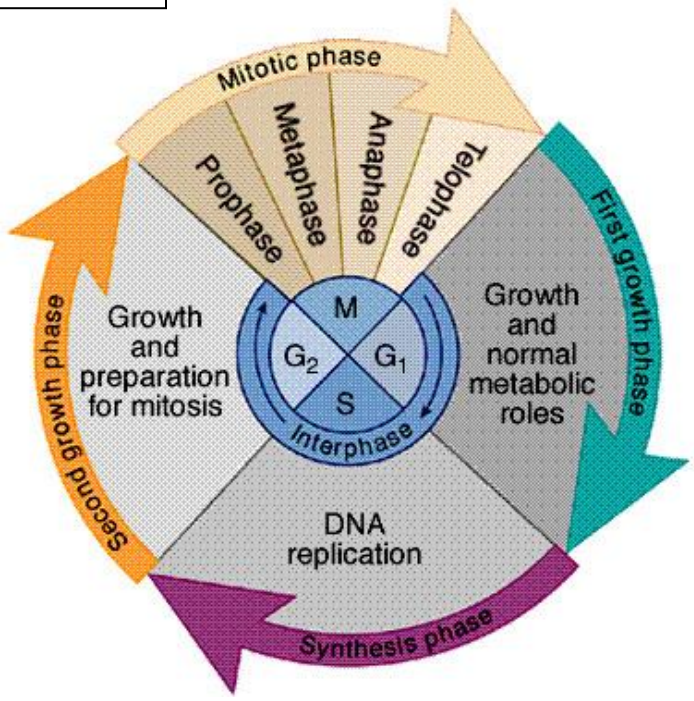
Concepts to Know

Main Concept #1: Describe the events that occur during the cell cycle: interphase, nuclear division (i.e. mitosis), cytokinesis.

- The Cell cycle – period of time from the beginning of one cell division to the beginning of the next
  - During the cell cycle, a cell grows, prepares for division, and divides to form two daughter cells, each of which then begins the cell cycle again
  - Consists of 4 phases
    - M phase – mitosis – the division of the cell nucleus and cytokinesis
    - G1 – intense growth and activity
    - S phase – copying of chromosomes
    - G2 – intense growth and activity
      - G stands for gap

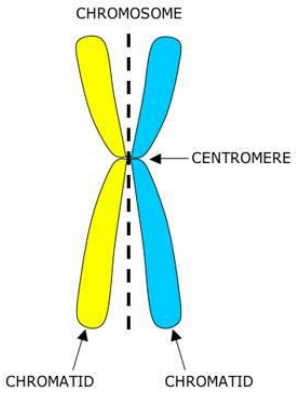
Interphase

- Interphase – time between two cell divisions
  - Interphase can be broken into 3 phases: G1, S, G2
    - G1 → cells do most of their growing, increasing in size and synthesizing new proteins and organelles
    - S → chromosomes are duplicated and the synthesis of DNA molecules takes place
      - Once cell enters S phase, it completes cell cycle
    - G2 → usually shortest of 3 phases
      - Organelles and proteins required for cell division are produced
      - Cell enters M phase once complete



MITOSIS

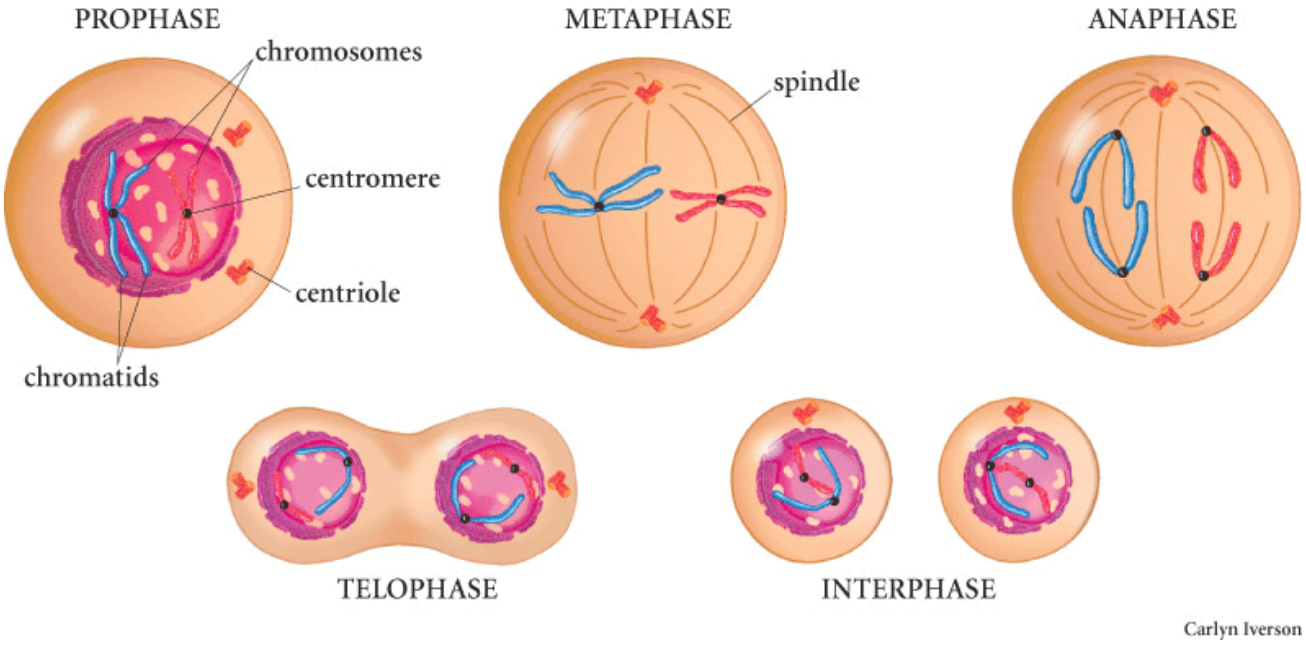
- Biologists divide the events of mitosis into 4 phases: prophase, metaphase, anaphase, and telophase
  1. prophase – 1st and longest phase of mitosis (50-60% of total time)
     - chromosomes become visible
     - centrioles separate and take up positions on opposite sides of the nucleus
       - focal point that helps organize spindle (fan-like microtubule structure that helps separate the chromosomes
       - chromosomes attach to spindle at the centromere
       - plants do not have centrioles
         - organize spindle from areas called centrosomes
     - nucleolus disappears
     - nuclear envelope breaks down



  2. metaphase – 2nd phase of mitosis
     - chromosomes line up along center of the cell
     - microtubules connect the centromere of each chromosome to the poles of the spindle

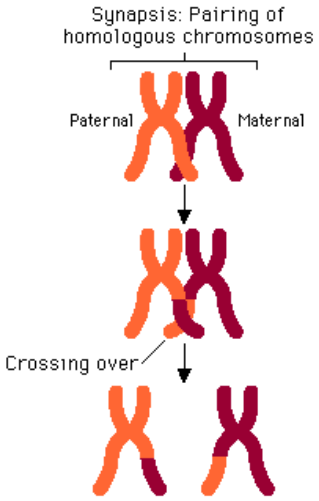
  3. anaphase – 3rd phase of mitosis
     - centromeres that join the sister chromatids split
     - chromatids separate and become individual chromosomes
     - chromatids get pulled apart, to the poles of the spindle
     - ends when they stop moving

  4. telophase – 4th phase of mitosis
     - chromosomes become loose and begin to disperse
     - nuclear envelope reforms
     - spindle breaks apart
     - a nucleolus reappears
     - cytokinesis – division of the cytoplasm
       - usually occurs at the same time as telophase
       - in animals, cell membrane pinches in at the middle
       - in plants, cell plate forms midway through the cell
         - beginning at the cell wall

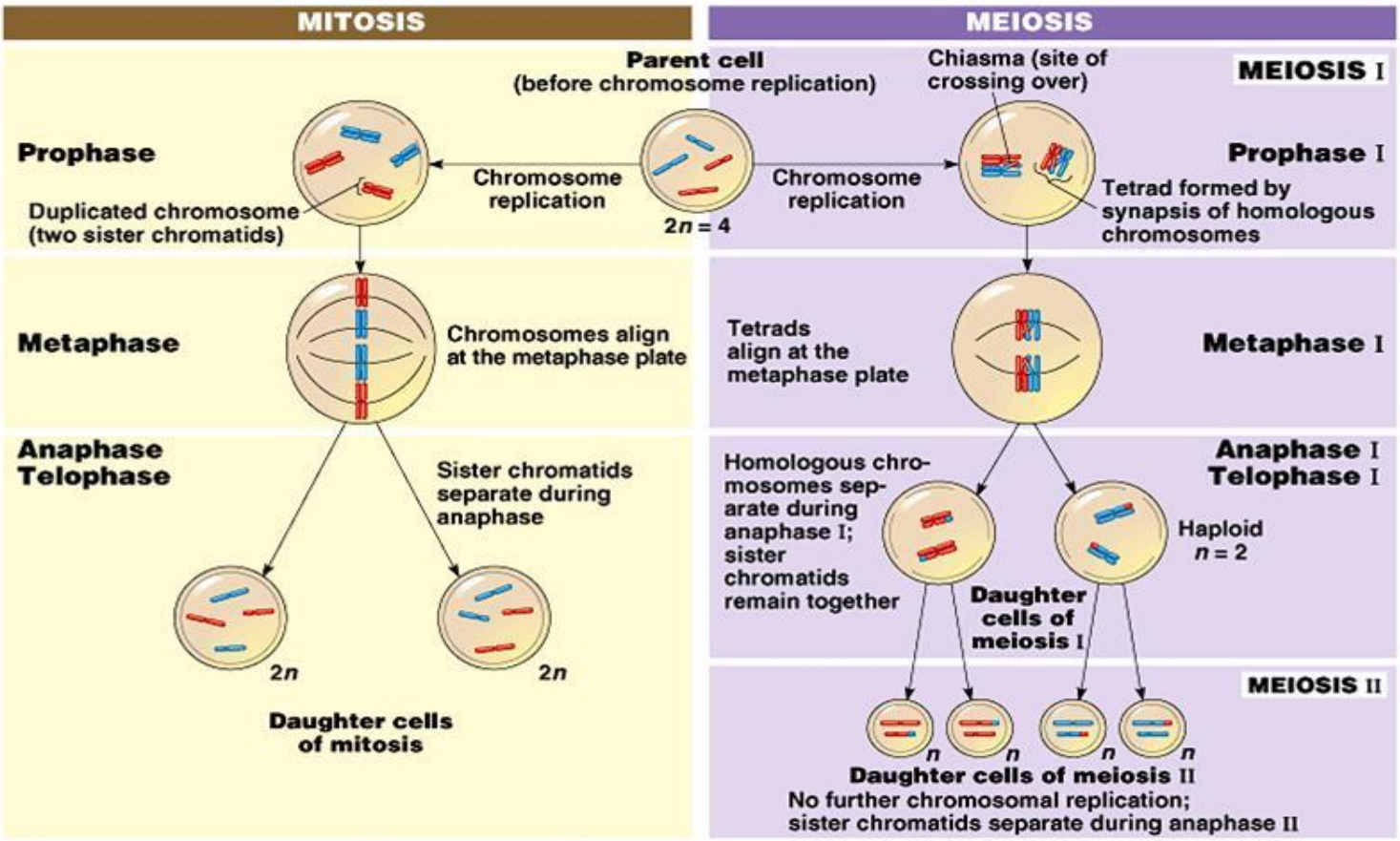


MEIOSIS

- meiosis is a process of reduction division in which the number of chromosomes per cell is cut in half and homologous chromosomes in a diploid cell are separated
    - involves two distinct stages: meiosis I and meiosis II
    - one diploid cell becomes 4 haploid cells
- homologous – two sets of chromosomes (one from mom and one from dad)
    - if a cell has both sets of chromosomes = diploid (2n)
        - 2 complete sets of chromosomes with 2 complete sets of genes
    - gametes with only one set of chromosomes = haploid (n)
        - contain only one set of genes
- **meiosis I** – prior to meiosis I, each chromosome is replicated
    - chromosomes line-up similar to mitosis, except the homologous chromosomes for a tetrad (4 chromatids)
        - occurs during prophase I
        - crossing over may occur – results in the exchange of alleles between homologous chromosomes and produces new combinations of alleles
    - homologous chromosomes separate and two new cells are formed
- **meiosis II** – cells from meiosis I enter meiosis II
    - cell does not undergo chromosome replication
    - anaphase II – chromatids separate



Main Concept #2: Compare the processes of mitotic and meiotic nuclear division.



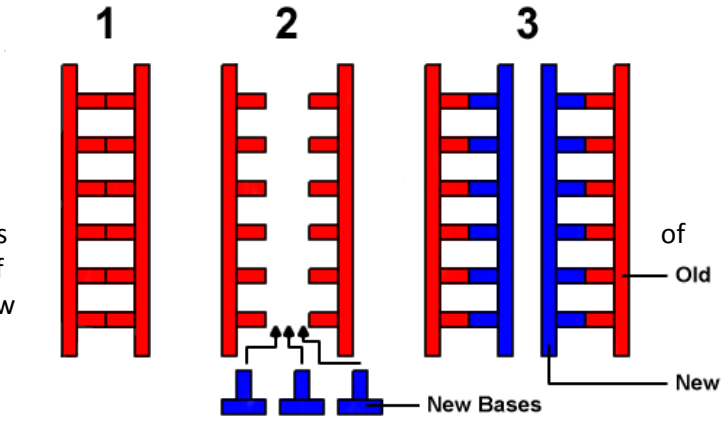
In the table provided, check all of the parts of the cell cycle that apply to the description in the left column. In mitosis, meiosis I, and meiosis II columns – state whether it happens in prophase (P), metaphase (M), anaphase (A), or telophase (T)

Description / Event	Interphase	Mitosis	Meiosis I	Meiosis II	Neither
Nuclear membrane breaks down					
Sex cells result					
Daughter cells are identical to parent					
Body cells result					
Chromatids line up single file during metaphase					
Final chromosome # is the same as the parent cell					
Diploid cells result at end					
Homologous chromosomes join					
Tetrads form					
DNA is replicated					
Chromosomes are double file					
Cytokinesis begins					
Transcription / translation occur					
Spindle fibers form					
Haploid Cells Result					
Sister chromatids separate					
Crossing over happens					
DNA Replication occurs					

- nondisjunction – failure of homologous chromosomes to separate during meiosis
    - if nondisjunction occurs, abnormal numbers of chromosomes may find their way into gametes, and a disorder chromosome numbers may result

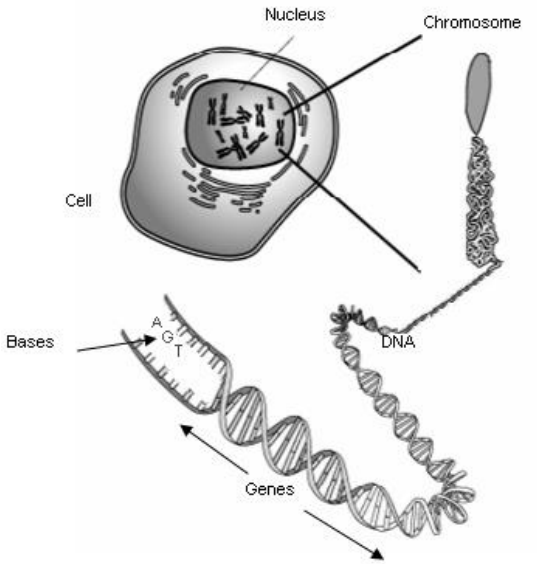
Main Concept #3: Describe how the process of DNA replication results in the transmission and/or conservation of genetic information.

- DNA Replication – copying of DNA
  - Ensures that each resulting cell will have a complete set of DNA molecule
  - During DNA replication, the DNA molecule separates into two strands, then produces two new complementary strands following the rules base pairing. Each strand of the double helix of DNA serves as a template against which the new strand is made → called semiconservative replication



Main Concept #4: Explain the functional relationships between DNA, genes, alleles, and chromosomes and their roles in inheritance.

- Two conclusions from Mendel's experiments with the pea plant
  1. biological inheritance is determined by factors that are passed from one generation to the next = **genes**
     - each gene controlled one trait with two contrasting characters
     - different forms of a gene = **alleles**
  2. principle of dominance – states that some alleles are dominant and others are recessive
     - organism with dominant allele for a particular form of a trait will always have that form
     - organism with recessive allele for a particular form of a trait will have that form only
- Segregation – separation of alleles
  - Done during formation of gametes (reproductive cells)



DNA is a molecule that carries genetic information which determines which proteins to make when

A **gene** is a specific segment of the DNA molecule that codes for a specific protein – EX: eye color

A **chromosome** is a whole bunch of genes linked together into organized structure (eukaryotes it is linear / prokaryotes it is circular)

An **allele** is a form of a gene – meaning it still is going to do what is asked (make eye color) but it has different information – blue eyes, brown eyes, hazel eyes…)

Main Concept #5: Describe and/or predict observed patterns of inheritance (ie. dominant, recessive, co-dominance, incomplete dominance, sex-linked, polygenic, and multiple alleles).

- Probability – likelihood that a particular event will occur
    - Probability of two events happening, you multiply the individual probabilities
        - Past outcomes do not affect future ones
    - The principles of probability can be used to predict the outcomes of genetic crosses
- Punnett square – diagram that helps determine gene combinations that might result from a genetic cross
- Capital letters represent dominant alleles; lower case letters represent lower case letters
- Homozygous – have two identical alleles – true-breeding
- Heterozygous – have two different alleles – hybrid – carrier
- Phenotype – physical feature
- Gentoype – genetic make-up

- for two genes, alleles segregate independently
    - independent assortment – genes segregate independently and do not influence each other's inheritance
        - the principle of independent assortment states that genes for different traits can segregate independently during the formation of gametes
- some alleles are neither dominant nor recessive, and many traits are controlled by multiple alleles or multiple genes
    - incomplete dominance – one allele is not completely dominant over another
        - heterozygous phenotype is somewhere between two homozygous phenotypes
    - codominance – both alleles contribute to the phenotype of the organism
        - heterozygous phenotypes have some of both homozygous phenotypes
    - multiple alleles – genes that have more than 2 possible alleles
    - polygenic traits – traits that result from the interaction of many genes
        - these traits are also greatly influenced by the environment

<u>Monohybrid Cross</u>

1. Two fish meet at the coral reef, fall in love, and get married that same night. They decide to make babies right away. The mom fish has a big fluffy tail (TT) while the dad has a very boring flat tail (tt). The dad is worried that he will pass his ugly tail down to his kids. What is the chance that the first child will have a flat tail?

T = fluffy tail t = flat tail

Genotypic Ratio: _____ Phenotypic Ratio: _____

Incomplete Dominance:

1. In Japanese four-o'clocks, the gene for red flower color (R) is incompletely dominant over the white flower color(r). For each of the following situations, predict the genotypic and phenotypic ratios of a red plant crossed with a white plant.

Codominance

1. The palomino horse is a hybrid (mix) showing a golden coat with a lighter mane and tail. A pair of codominant alleles, D1 and D2 is known to be involved in this trait. Horses with the D1D1 genotype are chestnut colored, horses with the D1D2 genotype are palomino, and horses with the D2D2 genotype are white in color.

    A. Two palomino horses are mated by artificial insemination. What types of offspring could be produced?

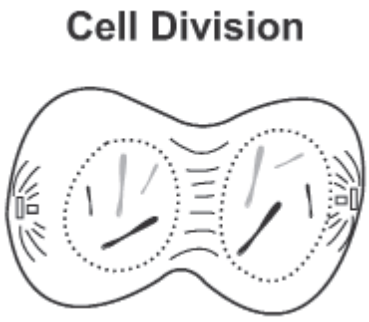
Sex-Linked Traits

1. White eyed fruit flies are the result of a sex-linked recessive gene. Show the results from a cross between a red-eyed (R) male and white-eyed (r) female fruit fly.

Main Concept #6: Explain how genetic engineering has impacted the fields of medicine, forensics, and agriculture (e.g., selective breeding, gene splicing, cloning, genetically modified organisms, gene therapy).

- selective breeding – allowing only those animals with desired characteristics to produce the next generation
    - humans use selective breeding to pass desired traits on to the next generation of organisms
- genetic engineering – making changes in the DNA code of living organisms
- Cutting / Splicing DNA
    - Restriction enzymes – cuts DNA at a specific sequence of nucleotides
    - cutting and pasting
        - recombinant DNA – taking DNA and "pasting" it to another organism's DNA
- transgenic organisms /genetically modified organisms– organisms that contain genes from other organisms
    - using the basic techniques of genetic engineering, a gene from one organism can be inserted into cells from another organism. These transformed cells can then be used to grow new organisms
- clone – member of a population or genetically identical cells produced from a single cell
- gene therapy is the process of attempting to cure genetic disorders by placing copies of healthy genes into cells that lack them

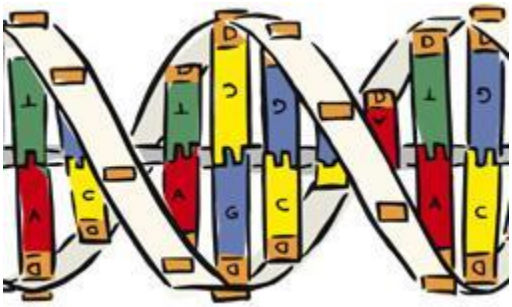
Practice Questions:



1. Which statement **best** describes the phase of the cell cycle shown?
   A. The cell is in prophase of mitosis because the number of chromosomes has doubled.
   B. The cell is in prophase I of meiosis because the number of chromosomes has doubled.
   C. The cell is in telophase of mitosis because the cell is separating and contains two copies of each chromosome.
   D. The cell is in telophase of meiosis because the cell is separating and contains two copies of each chromosome.

2. Mitosis and meiosis are processes by which animal and plant cells divide. Which statement **best** describes a difference between mitosis and meiosis?
   A. Meiosis is a multi-step process.
   B. Mitosis occurs only in eukaryotic cells.
   C. Meiosis is used in the repair of an organism.
   D. Mitosis produces genetically identical daughter cells.

Suppose that the central C-G base pair in the DNA molecule below is substituted by an A-T base pair.



3. What is the most likely result of this mutation?
   a. genetic variation
   b. genetic clones
   c. incomplete translation
   d. identical offspring

4. Hemophilia is an inheritable genetic disorder that prohibits the proper formation of blood clots. The recessive gene that causes hemophilia is located on the X-chromosome. Given this information, which of the following statements is true?
   a. In order for a male offspring to be a hemophiliac, his mother must be a hemophiliac.
   b. In order for a female offspring to be a hemophiliac, her father must be a hemophiliac.
   c. In order for a male offspring to be a hemophiliac, his father must be a hemophiliac.
   d. In order for a female offspring to be a hemophiliac, her mother must be a hemophiliac.

5. Which of the following statements is true?
    a. Mitosis results in the formation of two haploid gametes which can then combine to form a diploid daughter cell.
    b. During the process of meiosis, haploid cells are formed. After fertilization, the diploid number of chromosomes is restored.
    c. The process of meiosis forms daughter cells which are genetically identical to their parent cells.
    d. The daughter cells formed during mitosis are genetically similar to, though not identical to, their parent cell.

6. Which of the following best describes the way that genes, chromosomes, and DNA are related?
    a. Chromosomes contain several genes, which are made up of sequences of DNA.
    b. Genes contain several chromosomes, which are made up of sequences of DNA.
    c. Genes contain several sequences of DNA, which are made up of chromosomes.
    d. Sequences of DNA contain several genes, which are made up of chromosomes.

7. If a cat has 38 chromosomes in each of its body cells, how many chromosomes will be in each daughter cell after mitosis?
    a. 19 c. 11
    b. 76 d. 38

8. Tom is going to buy two hamsters. He wants to breed them and sell the baby hamsters to a local pet store. The store owner tells him that his customers prefer dark brown hamsters with white bellies, long fur, black eyes, and long tails. Tom found a female hamster with all of those characteristics. Which male hamster should Tom buy in order to have the BEST chance of breeding baby hamsters with MOST of those characteristics?

Hamster W	**Hamster X**	**Hamster Y**	**Hamster Z**
Tan Fur Dark	Brown Fur	Tan Fur	Dark Brown Fur
White Belly	White Belly	White Belly	Dark Brown Belly
Long Fur	Long Fur	Short Fur	Long Fur
Long Tail	Long Tail	Long Tail	Short Tail
Brown Eyes	Brown Eyes	Black Eyes	Black Eyes

    a. W c. Y
    b. Z d. X

Open-ended Question:

9. Patau syndrome can be a lethal genetic disorder in mammals, resulting from chromosomes failing to separate during meiosis.

    Part A: Identify the step during the process of meiosis when chromosomes would **most likely** fail to separate.

    _____
    _____
    _____
    _____
    _____
    _____

    Part B: Describe how chromosome separation in meiosis is different from chromosome separation in mitosis.

    _____
    _____
    _____
    _____
    _____
    _____

Part C: Compare the effects of a disorder caused by chromosomes failing to separate during meiosis, such as Patau syndrome, to the effects of chromosomes failing to separate during mitosis.

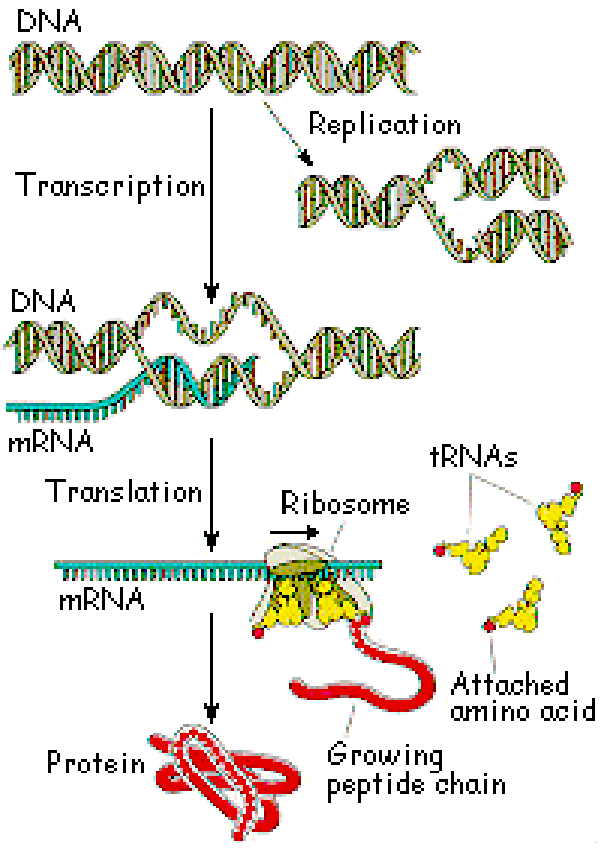
_____
_____
_____
_____
_____
_____

Protein Synthesis

Vocabulary

Transcription
Translation
Translocation
Chromosomal mutation
Deoxyribonucleic acid
Frame-shift mutation
Gene expression
Mutation
Point mutation

Concepts to Know



The Central Dogma: How our DNA code makes Phenotype
DNA → RNA → Protein

How are we so different? Why are we not identical to a plant? Or a bacterium? Or each other?

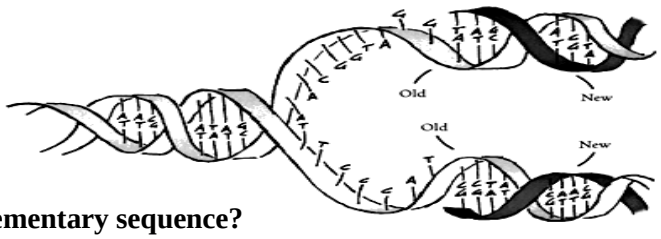
The DNA code is the same in all organisms but the sequence of the letters is different. All life uses A,C,T,G in double-stranded base pairs. This is the same concept that War and Peace is not identical to your IPod Warranty, but they're still written in English. DNA is just a language. A very, very, very important language.

This is why scientists can manipulate life in the laboratory so easily. This is also the key to understanding a single common ancestor.

DNA is the code of life – ACTGs are the alphabet of life, just like 0s and 1s are the binary code of computers. The ACTGs of DNA can be read by enzymes to create a triplet codon that is interpreted into 20 amino acids to make very diverse proteins. **DNA is letters; codons are words; proteins are messages that make sense.**

1st Idea: Life Contains DNA: it is a SELF-REPLICATING molecule.

DNA replicates itself (via DNA polymer**ase** and other enzymes) in ***a semi-conservative*** manner. This means that at the end of replication, each of the daughter molecules has one old strand, from the parent strand of DNA, and one strand that is newly synthesized. (see pic).



Adenine pairs with Thymine (A = T)
Guanine pairs with Cytosine (G ≡ C)
The bonds between the base pairs are **hydrogen bonds**

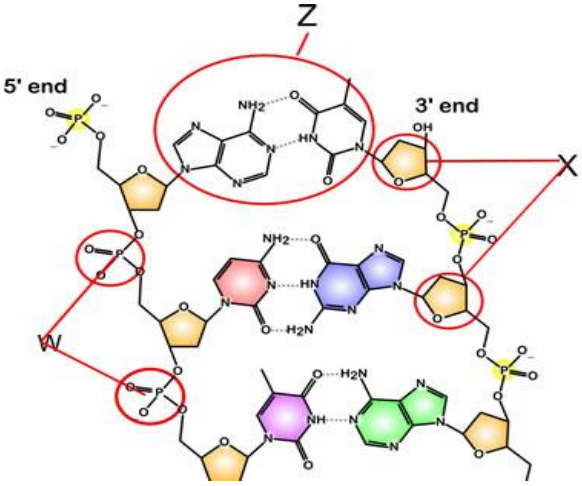
If given the template strand of DNA below, what is the complementary sequence?

5' A T G T A T G C C A A T G C A 3'

3'__ __ __ __ __ __ __ __ __ __ __ __ __ __ __ 5'

FYI: ***How'd they figure this stuff out?*** *With radioactive isotopes of nitrogen, sulfur and phosphorus.*

DNA proofreading: the enzymes involved make sure this process makes an exact message (only 1 in 10 billion base pairs would be incorrect; better than computer coding mechanisms)



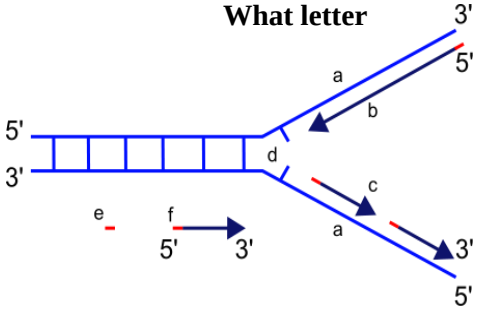
DNA STRUCTURE

Nucleic Acid (polymer) is made of nucleotides (monomer)
A nucleotide is made of: a sugar _____,
a phosphate group_____,
and a nitrogenous base _____.

IDENTIFY EACH AS W, X, OR Z IN THE DIAGRAM

I. DNA REPLICATION

DNA polymerase is an enzyme *(ends in –ase)*. **All enzymes have a specific active site.** The DNA in this example is the substrate and only can fit into the enzyme (DNA polymerase) a certain way. This is why DNA replication has a **leading** and a **lagging** strand when made. The enzyme can only fit onto DNA via the 3' hydroxyl side, not the 5' phosphate side.

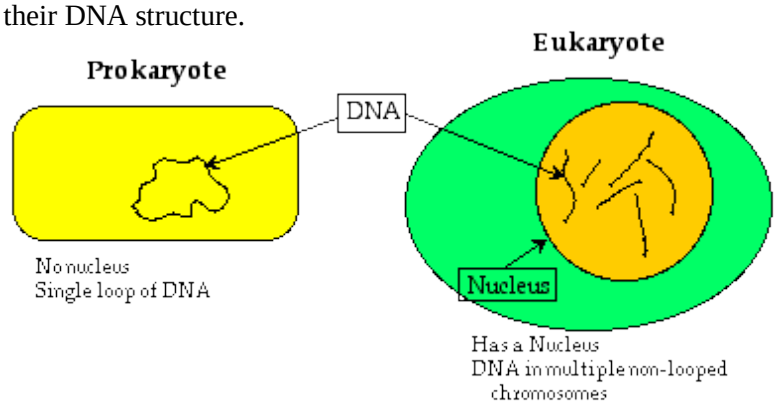


What letter in this diagram represents the *continuous* leading strand? _____

What letter represents the Okazaki *fragments* of the lagging strand? _____

II. P ROKARYOTES VS EUKARYOTES

Prokaryotes ("before nucleus") evolved before eukaryotes ("true nucleus") and have slight differences in their DNA structure.



➔ **What can you deduce from the picture?**

2nd Idea: DNA is the source message but RNA is the working copy

MAJOR DIFFERENCES BETWEEN DNA AND RNA

DNA	RNA
deoxiribose sugar	ribose sugar
thymine	uracil
double helix	single strand (mRNA) or unit (tRNA)
permanent	temporary
in nucleus (some in mitochondria)	leaves nucleus, works in cytoplasm
one kind	many kinds (at least 3)

The DNA is like the encyclopedia you can never check out of the library. However, you are allowed to make copies of the information. That's what RNA is – a copied message of the important pages. Making copies ensures that you don't 'ruin' the original by taking it out of the nucleus (*this only applies to eukaryotes*), you can make copies in bulk, AND you only have to make copies of what you need. You wouldn't copy all 6000 pages of an encyclopedia would you? No! Only the 4-5 pages you might need for a report. In eukaryotes, we only code for ~ 2% of our DNA!

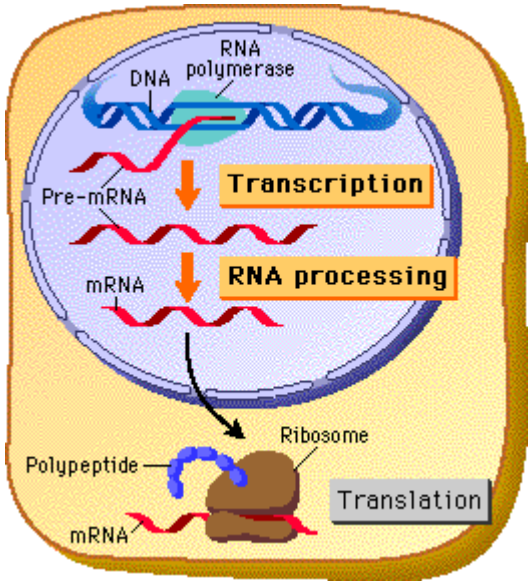
RNA (ribonucleic acid) is the intermediate between DNA and protein. It has slight differences to DNA. See the chart.

TRANSCRIPTION is the process of making RNA from DNA (via the enzyme RNA polymer**ase**). This happens in the nucleus for eukaryotes, but would happen in cytoplasm for prokaryotes.

Watch a refresher video of the process on the protein synthesis page for www.udkeystone.wikispaces.com

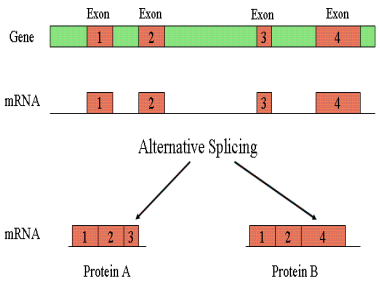
Can you complete this message?

T A C C C C T T T G G C A T A G A
A U G G G __ __ __ __ __ __ __ __ __ __ __ __



Important Points about TRANSCRIPTION: DNA → RNA → Protein

- **RNA Polymerase** scans the genome for the promoter region of DNA (the start signal)
- A single-stranded copy of RNA is made of the DNA gene, where **U is complementary to A instead of T.**
- Transcription and Translation occur simultaneously in the cytoplasm for prokaryotes, with no editing needed.
- **Transcription occurs in nucleus for eukaryotes.**
- Eukaryotic messageRNA has **EXONS** (expressed message) and **INTRONS** (in-between message)
- Introns get spliced (cut out) of the mRNA to make the mature transcript.



WHY INTRONS?

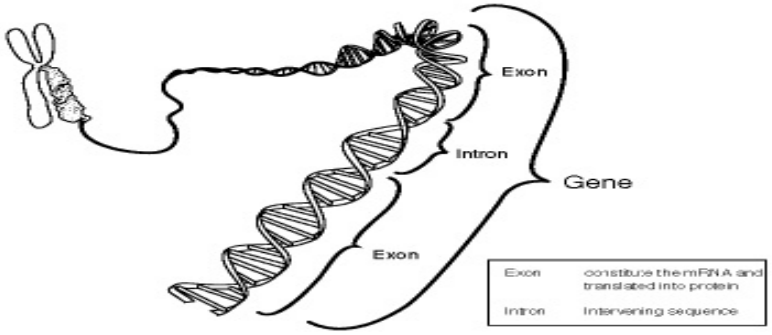
Alternative splicing allows to mix-n-match exons to make different proteins from the same sequence. This is a major source of eukaryotic evolution!

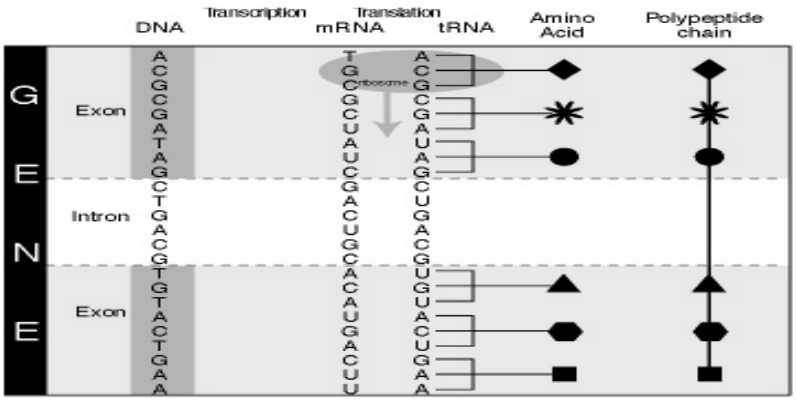
This is like you being able to make 20 different outfits in your closet from 4 pairs of pants and 5 shirts.

3rd Idea: Translation is matching an amino acid to the messageRNA in order to make the protein code

Important points about TRANSLATION

- The mRNA leaves the nucleus → cytoplasm *(in eukaryotes)*
- Message is read at the **ribosome**
- mRNA is read 3 letters at a time
- AUG is the start signal
- 1 Codon (3 letter message) is translated into 1 amino acid
- transferRNA molecule has one end (anticodon) that matches the mRNA . Each anticodon specifies an amino acid.
- There are 20 amino acids
- The amino acids are bonded together as peptide chains…which fold into proteins





If a mature mRNA transcript has 300 nucleotides, how many amino acids would that code for?

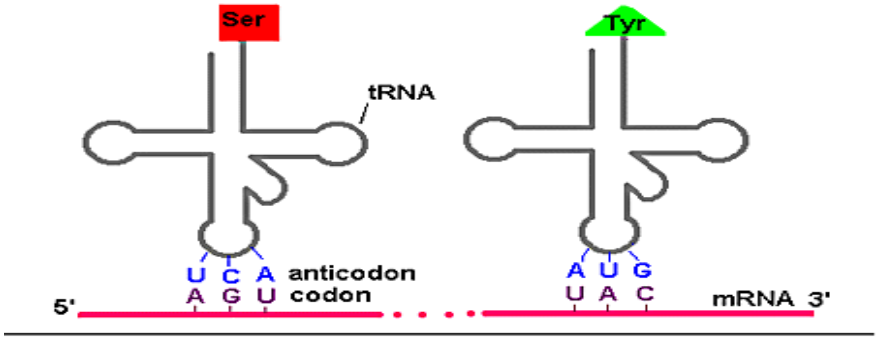
TRANSLATION :
DNA → **RNA → Protein**

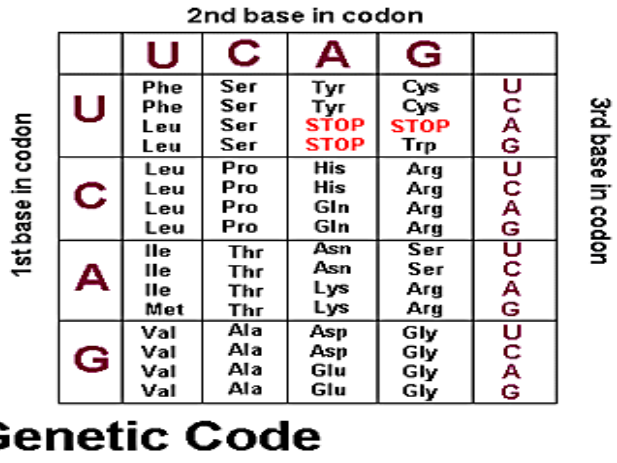
Ex: the message AUGGGGCAAUAA codes for Met-Gly-Gln-*
(the * tells the ribosome to stop)

What does this message code for?

AUG CUU CCA GAG UGA

____ _____ _____ _____ _____





The Genetic Code

- After a polypeptide chain is made from amino acids (at a ribosome), it might be used right away in the cytoplasm, or it might be sent to the Golgi apparatus to have more folding or carbohydrates added.
- Proteins made on free ribosomes will work in the cytoplasm
- Proteins made on the rough ER will go the cell membrane or be excreted

4TH Idea: Mutations in the DNA or RNA sequence produce the wrong amino acid sequence.

*****THE ULTIMATE SOURCE OF EVOLUTION IS MUTATION*****

MUTATION : A change in DNA sequence

- **Point Mutations**: Change one or two base pairs
  - ➔ **Insertion, Deletion, Substitution**

Only 2 of these are "**frameshift mutations**" - that is, they change the codon reading frame.

Other mutation vocabulary

- ➔ **Silent Mutation** = the mutation goes unnoticed – it does not change the amino acid sequence or is not in a coding region (the mutation is in an intron, or the 98% of the genome that doesn't code for protein, or in the 3rd base of a codon)
- ➔ **Missense** – an insertion, deletion, or substitution that would make the message different
- ➔ **Nonsense** – really bad; a stop codon is created and the message stops prematurely

Example: Remember that DNA and RNA are just a language. To emphasize the point of mutation, I am using English (an alphabet with 26 letters, not 4!) Imagine you have the following message:

THE CAT ATE THE RAT

Using the above bolded mutations, label the type of mutation each must be:

_____ THE HAT ATE THE RAT

_____ TTH EHA TAT ETH ERA T

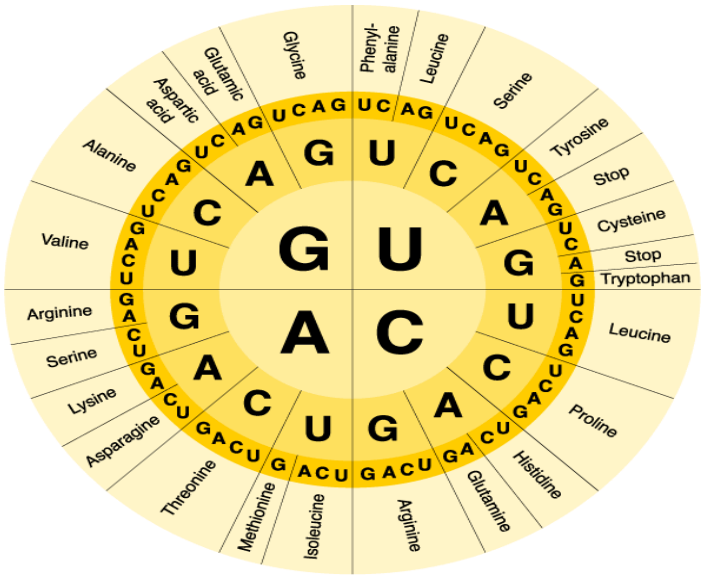
_____ THE ATA TET HER AT

The "Central Dogma of Biology" is summarized as:

_____ → _____ → _____

Fill in the chart:

DNA Triplet	mRNA Codon	tRNA Anticodon	Amino Acid
			met
		GGA	
TTC			
	UAG		



➔ ORDER THE FOLLOWING

_____ Intron sequences are spliced out and exons are joined together

_____ amino acids form peptide bonds as tRNA molecules match the mRNA

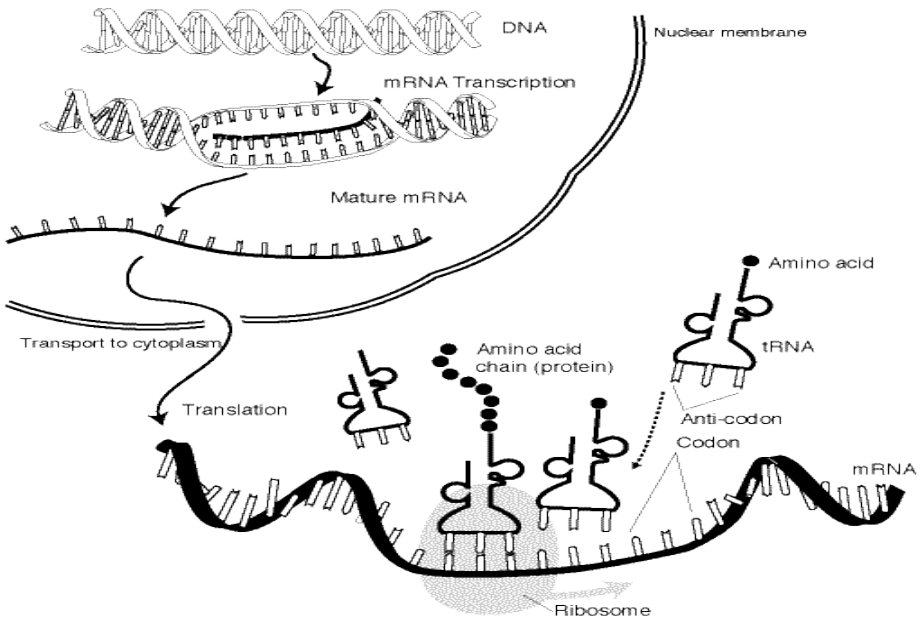
_____ RNA polymerase reads the DNA and builds complimentary sequence

_____ The mRNA attaches to the ribosome

_____ The ends of the mature transcript are protected before it leaves the nucleus

_____ RNA polymerase finds the promoter sequence on DNA

_____ transfer RNA arrives at the ribosome and the anticodon complements to the mRNA codon



Practice Questions:

1. Which process helps to preserve the genetic information stored in DNA during DNA replication?
   A. the replacement of nitrogen base thymine with uracil
   B. enzymes quickly linking nitrogen bases with hydrogen bonds
   C. the synthesis of unique sugar and phosphate molecules for each nucleotide
   D. nucleotides lining up along the template strand according to base pairing rule

2. In a flowering plant species, red flower color is dominant over white flower color. What is the genotype of any red-flowering plant resulting from this species?
   A. red and white alleles present on one chromosome
   B. red and white alleles present on two chromosomes
   C. a red allele present on both homologous chromosomes
   D. a red allele present on at least one of two homologous chromosomes

3. The endoplasmic reticulum is a network of membranes within the cell, and it is often classified as rough or smooth, depending on whether there are ribosomes on its surface. Which statement **best** describes the role of rough endoplasmic reticulum in the cell?
   A. It stores all proteins for later use.
   B. It provides an attachment site for larger organelles.
   C. It aids in the production of membrane and secretory proteins.
   D. It stores amino acids required for the production of all proteins.

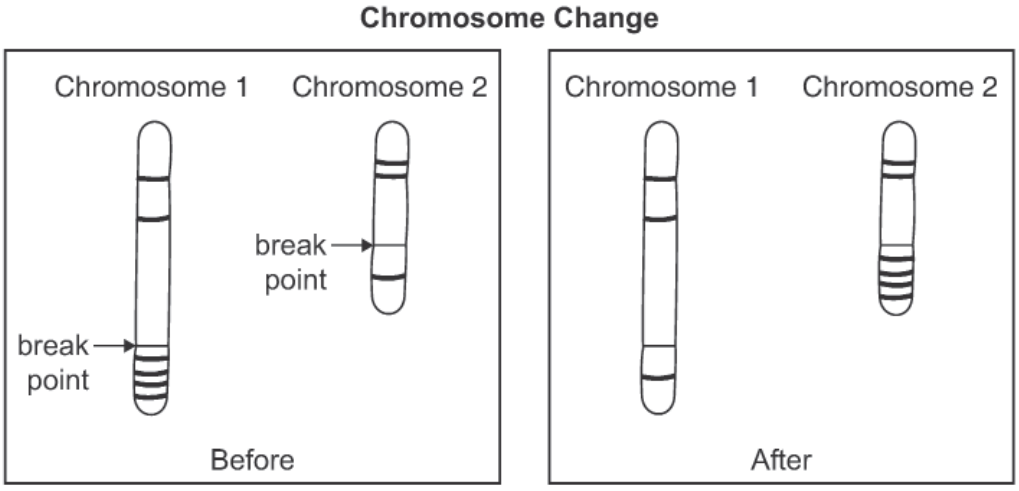
Use the table below to answer the question.

Blood Types

Genotypes	Phenotypes
ii	O
I^AI^A, I^Ai	A
I^BI^B, I^Bi	B
I^AI^B	AB

4. Blood type is inherited through multiple alleles, including I^A, I^B, and i. A child has type A blood. If the father has type AB blood, what are all the possible phenotypes of the mother?
    A. phenotypes O or A
    B. phenotypes A or AB
    C. phenotypes A, B, AB
    D. phenotypes O, A, B, AB

Use the diagram below to answer the question.



5. Which type of change in chromosome composition is illustrated in the diagram?
    A. deletion
    B. insertion
    C. inversion
    D. translocation

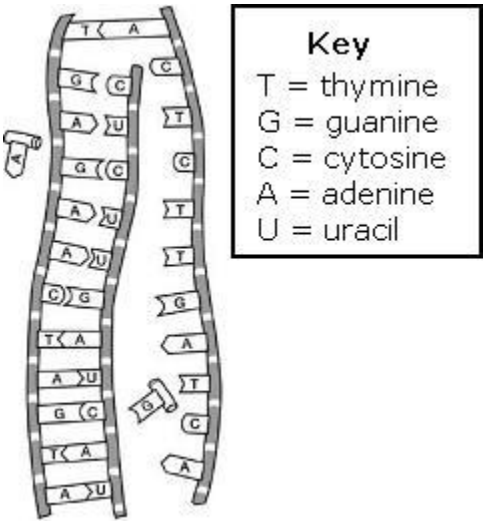
6. Which statement describes a cell process that is common to both eukaryotic and prokaryotic cells?
    A. Both cell types carry out transcription in the nucleus.
    B. Both cell types use ribosomes to carry out translation.
    C. Both cell types assemble amino acids to carry out transcription.
    D. Both cell types carry out translation in the endoplasmic reticulum.

7. A genetic mutation resulted in a change in the sequence of amino acids of a protein, but the function of the protein was not changed. Which statement **best** describes the genetic mutation?
    A. It was a silent mutation that caused a change in the DNA of the organism.
    B. It was a silent mutation that caused a change in the phenotype of the organism.
    C. It was a nonsense mutation that caused a change in the DNA of the organism.

D. It was a nonsense mutation that caused a change in the phenotype of the organism.

8. Genetic engineering has led to genetically modified plants that resist insect pests and bacterial and fungal infections. Which outcome would **most likely** be a reason why some scientists recommend caution in planting genetically modified plants?
   A. unplanned ecosystem interactions
   B. reduced pesticide and herbicide use
   C. improved agricultural yield and profit
   D. increased genetic variation and diversity

9. Which of the following is primarily responsible for the coding of the amino acids used in the synthesis of cellular proteins?
   A. DNA
   B. transfer RNA
   C. ribosomes
   D. Golgi apparatus



10. Which statement describes the diagram above?
    a. DNA transcription is producing ribosomal RNA.
    b. DNA translation is producing messenger RNA.
    c. DNA transcription is producing messenger RNA.
    d. DNA translation is producing ribosomal RNA.

Open-ended Question:

11. A cattle farmer genetically crosses a cow (female) with a white coat with a bull (male) with a red coat. The resulting calf (offspring) is roan, which means there are red and white hairs intermixed in the coat of the calf. The genes for coat color in cattle are co-dominant.

Part A: Although a farm has cattle in all three colors, the farmer prefers roan cattle over white or red cattle. Use the Punnett square to show a cross that would produce only roan offspring.

Part B: Explain how a roan calf results from one white- and one red-coated parent. In your explanation, use letters to represent genes. Be sure to indicate what colors the letters represent.

_____
_____
_____
_____
_____
_____

Part C: Predict the possible genotypes and phenotypes of the offspring produced from two roan cattle.

_____
_____
_____
_____
_____
_____

Evolution

Vocabulary

evolution
natural selection
speciation
genetic drift
competition
extinction
allele frequency
analogous structure
homologous structure
isolating mechanisms
embryology
genetic migration
endosymbiosis
fossils
founder effect
gradualism
population dynamics
punctuated equilibrium
selective breeding
vestigial structure

Concepts to Know

What are evolution and natural selection?

Evolution is how species change over time in response to the environment.

Natural selection is the mechanism by which species evolve.

Play a Game! … "Who Wants to Live A Million Years?"