Meiosis

- An Overview of Meiosis
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- Meiosis and Sex Determination

An Overview of Meiosis

- When one cell undergoes mitosis, two identical cells are formed
  - Each possesses 46 chromosomes in humans
    - 2 copies each of 23 different chromosomes
    - 2 full sets of 23 chromosomes
    - "Diploid"
      - "2n"

- When a cell undergoes meiosis, unique cells are produced
  - Sperm and egg cells
    - "Gametes"
  - Each has only 23 chromosomes
    - Half the (total) normal number
    - Only one copy of each chromosome
    - One set of 23 chromosomes
    - "Haploid"
      - "1n" or "n"

- A sperm and an egg can fuse
  - "Fertilization"
  - 23 + 23 = 46 chromosomes
- The resulting cell possesses the full human complement of 46 chromosomes
  - Diploid cell produced
  - 2 full sets of 23 chromosomes
  - 2 copies each of 23 different chromosomes

The Steps in Meiosis

- Mitosis involves the duplication of DNA, followed by the division of the nucleus and cell
  - Two cells are produced, with equivalent nuclear contents (equivalent division)
- Meiosis involves the duplication of DNA, followed by two sequential divisions of the nucleus and the cell

- Four cells are produced, each with reduced nuclear contents (reduction division)

- The function of meiosis is the production of sperm and/or eggs
- This happens only in reproductive organs
  - Testes in males and ovaries in females

- Meiosis is divided into phases
  - Meiosis I
    - Prophase I
    - Metaphase I
    - Anaphase I
    - Telophase I
  - Meiosis II…
    - Prophase II
    - Metaphase II
    - Anaphase II
    - Telophase II

- Meiosis in brief
  - Meiosis I
    - Homologous chromosomes pair up and then separate
    - Two haploid cells are formed
  - Meiosis II
    - Sister chromatids of duplicated chromosomes separate
    - Four haploid cells are formed

Prophase I

- Replicated DNA condenses into discretely visible chromosomes
  - *Homologous chromosomes are paired*
  - *Crossing over takes place*
- Spindle begins to form
  - Microtubules ultimately connecting chromosomes to "north and south poles"
- Nuclear membrane is disassembled
- The pairing of homologous chromosomes is the first important difference between mitosis and meiosis
  - Additional differences arise as a consequence of this pairing

Metaphase I

- Chromosomes lined up on equatorial plate
  - *Homologous chromosomes remain paired*
- Mitotic spindle is complete
  - Chromosomes attached to the centrosomes
  - *Homologous chromosomes* attached to opposite poles

Anaphase I

- *Homologous chromosomes* separate
  - Shortening microtubules pull *homologous chromosomes* toward opposite poles
    - *Chromosomes still consist of joined sister chromatids (duplicated)*
    - *Segregation is random*
    - *Segregation of chromosome 1 has no effect on segregation of chromosome 2*

Telophase I

- Chromosomes arrive at poles
- Chromosomes unwind (decondense)
  - Clearly discernible shape is lost
- Nuclear membranes are assembled
  - Result is one cell containing two nuclei

Cytokinesis

- Protein filaments contract, cells pinch off
  - Cytoplasm and contents are divided
- The resulting cells are haploid, not diploid
  - Each has only one copy of each chromosome, all duplicated
    - One full set of 23 chromosomes is in one cell, and the other full set of 23 chromosomes is in the other cell

Meiosis II

- The cells resulting from meiosis I each undergo a second division
  - No new DNA synthesis precedes this step
- The steps of meiosis II are identical to those of mitosis
  - Sister chromatids separate

Cytokinesis

- Cytokinesis is completed a second time following meiosis II
- Results in the production of four haploid cells from a single diploid cell
  - e.g., Four sperm cells

The Significance of Meiosis

- Meiosis results in genetic diversity in offspring
- Meiosis also results in large-scale diversity in the natural world

- Genetic diversity in offspring is the result of
  - Crossing over
  - Independent assortment of chromosomes

Crossing over

- Homologous chromosomes are paired for much of meiosis I
  - Crossing over occurs during prophase I
- Non-sister chromatids break and exchange information
  - "Hybrid" chromatids are formed
    - Have both maternal and paternal portions
- Homologous chromosomes have exchanged reciprocal portions of themselves
- Each chromosome packaged into a gamete contains both maternal and paternal portions
  - Genetic diversity of gametes is increased
  - Genetic diversity in offspring is increased

Independent assortment

- Chromosomes line up independently at the metaphase plate (metaphase I)
  - The orientation of chromosome 1 has no effect on the alignment of chromosome 2
  - Perhaps "maternal" chromosome 1 lines up on side "A"
  - Either the maternal or paternal chromosome 2 may line up on side "A"
  - Either the maternal or paternal chromosome 3 may line up on side "A"
  - And so on…
- Humans have 23 pair of chromosomes
  - 2^{23} different ways chromosomes could line up in meiosis
    - 8 million different ways
    - 8 million genetically different eggs
    - 8 million genetically different sperm
    - 64 trillion genetically different offspring (actually about 70 trillion)
- 64 trillion genetically different offspring that could be produced by a specific pair of people
  - This is dependent upon random segregation of chromosomes
  - This does not even include variation due to crossing over
    - Crossing over increases this number even more drastically`

The Significance of Meiosis

- Offspring produced through sexual reproduction are genetically unique
  - Identical siblings are the only exception
    - Develop from the same fertilized egg
- Sexual reproduction drastically increases genetic diversity within a species

- As a result of genetic diversity, individuals within populations vary from other
  - Some redwood trees grow a little taller than others
  - Some fish are able to dive a little deeper than others
  - Some deer are able to run a little faster than others

- This genetic diversity within populations makes evolution possible
  - Evolution acts upon variation within a population
  - Individuals with beneficial genetic traits are likely to produce more offspring than individuals lacking those traits
  - These beneficial traits will become more common in future generations

- This genetic diversity within populations makes evolution possible
  - A taller tree captures more sunlight
    - Better nourished
    - Likely to produce more offspring than others of its species
    - Its genetics will be overrepresented in the next generation
    - More taller trees will exist in the next generation

Meiosis and Sex Determination

- Human gender is determined by a pair of sex chromosomes
  - Females possess a pair of X chromosomes
  - Males possess a single X chromosome and a single Y chromosome
    - The presence of a Y chromosome that confers male gender

- The X chromosome is a fairly large chromosome
- The Y chromosome is the smallest human chromosome

- Female X chromosomes represent a pair of homologous chromosomes
- Male X and Y chromosomes are not homologous, but act as homologous chromosomes during meiosis

- In females, the homologous X chromosomes line up together during meiosis I
  - These chromosomes separate, going into different cells

- In males, the non-homologous X and Y chromosomes line up together during meiosis I as if they were homologous
  - These chromosomes separate, going into different cells

- Each egg produced by a female contains a single X chromosome
- Each sperm produced by a male possesses a single sex chromosome
  - Half of the sperm contain an X chromosome
    - These sperm will produce daughters
  - Half of the sperm contain a Y chromosome
    - These sperm will produce sons