

Class 13 9/22/17 Mitosis & Meiosis

- Announcements
- Class administration
- Check iLearn for suggested problems
- **Office hours HH668C:**
 - **NEXT WEEK 9/25 rescheduled to THU 9/28 3 – 5pm**

1

i>clicker

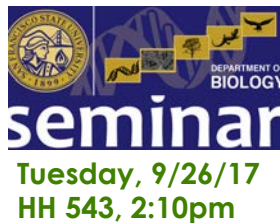


or



- ☐ Did you bring your clicker remote today? GREAT!!
- ☐ Please check iLearn for your clicker score in gradebook (Should now see only “**Sessions 1, 2, & 3**”)
- ☐ If your clicker score is missing, please e-mail me your clicker remote ID.

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Biol 572/872 Ecology, Evolution, & Conservation Biology Colloquium

<http://biology.sfsu.edu/content/EEC>

Tuesday, 9/26/17
HH 543, 2:10pm



Robin Elahi
Hopkins Marine Station
Benthic Ecology in a Changing Ocean

<https://hopkinsmarinestation.stanford.edu/people/robin-elahi>

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Romberg Tiburon Center Seminar Series

<http://rtc.sfsu.edu/seminar/index.htm>

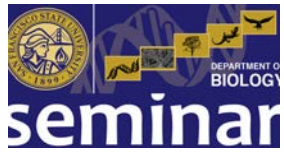
Wednesday, 9/27/17
Bay Conference Center, 3:30PM



Christopher Edwards
U.C. Santa Cruz
Coupled Biophysical Data Assimilation and its Application to the Recent Warm Blob and El Nino

<http://oceanmodeling.ucsc.edu/>

4



Thursday, 9/28/17
SCI 210, 2:10 pm

Biol 871 Colloquium in Microbiology, Cell & Molecular Biology

<http://biology.sfsu.edu/content/MCMB>



Hunter Fraser
Stanford University

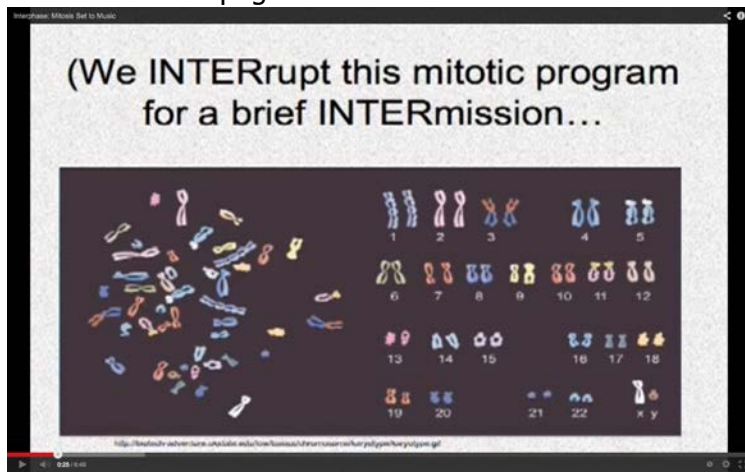
*Mapping human regulatory
variation*

<https://web.stanford.edu/~hbfraser/>

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Interphase: Mitosis set to Music

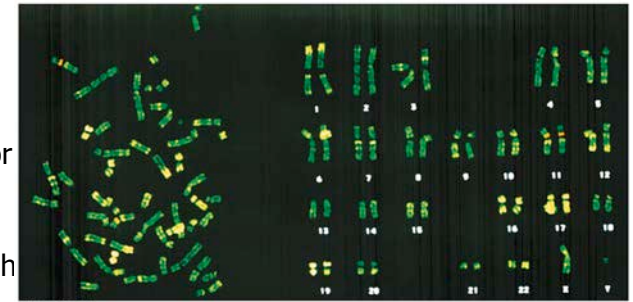
- Link on iLearn page



<https://www.youtube.com/watch?v=ODwt6OdN-8Y>

Even more chromosome terminology

- In **diploid** ($2n$) organisms, chromosomes occur in pairs, or **homologs**
- One homolog comes from each parent during fertilization



Human metaphase chromosomes and karyotype

- After meiosis, gametes are **haploid** (n) and contain one member of each homologous pair, either a maternal or paternal chromosome

See Table 2.1 - Haploid number for different organisms

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Figure 2.4

Clicker Question please think about this question and answer on your own

Which of the following statements (describing human chromosomes) do you agree with most?

- During G1 a chromosome contains 1 double helix of DNA.
- During G2, a chromosome contains 1 double helix of DNA.
- During M, a chromosome contains 1 double helix of DNA.
- None of the above

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Eukaryotic Cell Cycle - 1

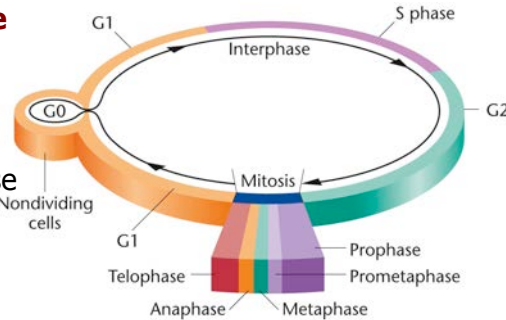
- **Mitosis and Interphase** (G1 - S - G2)

- **G1 phase**

- cell mass increases
- Preparation for S phase

- DNA is replicated during the **S phase** (DNA Synthesis)

- Each chromosome in the interphase nucleus is duplicated, generating two sister chromatids



- **G2 phase**

- Growth
- preparation for mitosis

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Figure 2.5

Eukaryotic Cell Cycle - 2

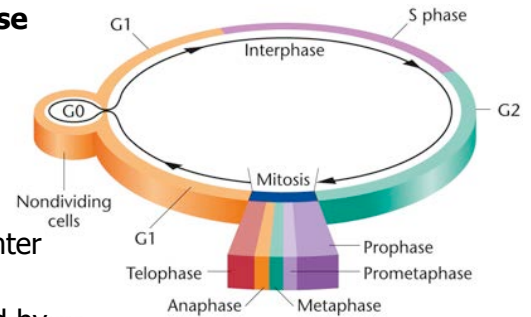
- **Mitosis and Interphase** (G1 - S - G2)

- **M phase** (Mitosis)

- sister chromatids separate from each other and enter the newly forming daughter cells

– **karyokinesis** followed by **cytokinesis**

- each cell receives a sister chromatid from each chromosome

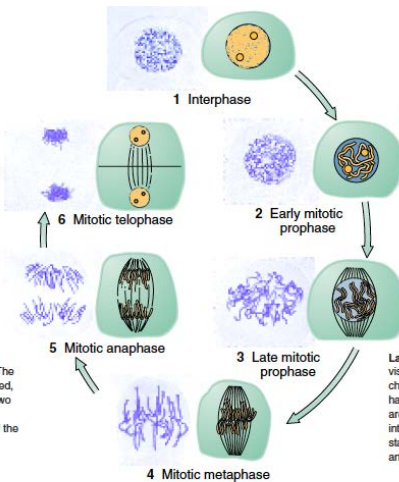


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Figure 2.5

Mitosis

Telophase. A nuclear membrane re-forms around each daughter nucleus, the chromosomes uncoil, and the nucleoli reappear—all of which effectively re-form interphase nuclei. By the end of telophase, the spindle has dispersed, and the cytoplasm has been divided into two by a new cell membrane.

Anaphase. The pairs of sister chromatids separate, one of a pair moving to each pole. The centromeres, which now appear to have divided, separate first. As each chromatid moves, its two arms appear to trail its centromere; a set of V-shaped structures results, with the points of the V's directed at the poles.



Metaphase. The nuclear spindle becomes prominent. The spindle is a birdcage-like structure that forms in the nuclear area; it consists of a series of parallel fibers that point to each of two cell poles. The chromosomes move to the equatorial plane of the cell, where the centromeres become attached to a spindle fiber from each pole.

Early prophase. The chromosomes become distinct for the first time. They get progressively shorter through a process of contraction, or condensation, into a series of spirals or coils; the coiling produces structures that are more easily moved.

Late prophase. As the chromosomes become visible, they appear double-stranded, each chromosome being composed of two longitudinal halves called chromatids. These "sister" chromatids are joined at the centromere. The nucleoli—large intranuclear spherical structures—disappear at this stage. The nuclear membrane begins to break down, and the nucleoplasm and cytoplasm become one.

- Figure 3-3 from Griffiths textbook
- The photographs show nuclei of root-tip cells of *Lilium regale*.

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Figure 3-3

Interphase

- Chromosomes are not distinct
- The **centrosome** which contains the **centrioles** in animal cells is duplicated during **S phase**
 - each centrosome copy acts as a **microtubule organizing center** and functions as the spindle pole during mitosis
 - pair of **centrioles** at the center replicate and eventually separate as microtubules radiate outwardly, forming an aster

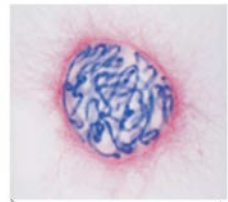


(a) Interphase

Chromosomes are extended and uncoiled, forming chromatin

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Figure 2.7a



(b) Prophase

Chromosomes coil up and condense; centrioles divide and move apart

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Prophase

- the two centrosomes (centrioles) move to opposite poles of the cells
- replicated chromosomes begin condensing so that by late prophase they are highly condensed and **sister chromatids** become visible
- The nuclear membrane fragments and the nucleolus disperses

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Figure 2.7b



(c) Prometaphase

Chromosomes are clearly double structures; centrioles reach the opposite poles; spindle fibers form

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Prometaphase & Metaphase

- During **prometaphase**, microtubules attach to the **kinetochores** at the centromeres to guide sister chromatid separation
- fully condensed chromosomes *move* to the metaphase plate
- During **metaphase**, chromosomes are lined up on the central equatorial plates between the centrosome poles



(d) Metaphase

Centromeres align on metaphase plate

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Figure 2.7c and 2.7d

Anaphase

- DISJUNCTION** - centromeres "split" and each carries a sister chromatid to opposite poles of the cell via microtubule shortening
- each chromatid is also now a chromosome so...
 - At this point, the mitotic cell has "doubled" its chromosome number



(e) Anaphase

Centromeres split and daughter chromosomes migrate to opposite poles

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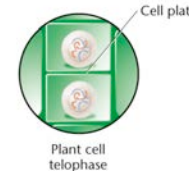
Figure 2.7e



(f) Telophase

Daughter chromosomes arrive at the poles; cytokinesis commences

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Plant cell telophase

Do these daughter cells carry identical chromosomes?

Telophase

- Chromosome movement ceases at each pole
- Microtubules disassemble
- Nuclear membrane reforms and nucleolus reappears
- Chromosomes decondense
- cell completes division by separating into two daughter cells via **cytokinesis**
- gradual midline constriction in most cells, but in plant cells with rigid cell walls a cell plate forms between daughters
- The 2 cells have now entered G1 and interphase

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Figure 2.7f

Mitosis & Meiosis questions - 1

1. A diploid cell has 6 chromosomes.

During mitosis, how many chromosomes are observed during anaphase?

- A. 3
- B. 6
- C. 12
- D. 24

Answer independently

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Mitosis & Meiosis questions - 2

Answer independently

2. A diploid cell has 6 chromosomes.

During meiosis, how many chromosomes are observed during anaphase I?

- A. 3
- B. 6
- C. 12
- D. 24

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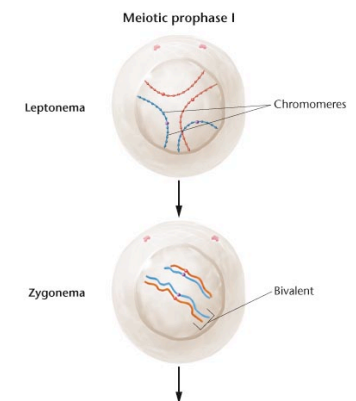
Prophase I

- Leptonema or leptotene stage
- Zygonema or zygotene stage
- Pachynema or pachytene stage
- Diplonema or diplotene stage
- Diakinesis or diakinetik stage
- "Lazy zebras ponder dire disasters"
- Lazy zebras ponder diplomatic disasters"
- Large Zippers Put Digits in Danger

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Meiosis I: Prophase I...(a)

- 1. **Leptonema**: Replicated chromosomes appear as a single threadlike structure
- 2. **Zygonema**: chromosomes continue condensing and homologs pair to form **bivalents**
 - ladder-like structure called the **synaptonemal complex (SC)** starts to form



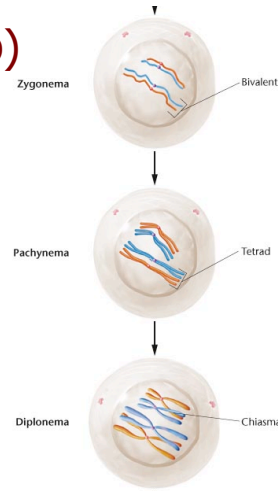
Note: mechanism for homolog pairing is unclear, initial pairing is not dependent on microtubules

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Klug 10th edition, Figure 2.10

Meiosis I: Prophase I...(b)

- 3. **Pachynema**: pairing at various sites is called **synapsis**
 - SC further develops and paired homologs (**tetrads**) resolve into a pair of recognizable replicated chromosomes, each containing a pair of sister chromatids
 - crossing over occurs between chromatids
- 4. **Diplonema**: Homologs desynapse and repel from each other but remain attached at the chiasmata (evidence of crossing over)

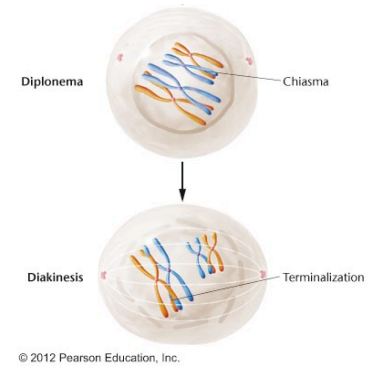


In human female fetuses, about 400,000 immature eggs or oocytes arrest at this stage until puberty when one egg continues through meiosis during each menstrual cycle

Klug 10th edition, Figure 2.10

Meiosis I: Prophase I...(c)

- 5. **Diakinesis**: Homologs pull further apart but retain chiasmata
 - Chiasmata move toward ends of tetrads (**terminalization** initiated in diplonema completes in diakinesis)
 - the nuclear membrane and nucleolus disperse
 - microtubules from the centrosomes attach to the kinetochore



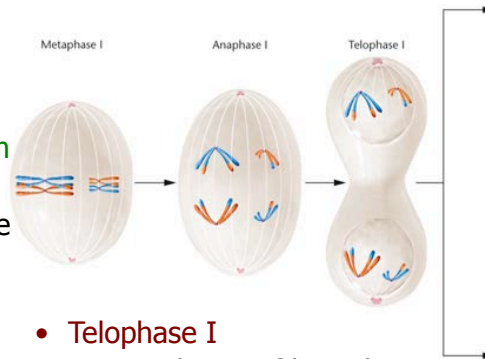
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Klug 10th edition, Figure 2.10

- **Metaphase I**
 - condensed homolog pairs lined up on opposite sides of the equatorial plate
- **Anaphase I**
 - **Chromosome disjunction**
 - homologs separate and move to opposite poles
 - centromeres do not divide so each homolog still contains a pair of sister chromatids

Meiosis I: M-A-T



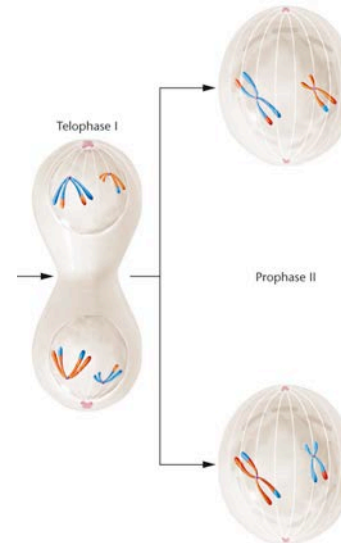
- **Telophase I**
 - completion of homolog movement to opposite poles
 - reformation of nucleolus and the nuclear membrane

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Klug, 10th ed. Figure 2.11

Note: If one pole sends microtubules and attaches to the centromeres of both sisters in one homolog, AND the microtubules are pulling that homolog to one pole...why do the two homologs stay at the metaphase plate? The chiasmata remaining after crossing over may help keep the homologs at the metaphase plate, until anaphase I.

Meiosis I --> Meiosis II



- **Cytokinesis**
 - cells have entered G1 of interphase II
 - there is **no replication** of DNA
 - each chromosome already contains a pair of sister chromatids
- **Are these sister chromatids identical?**

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Klug, 10th ed. Figure 2.11