For a species to survive, it must REPRODUCE!

Ch 13 NOTES – Meiosis

Genetics Terminology:
- Autosomes
- Sex chromosomes
- Somatic cell
- Diploid
- Gamete
- Haploid
- Karyotype
- Zygote
- Homologous chromosomes
- Synapsis
- Meiosis
- Crossing over
1) ASEXUAL REPRODUCTION:

- each new organism gets a set of chromosomes identical to parents
- DNA from generation to generation remains the same
- therefore, no differences or variations occur in the offspring (difficult to adapt!)
2) SEXUAL REPRODUCTION:

- fusion of nuclei from 2 special cells: **GAMETES**
  (female gamete = **egg**; male gamete = **sperm**)

- with 2 parents, offspring receive half of their chromosomes from the female parent and half from the male parent.

- therefore, the offspring will show new combinations of characteristics
**Sexual reproduction leads to VARIATION! (this ensures the survival of a species)**

- **SOMATIC CELLS** = *all cells EXCEPT the gametes*
- each somatic cell of an organism contains a specific # of chromosomes (*humans = 46*)
Sets of Chromosomes in Human Cells

- Each human somatic cell (any cell other than a gamete) has 46 chromosomes arranged in pairs.

- A **KARYOTYPE** is an ordered display of the pairs of chromosomes from a cell.
● the chromosomes occur in “matching pairs” (1 member of each pair came from the egg and 1 member came from the sperm)
● these pairs of chromosomes are called **HOMOLOGOUS PAIRS**
● Both chromosomes in a pair carry genes controlling the same inherited characteristics
Pair of homologous chromosomes

Centromere

Sister chromatids
• The sex chromosomes are called X and Y
• Human females have a homologous pair of X chromosomes (XX)
• Human males have one X and one Y chromosome
• The 22 pairs of chromosomes that do not determine sex are called AUTOSOMES
Human Gamete
~cells with half the # of chromosomes are \textbf{HAPLOID} (n)

Human Somatic Cell
~cells with full # of chromosomes are \textbf{DIPLOID} (2n)

\textbf{Egg} \quad \textbf{Sperm} \\
\begin{array}{cccc}
\text{Gene pair} & A & a \\
\end{array}
Key

Maternal set of chromosomes \((n = 3)\)

\[2n = 6\]

Paternal set of chromosomes \((n = 3)\)

Two sister chromatids of one replicated chromosomes

Two nonsister chromatids in a homologous pair

Pair of homologous chromosomes (one from each set)

Centromere
- Gametes are **haploid cells**, containing only one set of chromosomes
- For humans, the haploid number is 23 \( (n = 23) \)
- Each set of 23 consists of **22 autosomes** and a single sex chromosome
- In an unfertilized egg (ovum), the **sex chromosome** is X
- In a sperm cell, the sex chromosome may be either X or Y
• the union of 2 haploid gametes restores the diploid # of chromosomes *(Fertilization!)*

• **MEIOSIS**: cell division in which daughter cells receive only ½ of the chromosomes of the parent cell  
  
  – **RESULT**: formation of gametes!

• occurs only in reproductive tissues  
  
  **male** = testes  
  
  **female** = ovaries
Behavior of Chromosome Sets in the Human Life Cycle - OVERVIEW

- At sexual maturity, the ovaries and testes produce haploid gametes
- Gametes are the only types of human cells produced by meiosis, rather than mitosis
- Meiosis results in one set of chromosomes in each gamete
- Fertilization, the fusing of gametes, restores the diploid condition, forming a zygote
- The diploid zygote develops into an adult
Key
- Haploid (n)
- Diploid (2n)

Haploid gametes (n = 23)
- Ovum (n)
- Sperm cell (n)

MEIOSIS
- Ovary
- Testis

FERTILIZATION
- Diploid zygote (2n = 46)

Mitosis and development
- Multicellular diploid adults (2n = 46)

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The Variety of Sexual Life Cycles

- The alternation of meiosis and fertilization is common to all organisms that reproduce sexually.
- The three main types of sexual life cycles differ in the timing of meiosis and fertilization.
ANIMALS

• In animals, meiosis produces gametes, which undergo no further cell division before fertilization

• Gametes are the only haploid cells in animals

• Gametes fuse to form a diploid zygote that divides by mitosis to develop into a multicellular organism
(a) Animals
(b) Plants and some algae
(c) Most fungi and some protists
Plants and some algae exhibit an alternation of generations.

This life cycle includes two multicellular generations or stages: one diploid and one haploid.

The diploid organism, the SPOROPHYTE, makes haploid spores by meiosis.

Each spore grows by mitosis into a haploid organism called a GAMETOPHYTE.

A gametophyte makes haploid gametes by mitosis.
(b) Plants and some algae
Fungi and Protists

- In most fungi and some protists, the only diploid stage is the single-celled zygote; there is no multicellular diploid stage.
- The zygote produces haploid cells by meiosis.
- Each haploid cell grows by mitosis into a haploid multicellular organism.
- The haploid adult produces gametes by mitosis.
(c) Most fungi and some protists
Meiosis takes place in 2 stages:

1) **Meiosis I**

2) **Meiosis II**

Each sex cell has half the normal number of chromosomes.
1) Meiosis I

- preceded by **Interphase**: DNA is copied
- **Prophase I**: each chromosome pairs up with its homologous chromosome to form a TETRAD (4 chromatids)
- **Metaphase I**: tetrads line up in the center of the cell
- **Anaphase I**: homologous chromosomes are pulled apart from one another
- **Telophase I**
no DNA replication occurs before the 2nd round of division
2) Meiosis II

- the 2 cells produced in meiosis I undergo a second division (PMAT - II)
- the result: 4 haploid daughter cells!
MEIOSIS II: Separate the Sister Chromatids (by mitosis)
A Comparison of Mitosis and Meiosis:

- Mitosis conserves the number of chromosome sets, producing cells that are genetically identical to the parent cell.
- Meiosis reduces the number of chromosomes sets from two (diploid) to one (haploid), producing cells that differ genetically from each other and from the parent cell.
- The mechanism for separating sister chromatids is virtually identical in meiosis II and mitosis.
Three events are unique to meiosis, and all three occur in meiosis I:

1) **Synapsis and crossing over in prophase I:** Homologous chromosomes physically connect and exchange genetic information

2) At the metaphase plate, there are paired homologous chromosomes (tetrads), instead of individual replicated chromosomes

3) At anaphase I, it is homologous chromosomes, instead of sister chromatids, that separate and are carried to opposite poles of the cell
Propose

Duplicated chromosome (two sister chromatids)

Chromosome replication

2n = 6

Parent cell (before chromosome replication)

Chromosome replication

Chiasma (site of crossing over)

Tetrad formed by synapsis of homologous chromosomes

Metaphase

Chromosomes positioned at the metaphase plate

Metaphase

Chromosomes positioned at the metaphase plate

Anaphase

Sister chromatids separate during anaphase

Daughter cells of mitosis

Anaphase

Daughter cells of meiosis I

Haploid

n = 3

Daughter cells of meiosis II

Sister chromatids separate during anaphase II
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<th>Meiosis</th>
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<td>During interphase</td>
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Genetic variation produced in sexual life cycles contributes to evolution

- Mutations (changes in an organism’s DNA) are the original source of genetic diversity
- Mutations create different versions of genes
- Reshuffling of different versions of genes during sexual reproduction produces genetic variation
Origins of Genetic Variation Among Offspring

- The behavior of chromosomes during meiosis and fertilization is responsible for most of the variation that arises in each generation.
- Three mechanisms contribute to genetic variation:
  1) Independent assortment of chromosomes
  2) Crossing over
  3) Random fertilization
1) Independent Assortment of Chromosomes

- Homologous pairs of chromosomes orient randomly at metaphase I of meiosis.
- In independent assortment, each pair of chromosomes sorts maternal and paternal homologues into daughter cells independently of the other pairs.
- The number of combinations possible when chromosomes assort independently into gametes is $2^n$, where $n$ is the haploid number.
- For humans ($n = 23$), there are more than 8 million ($2^{23}$) possible combinations of chromosomes!
Maternal set of chromosomes
Paternal set of chromosomes

Possibility 1

Possibility 2

Two equally probable arrangements of chromosomes at metaphase I

Metaphase II

Daughter cells

Combination 1
Combination 2

Combination 3
Combination 4

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2) Crossing Over

- Crossing over produces **recombinant chromosomes**, which combine genes inherited from each parent.
- Crossing over begins very early in prophase I, as homologous chromosomes pair up gene by gene.
- In crossing over, homologous portions of two nonsister chromatids trade places.
- Crossing over contributes to genetic variation by combining DNA from two parents into a single chromosome.
crossing over during synapsis of prophase I

first meiotic division

second meiotic division
Prophase I of meiosis

Tetrad

Nonsister chromatids

Chiasma, site of crossing over

Metaphase I

Metaphase II

Daughter cells

Recombinant chromosomes
4 different cells!
3) Random Fertilization

- Random fertilization adds to genetic variation because any sperm can fuse with any ovum (unfertilized egg)
- The fusion of gametes produces a zygote with any of about 64 trillion diploid combinations
- Crossing over adds even more variation
- Each zygote has a unique genetic identity
Evolutionary Significance of Genetic Variation Within Populations

- **Natural selection** results in accumulation of genetic variations **favored by the environment**
- Sexual reproduction contributes to the genetic variation in a population, which ultimately results from mutations