Zoology – Cell Division and Inheritance

I. A Code for All Life

A. Before Genetics - _____

1. If a very tall man married a short woman, you would expect their children to be intermediate, with average height.
2. The history of blending inheritance, as an idea, remains in some animal scientific names. For example…
    a. Giraffe = *Giraffa camelopardalis* (described as having characteristics like both a camel and a leopard)
    b. Mountain Zebra = *Equus Hippotigris zebra* (having characteristics of a hippo and a tiger)

B. History of Central Tenets of Genetics

1. Genetics accounts for resemblance and fidelity of reproduction. But, it also accounts for variation.
2. Genetics is a major unifying concept of biology.
3. _____ described particulate inheritance.
4. _____&_____described nature of the coded instructions (the structure of DNA).

C. Some vocabulary

1. _____ – a unit of heredity. A discreet part of the DNA of a chromosome that encodes for one trait, or protein, or enzyme, etc.
2. _____ – (deoxyribonucleic acid) a molecule that carries the genetic instructions for what the cell will do, how it will do it, and when it will do it.
3. _____ – a linear sequence of genes, composed of DNA and protein.
    a. Think of the chromosome as a bus that the genes are riding in. Where the bus goes, the genes must go.
4. _____- The location of any one gene on a chromosome.
5. _____ - Alternative forms of a gene; one or both may have an effect and either may be passed on to progeny.
6. _____**pairs of chromosomes** – Chromosomes that have the same banding pattern, same centromere position, and that encode for the same traits.
    a. One member of the pair you inherit from your mother & one member of the pair you inherit from your father.

II. Sexual Reproduction

A. Humans have 46 chromosomes in _____

(normal body cells)

1. This represents _____ homologous pairs of chromosomes (you inherit one member of the pair from your mother & one member of the pair from your father)
2. Normal body cells are _____ or _____.

In diploid cells, each organism has two genes for each trait, one on each homologous chromosome. (In other words, you inherit one gene for a trait from your mother & one gene for a trait from your father.)

a. Remember that normal body cells reproduce through **mitosis** and **cytokinesis**.

B. _____ are sex cells. Females produce eggs, and males produce sperm.

1. Gametes are _____ or _____.

Gametes do NOT have homologous chromosome pairs. When you make gametes, the gamete receives EITHER the gene you inherited from your mother OR the gene you inherited from your father, but not both.

2. In humans, eggs and sperm have 23 chromosomes.
3. Sexual reproduction involves _____, when the sperm joins the egg.

a. The sperm carries 23 paternal chromosomes & the egg carries 23 maternal chromosomes.
b. 23 maternal + 23 paternal chromosomes = 23 homologous pairs or 46 chromosomes in the newly formed _____ (a fertilized egg).
c. This restores the diploid condition in the offspring.

C. Gametes are produced through a special type of cell division, _____. In meiosis, one duplication and two divisions result in gametes with one member of each homologous pair.

Animal Cell Meiosis
Sex Cell (Gamete) Production

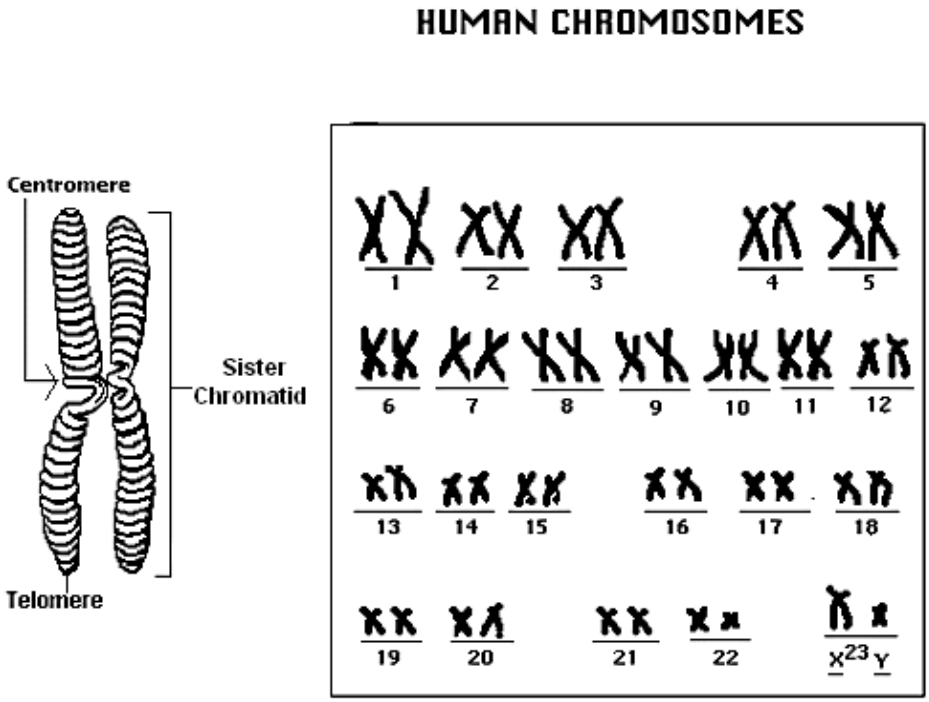
Sexual Reproduction:

Sexual reproduction involves the union of male and female **gametes** (sex cells; eggs and sperm) through **fertilization**. Each gamete contributes half of the genetic makeup of the resulting **zygote** (fertilized egg). This insures that the offspring are not genetic clones of their mother or father. It increases genetic variation in the population and helps the species survive environmental challenges.

Watch this video covering the basics of meiosis: http://www.youtube.com/watch?v=D1_-mQS_FZ0

What does haploid and diploid mean?

Ploidy is a term referring to the number of sets of chromosomes. Humans have 23 pairs of chromosomes. The chromosome pairs are numbered 1-23. These pairs are **homologous chromosomes** that have the same banding pattern, centromere position, and carry genes for the same traits. People inherit one member of each homologous pair from their mother (the **maternal chromosome**) and one member of each homologous pair from their father (the **paternal chromosome**). Haploid and diploid are terms referring to the number of sets of chromosomes in a cell. Most animal cells are said to be **diploid** because they have pairs of every chromosome. Di refers to "two." We abbreviate diploid as **2n**.

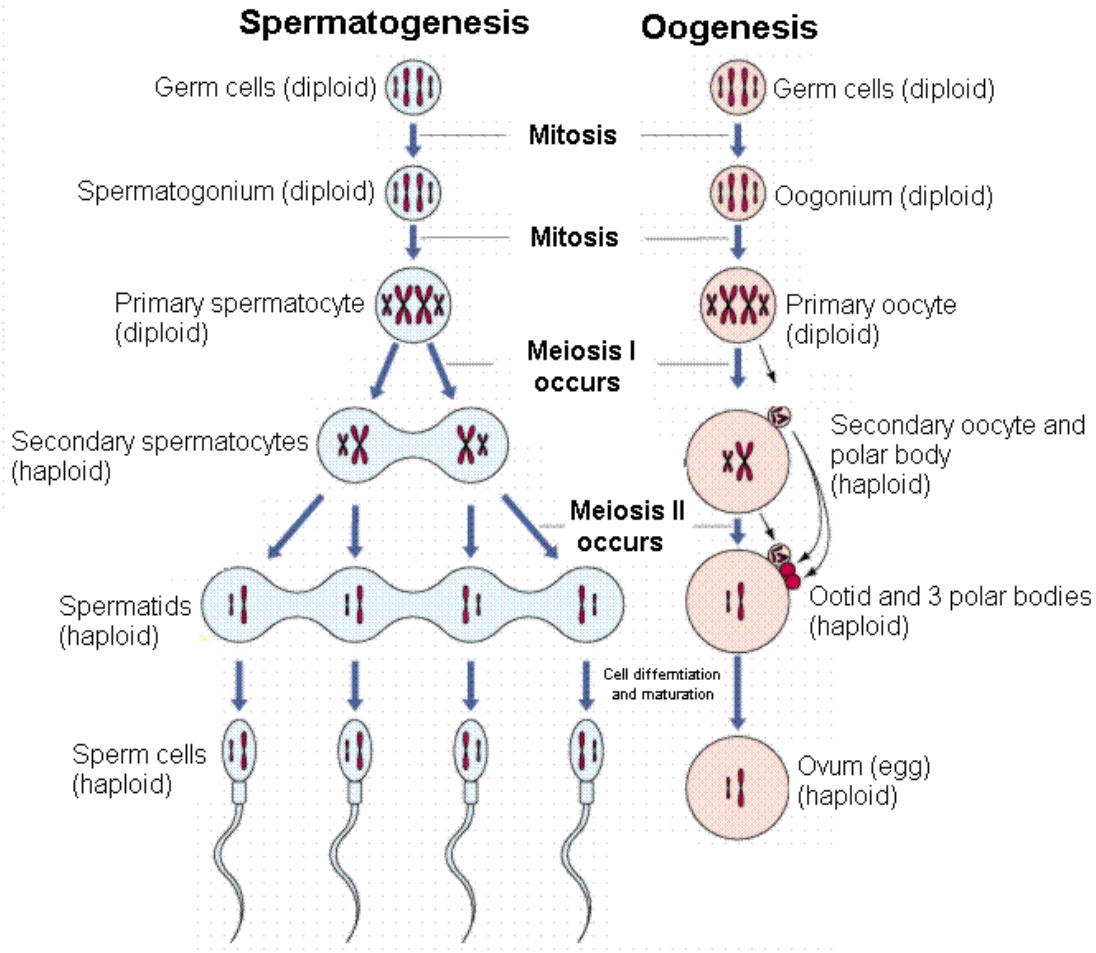


Meiosis is a special type of nuclear division which segregates the homologous chromosomes into separate gametes, reducing the chromosome number by half. A sperm will receive one member of each homologous chromosome pair from the man. Likewise, an egg will receive one member of each homologous chromosome pair from the woman. Because these gametes have only one member of each chromosome pair, they are said to be **haploid**, abbreviated as **n.**

Meiosis is necessary because when the sperm fertilizes the egg, the resulting zygote will receive one of each type of chromosome from the sperm and one of each type from the egg. This will produce a baby that is again diploid, with the normal chromosome number.

Gametogenesis (Gamete Production):

Spermatogenesis refers to production of sperm, the male gamete. **Oogenesis** refers to the production of ovum (eggs), the female gamete. **Notice that meiosis produces four sperm, but only one egg.** Sperm primarily contribute only nuclear DNA to the zygote. All the organelles, cytoplasm, etc. come from the egg. Thus, the egg is much larger than the sperm. (The diagram below illustrates a species in which 2n = 4 chromosomes.)



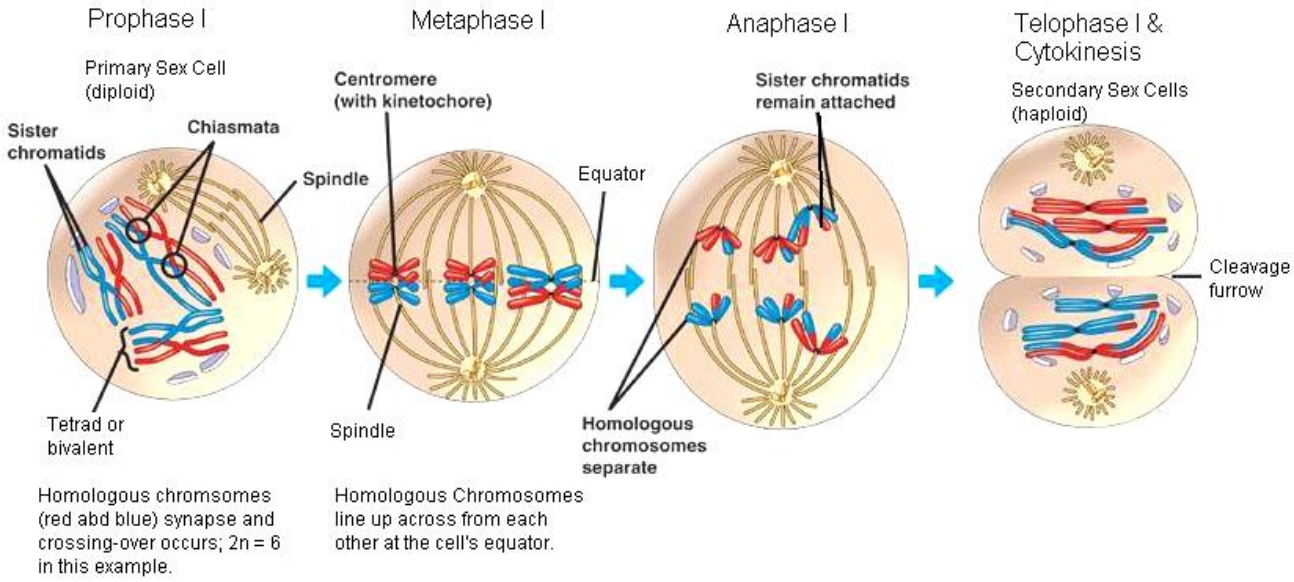
Events of Meiosis:

Meiosis is actually a series of two cellular divisions (termed meiosis I and meiosis II) that produces four haploid cells.

- **Meiosis I** (also known as **reductional division**) reduces the ploidy level from 2n to n.
- **Meiosis II** (also known as **equational division**) divides the remaining sets of chromosomes in a mitosis-like process. Most of the differences between mitosis (which produces 2 diploid cells for growth and repair) and meiosis (which produces sex cells) occur during prophase I.

Meiosis I (or reductional division):

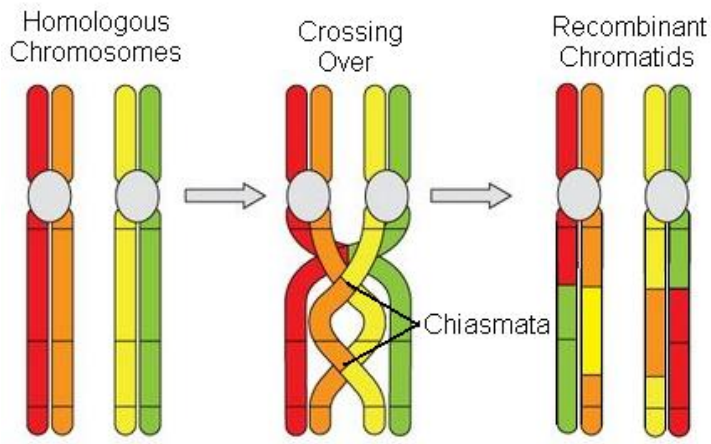
Below is a diagram illustrating the events that take place during Meiosis I. Meiosis I begins with a diploid **primary sex cell**. Note that in this example, 2n = 6. The primary sex cell has 3 pairs of homologous chromosomes. By the conclusion of Meiosis II, two haploid **secondary sex cells** will have been formed. The secondary sex cells are n. They have no homologous pairs of chromosomes.



Prophase I:

Prophase I begins with a **primary sex cell** that is **diploid**. Most of what occurs in Prophase I is similar to prophase of mitosis. Just as in mitosis, the spindle forms and spindle fibers attach to the chromosomes via their centromeres. Also, the nuclear envelope breaks down as the nuclear chromatin condenses into visible chromosomes. However, two unique events occur in Prophase I:

1. Homologous chromosomes pair through a process termed **synapsis**.
    a. The synapsed chromosomes are called **tetrads** because they consist of 4 (tetra = 4) chromatids.
    b. Synapsed chromosomes are also known as **bivalents** because they consist of 2 chromosomes (bi = 2).
2. During synapsis, **crossing-over** may occur. Crossing-over is the reciprocal exchange of chromosome arms between homologous chromosomes. It occurs when the synapsed chromosomes become tightly wound together and break. Sometimes the broken arms then “heal” (are reattached) to the wrong chromosome.
    a. This process provides for greater **genetic variation** among a species.



Electron Microscope View of Chiasmata

Metaphase I:

The homologous pairs of chromosomes line up across from each other at the cell's equator. This event explains **Mendel's Law of Independent Assortment**, which will be explored further during our genetics lecture.

Anaphase I:

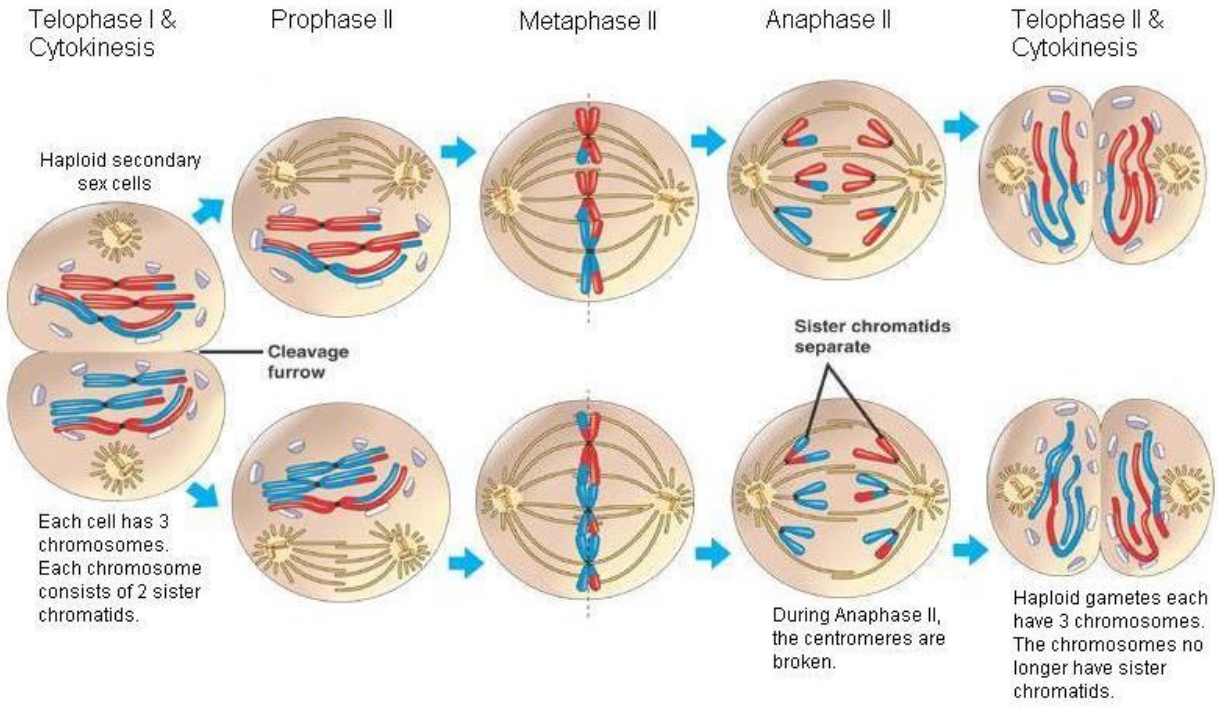
The spindle fibers drag the homologous chromosome pairs away from each other, towards opposite poles of the cell. **Note that no centromeres are broken in this process.*

Telophase I:

The chromosomes reach opposite poles as the spindle begins to break down. **Cytokinesis**, the division of the cell's cytoplasm between what will be two daughter cells begins with a **cleavage furrow**. The daughter cells are known as **secondary sex cells**. They are haploid. This event explains **Mendel's Law of Segregation**, which will be explored further during our genetics lecture.

Meiosis II (or equational division):

Below is a diagram illustrating the events that take place during Meiosis II. Meiosis II begins with two haploid **secondary sex cells**. By the conclusion of Meiosis II, 4 sperm or 1 egg (the **gametes**) will be produced. The events of Meiosis II are very similar to those of mitosis, except that the cells are haploid.



Prophase II:

Prophase I begins with a two **secondary sex cells** that are **haploid**.

1. The spindle forms and spindle fibers attach to the chromosomes via their centromeres.
2. The nuclear envelope breaks down as the nuclear chromatin condenses into visible chromosomes.

Metaphase II:

The spindle fibers drag the chromosomes into a line at the cell's equator.

Anaphase II:

The **centromeres** break, allowing the **sister chromatids** to be dragged toward opposite poles by the spindle fibers. Once separated, the sister chromatids are termed **daughter chromosomes**.

Telophase II:

The daughter chromosomes reach opposite poles as the spindle begins to break down. **Cytokinesis**, the division of the cell's cytoplasm begins with a **cleavage furrow**. The resulting **haploid** cells are known as **sex cells** or **gametes**.

Complete this study guide covering the events of meiosis:
http://www.clarendoncollege.edu/programs/NatSci/Biology/Zoology/zoo%20online%20outlines/Animal Cell Meiosis Review.htm

E. Sex Determination

1. McClung in 1902 studied bugs.
    a. Half the sperm lacked one chromosome found in the other half and in all eggs.
    b. When the sperm with the full number fertilized an egg, a female resulted; when a sperm lacking one chromosome fertilized an egg, it produced a male.
    c. **Sex chromosomes** were those that determined sex; _____ were the remainder.
    d. The bug's sex determination system is called XX-XO indicating the missing chromosome as "O."
2. Humans and many others use an XX-XY system; the male has the different sex chromosomes.
    a. Half the sperm carry X and half carry Y; they fertilize an X egg to produce 50% of each sex in offspring.
    b. The Y chromosome is smaller than the X and contains fewer genes.
3. Birds, moths, butterflies and some fish use an XX-XY system but the female is the XY.
4. Some animals across many taxa, use environmental and behavioral conditions rather than sex chromosomes.
    a. In crocodiles, turtles and lizards, temperature of the nest determines sex ratio; lower temperatures may produce females, higher produce males.
    b. Some fish are _____ and sensory stimuli trigger male or female development.

III. Gregor Mendel – _____

A. Mendel's Investigations

1. Gregor Mendel conducted his plant breeding experiments from _____.
2. His discoveries were published in 1866 but not appreciated until 1900, 16 years after his death.
3. Genes and chromosomes were as yet unknown; his experiments were based on crossbreeding.
    a. Mendel carefully controlled pollination of pea plant stigmas by stamens.
    b. Mendel carefully documented offspring of different parents (hybrids) and then crossed the hybrids.

B. Some Vocabulary

1. **Pure line** – strains that consistently yield offspring with the

same traits generation after generation
2. **F_1 generation** – 1st filial generation (the children)
3. **F_2 generation** – 2nd filial generation (the grandchildren)
4. _____ – the combination of alleles producing a trait in an individual
5. _____ – an individual's visible, physical trait
6. _____ – an individual in which the two alleles of a pair are the same
7. _____ – an individual in which the two alleles of a pair differ

C. **Mendelian Laws of Inheritance**

1. _____– when the gametes are formed, only one member of each allele pair is included in a gamete.
    a. For any given trait, the gamete will have either the maternal allele OR the paternal allele, but not both
    b. When fertilization occurs, the union of the egg & the sperm will restore the allele pair
    c. **Refuted blended inheritance.**
        1) Tall and dwarf plants produce tall F1 progeny; hence there is no blending.
        2) Self-pollinating the F1 progeny produce tall and short in a 3:1 ratio; again there was no blending and this ratio held for crosses of six other traits.
2. _____ – whenever the 2 alleles of a pair in an individual differ, only one, the dominant, will be expressed.
    a. **Dominant allele** – the allele that indicates the appearance of _____.
        1) One allele is said to be dominant over another if a heterozygote has the same appearance as an individual homozygous for the trait
        2) Mendel called the tall factor **dominant**; when it was present the **recessive** factor is not expressed.
    b. **Recessive allele** – an allele whose phenotype effects are masked in heterozygotes by the presence of a dominant allele
        1) Recessive traits appear only in homozygotes who inherit both recessive alleles for a that trait.
3. _____ - during formation of gametes, paired alleles on different chromosomes segregate independently. (Genes located on different pairs of homologous chromosomes assort independently during meiosis.)

a. This deals with two different characters on two different chromosomes.
b. When tall plants with yellow seeds (both dominant traits) were crossed with dwarf plants with green seeds, the F1 plants were all tall and yellow as expected.
c. When the F1 hybrids were crossed, it yielded a **9:3:3:1 ratio**, which is a combination of the two 3:1 ratios for each set or a dihybrid cross.
d. Segregation of alleles for heights was independent of segregation of alleles for seed color.

IV. NeoMendelian Genetics – remember that when Mendel did his work, chromosomes and genes were still unknown. Since Mendel, further discoveries in genetics have been made.

A. **Intermediate Inheritance**
1. Sometimes, neither allele is completely dominant, resulting in intermediate inheritance or **incomplete dominance**.
2. Red and white homozygous four-o-clock flowers cross to form heterozygous pink flowers.

B. **Multiple Alleles**
1. While only two alleles can exist at one locus, more than two types of alleles may exist in a population. (While you have only 2 alleles for a trait, more alleles may exist in the population.)
2. For instance, rabbits may possess two alleles from among four for coat color: C (normal), cch (chinchilla), ch (Himalayan) and c (albino).

C. **Gene Interaction**
1. Many different genotypes may affect a single phenotype.
2. Many genes have more than one effect (i.e. eye color, intelligence, etc.).
3. An allele at one location that masks expression of an allele at another locus acting on the same trait is called **epistasis**.
4. Several sets of alleles may produce a cumulative effect on the same character.
5. Polygenic characters show continuous variation between extremes (blending or quantitative inheritance); skin pigmentation in humans probably involves 3 or 4 genes.

D. **Sex-Linked Inheritance**
1. Some traits depend on the sex of the parent carrying the gene.
a. Hemophilia is a recessive trait on the X chromosome.
b. Red-green color blindness is also a recessive trait and on the X chromosome.
c. Carriers are heterozygous for these genes and are phenotypically normal.
d. Males are **hemizygous** for traits carried on the X

chromosome.

E. **Autosomal Linkage** and Crossing Over
    1. Linkage
        a. Not all factors segregate as stated in Mendel's Law of Independent Assortment
        b. Genes on the same chromosome are linked, and the traits are inherited together.
    2. Crossing Over
        a. Linkage is not absolute; some separation of alleles on the same chromosome occurs due to crossing over.

F. Chromosomal Aberrations
    1. Structural and numerical deviations from the norm that affect many genes are chromosomal aberrations.
    2. It is estimated that five of every 1,000 humans are born with a serious genetic defect from chromosomal anomalies.

V. The Central Dogma of Molecular Biology – the flow of information from DNA to RNA to proteins

A. _____ – the process of duplicating double-stranded DNA, prior to mitosis
    1. DNA is composed of a double strand of nucleotides in the form of a double helix.
    2. The nucleotides include nitrogen containing bases: A, G, C, and T

B. _____ – the process of copying the information encoded on DNA into RNA.
    1. RNA is a single-stranded molecule, containing the bases A, G, C, and U
    2. A set of 3 nucleotides (a triplet) on mRNA = a codon.
        i. Codons encode for 20 specific amino acids (aa)
        ii. More than one codon may specify a single amino acid, so the code is redundant or degenerate
    3. RNA, unlike DNA, leaves the nucleus

C. _____ – the process of interpreting the information carried by messenger RNA (mRNA) in order to synthesize the encoded protein.
    1. Proteins are long chains of amino acids (aa). The sequence of the aa is determined by the codons on mRNA.
    2. The aa are joined together by peptide bonds. (proteins, therefore, are also known as polypeptides)
    3. Proteins may be structural (and form membranes, etc.) or may mediate cellular activities (e.g. enzymes)

D. Gene Expression

1. A _____ is a segment of the DNA chromosome that contains the instructions to build a protein.
2. Transcription begins when **RNA polymerase** recognizes and binds to the gene on DNA molecule.
3. Translation begins when a _____ joins the mRNA and begins the process of translation.
    i. The ribosome is made of ribosomal RNA (rRNA).
    ii. The ribosome reads the mRNA one codon at a time, bonding the appropriate amino acids together as it goes.
    iii. Transfer RNA (tRNA) picks up amino acids in the cytoplasm and brings them to the ribosomes.
    iv. _____ – When the ribosome reaches a "Stop" codon (UGA, UAA, or UAG), there are no amino acids that match & translation ends.
        1. The protein is freed
        2. The ribosome falls off the mRNA

E. Regulating the Expression of Genes
    1. Protein synthesis is generally controlled by regulating the synthesis of mRNA molecules.
    2. mRNA is a short-lived molecule because **RNases** degrade it within minutes.

F. _____ – permanent alterations in DNA
    1. These random events alter the gene products in an organism.
    2. May be caused by chemicals, radiation, viruses, or random chance
    3. The outcome is genetic variability

G. **Aneuploidies** are additions or deletions of chromosomes; usually caused by random events.
    1. A trisomy is an additional chromosome.
        i. The most common cause of Down syndrome is a trisomy of chromosome 21.
    2. A monosomy is a missing chromosome.
    3. Changes in chromosome number are typically due to nondisjunction during meiosis I or II.

H. Breaks or duplications of parts of chromosomes can also have serious effects.