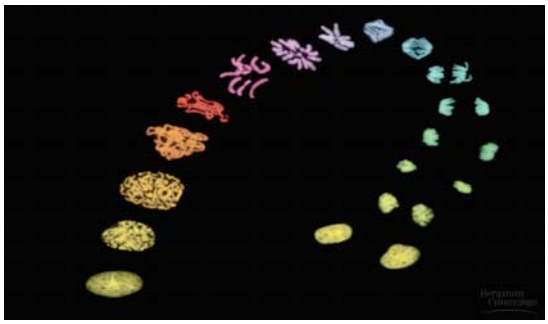
Cell Cycles, Sex, & Ploidy



The DNA Gene Theory

1. DNA is the molecule of inheritance.
2. A **chromosome** is one long dsDNA.
   - In eukaryotes, the dsDNA molecule is wrapped with histones & other proteins to form ***chromatin***.
3. A **gene** (a discrete unit of heredity) is a specific region of DNA on a chromosome.
   - Specific gene: instructions for a specific protein
4. Each chromosome = 100s–1000s of genes.

The Cell Theory
"Cell Doctrine"

1. All organisms are constructed of one or more cells.
2. The cell is the basic unit of life.
3. **All cells arise from previous cells.** ***"Omnis cellula e cellula!"***

- **cellular reproduction must include copying & transmitting DNA**

Cellula e Cellula

- Growth & Development
  - New cells produced
  - Need the right number of cells in the right location
    - Either too few or too many is bad.
- Cell Replacement
  - Lost or damaged cells replaced
- Asexual Reproduction
  - New organism formed

Sea star regenerating

Cellula e Cellula

- Cells divide to reproduce

I. **Asexual Reproduction** offspring from single parent (daughter cells have identical DNA as parent cell)

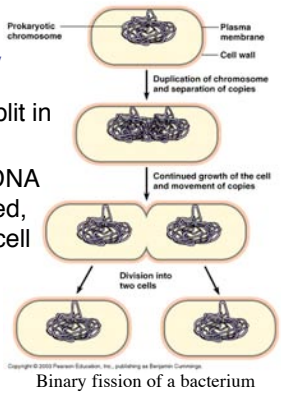
II. **Sexual Reproduction** offspring from union of egg and sperm (combine some DNA from both parent cells)

Budding *Hydra*

Sperm cells and egg cell

Prokaryotes Divide Asexually

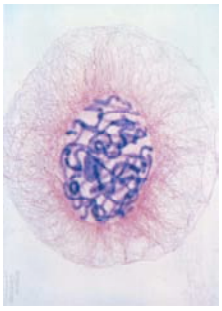
- **Binary Fission** "to split in half"
- A **Chromosome** (1 DNA molecule) is duplicated, separates, and then cell divides



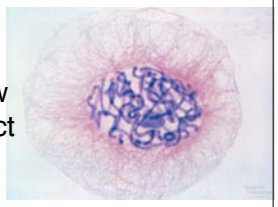
Binary fission of a bacterium

Eukaryotic Cells Have Multiple Chromosomes

- Eukaryotic cells have 5–20x more DNA per cell than do bacteria.
- Divided into linear dsDNA + histone & other proteins : **chromosomes**
- If straight, typical chromosome would be ~ 4 cm long.
- Humans have 46 different chromosomes
  - So collectively amounts to ~ 2 m long dsDNA packed into each cell nucleus! (4 m after replication!)

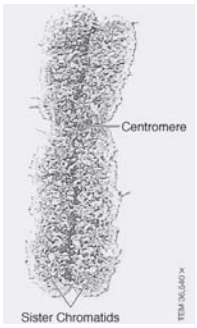


Eukaryotic Cells Have Multiple Chromosomes

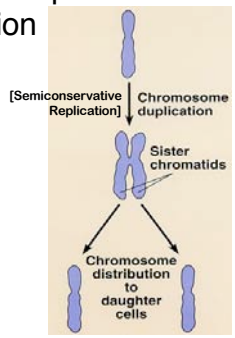


- In division, each new cell needs the correct number and kind of chromosomes
  - Replicate and divide chromosomes in nucleus
  - Distribution of organelles

Chromosomes Must Duplicate Before Division



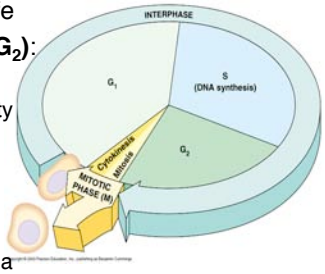
Human duplicated chromosome



Chromosome duplication and separation

The Cell Cycle

- Ordered sequence of events in a cell's life
- **Interphase (G_1/S/G_2)**: 90% of cell cycle
  - Most cellular activity
- **Mitotic phase (M)**
  - Mitosis = nucleus divides
  - Cytokinesis = cytoplasm & plasma membrane divides

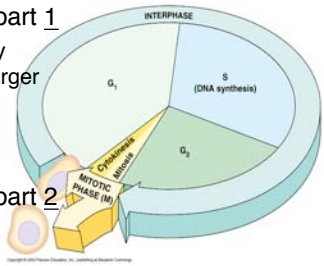


The eukaryotic cell cycle

The Cell Cycle

Interphase:

1. **G_1:** Growth stage, part 1
   - Cell is metabolically active and grows larger
2. **S:** Synthesis stage
   - DNA is replicated
3. **G_2:** Growth stage, part 2
   - More metabolism & growth



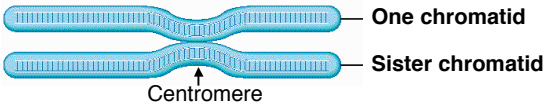
The eukaryotic cell cycle

S Stage —

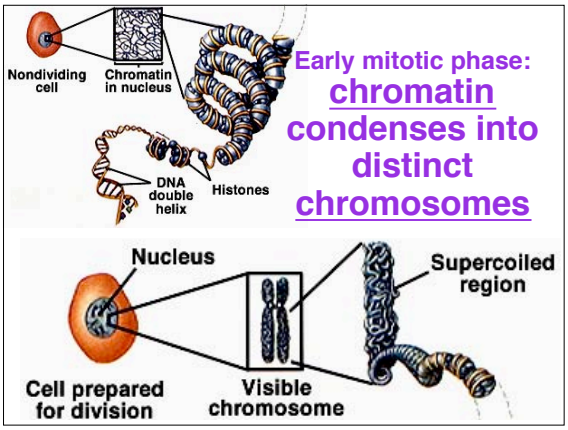
All cell reproduction requires DNA duplication

- Each cell must have its own copy of genetic material
  - **DNA replication in S Stage of Interphase**
- Then DNA must be separated (**segregation**) so that each cell has a complete copy
  - **Mitosis of Mitotic Phase**

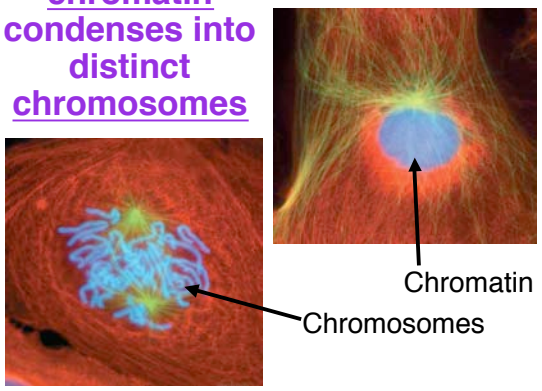
Duplicated chromosomes



- Duplicated chromosome: two sister **chromatids**
- Sister chromatids contain identical DNA
- Sister chromatids are held together by the **centromere**

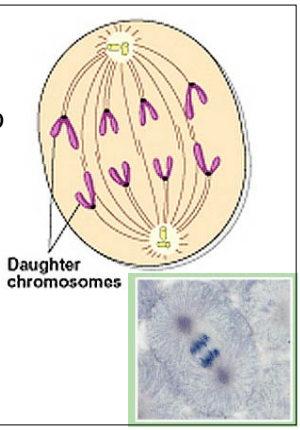


chromatin condenses into distinct chromosomes



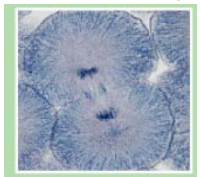
Mitosis

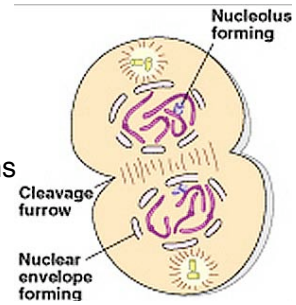
- Sister chromatids separate, move to opposite poles
- Sister chromatids are now "unduplicated chromosomes"
- Cell elongates



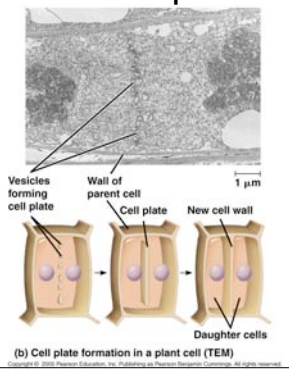
Late Mitosis

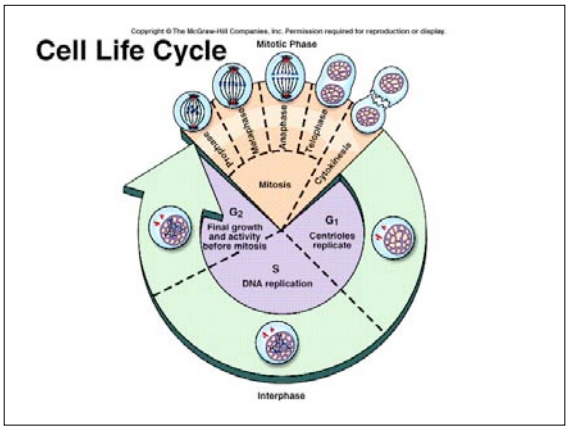
- New nuclear envelopes form
- Chromosomes de-condense
- Cytokinesis begins



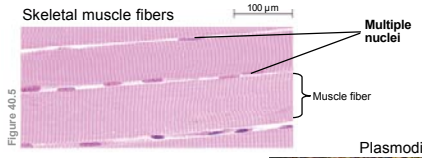


Cytokinesis in plant cells





Mitosis without cytokinesis
⇒ Syncytium



Plasmodial slime mold

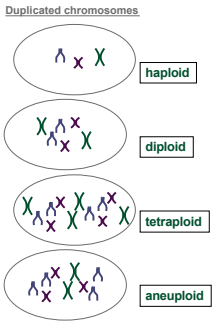
- Giant or elongated cell with multiple nuclei

Cells Arise From Preexisting Cells

I. **Asexual (Mitotic) Reproduction**
   a. Mitosis: production of two identical nuclei
   b. Cytokinesis: physical division of the cell into two

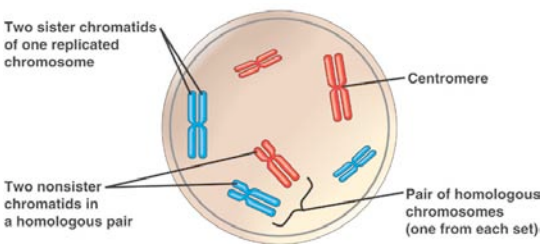
II. **Sexual (Meiotic) Reproduction**
   a. Meiosis: production of four *non*-identical nuclei
   b. Cytokinesis: physical divisions of the cell
   c. Fertilization: fusion of two sex cells
   d. Syngamy: fusion of two nuclei

Ploidy: how many copies of the *same* chromosome?



- **Haploid**: one version of each chromosome (n)
- **Diploid**: two versions of each chromosome (2n)
- **Polyploid**: many versions of each chromosome
- **Aneuploid**: abnormal number of chromosomes

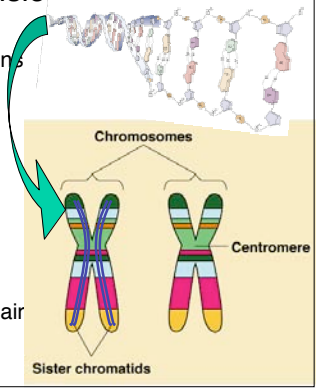
Diploid cells have homologous pairs of chromosomes: 1 set from mom, 1 set from dad.



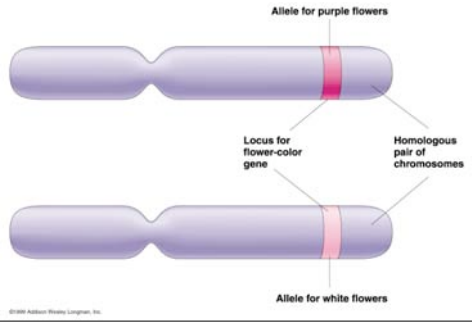
Cellular Divisio[illegible]bulary

Levels of Doubles —

- Each chromatid contains double-stranded DNA
  - Two **complementary** strands
- Each *duplicated* chromosome contains sister chromatids
  - Two **identical** sisters
- In *diploid* organisms, chromosomes are in pair
  - Two **homologous** chromosomes

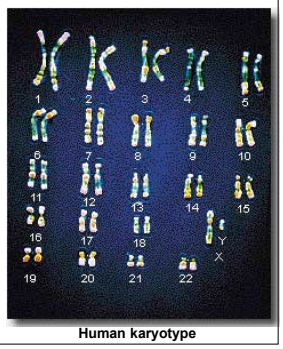


Homologous chromosomes (homologs): same set of genes, but maybe different versions of those genes (alleles)



Chromosomes Matched in Homologous Pairs

- Each human cell
  - ✓23 pairs = 46 chromosomes
  - ✓Homologs: same size, shape, band pattern, position of centromere, and gene loci



Human karyotype

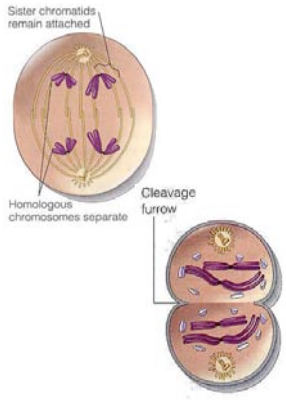
Meiosis: *Reductive* Division of ***Diploid*** Cells

— Reduces Chromosome Number in Half

- Meiosis has 2 consecutive divisions
  - **Meiosis I**: Homologs separate from homologous pairs (diploid haploid)
  - **Meiosis II**: Sister chromatids separate (duplicated unduplicated chromosomes)

Meiosis I

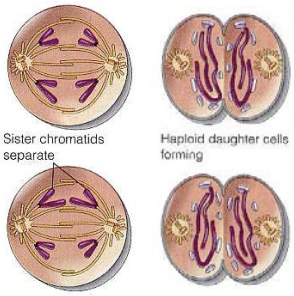
- Homologous pairs separate
- 2 new daughter cells
- Both are now **haploid**, but with duplicated chromosomes



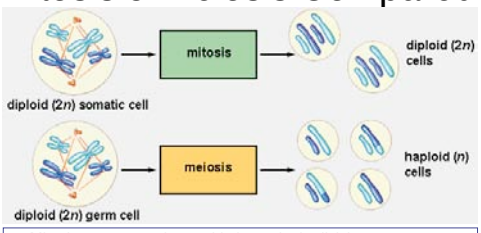
Meiosis II

In both cells from first meiotic division:

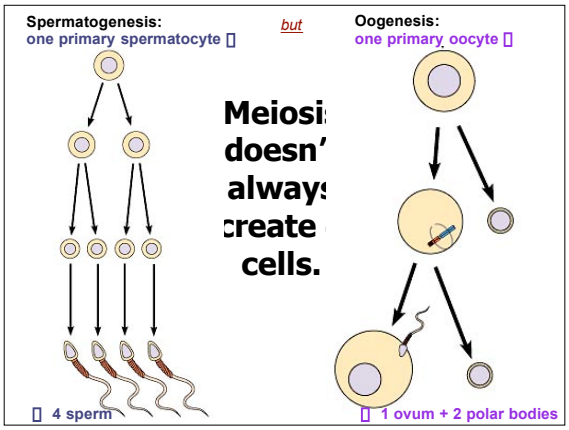
- Sister chromatids separate
- Daughter chromosomes now unduplicated
- Total of 4 haploid cells produced

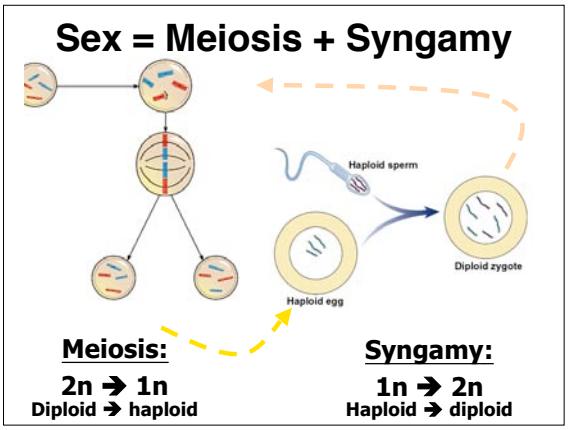


Mitosis & Meiosis Compared



- Mitosis separates chromatids in a single division event
  - If diploid cell then diploid daughter cells
  - If haploid cell then haploid daughter cells
- Meiosis I separates homologs, then Meiosis II separates chromatids
  - **Diploid** cell **Haploid** daughter cells

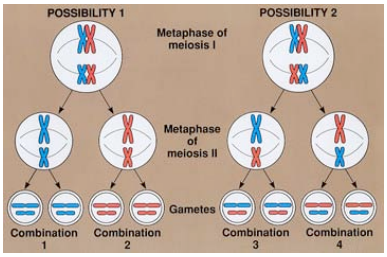




Sexual Reproduction Produces Genetic Variation

- Variation arises from
  - I. Independent chromosome assortment in meiosis
  - II. Crossing-over between homologous chromosomes in meiosis
  - III. Random process of fertilization

I. Independent Assortment

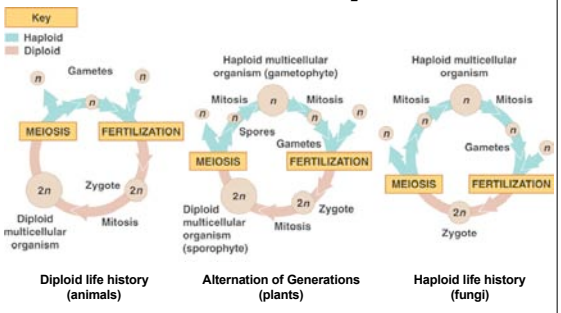


- Homologs line up by chance in Meiosis I
- Results in many different possible chromosome combinations in gametes
- 2^n possible combinations (2^{23} = >8 mill. for humans)

III. Random Fertilization

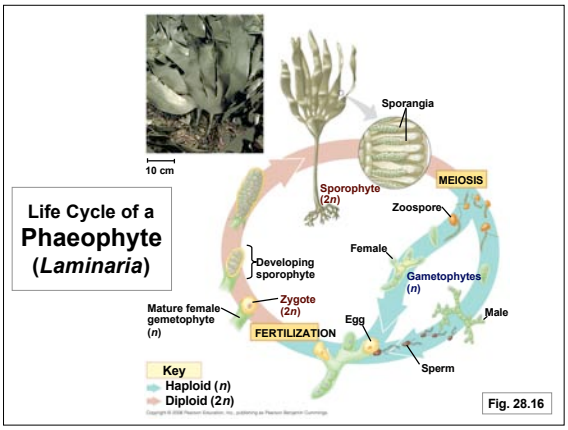
- Fertilization is a random process
- A **gamete** (sex cell) from one individual unites with one from another individual
- Given that a man can produce 2^{23} genetically different sperm, and a woman can produce 2^{23} genetically different ova:
- One mating couple can produce a diploid zygote with any of **>70 trillion** combinations of chromosomes! (2^{23} x 2^{23})
- (Not even counting variation from crossing-over!)

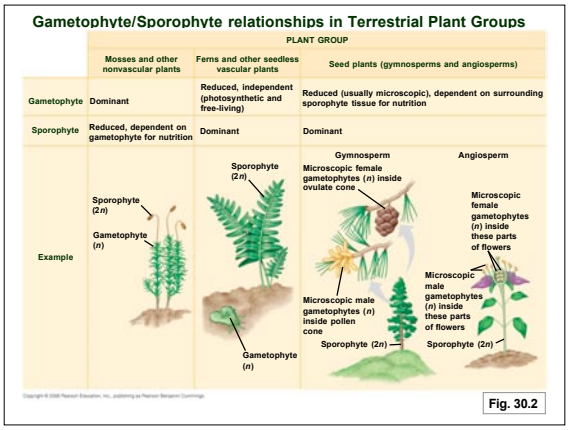
Sexual Life Cycles

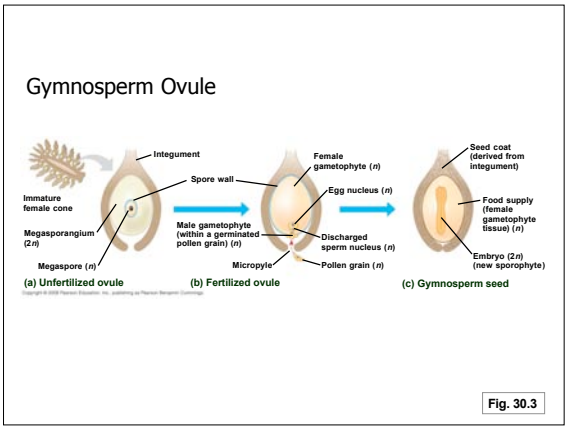


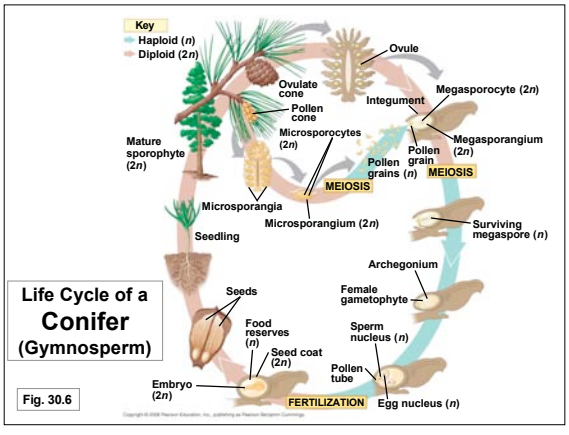
Fertilization

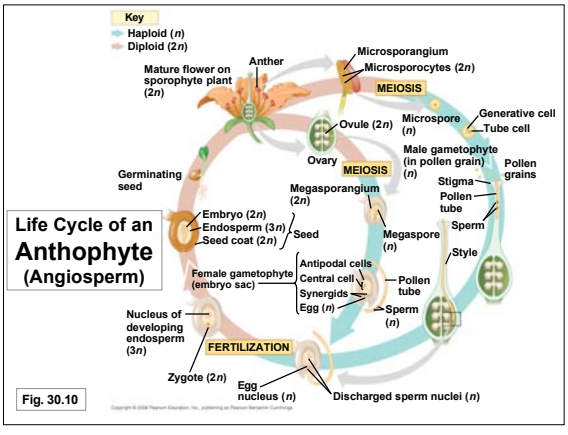
- Two haploid sex cells (**gametes**) one diploid cell (**zygote**)
  1. **Plasmogamy**: fusion of gamete cell plasma membranes
  2. **Syngamy** or **Karyogamy**: fusion of haploid nuclei
- **Isogametes**: both gametes contribute significant cytoplasm to the zygote.
  - Mating types: **+** or **–**
- **Heterogametes**: one gamete (**ova**) contributes most/all of zygote's cytoplasm.
  The other gamete (**sperm**) only provides the second haploid nucleus.
  - Mating types: **female** or **male**











Sexual Variants in the Protista

- **Unicellular Chlorophyte**
- **Plasmodial Slime Mold**
- **Cellular Slime Mold**
- **Apicomplexan parasite**
- **Ciliate**