Chapter 5

Cancer:

DNA Synthesis, Mitosis, and Meiosis
5.6 Meiosis

• Another form of cell division, meiosis, occurs within gonads, or sex organs
  – The point of meiosis is to cut the number of chromosomes in half

• Male gonads are testes and female gonads are ovaries
  – Meiosis (my-oh-sis) happens in my ovaries
  – Mitosis (my-toe-sis) happens in my toes

• Meiosis produces sex cells = gametes:
  – Male gametes: sperm cells
  – Female gametes: egg cells
Meiosis

• Gametes have half the chromosomes (23) that somatic or regular body cells do (46)

• Meiosis reduces the number of chromosomes by one-half (23)

• Fertilization or joining of the male (23) and female (23) gamete will result in 46 chromosomes
Meiosis

• Which 23 of the 46 chromosomes end up in each gamete?
  – One of each kind or pair

• Chromosomes come in homologous pairs

• Each somatic body cell has two of every chromosome
  – 1 through 22 pairs of autosomal chromosomes
    • Two copies of chromosome #1, two copies of chromosome #2, etc
  – And XX (female) or XY (male) sex chromosomes

• Each gamete has one chromosome from each homologous pair
  – One copy of chromosome #1, one copy of chromosome #2, etc
  – And an X or a Y but not both
Autosomes (22 pairs)

Sex chromosomes (1 pair)

Female

or

Male

Figure 5-20  Biology: Science for Life, 2/e
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Meiosis

• There are 22 pairs of **autosomes**
  – non-sex chromosomes

• Each pair of chromosomes carry the same genes
  – That’s why they are called **homologous pairs**
  – Homo = same

• There is one pair of sex chromosomes:
  – Males have one X and one Y chromosome
  – Females have two X chromosomes
Figure 5-21  Biology: Science for Life, 2/e
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Meiosis

• Each homologous pair has the same genes

• Both chromosomes of the pair will have the genes on them in the exact same place

• Alleles are
  – The same genes on a homologous chromosome pair
  – For example:
    • You have 2 alleles for the gene for earlobe shape
    • 1 on each of the homologous pair, say chromo 1
      – (in reality it is not known on what chromosome the gene for earlobe shape is located)
    • 1 allele may be for attached earlobes
    • The other allele may be for unattached earlobes
Meiosis

• Just like in mitosis, during the S phase of interphase:
  – the chromosomes are copied or replicated
  – now each of the homologous chromosomes have an identical copy called a sister chromatid

• All four sister chromatids carry the same genes at the same locations
  – but not necessarily the exact same information
–the chromosomes are replicated
–now each of the homologous chromosomes have an identical copy called a sister chromatid
Meiosis

• During meiosis, the homologous pairs are separated
  – so each cell has only one of each pair
  – Each has half the amount of chromosomes
    • Normal cells have 2 of each pair

• This condition is called **haploid** \((n)\)
  – having only one of each kind of chromosome
  – Haploid = half
Meiosis and Fertilization

• Meiosis occurs in the sex cells in either the testes or ovaries (for humans) producing gametes
  – Egg or sperm

• The joining of egg and sperm in fertilization forms
  – a **zygote**, or fertilized egg

• The zygote is **diploid** (2n)
  – It has two of each kind of chromosome now
    • One of each of the pairs of chromosomes from each gamete
      – Egg has 1 of each homologous pair
        » one chromosome #1, one chromosome #2, etc
      – Sperm has 1 of each homologous pair
        » one chromosome #1, one chromosome #2, etc
      – Zygote has 2 of each homologous chromosome
        » two chromosome #1, two chromosome #2, etc
Meiosis and Fertilization

Gamete formation in humans

Egg-producing cells in the ovary have 46 chromosomes (23 pairs).

Sperm-producing cells in the testes have 46 chromosomes (23 pairs).

Egg cell has 23 chromosomes (unpaired).

Sperm cell has 23 chromosomes (unpaired).

Fertilization

Zygote has 46 chromosomes (23 homologous pairs).

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Figure 5-23a Biology: Science for Life, 2/e © 2007 Pearson Prentice Hall, Inc.
Meiosis

• Interphase (G1, S, G2), then meiosis I and a cell division, and then meiosis II and a cell division
  – Equals 4 cells at the end
  – with half the number of chromosomes in each

• Meiosis consists of phases:
  – Meiosis I
    • the homologous pairs are separated
    • Cell divides into 2 cells
  – Meiosis II
    • the sister chromatids are separated
      – In both the 2 cells from meiosis I
    • Both cells divide into 2 cells
Interphase and Meiosis

Cell growth and preparation for division

G₂

S

G₁

MEIOSIS I

MEIOSIS II

End of previous mitotic event

Cell growth

S and G phases similar to the S and G phases of mitosis

DNA is copied

INTERPHASE (G₁, S, G₂)
Meiosis

Chromosomes replicate one time, nuclei divide twice
Meiosis

• Notice that the gametes are haploid
  – having one chromosome from each pair

• Each gamete carries half the genetic information as the parent
  – Half the number of chromosomes

• So when the egg and sperm get together
  – they now have the full amount of genetic information as the parent

• If the gametes did not have half number of chromosomes
  – Offspring would have twice as many chromosomes as the parents at every generation.
  – Too many chromosomes!
Meiosis and Nondisjunction

- Sometimes the homologous pairs do not separate during meiosis

- Supposed to have one chromo #1 go into one cell and the other Chromo #1 go into the other cell

- Sometimes, both Chromo #1 goes into one cell and no chromo #1 into the other cell

- This is called **nondisjunction** of meiosis 1

- If the sister chromatids do not separate, then it is **nondisjunction** of meiosis II
During fertilization, these gametes produce an individual that is **trisomic** for the missing chromosome.

*(a) Nondisjunction in meiosis I*

All four gametes are abnormal.

During fertilization, these gametes produce an individual that is **monosomic** for the missing chromosome.
(b) Nondisjunction in meiosis II

50 % Abnormal gametes

50 % Normal gametes
Meiosis and Nondisjunction

- Nondisjunction results in gametes with incorrect number of chromosomes
  - If fertilized, the offspring has an incorrect number of chromosomes

- An incorrect number of chromosomes is detrimental to humans
  - One example is trisomy 21 (Down Syndrome)
    - One extra chromosome #21

### Conditions Caused by Nondisjunction of Autosomes

<table>
<thead>
<tr>
<th>Conditions Caused by Nondisjunction of Autosomes</th>
<th>Approximate Frequency Among Live Births</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trisomy 21 — Down syndrome</td>
<td>The probability that a woman will have a child with Down syndrome increases with age. In mothers younger than age 35, Down Syndrome occurs in approximately 1 per 1000 births and at age 45, around 4 per 1000 births.</td>
<td>People with Down syndrome tend to be mentally retarded, have abnormal skeletal development, and have heart defects.</td>
</tr>
</tbody>
</table>

Table E7-3  part 1  Biology: Science for Life, 2/e  
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Age 45 = 33 per 1000
Russell, iGenetics

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Meiosis and Nondisjunction

Hartwell, Genetics, From Genes to Genomes

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<table>
<thead>
<tr>
<th>Age of Mother</th>
<th>Frequency of Trisomy 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-34</td>
<td>1/1700</td>
</tr>
<tr>
<td>35-39</td>
<td>1/333</td>
</tr>
<tr>
<td>40-44</td>
<td>1/100</td>
</tr>
<tr>
<td>45-47</td>
<td>1/30</td>
</tr>
</tbody>
</table>
# Meiosis and Nondisjunction

<table>
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<th>Approximate Frequency Among Live Births</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trisomy 13—Patau syndrome</td>
<td>1 in 5000</td>
<td>Affected individuals are mentally retarded, deaf, and have a cleft lip and palate.</td>
</tr>
</tbody>
</table>

Table E7-3 part 2 Biology: Science for Life, 2/e © 2007 Pearson Prentice Hall, Inc.

<table>
<thead>
<tr>
<th>Conditions Caused by Nondisjunction of Autosomes</th>
<th>Approximate Frequency Among Live Births</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trisomy 18—Edwards syndrome</td>
<td>1 in 6000</td>
<td>Babies with Edwards syndrome have malformed organs, ears, mouth, and nose, leading to an elfin appearance. They are mentally retarded and usually die within 6 months of birth.</td>
</tr>
</tbody>
</table>

Table E7-3 part 3 Biology: Science for Life, 2/e © 2007 Pearson Prentice Hall, Inc.
Mitosis and Meiosis

• Both are types of cell division

• Occur in different types of cells
  – Somatic body cells = mitosis
  – Sex cells or gametes = meiosis

• Produce very different products
  – Mitosis
    • 2 cells exact same number of chromosomes
  – Meiosis
    • 4 cells with half the number of chromosomes
Mitosis and Meiosis

Mitosis

1. **Prophase**
   - Chromosomes align along the equator.

2. **Metaphase**
   - Chromosomes align as pairs.

3. **Anaphase**
   - Two diploid daughter cells that are both genetically identical to the original parent cell.

4. **Telophase**
   - Daughter cells are haploid (have half as many chromosomes as the parent cell).

Meiosis

1. **Prophase I**
   - Homologues align as pairs.

2. **Metaphase I**
   - Homologues align along the equator.

3. **Anaphase I**
   - MEIOSIS II (separates sister chromatids)

4. **Telophase I**
   - Daughter cells are haploid (have half as many chromosomes as the parent cell).