UNIT 8 – Human Genetics
Quiz 1-30/31
Test Tues. Feb 5
A. Human Somatic Cells

Human somatic cells (body cells) are diploid or 2n. Each cell contains 46 chromosomes, or 23 pairs of chromosomes. Of these pairs of chromosomes, 22 pairs are homologous pairs, meaning they contain the same genes in the same order.
A. Human Somatic Cells

The 44 chromosomes that make up the 22 homologous pairs in each cell are called **autosomes**. The 23rd pair of chromosomes are the **sex** chromosomes. In female somatic cells, the sex chromosomes are **XX**; in a male’s cells, the sex chromosomes are **XY**.
B. Human Gametes

Gametes are **haploid**, or **n**, and contain **23** chromosomes. Female gametes are **egg** cells and male gametes are **sperm** cells. Gametes are produced through the process of **meiosis** in the **ovaries** or **testes**, respectively.
B. Human Gametes

In meiosis, when the **homologous** pairs of chromosomes separate in **anaphase I**, the sex chromosomes separate also. The resulting egg cell can only contain an **X** chromosome, while the sperm cell produced has a **50%** chance of containing a **Y** and a **50%** chance of containing an **X**. Therefore, the **male** determines the sex of the offspring.
C. Analyzing Human Chromosome Numbers

1. **Nondisjunction** - Abnormal numbers of chromosomes in **gametes** result in genetic disorders called **number disorders**. This must often is a result of **nondisjunction**, which means “not coming apart”.
Nondisjunction

- In Anaphase I if homologous pairs do not separate correctly
- In Anaphase II if sister chromatids do not separate correctly
- In either case, Gametes are produced with an abnormal number of chromosomes.

Number disorders are not inherited; therefore, they cannot be predicted with Punnett squares.
C. Analyzing Human Chromosome Numbers

2. Karyotypes - A karyotype is a photograph of chromosome pairs.

Cells from the developing embryo or individual being tested are cultured in a nutrient growth medium, and then chemically treated to stop mitosis in metaphase. The cells are stained, the chromosomes photographed, and the photograph is enlarged.
C. Analyzing Human Chromosome Numbers

The chromosomes are cut out and arranged in ____________ pairs in size order, with the ____ chromosomes making up the 23rd pair. Karyotypes can only be used to detect _____ disorders and to determine the ______ of an unborn child.

homologous
sex
number
gender
C. Analyzing Human Chromosome Numbers

They do not detect abnormal genes; therefore, a normal karyotype does not guarantee a normal child!
A. Autosomal Number Disorders

Most autosomal number disorders are ___lethal____. The only autosomal number disorder that allows survival into adulthood is ___Down syndrome____________________.
Is there a problem with this karotype
A. Autosomal Number Disorders

Down syndrome is also known as \textit{trisomy 21} because there are 3 chromosomes at the 21st position, instead of 2.
Down Synd
Autosomal Number Disorders
Down syndrome

Individuals have characteristic facial features; growth, behavior, and mental development are all affected. There is also a higher risk of congenital heart defects. The incidence of babies with Down syndrome is much higher in older mothers.
Patau Syndrome (Trisomy 13)
Trisomy 13

- **Cleft lip or palate**
- Clenched hands (with outer fingers on top of the inner fingers)
- Close-set eyes -- eyes may actually fuse together into one
- Extra fingers or toes (*polydactyly*)
- Hole, split, or cleft in the iris (*coloboma*)
- Low-set ears
- Mental retardation, severe
- Scalp defects (missing skin)
- **Seizures**
- Single palmar crease
- Skeletal (limb) abnormalities
- Small head (*microcephaly*)
- Can have 3 types
  - One extra 13th chromosome in all cells
  - Trisomy 13 mosaicism-Extra 13 only in some cells, caused by mitosis after fertilization
  - Partial Trisomy-due to translocation presence of a part of extra chromosome 13 in all cells
Edwards or Trisomy 18

Karyotype From a Female With Edwards Syndrome (47,XX,+18)
Edward’s Syndrome (Trisomy 18)

- Symptoms
- Clenched hands
- Crossed legs (preferred position)
- Feet with a rounded bottom (rocker-bottom feet)
- **Low birth weight**
- Low-set ears
- Mental deficiency
- Small head (**microcephaly**)
- Small jaw (**micrognathia**)
- Underdeveloped fingernails
- **Undescended testicle**
- Unusual shaped chest (**pectus carinatum**) Trisomy 18 is a relatively common syndrome. It is three times more common in girls than boys. The syndrome is caused by the presence of extra material from chromosome 18. The extra material interferes with normal development.
- Can also be Full Trisomy 18, Partial Trisomy 18, or Mosaicism
Is there a problem with this karyotype?
B. Sex Chromosome Number Disorders

1. Turner Syndrome

Also called ______ because individuals lack ______. Affected individuals are _______, typically short in stature, underdeveloped sexually, with a normal life expectancy.

* Generally infertile
Turner’s Syndrome
Does this individual have a number disorder?
B. Sex Chromosome Number Disorders

2. Klinefelter Syndrome

Also called **47 XXY**. Symptoms do not appear until **puberty** at which time affected **males** show poor sexual development and infertility. Treated with **testosterone**. Normal life expectancy.
● Klienfelter’s Syndrome
III. ANALYSIS OF HUMAN INHERITANCE

A. Punnett Squares & Multiple Alleles (pp. 345-346)

A multiple alleles gene has that is, more than 2 alleles. An example of this is ABO blood groups. There are 3 alleles for this gene.
**Punnett Squares & Multiple Alleles**

(pp. 345-346)

A and B are **co-dominant**, meaning they always show __________ if present. The third allele, _i (o)_, is recessive, meaning it will only show if the genotype is ____.
## ABO Blood Types

<table>
<thead>
<tr>
<th>Erythrocytes</th>
<th>Antigen A</th>
<th>Antigen B</th>
<th>Antigens A and B</th>
<th>Neither antigen A nor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-B antibodies</td>
<td>Anti-A antibodies</td>
<td>Neither anti-A nor anti-B antibodies</td>
<td>Both anti-A and anti-B antibodies</td>
<td></td>
</tr>
</tbody>
</table>

### Blood Type
- **Type A**: Erythrocytes with type A surface antigens and plasma with anti-B antibodies
- **Type B**: Erythrocytes with type B surface antigens and plasma with anti-A antibodies
- **Type AB**: Erythrocytes with both type A and type B surface antigens, and plasma with neither anti-A nor anti-B antibodies
- **Type O**: Erythrocytes with neither type A nor type B surface antigens, but plasma with both anti-A and anti-B antibodies
The possibilities for blood group genotypes and phenotypes are:

<table>
<thead>
<tr>
<th>Phenotypes</th>
<th>Genotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A blood</td>
<td>( A^A ) or ( A^i )</td>
</tr>
<tr>
<td>Type B blood</td>
<td>( B^B ) or ( B^i )</td>
</tr>
<tr>
<td>Type AB blood</td>
<td>( A^A B^B )</td>
</tr>
<tr>
<td>Type O blood</td>
<td>( ii )</td>
</tr>
</tbody>
</table>
B. Pedigrees

- A **pedigree** is a diagram that follows the inheritance of a single **trait** through several **generations** of a family.
- Males are represented by **squares** and females, by **circles**.
- Individuals **with the trait** are represented with **shaded** figures.
B. Pedigrees

- Vertical lines connect parents and children. Horizontal lines connect spouses or siblings.
- Children are placed in birth order, from left to right.
Inherited human genetic disorders are the result of gene mutations; that is, a change in the DNA sequence of the gene.
B. Types of Inherited Genetic Disorders

1. **Sex-Linked Disorders** – Mutated gene is on the **X** chromosome.

2. **Autosomal Genetic Disorders** – Gene mutation is on any chromosome other than **sex chromosomes**
V. GENETIC DISORDERS - SEX-LINKED DISORDERS

A. Sex-Linked Inheritance (pp.350, 351)

A gene is referred to as “sex-linked” if it is located on a sex chromosome (X or Y). In humans, sex-linked genes are almost always located on the larger X chromosome. The Y chromosome is much smaller and carries only a few genes related to male sexual development.
A. Sex-Linked Inheritance (pp.350, 351)

Females have **2** X chromosomes; males have **one**. Females will only show recessive traits located on the X chromosome if they are **homozygous recessive**. But a male will **always** show a recessive trait located on the X chromosome because he only has **one** X chromosome, so all **genes** on the X chromosome will show.

This results in **males** having a much higher incidence of sex-linked disorders.
A. Sex-Linked Inheritance

1. Genotypes

- **Genotypes** for sex-linked traits are written using the X and Y chromosomes to show path of inheritance.

- Male-pattern baldness is a sex-linked recessive trait. If \( H = \) normal head of hair and \( h = \) baldness
  - bald male = \( X^h Y \); bald female = \( X^h X^h \).
  - Females can be **carriers** for sex-linked recessive disorders. A **carrier** has the defective allele, but it does not show \( H \). The genotype of a female carrier is \( X^H X^h \).
  - Males **cannot** be carriers for sex-linked traits because their 2nd sex chromosome is the **naked** Y!
Savin Scale
Female Pattern Baldness
2. Sex-Linked Punnett Squares

In sex-linked traits, probabilities for male and female offspring must be calculated separately because traits are inherited differently.

If a man with a full head of hair marries a woman who is heterozygous, what is the probability they would have a son who would go bald? A daughter?
B. Sex-Linked Disorders

All of these disorders are sex-linked recessive.

1. Color Blindness – Inability to differentiate and distinguish colors.
**Results For Ishihara Test(above)**

<table>
<thead>
<tr>
<th>Normal Color Vision</th>
<th>Red-Green Color Blind</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
</tr>
<tr>
<td>Top</td>
<td>25</td>
</tr>
<tr>
<td>Middle</td>
<td>45</td>
</tr>
<tr>
<td>Bottom</td>
<td>6</td>
</tr>
</tbody>
</table>
B. Sex-Linked Disorders

2. Hemophilia –

● Missing an enzyme required for normal blood clotting -

● results in uncontrolled bleeding

● Treated with blood transfusions, injections of missing factor.
Gene Therapy for Hemophilia

- Isolation
  - Somatic cells
- Reprogramming
  - iPS cells
- Expansion
- Gene therapy
  - Differentiation
    - Liver-like cells
- Transplantation

Hemophilia patient
B. Sex-Linked Disorders

3. Duchenne’s Muscular Dystrophy
   – Symptoms develop at 3-6 years.
   – Muscles weaken, break down, leading to eventual death.
   – No available treatment or cure. Death usually occurs before adulthood.
DMD

Healthy father × Healthy mother (carrier)

- Healthy son
- Healthy daughter (noncarrier)
- Healthy daughter (carrier)
- Son with Duchenne Muscular Dystrophy (DMD)

Legend:
- Red: Healthy
- Blue: Carrier
- Green: DMD
Fig. 1. Family showing familial type of Haemophilia A.  
*Haemophilia* (2002), 8, 680–684
VI. GENETIC DISORDERS - AUTOSOMAL DISORDERS (pp. 345-348)

More common than sex-linked disorders because

most genes are carried on the autosomes.

These disorders affect males and females equally and are due to gene mutations.

Autosomal disorders can be divided into three groups based on the pattern of inheritance.
Autosomal Recessive Disorder

1. Albinism
   1. Characterized by failure to produce pigment, **melanin**
   2. Very susceptible to **UV rays**
Autosomal Recessive Disorders

- **Cystic Fibrosis**
  - Characterized by excess **mucus** in **lungs**, **digestive** system.
  - Symptoms appear just after birth and include frequent respiratory infections and poor nutrition.
  - With treatment, patients can survive into adulthood.
  - Most common **fatal** genetic disorder in the **United States** among Caucasians.
Cystic Fibrosis gene resides on chromosome 7 and normally gives rise to a protein called the cystic fibrosis transmembrane conductance regulator (CFTR). The defect that most often leads to the disease is the deletion of three nucleotides from the gene (red letters above); this alteration, known as the ΔF508 mutation, results in the loss of one amino acid - phenylalanine at position 508 - in the CFTR protein. Phenylalanine is lost because the protein-making machinery of the cell now sees ATT (an alternative way to encode isoleucine) at the gene region coding for the protein's 507th amino acid, followed by the GGT sequence for the glycine that normally follows phenylalanine.
Phenylketonuria or PKU

- Characterized by an inability to breakdown the amino acid, Phenylalanine
- If untreated, results in severe mental retardation
- All babies born in US hospitals are tested for PKU because it is easily treated with a diet low in proteins
In a person without PKU:

Phenylalanine → Phenylalanine-hydroxylase → Tyrosine

In a person with PKU:

Phenylalanine → No phenylalanine-hydroxylase

Phenylalanine → Build-up of phenylalanine to toxic levels

Individually with the homozygous dominant genotype do not live to birth; or die shortly after birth. Heterozygote genotype is the only viable genotype.
Tay-Sachs disease

- Neurodegenerative disease of the **brain** and **spinal cord** in **infants** involving the toxic build-up of **lipids** due to a missing enzyme.
- Symptoms appear at about 6 months
- Ability to crawl and move is lost, and deafness, blindness, and loss of ability to swallow precedes **death** usually by 4 years of age
- More common in certain **Jewish** populations and **Cajuns**.
Autosomal Co-Dominant Disorders

- Sickle cell anemia is an autosomal co-dominant disorder that affects ________ production. Hemoglobin is the protein that binds ________ to red blood cells.
Sickle Cell Anemia

1. AA

- Individuals with the normal genotype do not have the sickle cell allele and produce only normal hemoglobin.
Sickle Cell Anemia

2. SS

- Sickle Cell Anemia
- Produce abnormal hemoglobin that causes the red blood cells to “sickle” when oxygen availability is decreased; for example, in high altitudes or during period of stress.
- Sickled RBCs are more fragile, easily destroyed—results in lack of energy due to decreased oxygen production in cells, blockage of blood vessels, and severe pain.
- Shortened life expectancy.
- Most common inherited disease in individuals of ____________ ancestry.
3. AS

- Described as \textit{heterozygous}
- Produce both normal and abnormal hemoglobin
- Do not typically show symptoms of the disorder.
- \textbf{Heterozygote Advantage}-Provides resistance to \textit{malaria}
C. Autosomal Dominant Disorders

1. Huntington’s Disease
   - Fatal genetic disorder in which symptoms do not show until middle age
   - Characterized by deterioration of Mental functions and uncontrollable movements
Achondroplasia
Achondroplasia

- **Dwarfism** (one form)

- Individuals with the **Homozygous dominant** genotype do not live to birth; or **die** shortly after birth. **Heterozygous** genotype is the only **viable** genotype.
Marfan Syndrome [add to notes]

- Marfan syndrome- Dominant disorder that affects the connective tissue of the **skeletal** system, eyes, and circulatory system.
- Affected individuals have very **long limbs**, vision problems, and are susceptible to aortic rupture.
Marfan Syndrome

**PARTS OF THE BODY AFFECTED BY MARFAN SYNDROME**

<table>
<thead>
<tr>
<th>Category</th>
<th>Conditions</th>
</tr>
</thead>
</table>
| **EYESIGHT**                    | near-sighted (myopic)  
eye (or ocular) lens dislocation  
retinal detachment               |
| **LUNGS**                       | spontaneous lung collapse (pneumothorax)                                    |
| **CARDIO-VASCULAR SYSTEM**      | aorta widening or dilatation  
aortic aneurysms  
mitral and/or aortic valve(s) prolapse / leakage |
| **SKELETON**                    | curvature of the spine (scoliosis)  
pigeon or funnel chest (pectus deformity)  
tall stature  
loose jointedness                |