

Cell Division and Inheritance

تقسیم سلولی و وراثت

CELL DIVISION

- Continuing life relies on reproduction
 - Individual organism—replacing dead or damaged cells
 - Species—making more of same species
- Reproduction
 - Cells divide, grow, divide again

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CELL DIVISION

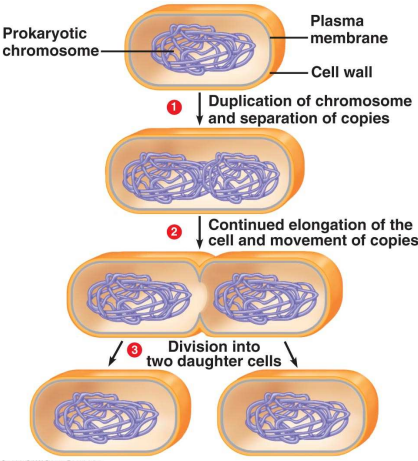
- Mitosis—division of body (somatic) cells by multicelled organisms
 - Increasing number of cells during growth
 - Replaces cells that are worn-out, dead, or damaged
 - Asexual reproduction by some plants, animals, fungi, single-celled protists
 - In undifferentiated somatic cells (skin, liver, bone marrow, blood vessels), not in differentiated cells (nerve and Muscle cells, adult stem cells)
- Meiosis—formation of sex (germ) cells (sperm, eggs) and spores
 - Basis for sexual reproduction
 - Creates gametes
- Prokaryotic (Binary) fission

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BINARY FISSION

- Prokaryotes have no nucleus or organelles.
- As chromosome duplicates, copies move to opposite sides of cell.
- After duplication and cell growth, membrane grows inward, dividing the cell.
- Daughter cells same genes as parent cell
 - Effectively are clones of the parent cell

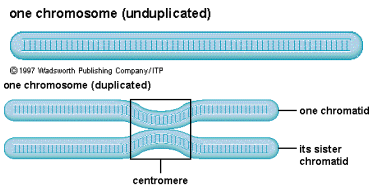
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CHROMOSOMES

- Basis for genetic code
- Different number of chromosomes in each species
- Copied before cell division
 - Sister chromatids



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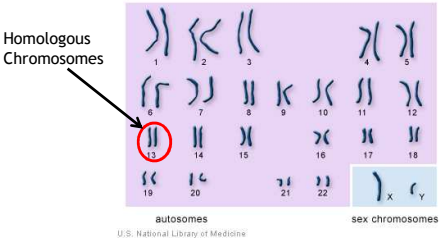
CHROMOSOMES

- Chromosome number—sum total of chromosomes
- Diploid number—number of chromosomes when including pairs, “2n”
 - One set from each parent\
 - Somatic cells
- Homologous chromosomes—each chromosome in a matched pair
 - Only one set of each sex chromosome
- Haploid number—half of the normal chromosome number, “n”
 - Gametes

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CHROMOSOMES

- Diploid number = 46 in humans (“2n”)
- Haploid number = 23 in humans (“n”)



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CHROMOSOMES

- DNA helix wraps around histones, forms nucleosome
- Multiple levels of coiling into chromatin
- Condensed into chromosome

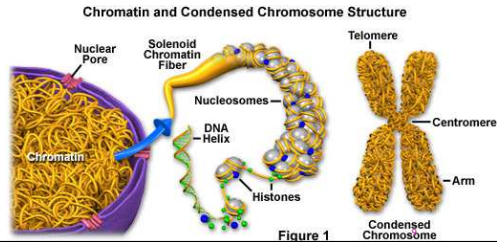
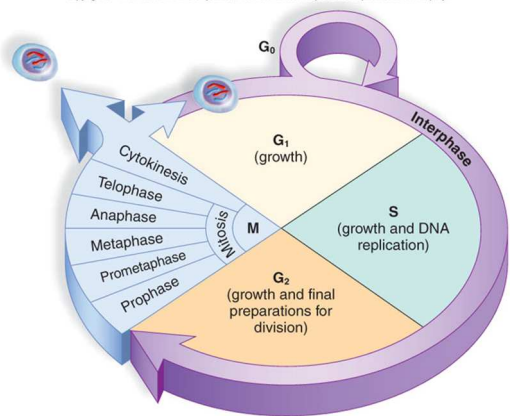


Figure 1

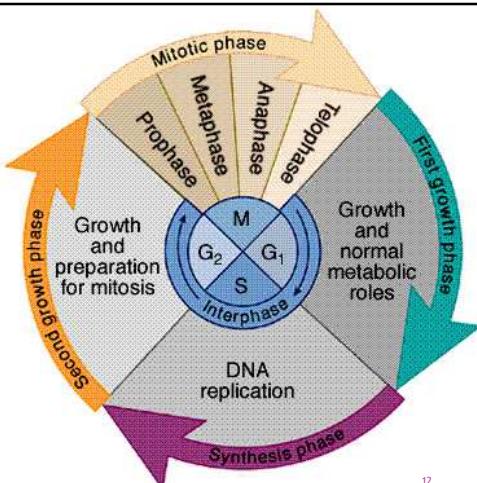
CELL CYCLE

- Interphase—normal growth and function
 - G1—initial growth & normal roles
 - S—DNA replication
 - G2—preparation to divide
- Mitosis (about 10% of cell’s cycle)
 - Prophase
 - Metaphase
 - Anaphase
 - Telophase
- Mitosis - nuclear division in the cell cycle
- Cytokinesis - division of the cytoplasm

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EUKARYOTIC CHROMOSOMES ARE VISIBLE DURING CELL DIVISION

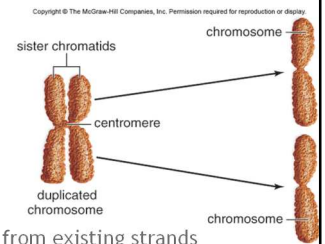
When a eukaryotic cell is not undergoing division, the DNA within a chromosome is a mass of thin threads called **chromatin**

- Before nuclear division chromatin condenses,
- 2 identical chromatids are **sister chromatids**

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INTERPHASE

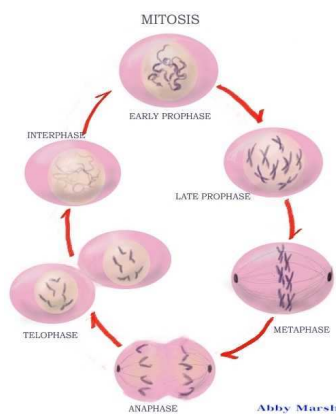
- G1
 - Most of life for many cells
 - Normal functions
- S
 - New strands of DNA created from existing strands
 - Chromosome doubles into connected sister chromatids
- G2
 - Microtubules and other structures made for cell division
 - Organelles duplicated



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MITOSIS

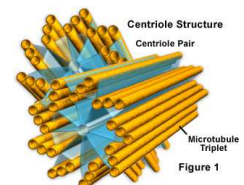
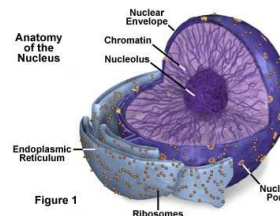
- During interphase, chromosomes double
- Cell divides once
- Chromatid divides once
- Leaves 2n in each daughter cell



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MITOSIS

- Prophase
 - Chromosomes become visible
 - Centrioles form spindle fibers
 - Nuclear membrane starts to break down
 - Centromeres modified into kinetochores
 - Site of spindle attachment



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MITOSIS

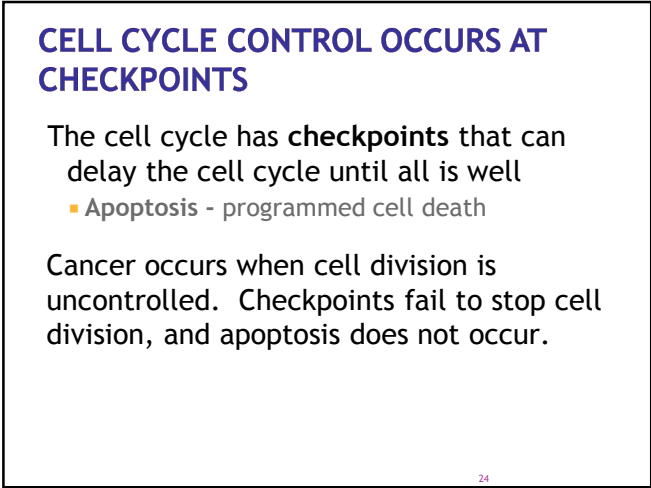
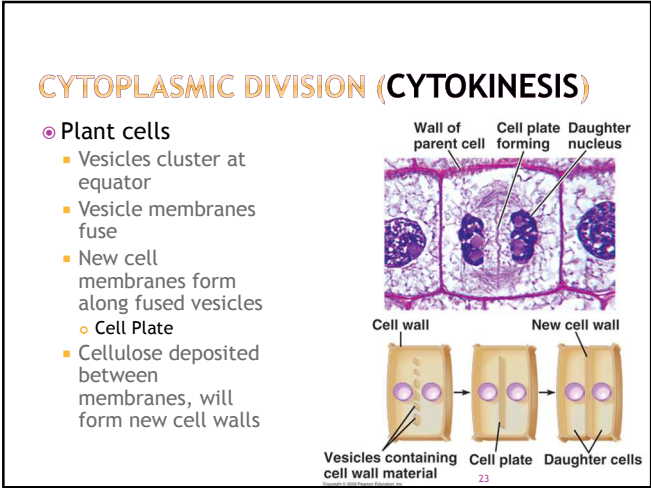
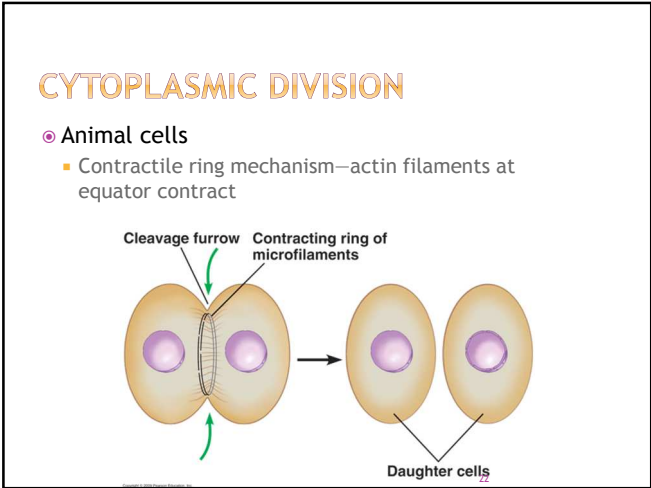
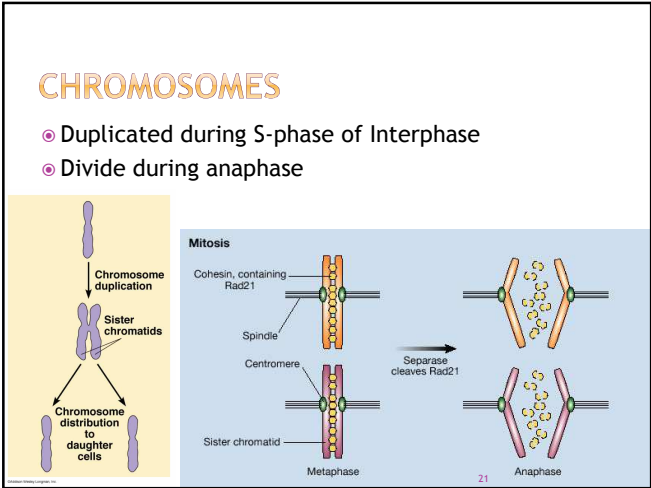
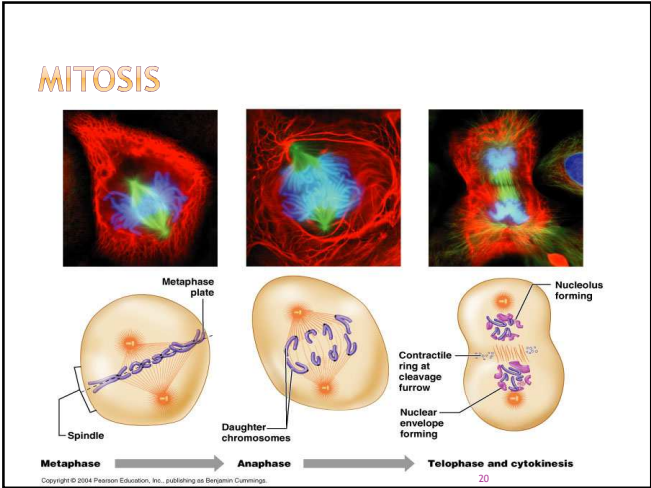
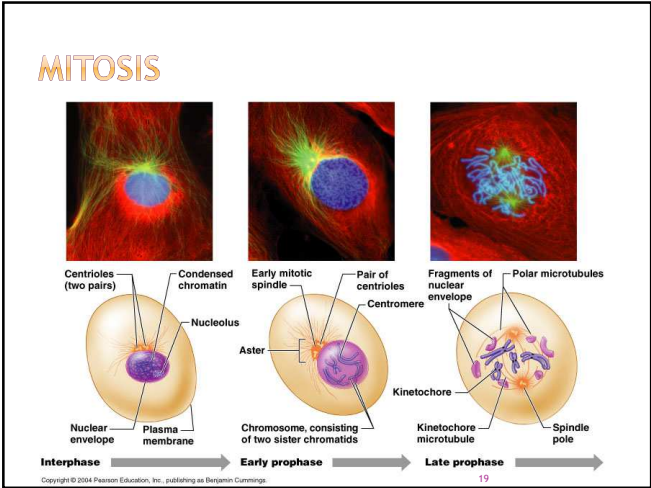
- Metaphase
 - Centrioles moved to opposite ends of the cell ("poles")
 - Chromosomes lined up in middle of cell
 - Spindle fibers attached to centromeres
- Anaphase
 - Sister chromatids pulled towards each pole and separate
 - Cell elongates in direction of poles

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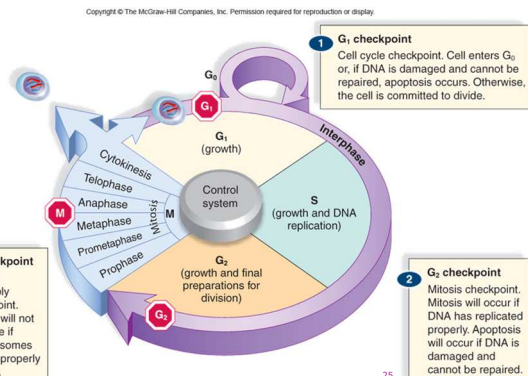
MITOSIS

- Telophase
 - Cell divides in middle, forms cleavage furrow
 - Cytokinesis—complete cell division
 - Nuclear membrane re-forms around each set of chromosomes

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CELL CYCLE CHECKPOINTS



CELL CYCLE INHIBITION

Contact Inhibition - In a culture, cells divide until they line a container in a sheet and then stop dividing

- Cells “remember” number of divisions

Telomere - repeating DNA base sequence

- Each time a cell divides some portion of a telomere is lost (approx. 70 cycles)
- When telomeres become too short, chromosomes fuse and do not duplicate

CANCER CELLS HAVE ABNORMAL CHARACTERISTICS

A **mutation** (a DNA change) causes a cell to divide uncontrollably or ignore apoptosis

- Carcinogenesis** - development of cancer

Characteristics of cancer cells:

- Lack differentiation
- Have abnormal nuclei
- Form tumors
- Metastasis - establishing new tumors
- Angiogenesis - formation of new blood vessels

NORMAL CELL DIVISION

- Growth Factors**
 - Proteins produced by an organism that can trigger cell division
- Density-dependent inhibition**
 - Crowded cells stop dividing
 - Respond to touch of bordering cells
 - Keep overgrowth from happening
- Anchorage dependence**
 - Most animal cells must be in contact with a solid surface in order to divide.

ABNORMAL CELL DIVISION

- Teratogens**—environmental factors that cause abnormal cell division
 - Radiation (UV, x-rays, radon)
 - Organic chemicals (nicotine, pesticides)
 - Viruses (polio, German measles, chicken pox)
- Normal protective mechanisms**
 - Keep cells in certain stages (such as G₁)
 - Triggers to start and stop cell division & growth
 - Fix damaged DNA
 - Destroy abnormal cells

CANCER

- Controls on cell division broken
- Cells grow and divide uncontrollably
 - Ignore density-dependent inhibition
- Cytoplasm and plasma membrane altered
 - Enzyme actions within the cell shift
- Weakened adhesion
 - Break away and establish colonies—metastasis
- May be lethal
 - Chemical byproducts of tumor
 - Invading and crowding out other tissues

SEXUAL REPRODUCTION

- Meiosis → Gamete formation → Fertilization
- Diploid → Haploid → Fertilization → Diploid

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MEIOSIS

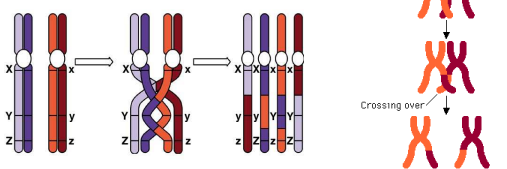
- Almost identical to mitosis
- Chromosomes mix
- Cells and chromosomes divide *TWICE* before process ends
- Ends with 4 daughter cells, each haploid
- Pro-, Meta-, Ana-, Telophase I
- Pro-, Meta-, Ana-, Telophase II

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MEIOSIS

- Prophase 1
 - Homologous chromosomes pair up (Synapsis)
 - Usually swap segments (crossing over)
 - Otherwise normal prophase

Crossing over during meiosis



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MEIOSIS

- Metaphase 1
 - Spindle fibers attach to centromere of each type of chromosome
 - Otherwise normal metaphase
- Anaphase 1
 - Homologous chromosomes separated to each pole of cell
 - Otherwise normal anaphase
- Telophase 1
 - Cytokinesis (normal telophase)
 - Does *NOT* go to Interphase

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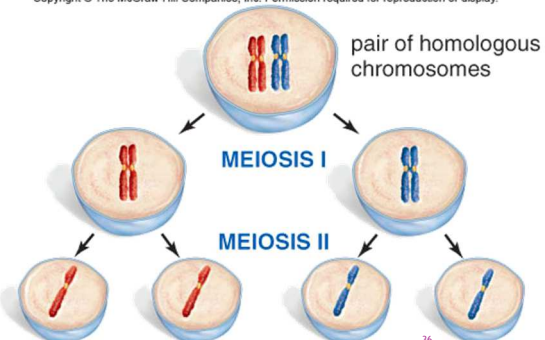
MEIOSIS

- DNA is *NOT* duplicated prior to 2nd stage of Meiosis
- Prophase II
 - New centrioles move to poles of new cells
- Metaphase II
 - Spindle fibers attach to centromeres
 - Chromosomes line in middle
- Anaphase II
 - Sister chromatids break apart, move to poles
- Telophase II
 - Cytokinesis
 - Each daughter cell is haploid

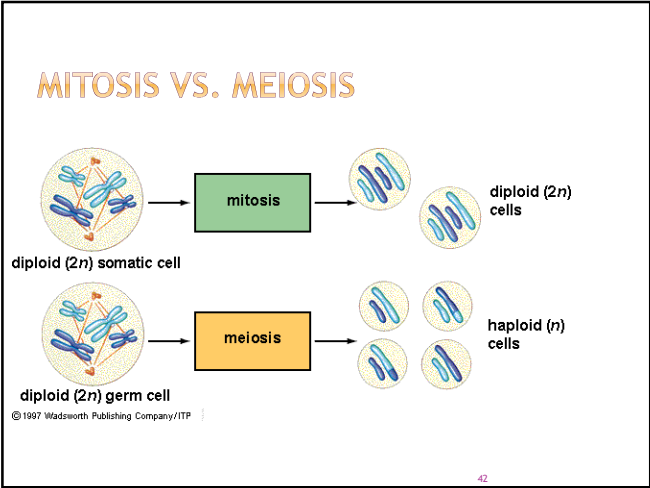
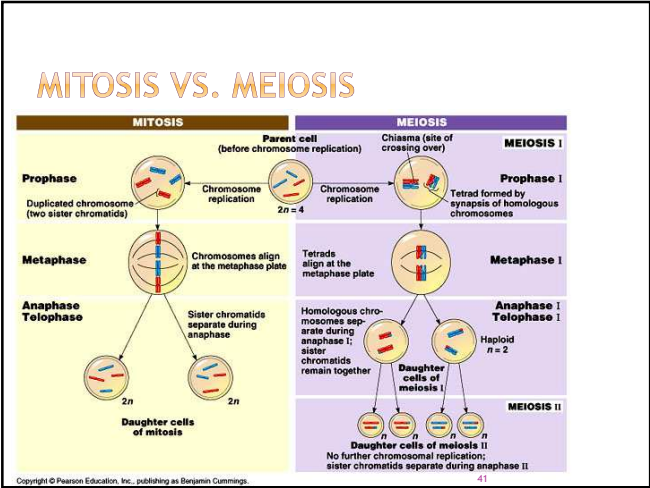
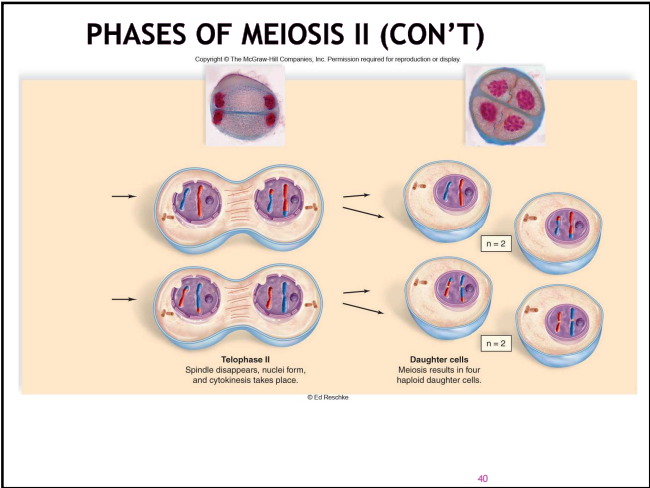
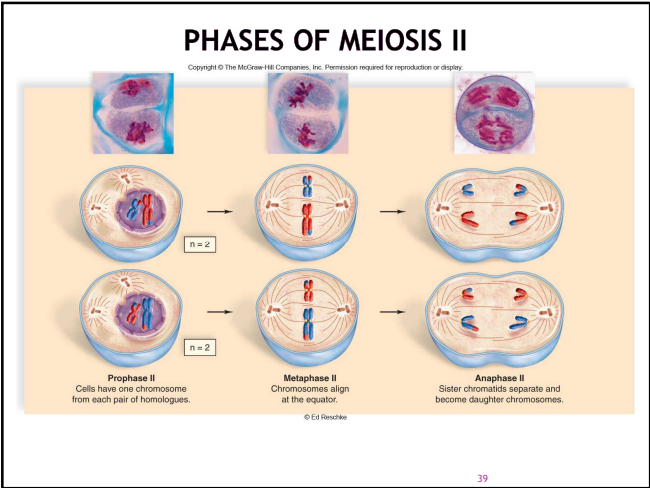
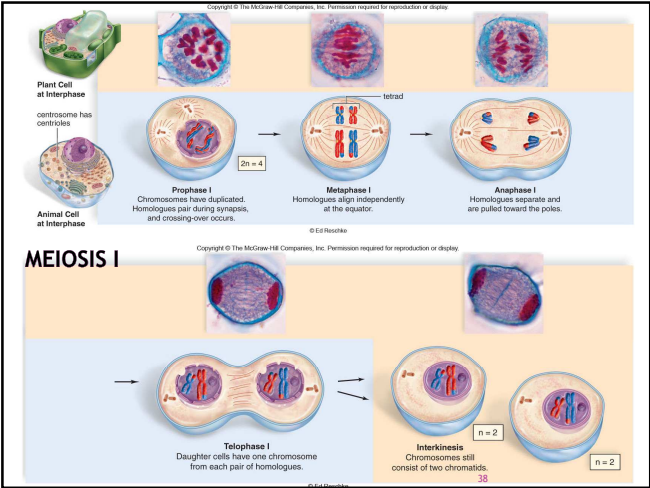
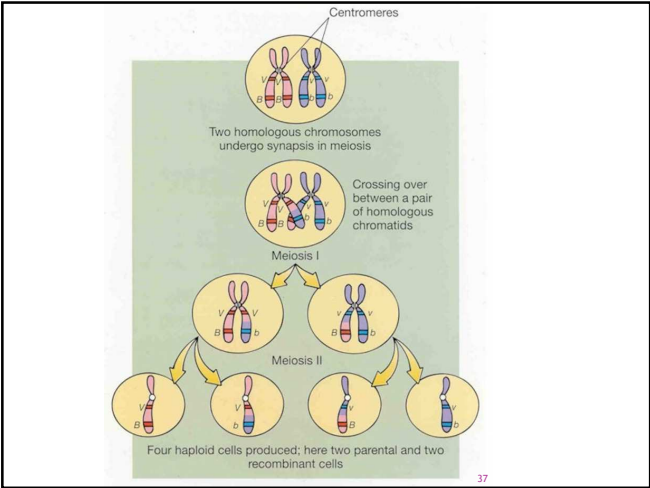
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No replication of DNA occurs during **interkinesis** (the period between meiosis I and II)

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MITOSIS VS. MEIOSIS

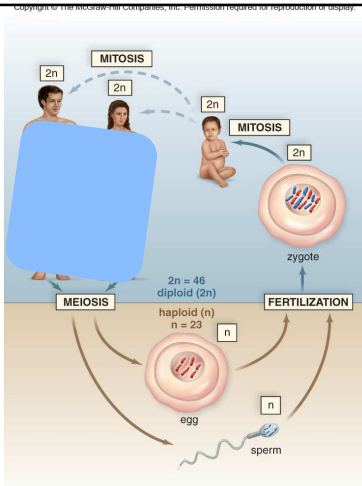
MITOSIS	MEIOSIS
<ul style="list-style-type: none">• Somatic cells• Grow, replace, repair• 2 daughter cells, 2n• No synapsis• No genetic diversity, minimal variation• One division• Used for asexual reproduction	<ul style="list-style-type: none">• Sex cells• Reproduction• 4 daughter cells, n• Frequent synapsis• Great genetic diversity• Two divisions• Used for sexual reproduction

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THE LIFE CYCLE OF MOST MULTICELLULAR ORGANISMS INCLUDES BOTH MITOSIS AND MEIOSIS

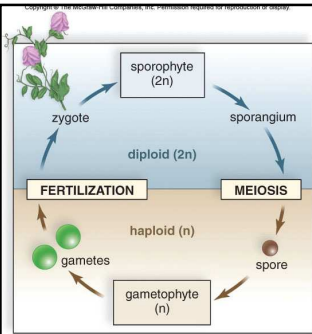
- Life cycle** - in sexually reproducing organisms, all the reproductive events from one generation to the next
- Spermatogenesis in males, occurs in the testes and produces sperm
 - Oogenesis in females, occurs in the ovaries and produces eggs
- Zygote** - product of the sperm and egg joining during fertilization, has homologous pairs of chromosomes

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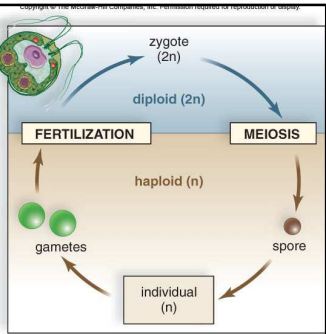
LIFE CYCLE OF HUMANS

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Life Cycle of Plants

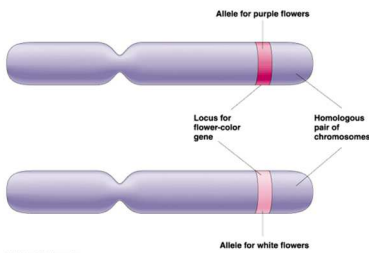
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Life Cycle of Algae

GENETIC VARIATION

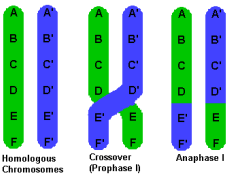
- Allele—different forms of the same gene
 - Affects different traits— “dimple”, “no-dimple”
 - Mixing alleles results in variations of traits



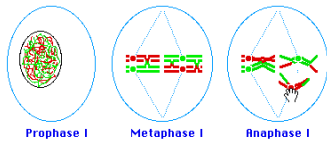
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GENETIC VARIATION

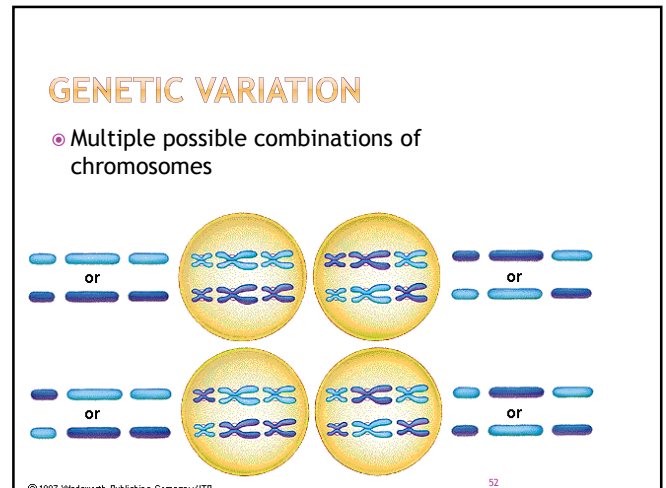
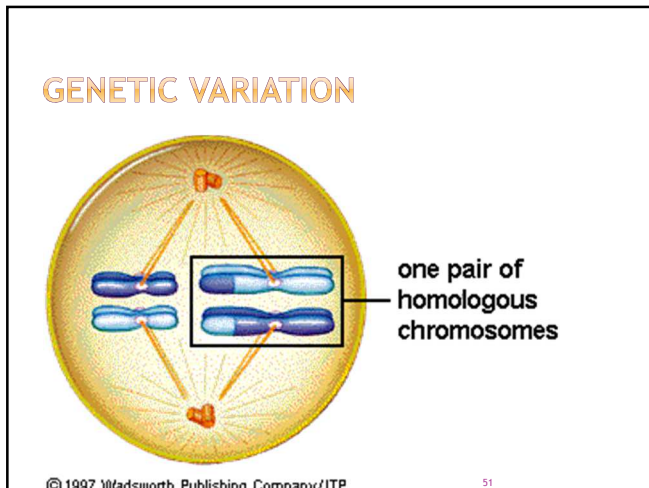
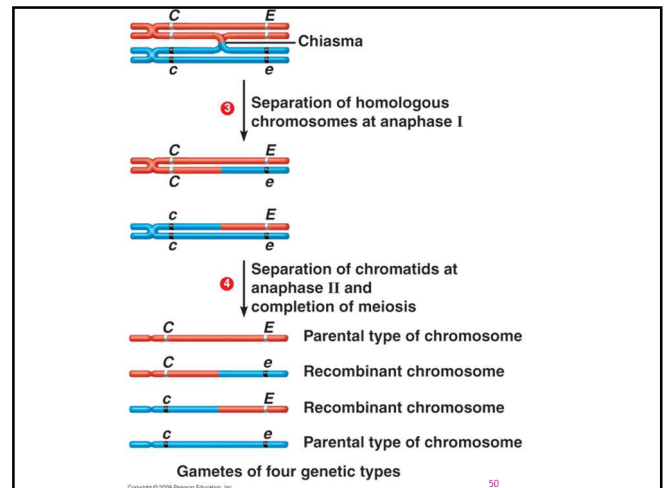
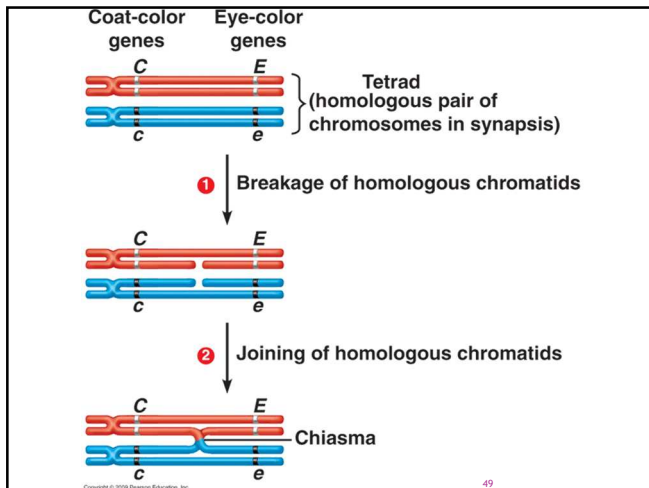
- Crossover (Prophase I)
 - Switches alleles



- Homologous Alignments (Metaphase I)



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GENETIC VARIATION--HUMANS

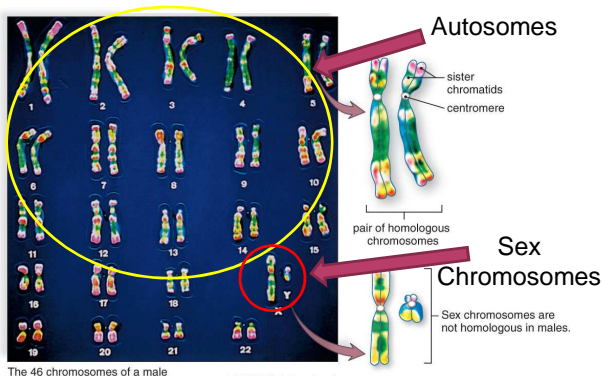
- In a single fertilization (one baby) there are...
- 8,388,608 combinations of homologous chromosomes
- 70,368,744,000,000 possible variations of offspring
- Including crossing over--
4,951,760,200,000,000,000,000,000 possible genetic variations!!!!

HOMOLOGOUS CHROMOSOMES SEPARATE DURING MEIOSIS

Karyotype - picture of chromosomes in numbered pairs called **homologous chromosomes** or **homologues**

- X and Y chromosomes are the **sex chromosomes** because they contain the genes that determine gender
- **Autosomes** - all the pairs of chromosomes except the sex chromosomes

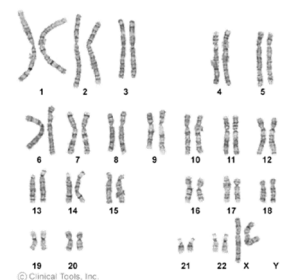
A KARYOTYPE SHOWS THAT THE CHROMOSOMES OCCUR AS PAIRS



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KARYOTYPING

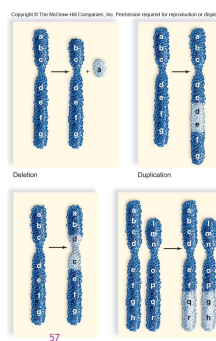
- Culture cells, stimulate mitosis, stop division at metaphase
- Hypotonic solution swells cells, separates them & chromosomes
- Take picture, cut & paste
- Gives an image of the person's/animal's actual chromosomes
- Can analyze for abnormalities



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CHROMOSOME ABNORMALITIES

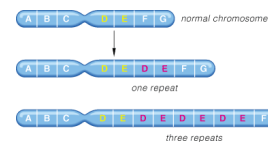
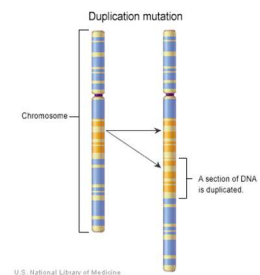
- Changes in physical structure of chromosome
- Cause genetic disorders or abnormalities
- Often a disruption during crossing over
- Rare
- Duplication
- Deletion
- Inversion
- Translocation



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DUPLICATION

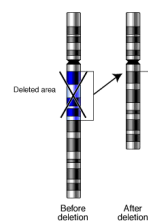
- DNA sequences are repeated 2 or more times
- Unequal crossing-over
- Broken piece of chromosome attaches to homologous chromosome
- **Huntington's Disease**
 - Affects coordination & movement
 - Affects mental abilities, personality



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DELETION

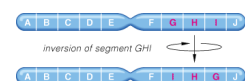
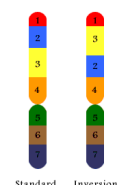
- DNA sequence deleted
- Unequal crossing-over
- Chemical damage
- Most cause serious disorders or death
- **Cri du chat syndrome**
 - Severe developmental & neurological problems
 - Unusual cry of infant ("cry of the cat")
 - Unusual physical appearance



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INVERSION

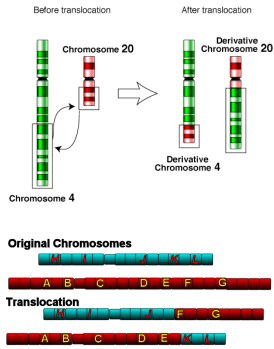
- DNA sequence reverses
- No loss of DNA or chromosome part
- No problem for carrier if non-crucial gene
- Some may not know until children have problem
- **Chromosome 9**
 - No health problems for parent
 - May increase risk of miscarriage



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TRANSLOCATION

- Broken part of one chromosome attaches to another
 - Non-homologous chromosomes
- Usually reciprocal (both exchange broken parts)
- Often cause reduced fertility
- Severe problems rare
 - Can include several cancers
 - Can cause death or disorders: e.g., Burkitt's lymphoma



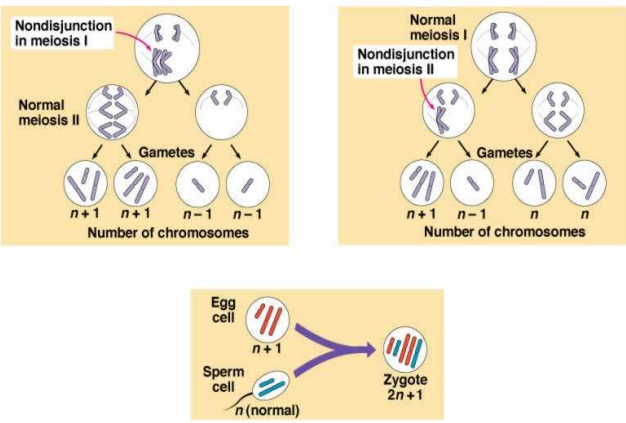
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CHROMOSOME NUMBER

- Aneuploidy**—one more one less chromosome than normal
 - Monosomy ($2n - 1$) only one of a type of chromosome
 - Trisomy ($2n + 1$) three of a type of chromosome
 - Usually fatal for humans
 - Most miscarriages
- Nondisjunction**—one or more pairs do not separate during meiosis
- Polyploidy**—cells with 3 or more copies of one or more chromosomes (e.g., triploid = $3n$, tetraploid = $4n$)
- Trisomy**—cells with $2n+1$ of one chromosome, $2n$ of all others
 - Special form of polyploidy

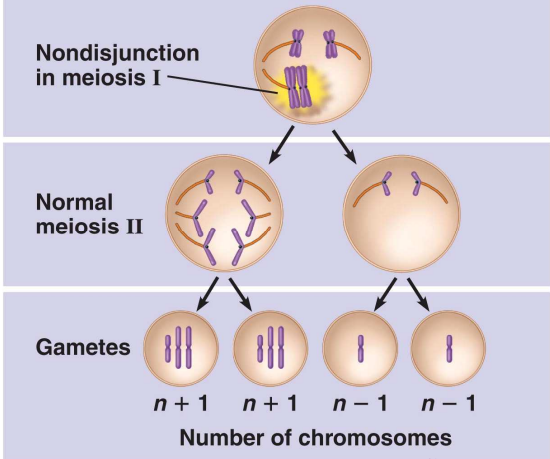
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NONDISJUNCTION



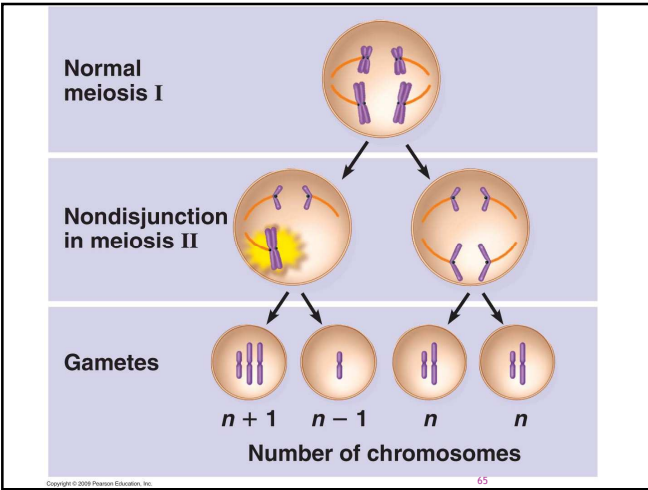
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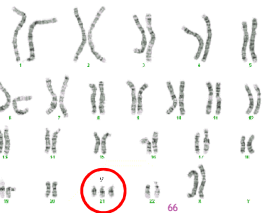


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DOWN SYNDROME (TRISOMY 21)

- Only trisomy that reaches adulthood
- Extra copy of chromosome 21
- Mostly through nondisjunction at meiosis
- Abnormal mental, heart, and skeletal development



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SEX CHROMOSOME ABNORMALITIES

- ◉ **Turner syndrome (females)**
 - Nondisjunction of sex chromosomes
 - Only one X, noted as “XO”
 - 98% of embryos miscarry
 - Adults very short, but well proportioned
 - Sterile, limited sex hormones
 - Female
- ◉ **Klinefelter syndrome (male)**
 - 2/3 Nondisjunction of sex chromosomes
 - XXY
 - Mostly normal, some learning disabilities
 - Lower testosterone, higher estrogen
 - “Feminized” male characteristics
 - Male

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