10	4/23	Reproduction & Inheritance	潘建源	8~9
11	4/30	Gene and How genes are controlled	潘建源	10~11
12	5/07	DNA technology **Unit II Cellular Reproduction and Genetics**	潘建源	12
13	5/14	Animal Diversity	潘建源	18~19
14	**5/21**	**Mid-term Exam II 9:10~10:20 範圍：10-13th weeks**		
14	**5/21**	Animals: Form & Function I 10:30 ~ 12:10	潘建源	20, 26
15	5/28	Animals: Form & Function II **Unit IV Animal Physiology**	潘建源	28~29
16	6/04	Animals: Form & Function III	潘建源	23~24
17	6/11	Animals: Form & Function IV	潘建源	27
18	**6/18**	**FINAL EXAM 9:10~10:40 範圍：5/29 ~ 6/19**		

考試方式: 1. 40 題選擇，每題2分；2. 報告 20分

報告

1. 繳交期限

Exam II: **107.5.26 (Sun.) 9:00 p.m.**

Final Exam: **107.6.23 (Sun.) 9:00 p.m.**

遲交拒收！！！

2. 由National Public Radio (http://www.npr.org/)或British Broadcasting Corporation (www.bbc.com)中，選一篇最近一年內與該次考試範圍相關的報導進行撰寫。內容包括：

i. 該文章題目與網址　　ii. 文章大意

iii. 與課程內容相關之處　　iv. 個人感想

12號字，單行，不附圖，共**A4一頁**。不准超過！

WORD or PDF file (PDF preferred)

First U.S. Patients Treated With CRISPR As Human Gene-Editing Trials Get Underway April 16, 201911:01 AM ET
https://www.npr.org/sections/health-shots/2019/04/16/712402435/first-u-s-patients-treated-with-crispr-as-gene-editing-human-trials-get-underway

Ketamine May Relieve Depression By Repairing Damaged Brain Circuits April 11, 20192:01 PM ET
https://www.npr.org/sections/health-shots/2019/04/11/712295937/ketamine-may-relieve-depression-by-repairing-damaged-brain-circuits

As Weeds Outsmart The Latest Weedkillers, Farmers Are Running Out Of Easy Options April 11, 20195:12 AM ET
https://www.npr.org/sections/thesalt/2019/04/11/710229186/as-weeds-outsmart-the-latest-weedkillers-farmers-are-running-out-of-options

Ancient Bones And Teeth Found In A Philippine Cave May Rewrite Human History April 10, 20191:24 PM ET
https://www.npr.org/sections/health-shots/2019/04/10/710278943/ancient-bones-and-teeth-found-in-a-philippines-cave-may-rewrite-human-history

生技醫療發表會壓軸保瑞、皇將、醫揚聚焦營運展望

中時電子報 (新聞發布) - 2019年4月15日

櫃買中心系列主題「櫃買市場業績發表會」，今（16）日「生技醫療（二）」主題業績發表會壓軸登場，由保瑞藥業（6472）、皇將（4744）、及醫揚（6569）等 ...

保瑞雙喜營運吃補

經濟日報 (新聞發布) - 2019年4月16日

經濟日報 (新聞發布)

保瑞、醫揚看好今年營運

深入報導 - 自由時報電子報 - 2019年4月16日

查看全部

創業之星複賽開打生技醫療業好熱門

經濟日報 (新聞發布) - 2019年4月11日

第三屆創業之星複賽今（11）日展開，30組新創團隊互相較勁，特別的是，這次生技醫療產業紛紛冒出頭，複賽有8家業者來自生技醫療產業，且多半 ...

udn 聯合新聞網

智慧科技、生技醫療業績發表會下周壓軸登場

中時電子報 (新聞發布) - 2019年4月10日

另鑑於生技醫療產業為櫃買中心長期推動的特色產業，且衡酌該產業107年度營收成長且整體類股獲利成長近2倍，櫃買中心特別為該類股加碼推出4 ...

櫃買中心4/15、16舉辦以智慧科技、生技醫療為主題之業績發表會

Yahoo奇摩股市 (新聞發布) - 2019年4月10日

查看全部

基因治療進入發展期醫療生技股長線值得期待

經濟日報 (新聞發布) - 2019年4月15日

今年年初，全球生物製藥公司必治妥施貴寶宣佈以740億美元收購生技公司Celgene，成為製藥業史上規模數一數二的併購交易，令市場驚嘆。但只要 ...

潘建源 Chien-Yuan Pan
生命科學系
神經細胞生理研究室
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33662452
cypan@ntu.edu.tw

Chapter 8

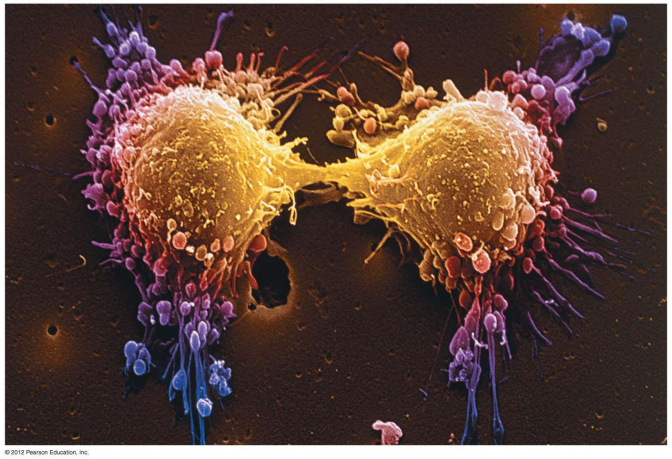
The Cellular Basis of Reproduction and Inheritance

PowerPoint Lectures

***Campbell Biology: Concepts & Connections,* 8th Edition, Global Edition**

REECE • TAYLOR • SIMON • DICKEY • HOGAN

Introduction



- Cancer cells
  - start out as normal body cells,
  - undergo genetic mutations,
  - lose the ability to control the tempo of their own division,
  - run amok, causing disease. 瘋狂地
- Cancer therapy seeks to disrupt one or more steps in cell division.
- In a healthy body, cell division allows for
  - growth,
  - the replacement of damaged cells, and
  - development from an embryo into an adult.
- In sexually reproducing organisms, eggs and sperm result from: mitosis and meiosis.

Can cancer therapy be personalized?

If mammogram (breast X-ray) revealed DCIS (ductal carcinoma *in situ)*: stage 0 breast cancer, not invasive yet

Options: lumpectomy, single or double mastectomy, radiation therapy, cancer drugs …

What does it means for cells to be cancerous?

Mammograms uncover 60,000 cases in US each year; how do patients decide?

Uncontrolled cell division

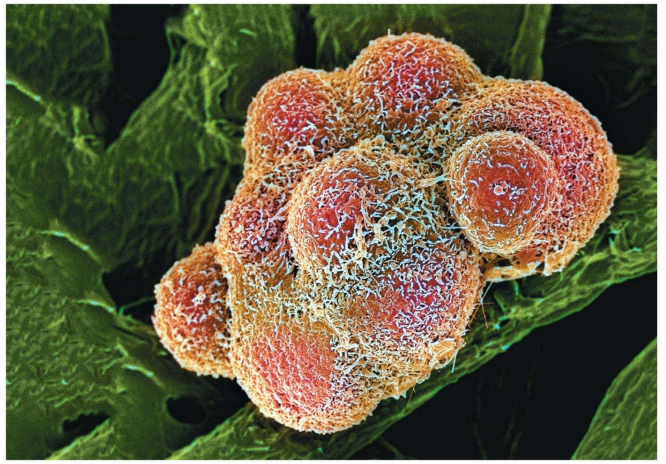
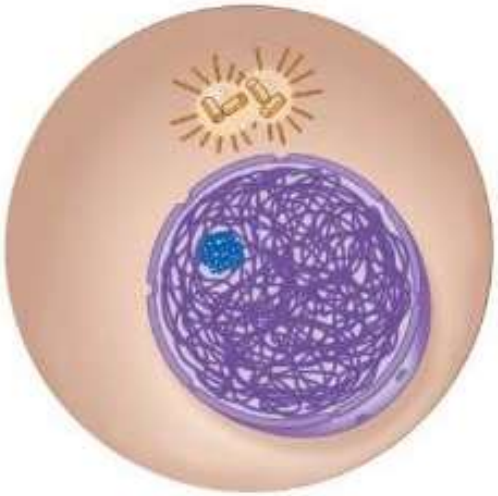
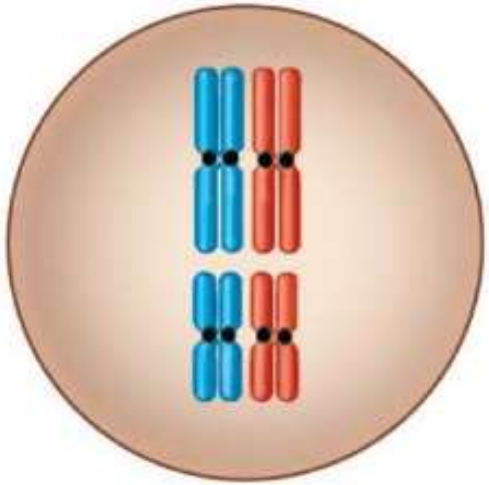


Figure 8.0_0 Can cancer therapy be personalized?

Cell Division and Reproduction 8.1-8.2



The Eukaryotic Cell Cycle and Mitosis 8.3-8.10



Meiosis and Crossing Over 8.11-8.17

Alterations of Chromosome Number and Structure 8.18-8.23

CELL DIVISION AND REPRODUCTION

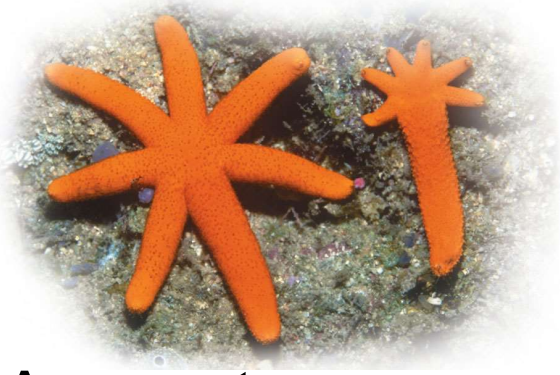
8.1 Cell division plays many important roles in the lives of organisms

- Organisms reproduce their own kind, a key characteristic of life.
- Cell division
  - is reproduction at the cellular level,
  - produces two "daughter" cells that are genetically identical to each other and the original "parent" cell,
  - requires the duplication of **chromosomes**, the structures that contain most of the cell's DNA, and
  - sorts new sets of chromosomes into the resulting pair of daughter cells.
- Cell division is used
  - for reproduction of single-celled organisms,
  - growth of multicellular organisms from a fertilized egg into an adult,
  - repair and replacement of cells, and
  - sperm and egg production.

8.1 Cell division plays many important roles in the lives of organisms

- Living organisms reproduce by two methods.
  - **Asexual reproduction** 無性生殖
    - produces offspring that are identical to the original cell or organism and
    - involves inheritance of all genes from one parent.
  - **Sexual reproduction**
    - produces offspring that are similar to the parents, but show variations in traits and
    - involves inheritance of unique sets of genes from two parents.

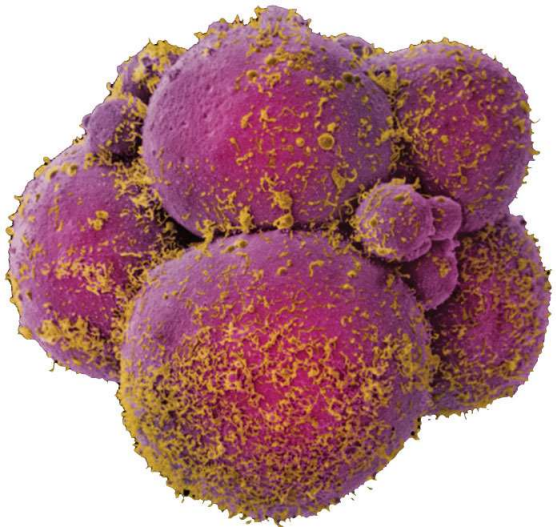
Yeast division



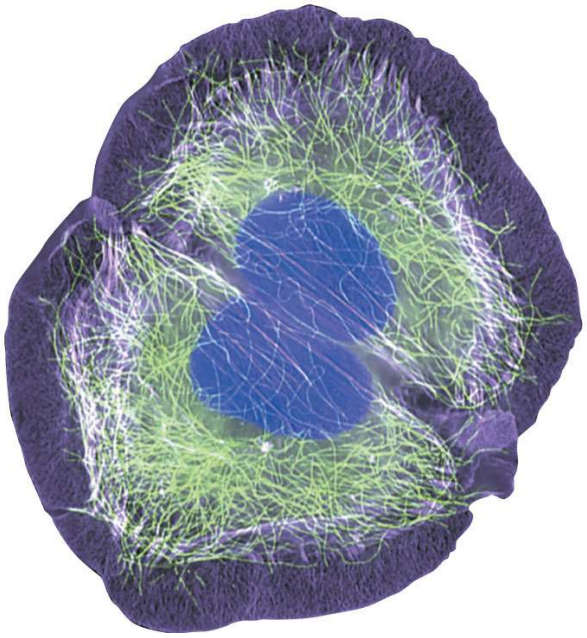
A sea star reproducing asexually

An African violet 非洲堇 reproducing asexually from a cutting

Sexually reproduction offspring with unique **combination** of genes



Dividing cells in an early human embryo

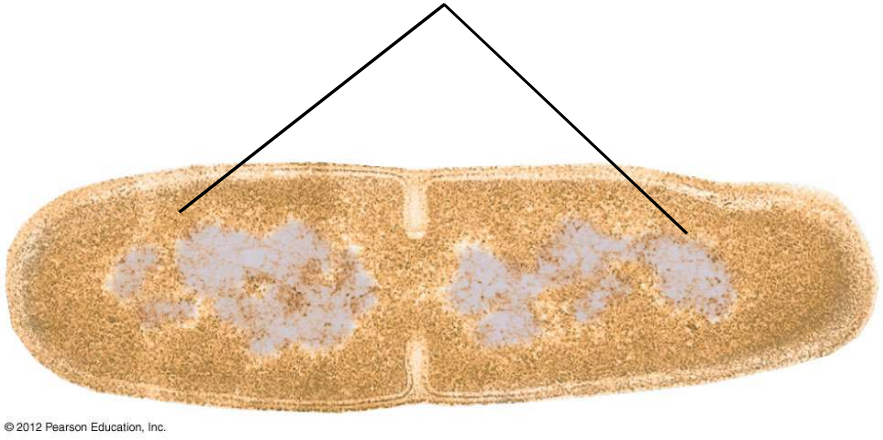


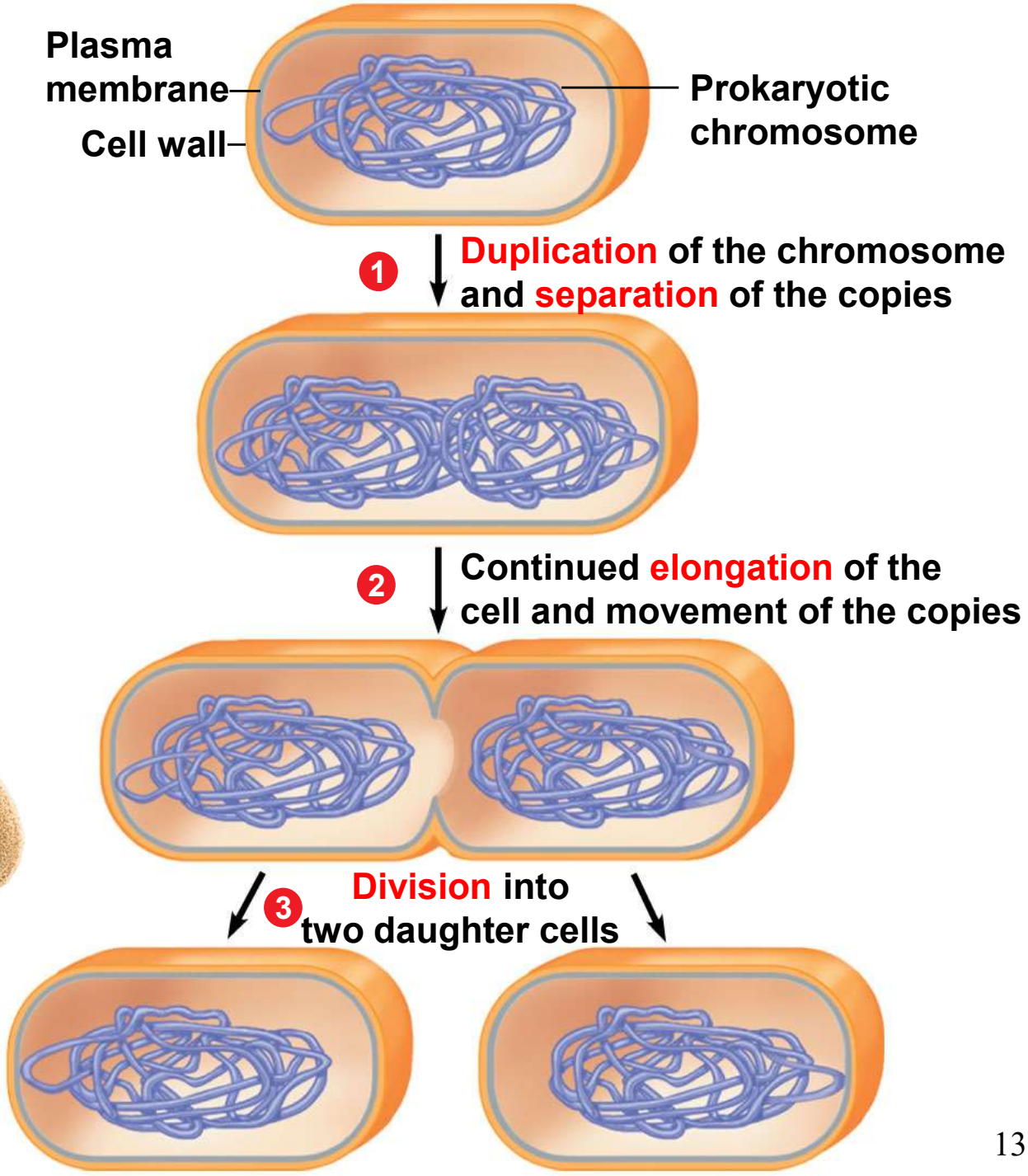
A human kidney cell dividing

8.2 Prokaryotes reproduce by binary fission

原核生物

singular **circular** DNA



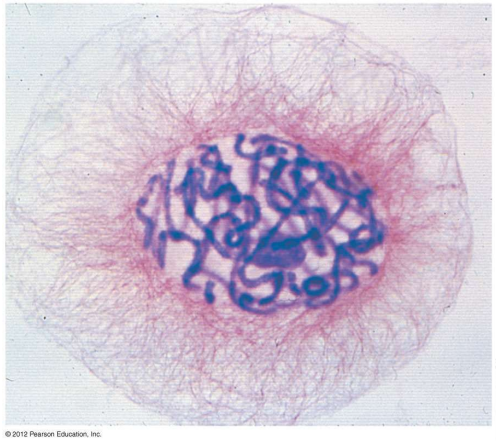


- Prokaryotes (single-celled bacteria and archaea) reproduce by **binary fission** ("dividing in half").
- The chromosome of a prokaryote is typically
  - a single circular DNA molecule associated with proteins and
  - much smaller than those of eukaryotes.
- Binary fission of a prokaryote occurs in three stages:
  1. duplication of the chromosome and separation of the copies,
  2. continued elongation of the cell and movement of the copies, and
  3. division into two daughter cells.

THE EUKARYOTIC CELL CYCLE AND MITOSIS

8.3 The large, complex chromosomes of eukaryotes duplicate with each cell division

- Eukaryotic cells
  - are more complex and larger than prokaryotic cells,
  - have more genes, and
  - store most of their genes on multiple chromosomes
- Each eukaryotic species has a characteristic number of chromosomes in each cell nucleus.
- Eukaryotic chromosomes are composed of **chromatin** 染色質/絲 consisting of
  - one long DNA molecule and
  - proteins that help maintain the chromosome structure and control the activity of its genes.
- To prepare for division, the chromatin becomes
  - highly compact and
  - visible with a microscope.

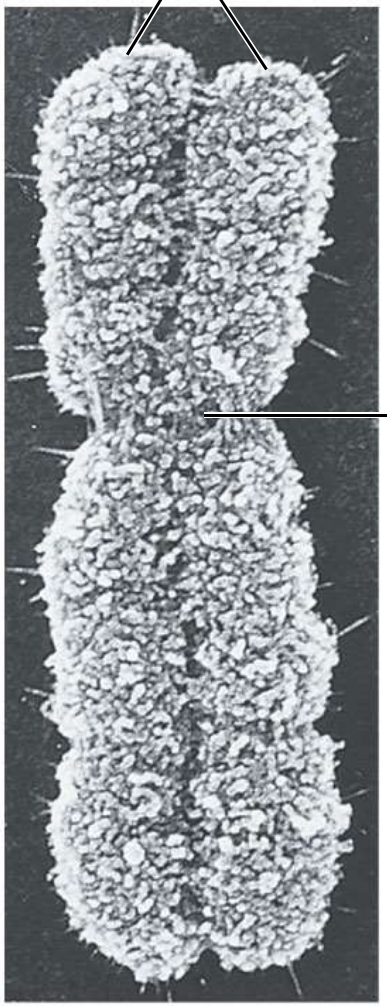


Chromosomes

DNA molecules

染色體

Sister chromatids



Chromosome duplication

Centromere

著絲粒

Sister chromatids

染色單體

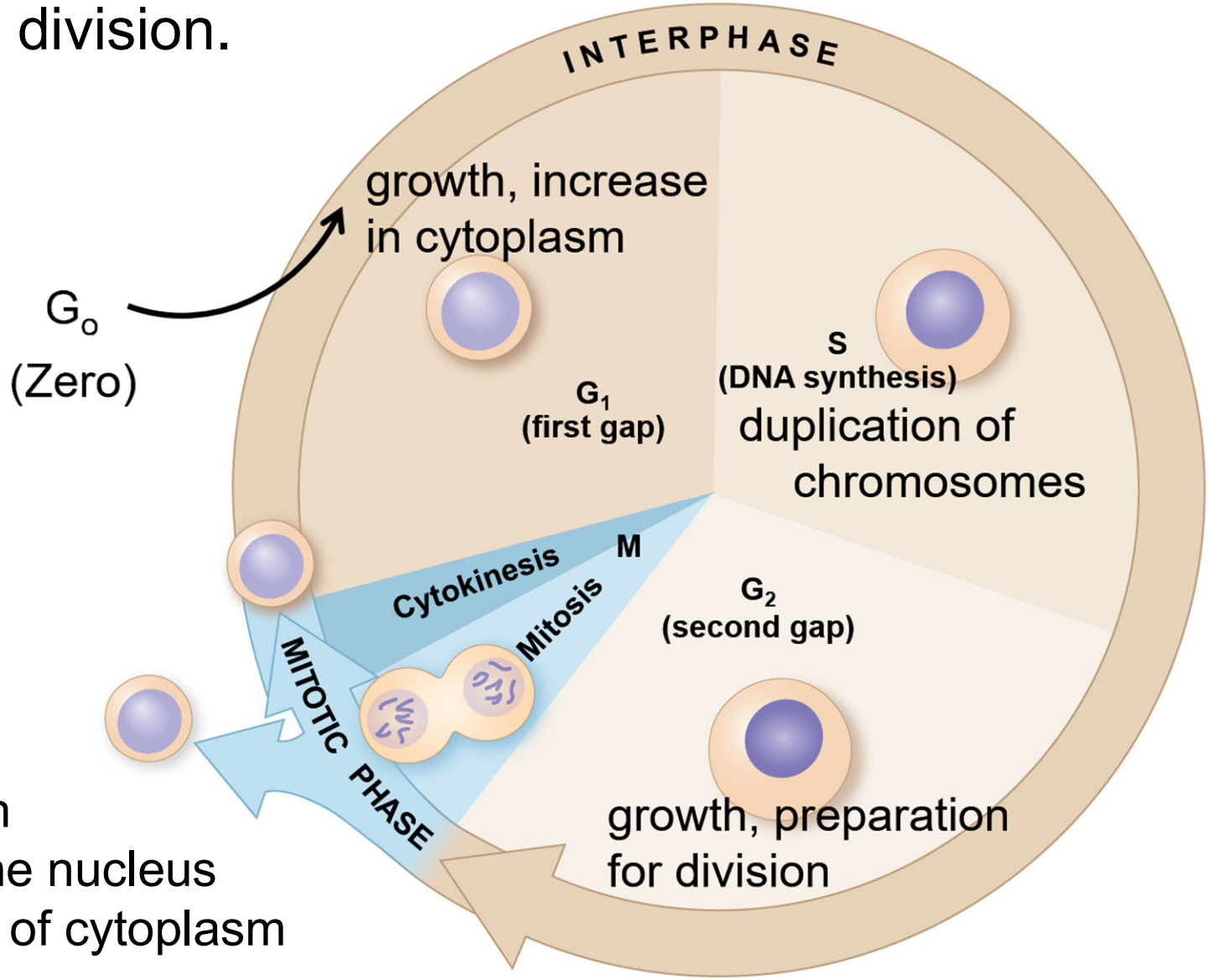
Chromosome distribution to the daughter cells

8.3 The large, complex chromosomes of eukaryotes duplicate with each cell division

- Before a eukaryotic cell begins to divide, it duplicates all of its chromosomes, resulting in two copies called **sister chromatids**.
- The sister chromatids are joined together along their lengths and are cinched especially tightly at a narrowed "waist" called the **centromere**.
- When a cell divides, the sister chromatids
  - separate from each other and are then called chromosomes, and
  - sort into separate daughter cells.

8.4 The cell cycle multiplies cells

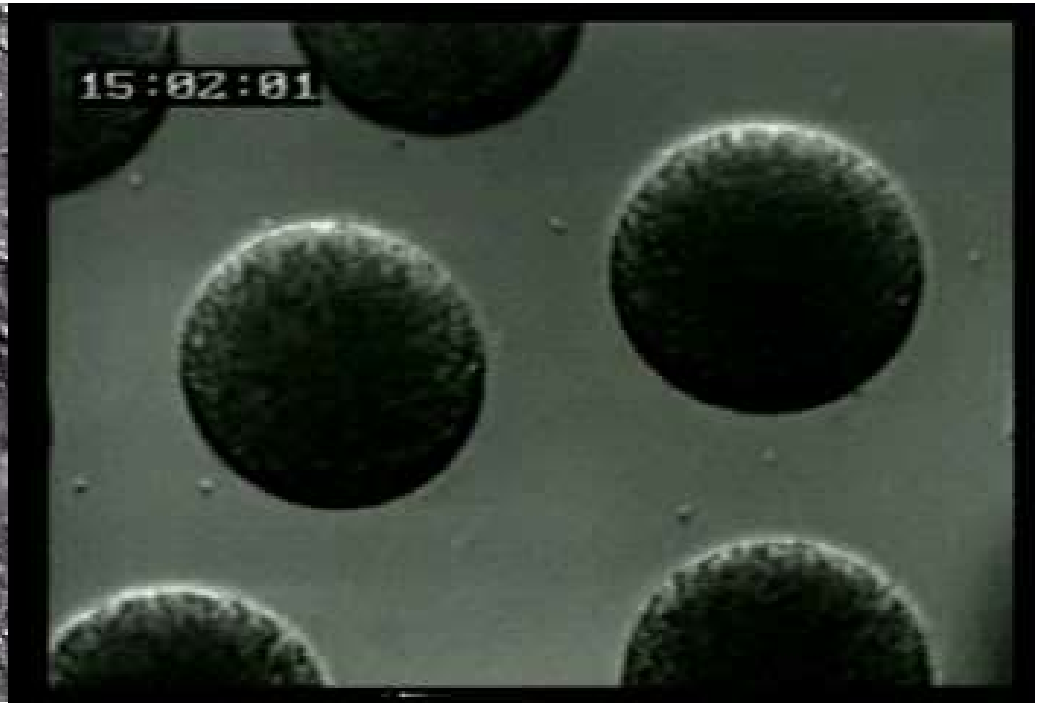
- The **cell cycle** is an ordered sequence of events that extends
  - from the time a cell is first formed from a dividing parent cell
  - until its own division.



Mitotic phase: division
Mitosis—division of the nucleus
Cytokinesis—division of cytoplasm

8.5 Cell division is a continuum of dynamic changes

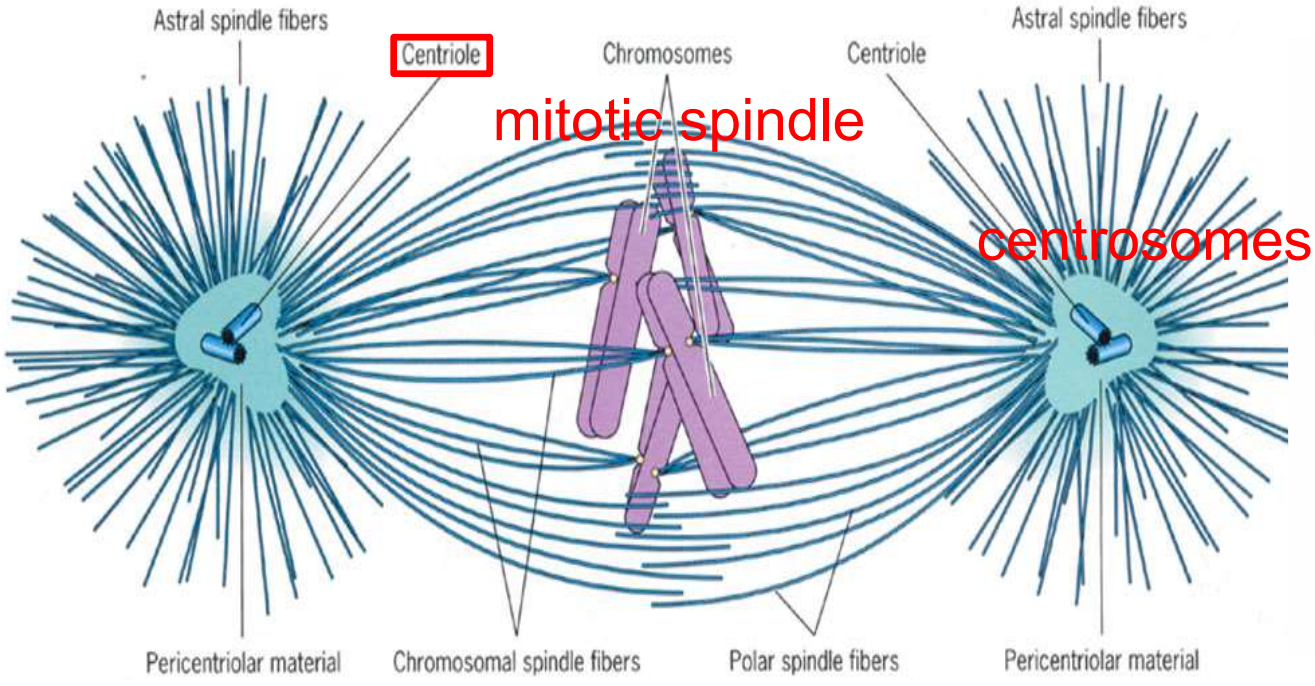
- Mitosis progresses through a series of stages:
  prophase, prometaphase, metaphase, anaphase, and telophase.
- Cytokinesis often overlaps telophase.
- A **mitotic spindle** 有絲分裂紡錘體
  - is required to divide the chromosomes,
  - guides the separation of the two sets of daughter chromosomes, and
  - is composed of microtubules 微管 and associated proteins.
- Spindle microtubules emerge from two **centrosomes**, 中心體 microtubule-organizing regions in the cytoplasm of eukaryotic cells.
  - produced by **centrosomes**, structures in the cytoplasm that
    - organize microtubule arrangement and
    - contain a pair of centrioles in animal cells. 中心粒



Video: Animal Mitosis

Use windows controls to play

Sea Urchin 海膽



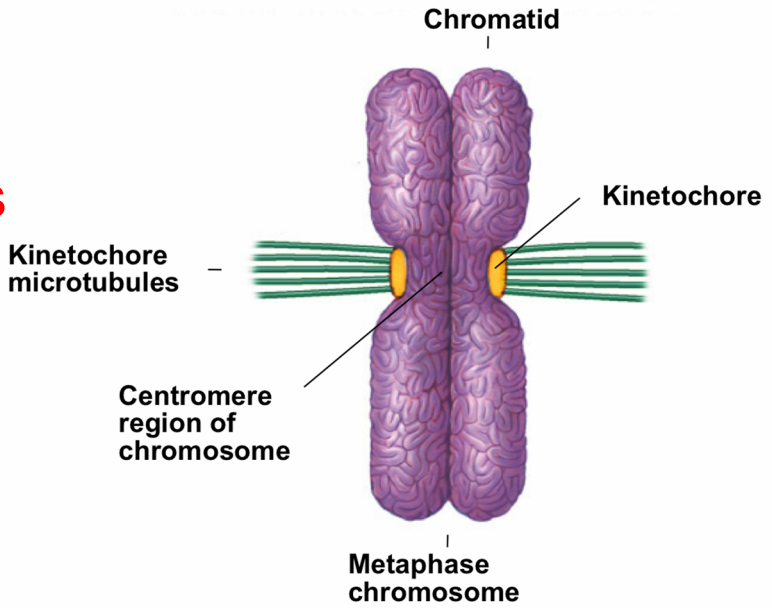


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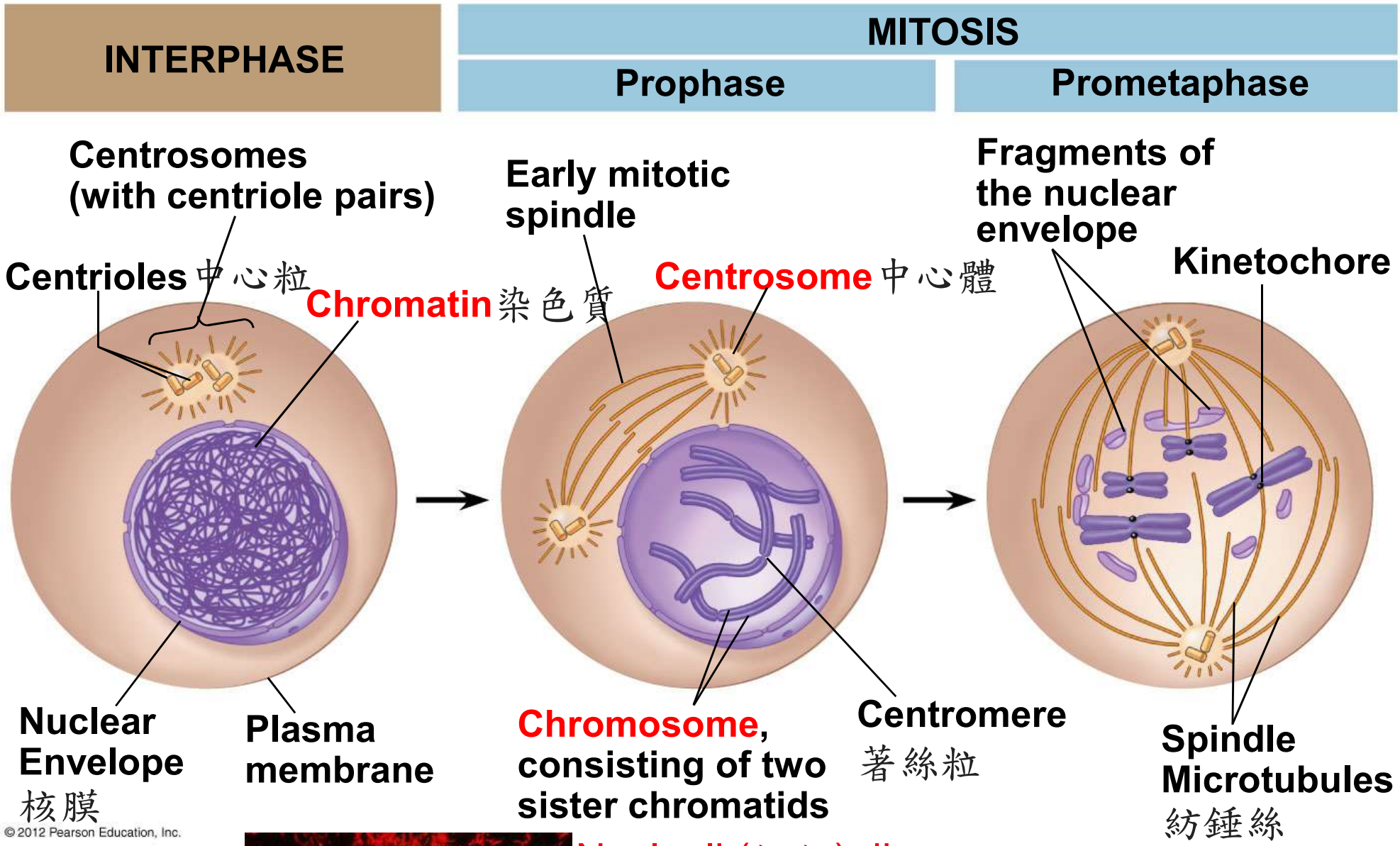
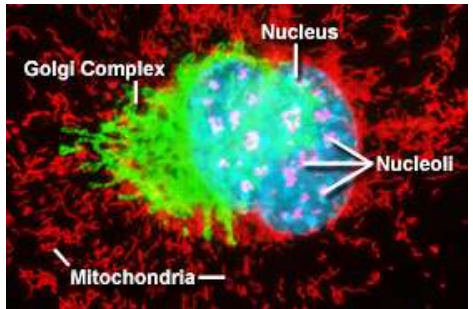
Figure 8.5_1





Nucleoli (核仁) disappear

8.5 Cell division is a continuum of dynamic changes

- Interphase
  - The cytoplasmic contents double,
  - two centrosomes form,
  - chromosomes duplicate in the nucleus during the S phase, and
  - nucleoli, sites of ribosome assembly, are visible.
- Prophase
  - In the nucleus, chromosomes become more tightly coiled and folded.
  - In the cytoplasm, the mitotic spindle begins to form as microtubules rapidly grow out from the centrosomes.
    - nucleoli disappear.

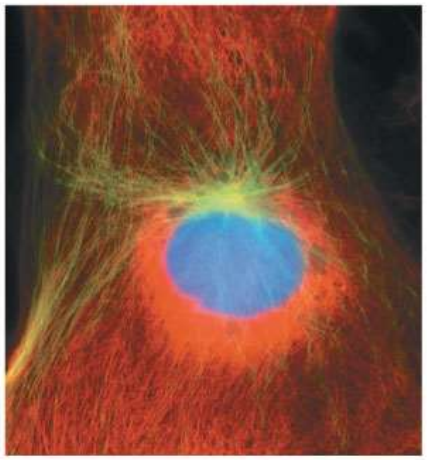
INTERPHASE

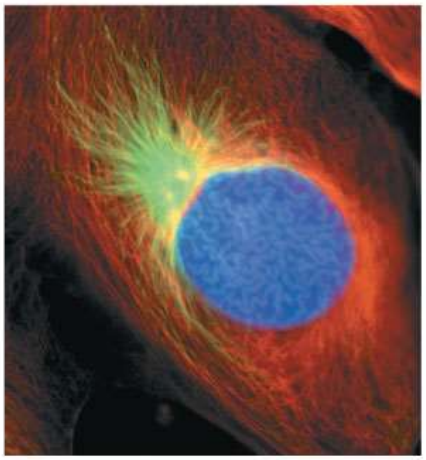
MITOSIS

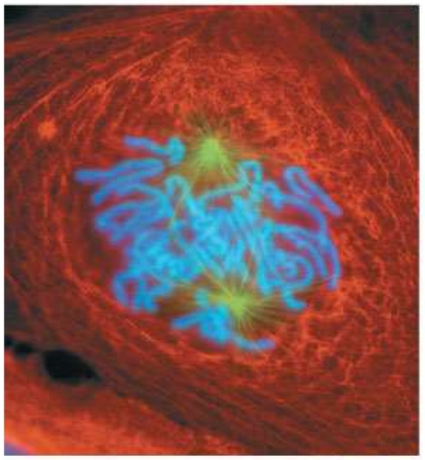
Prophase

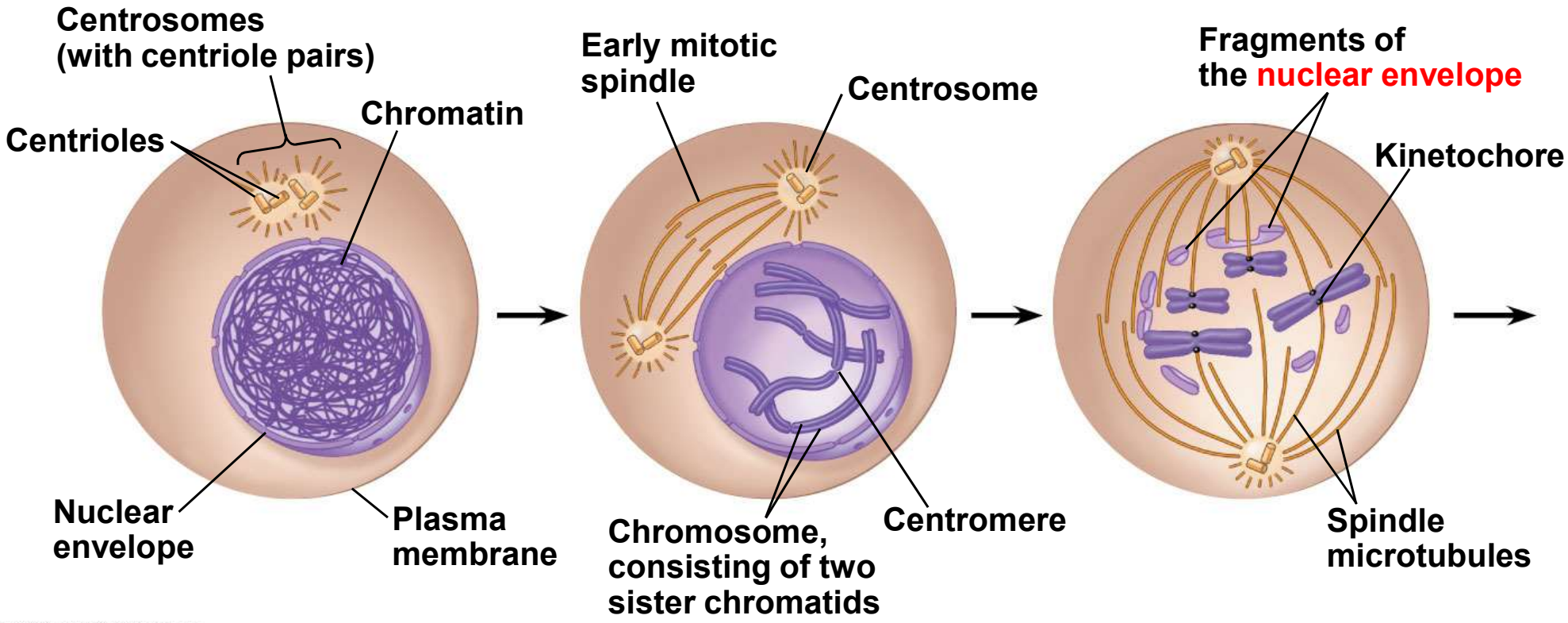
Prometaphase

Green:
微管
Blue:
DNA





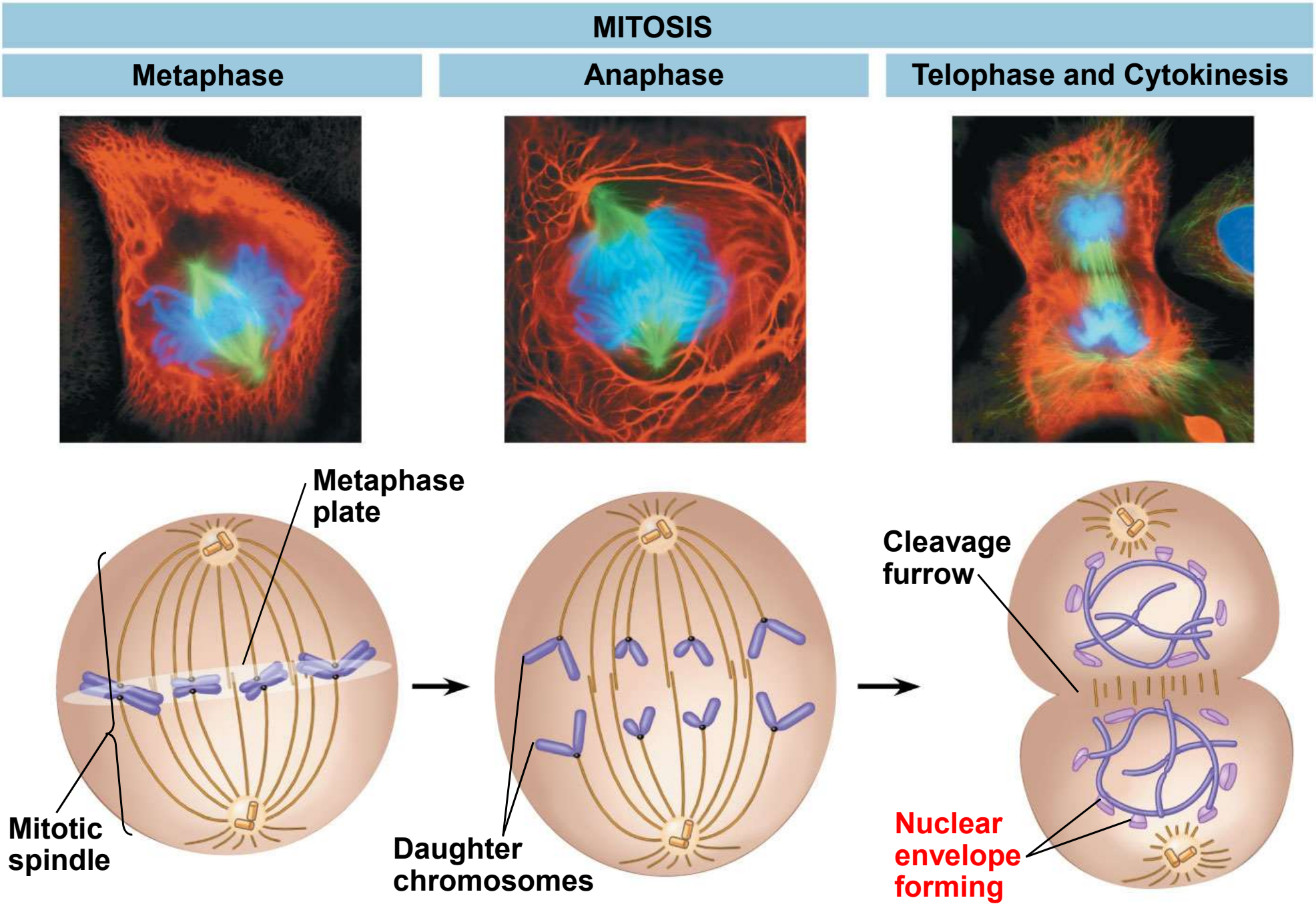




8.5 Cell division is a continuum of dynamic changes

- Prometaphase
  - The nuclear envelope breaks into fragments and disappears.
  - Microtubules extend from the centrosomes into the nuclear region.
  - Some spindle microtubules attach to the kinetochores.
  - Other microtubules meet those from the opposite poles.
- Metaphase
  - The mitotic spindle is fully formed.
  - Chromosomes align at the cell equator.
  - Kinetochores of sister chromatids are facing the opposite poles of the spindle.

Figure 8.5_right



nonkinetochore microtubule lengthen

8.5 Cell division is a continuum of dynamic changes

- **Anaphase**
  - Sister chromatids separate at the centromeres.
  - Daughter chromosomes are moved to opposite poles of the cell as motor proteins move the chromosomes along the spindle microtubules and kinetochore microtubules shorten.
  - Spindle microtubules not attached to chromosomes lengthen, moving the poles farther apart.
  - At the end of anaphase, the two ends of the cell have equal collections of chromosomes.
  - The cell elongates due to lengthening of nonkinetochore microtubules.

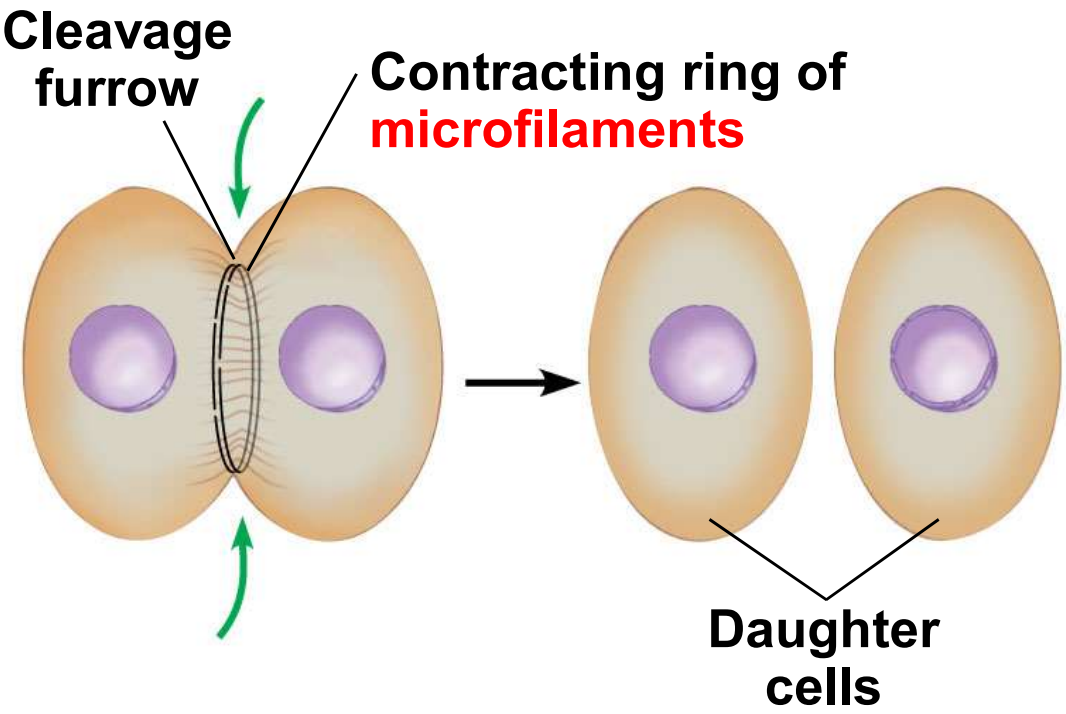
8.5 Cell division is a continuum of dynamic changes

- **Telophase**
  - The cell continues to elongate.
  - The nuclear envelope forms around chromosomes at each pole, establishing daughter nuclei.
  - Chromatin uncoils and nucleoli reappear.
  - The mitotic spindle disappears.
- During **cytokinesis**, the cytoplasm is divided into separate cells.
- Cytokinesis usually occurs simultaneously with telophase.

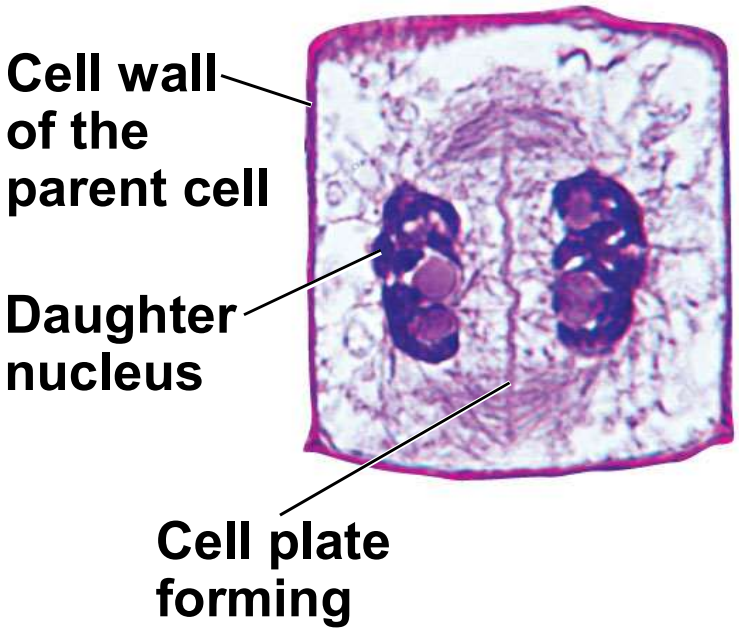
8.6 Cytokinesis differs for plant and animal cells

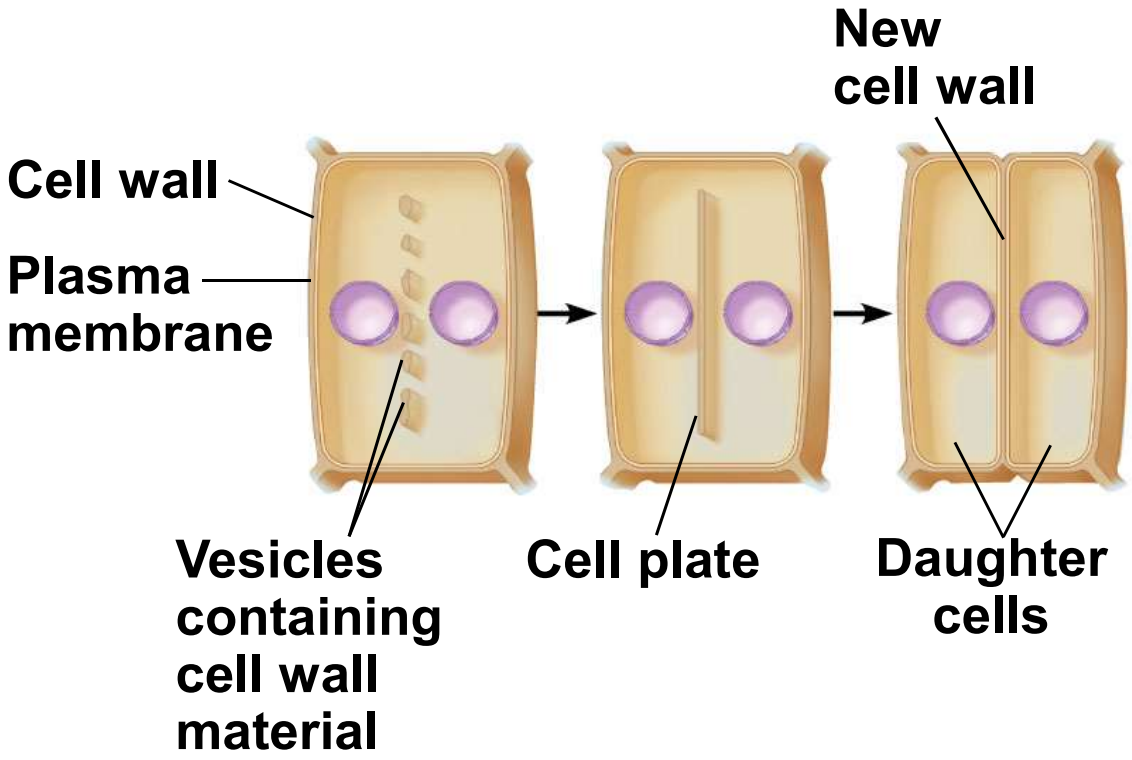
- In animal cells, cytokinesis occurs as
  1. a **cleavage furrow** forms from a contracting ring of microfilaments, interacting with myosin, and
  2. the cleavage furrow deepens to separate the contents into two cells.

Cytokinesis



Cytokinesis

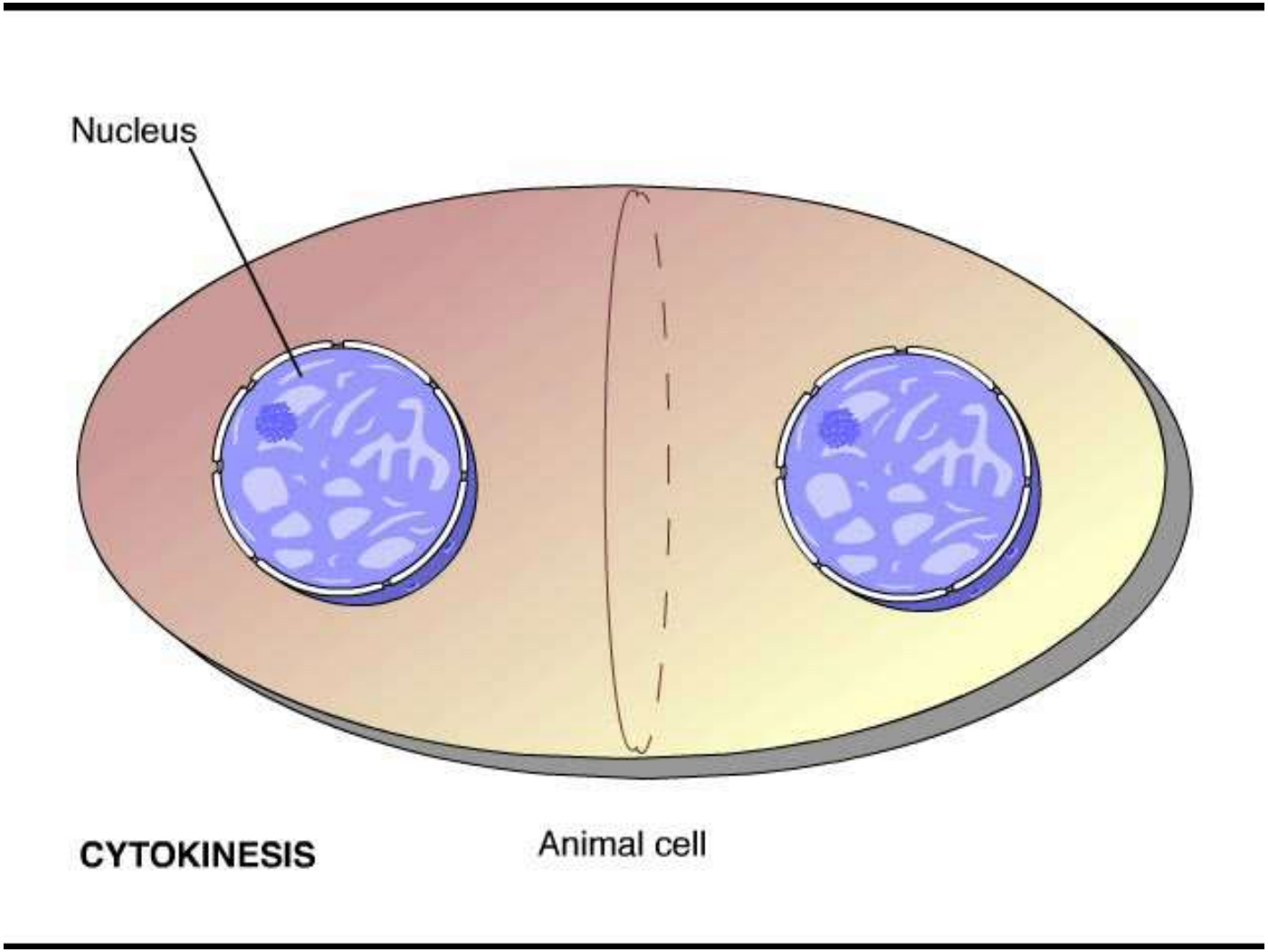




In plant cells, cytokinesis occurs as

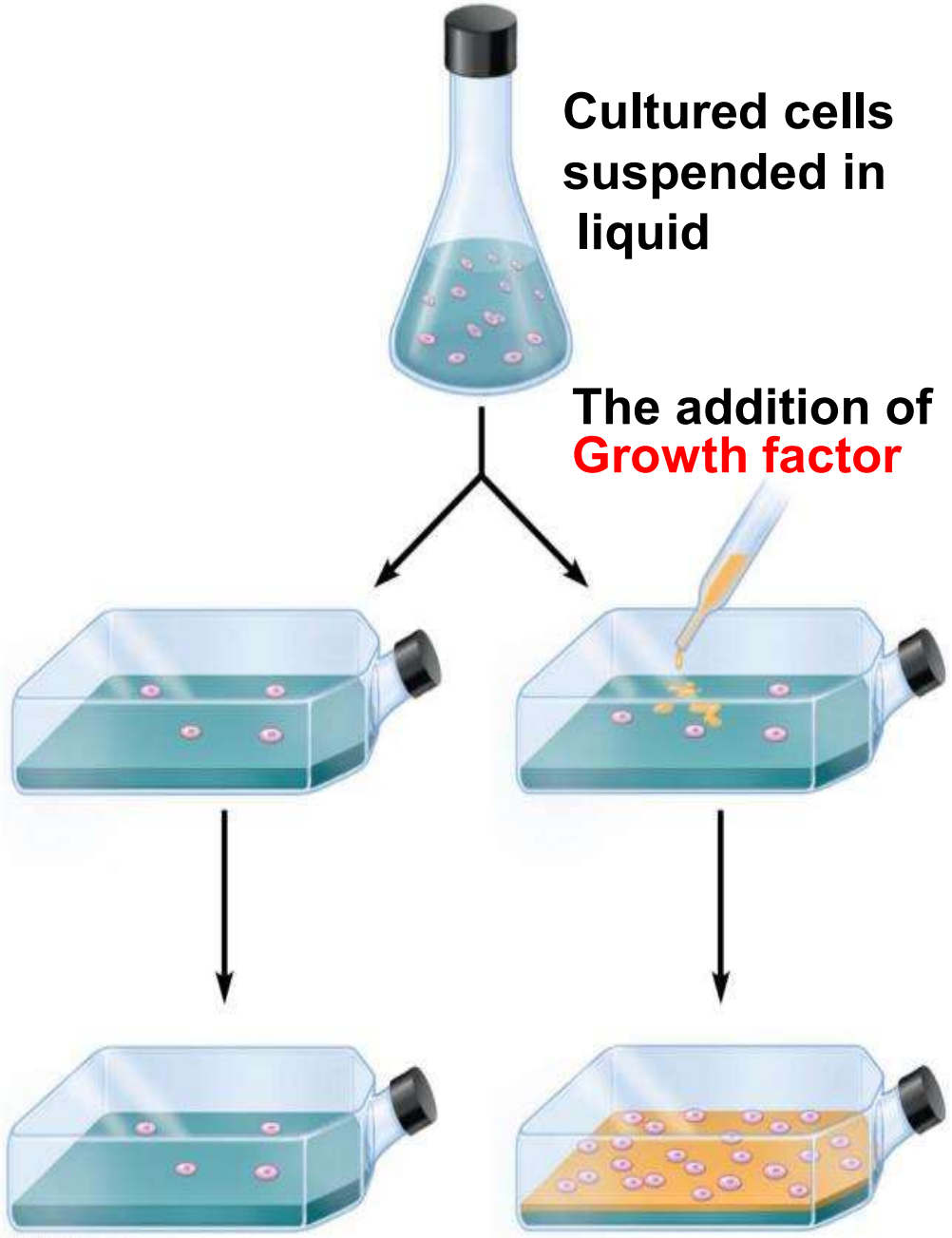
1. a **cell plate** forms in the middle, from vesicles containing cell wall material,
2. the cell plate grows outward to reach the edges, dividing the contents into two cells,
3. each cell now possesses a plasma membrane and cell wall.

Animation: Cytokinesis



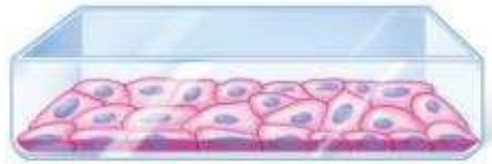
8.7 Anchorage, cell density, and chemical growth factors affect cell division

- The cells within an organism's body divide and develop at different rates.
- Cell division is controlled by
  - the presence of essential nutrients,
  - **growth factors**, proteins that stimulate division,
  - **density-dependent inhibition**, in which crowded cells stop dividing, and
  - **anchorage dependence**, the need for cells to be in contact with a solid surface to divide.

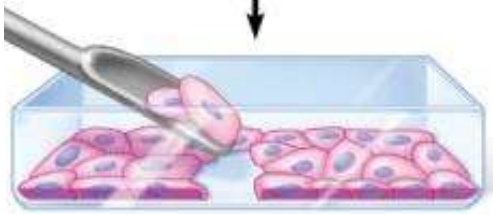


Anchorage

Density



Single layer of cells



Removal of cells

Restoration of Single layer by cell division

Cancer cells forming clump of overlapping cells

8.8 Growth factors signal the cell cycle control system

- The **cell cycle control system** is a cycling set of molecules in the cell that triggers and coordinates key events in the cell cycle.
- Checkpoints in the cell cycle can
  - stop an event or signal an event to proceed.
- There are three major checkpoints in the cell cycle.
  1. G_1 checkpoint
     - allows entry into the S phase or
     - causes the cell to leave the cycle, entering a nondividing G_0 phase.
  2. G_2 checkpoint, and
  3. M checkpoint.
- Research on the control of the cell cycle is one of the hottest areas in biology today.

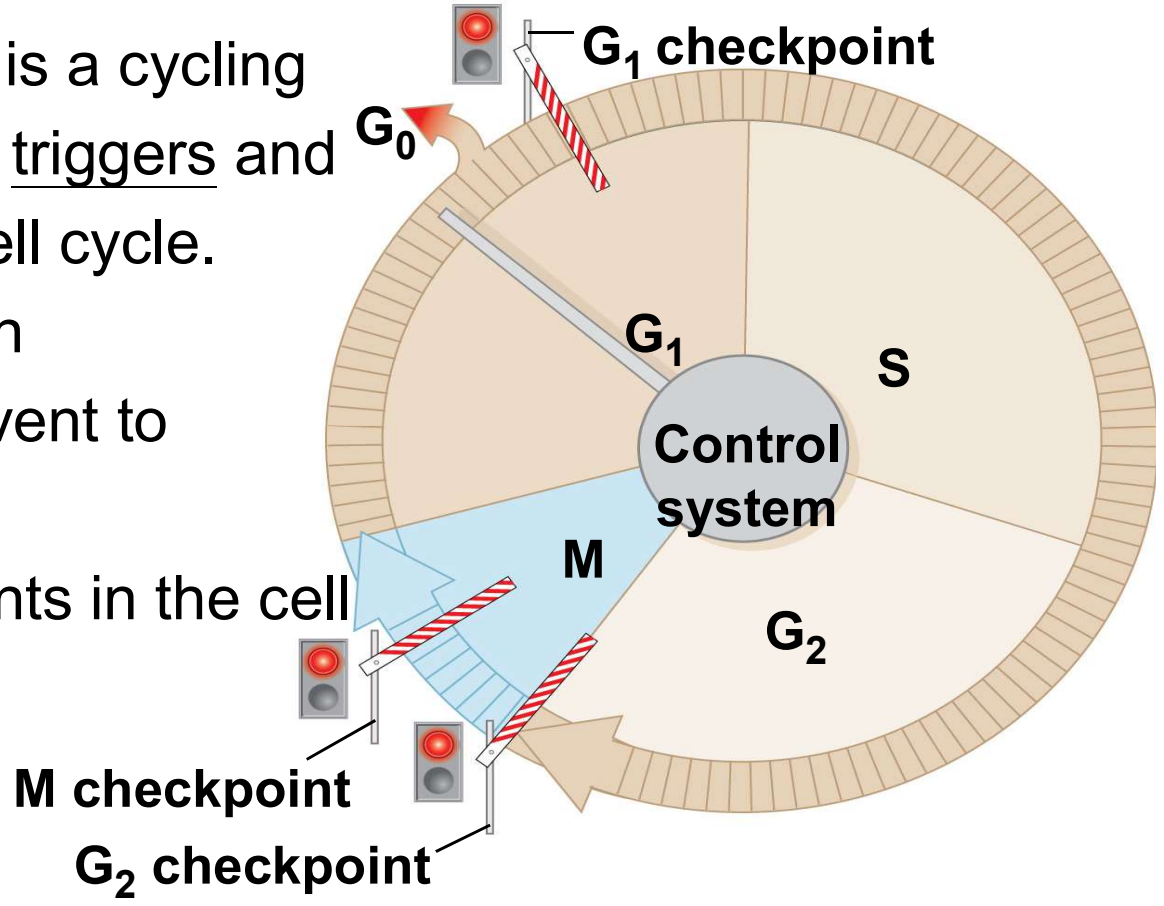
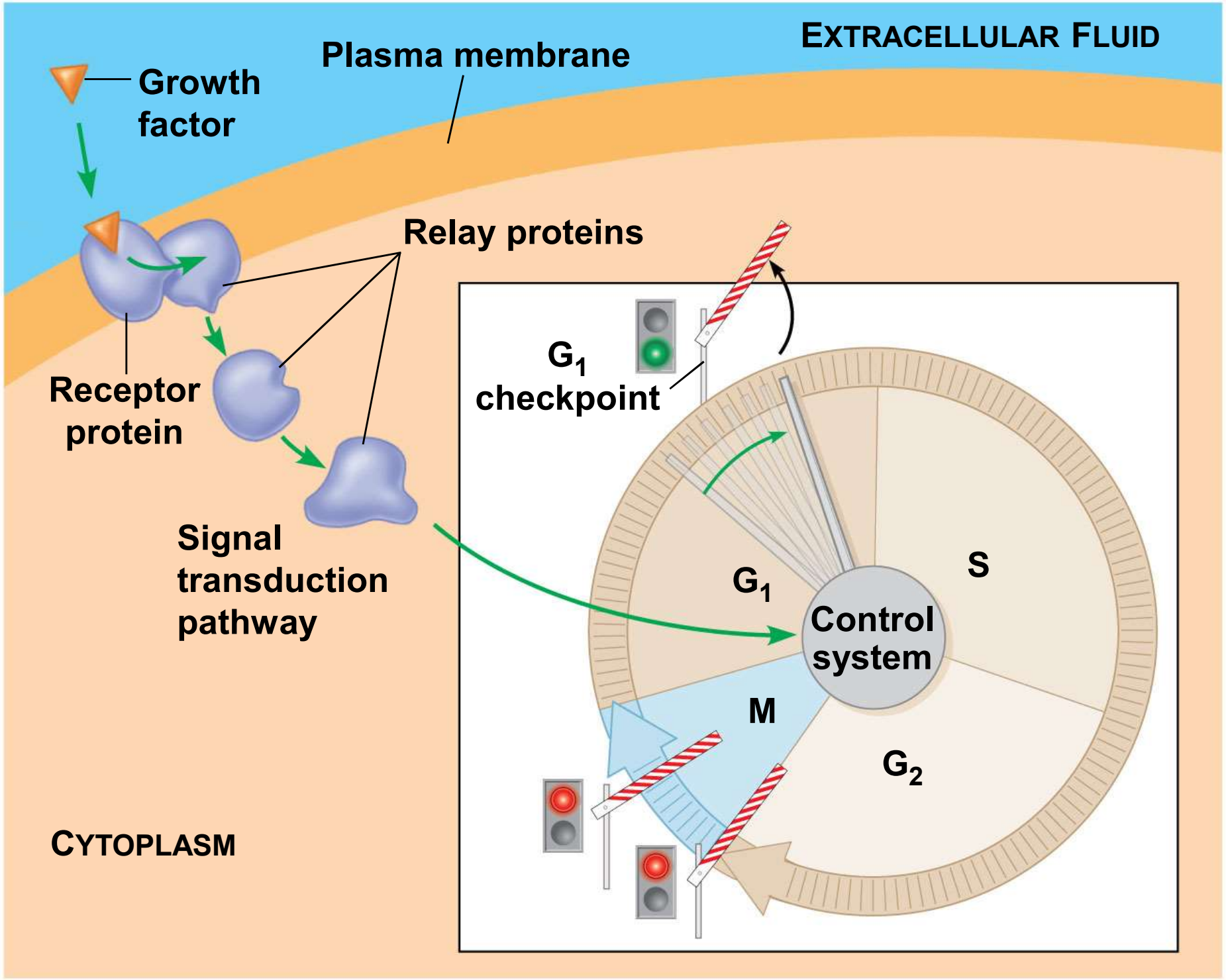


Figure 8.8B

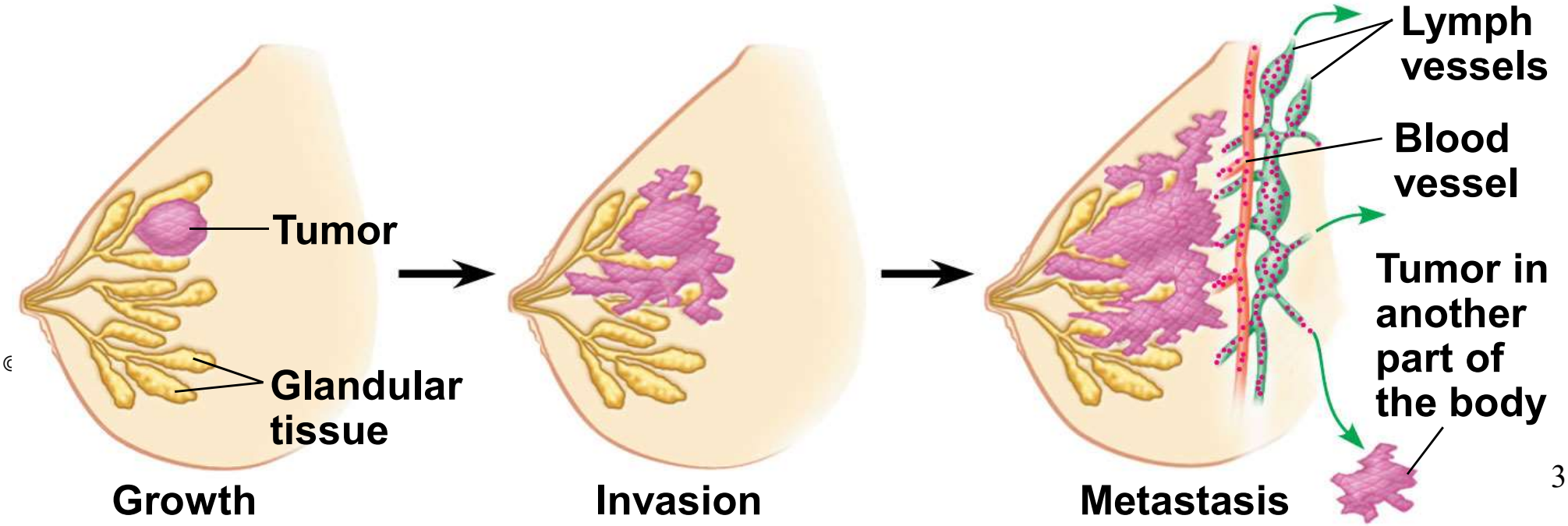


8.9 Growing out of control, cancer cells produce malignant tumors

- Cancer currently claims the lives of 20% of the people in the United States and other industrialized nations. (about 25% in Taiwan)
- Cancer cells escape controls on the cell cycle.
- Cancer cells divide excessively and invade other tissues of the body.
  - divide rapidly, often in the absence of growth factors,
  - spread to other tissues through the circulatory system, and
  - grow without being inhibited by other cells.

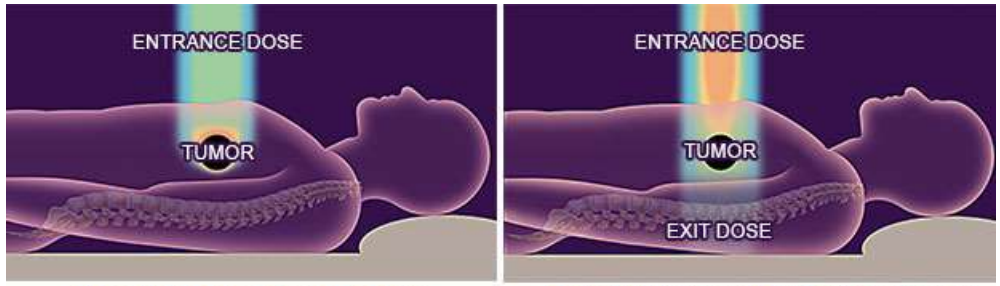
8.9 Growing out of control, cancer cells produce malignant tumors

- A **tumor** is a mass of abnormally growing cells within otherwise normal tissue.
  - **Benign tumors** remain at the original site but may disrupt certain organs if they grow in size. 良性瘤
  - **Malignant tumors** spread to other locations, called **metastasis**. 轉移
  - An individual with a malignant tumor is said to have **cancer**.



8.9 Growing out of control, cancer cells produce malignant tumors

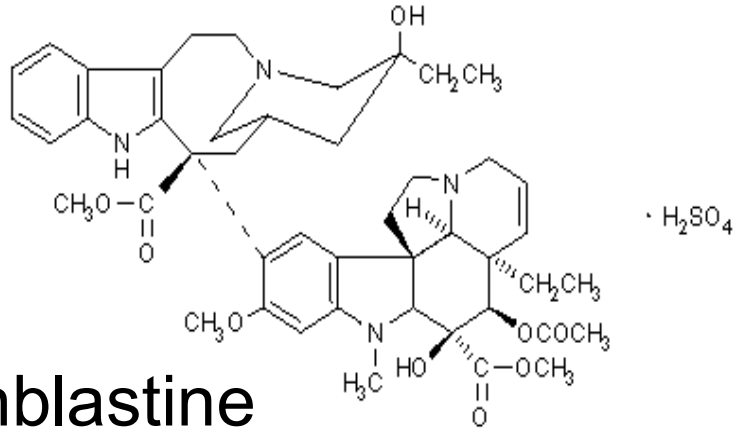
- Cancers are named according to the organ or tissue in which they originate.
  - **Carcinomas** arise in external or internal body coverings. 表皮細胞
  - **Sarcomas** arise in supportive and connective tissue. 結締組織
  - **Leukemias** and **lymphomas** arise from blood-forming tissues.
- Cancer treatments
  - Localized tumors can be
    - removed surgically and/or
    - treated with concentrated beams of high-energy radiation.
  - Chemotherapy is used for metastatic tumors.



質子治療

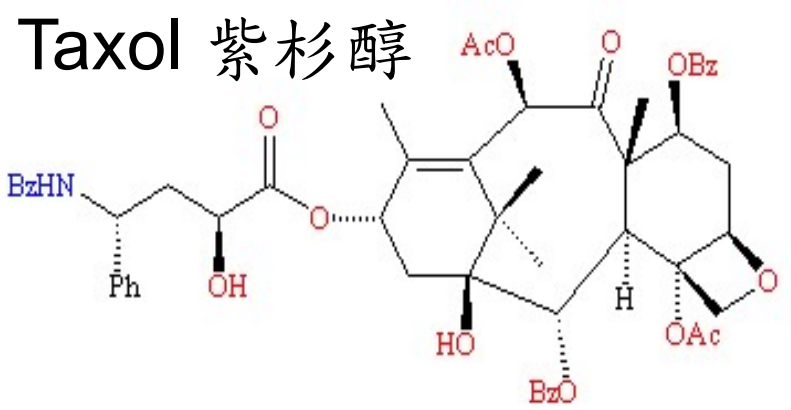
Vinblastine: from periwinkle, prevents spindle formation

Taxol: paclitaxel from bark of Pacific yew, freeze the spindle after it forms



Vinblastine

Taxol 紫杉醇



長春花

http://home.howstuffworks.com/periwinkle-myrtle.htm

http://www.flickr.com/photos/pdxfan/2080940389/

8.10 Tailoring treatment to each patient may improve cancer therapy

- It is increasingly possible to personalize cancer treatment by
  - sequencing the genome of tumor cells

TABLE 8.10 NUMBERS OF CANCER PATIENTS RESPONDING TO THE DRUG EVEROLIMUS ($N = 13$)

	Patients Responding to Everolimus	Patients *Not* Responding to Everolimus
Patients who had *TSC1* mutation	3	1
Patients who *did not* have *TSC1* mutation	1	8

  - tailoring treatment based upon the tumor's specific genetic profile.
  - A bladder cancer patient responded well to everolimus
  - Identify the everolimus-related proteins: one candidate, TSC1
  - Other bladder patients with or without TSC1 mutations
  - Could this be a routine approach?

Targeted Therapy 標靶治療

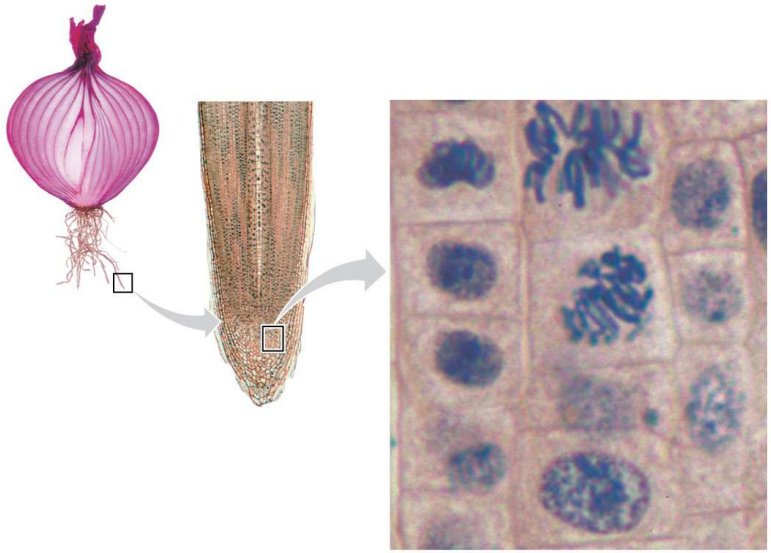
Blocking the growth of cancer cells by interfering with specific targeted molecules needed for carcinogenesis and tumor growth

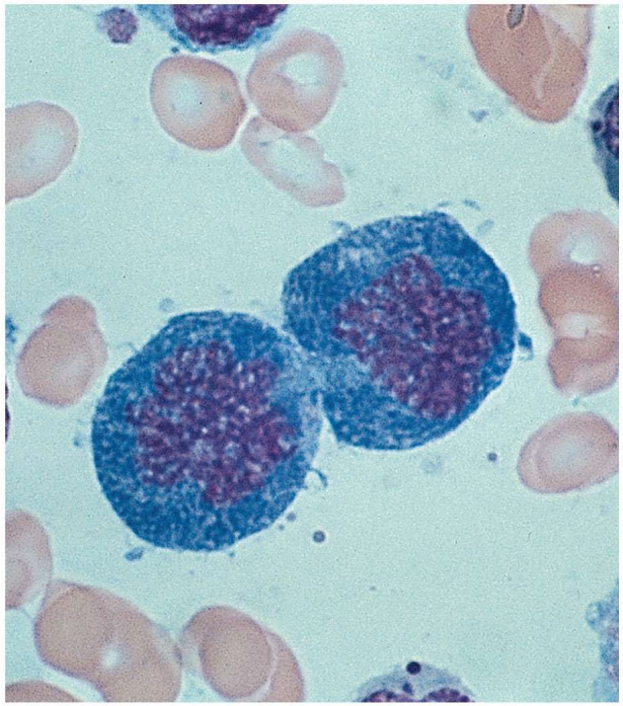
	藥物名稱	主治	若自費費用	平均年治療費	概況
1	賀癌平（Herceptin）	乳癌	每瓶約6萬1千元	90多萬	目前健保只補助「淋巴腺有轉移」的乳癌病人，此藥對淋巴無轉移也有極佳療效
2	基利克（Imatinib）	慢性骨髓性白血病(俗稱血癌)	1顆約800元，1天約3200-4800元，且不能停藥	100萬以上	健保總額給付制度下，醫院必須能「接受」這類高藥費病人，可能對整體費用的占比
3	蕾莎瓦（Nexavar）	晚期腎細胞癌	每天6000元，每月18萬元。	半年108萬，一年216萬	1. 健保有條件給付 2. 每2個月評估是否再給付
4	癌思停（Avastin）	轉移性大腸直腸癌、轉移性乳癌	每2周打1次，每次約2-3萬元	半年36萬，一年72萬	1. 健保僅給付18次。 2. 後續仍有醫療需自費施打18次，約50多萬左右
5	爾必得舒(Cetuximab)	轉移性直腸結腸癌、頭頸部癌症	每瓶約9千元，每月約費14-18萬元	半年108萬，一年216萬	1. 大腸癌療程建議半年 2. 若用於頭頸癌配合放射線治療療程8周自費30萬左右
6	愛寧達(Alimta)	惡性肋膜間質細胞瘤、晚期或轉移性非小細胞肺癌	每瓶約3萬多元，3周打一次，6次為一療程	半年約24萬	配合傳統化療
7	妥復克（Afatinib）	晚期或轉移性之非小細胞肺癌	每顆約1500元，平均每月藥費約4萬元。	一年約50萬	艾瑞莎、得舒緩、妥復克是於表皮生長因子受體（EGFR）阻斷劑的同家族藥物，健保不給付三藥併用或輪流使用
8	得舒緩（Tarceva）	肺腺癌	每月藥費約6萬多元。	一年約70萬多	同上
9	艾瑞沙(Iressa)	肺腺癌	1顆2100元，每月6萬3千元。	一年約75萬多	同上
10	抗癌妥(Campto)	大腸直腸癌	一劑約1萬元，一個月要打4-5次，每月4-5萬。	一年約60萬多	

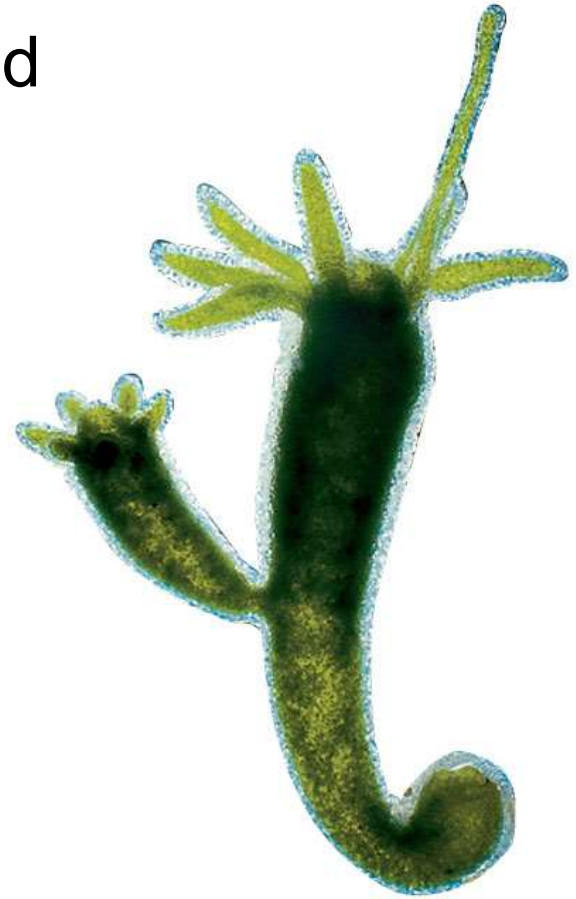
https://www.phew.tw/article/cont/phewretire/Wealth-planning/Insurance-planning/3335/201803063335

Review: Mitosis provides for growth, cell replacement, and asexual reproduction

- When the cell cycle operates normally, mitosis produces genetically identical cells for
  - growth,
  - replacement of damaged and lost cells, and
  - asexual reproduction.







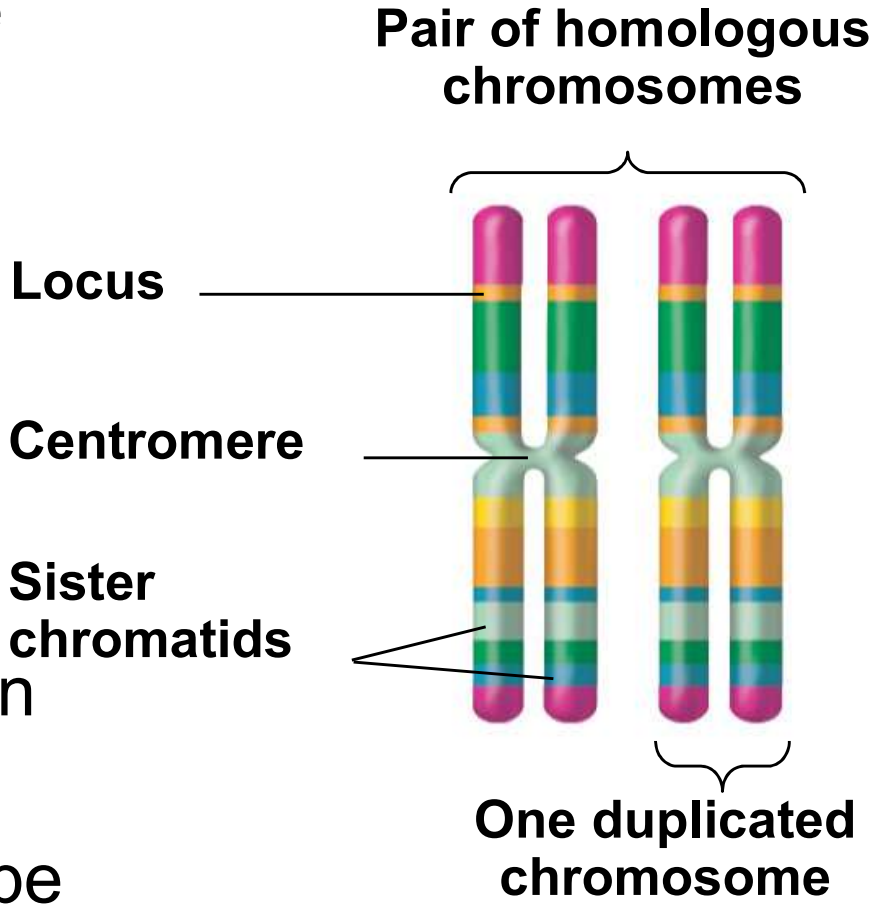
MEIOSIS AND CROSSING OVER

8.11 Chromosomes are matched in homologous pairs

- In humans, **somatic cells** have 體細胞
  - 23 pairs of homologous chromosomes and
  - one member of each pair from each parent.
- The human **sex chromosomes** X and Y differ in size and genetic composition. 性染色體
- The other 22 pairs of chromosomes are **autosomes** with the same size and genetic composition. 體染色體

8.11 Chromosomes are matched in homologous pairs

- **Homologous chromosomes** are matched in 同源染色體
  - length,
  - centromere position, and
  - Staining pattern (gene locations).

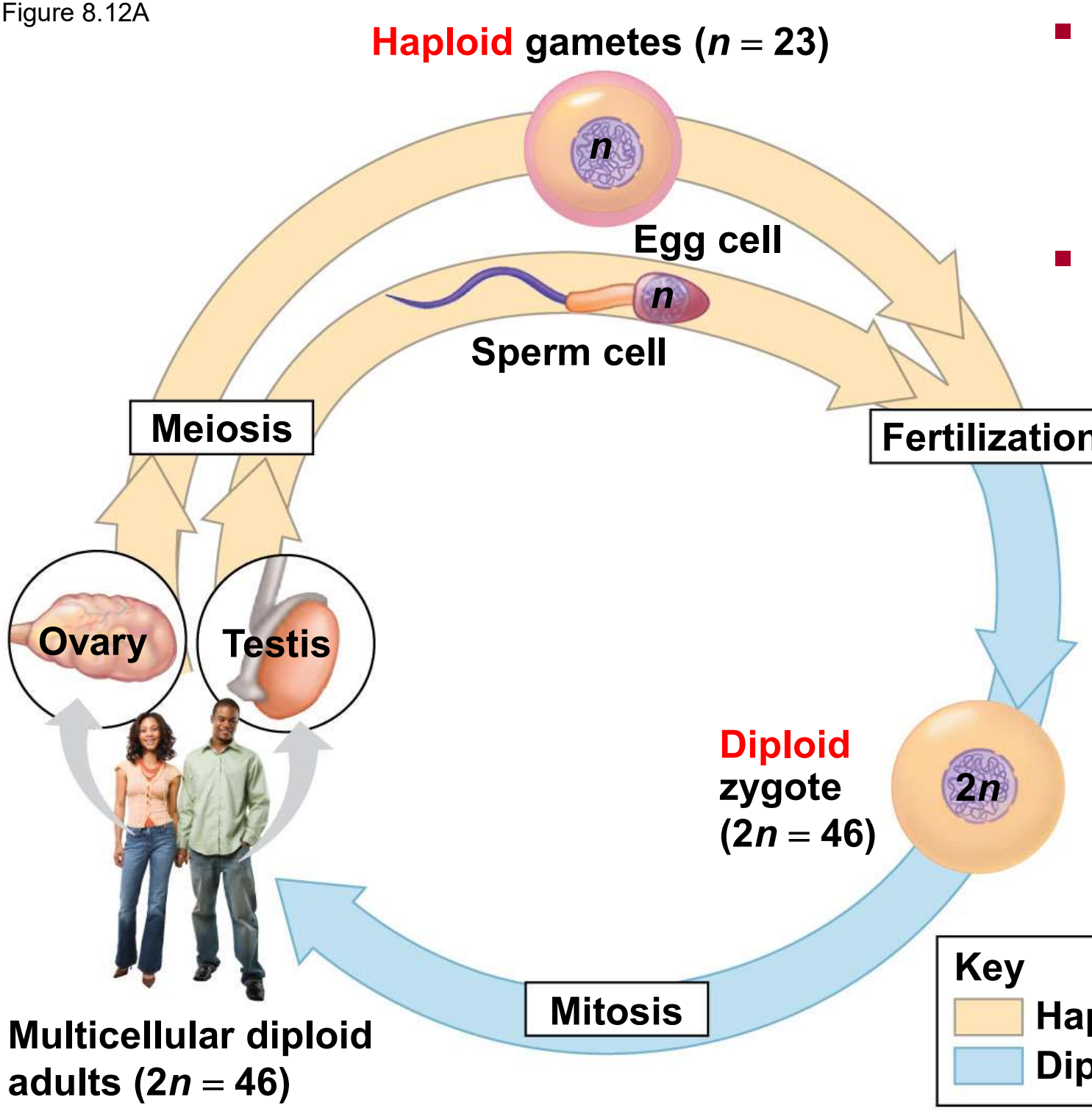


- A **locus** (plural, *loci*) is the position of a gene.
- Different versions of a gene may be found at the same locus on the two chromosomes of a homologous pair. (maternal and paternal)

8.12 Gametes have a single set of chromosomes 配子

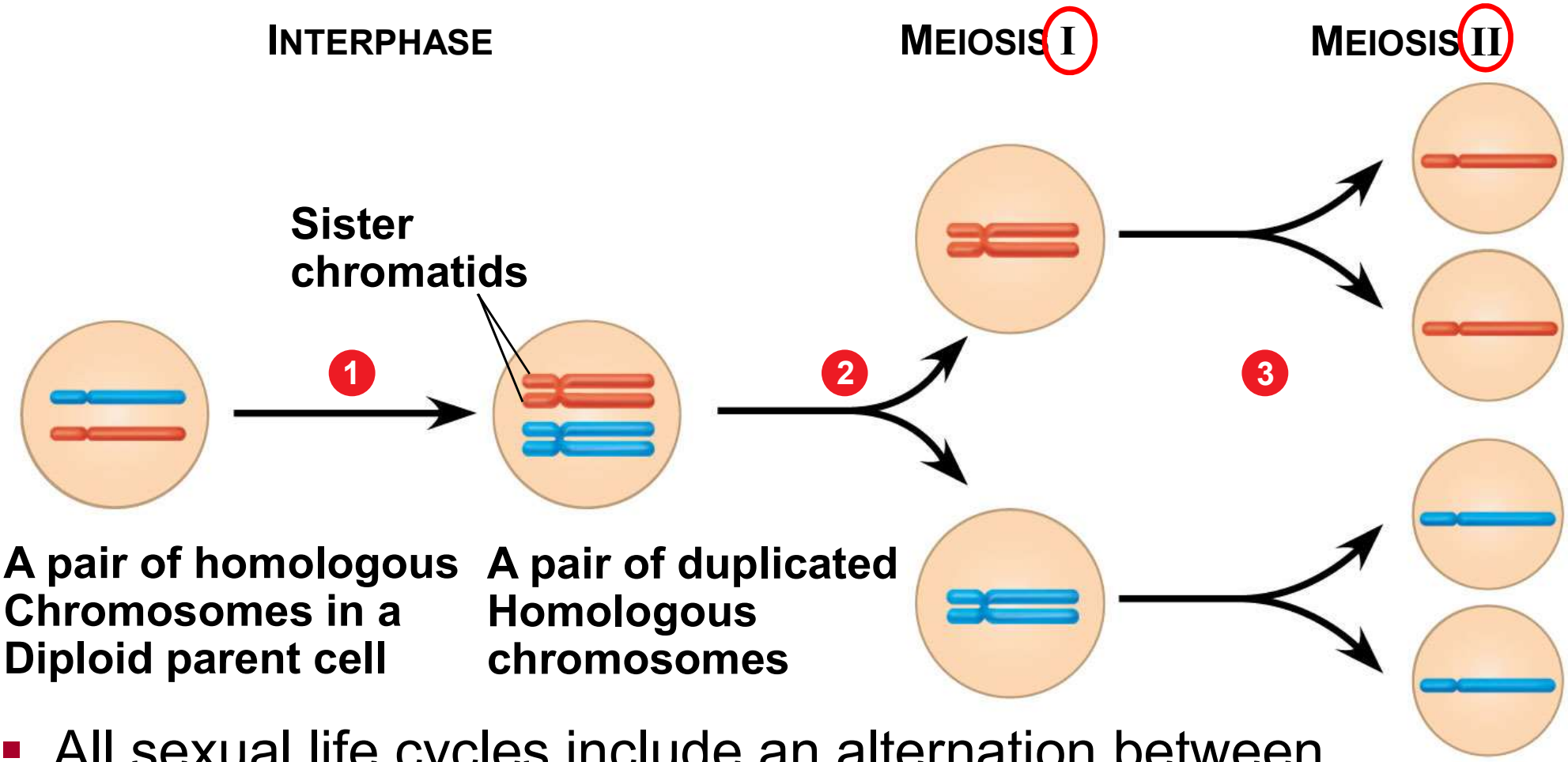
- An organism's **life cycle** is the sequence of stages leading from the adults of one generation to the adults of the next.
- Humans and many animals and plants are **diploid**, because all somatic cells contain pairs of homologous chromosomes.
- Gametes
  - are eggs and sperm and
  - are said to be **haploid** because each cell has a single set of chromosomes.
- The human life cycle begins when a haploid sperm fuses with a haploid egg in **fertilization**.
- The **zygote**, formed by fertilization, is now diploid. 受精卵
- Mitosis of the zygote and its descendants generates all the somatic cells into the adult form.

Figure 8.12A



- Gametes are made by meiosis in the ovaries and testes.
- Meiosis reduces the chromosome number by half.

8.12 Gametes have a single set of chromosomes



- All sexual life cycles include an alternation between
  - a diploid stage and a haploid stage.
- Producing haploid gametes prevents the chromosome number from doubling in every generation.

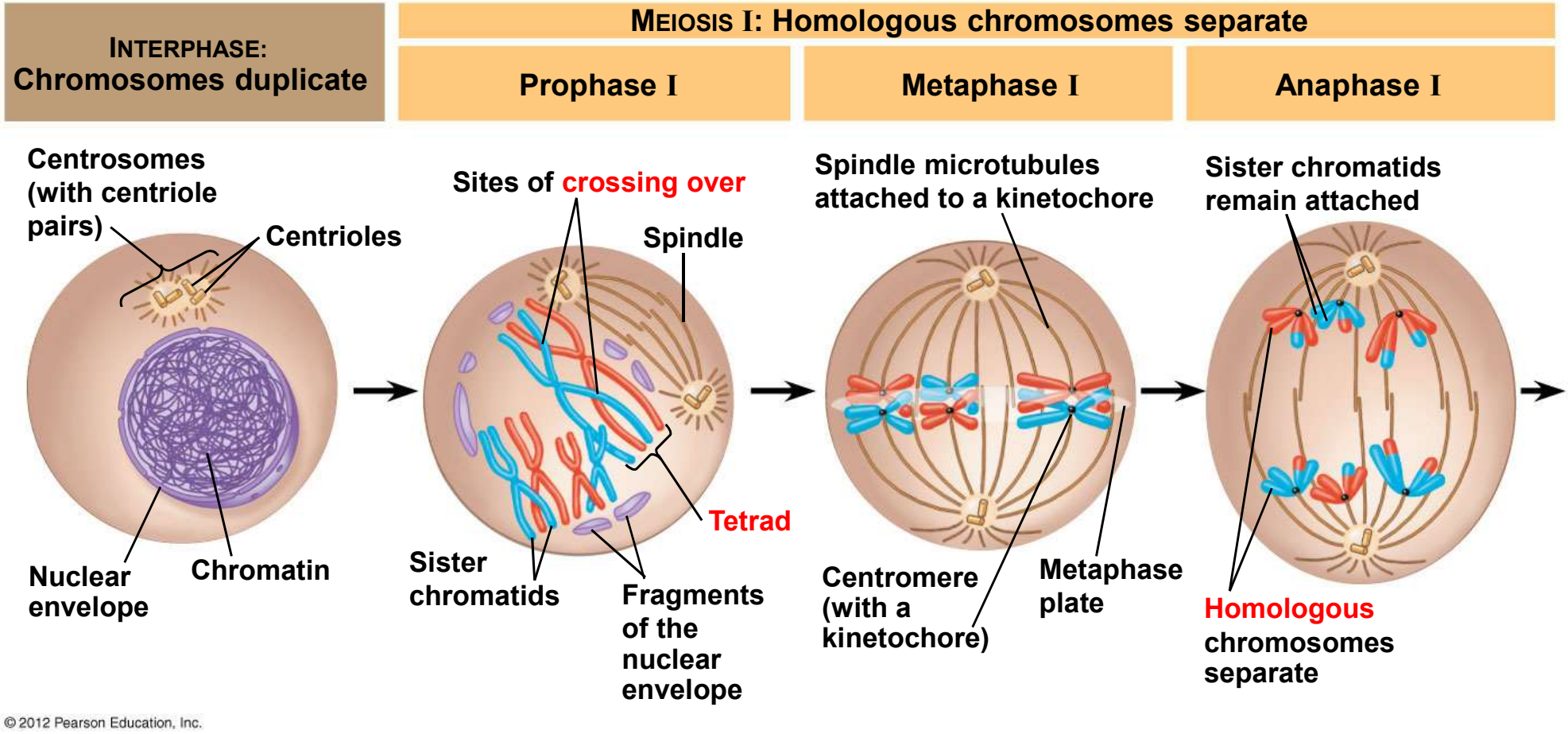
8.13 Meiosis reduces the chromosome number from diploid to haploid

- **Meiosis** is a type of cell division that produces haploid gametes in diploid organisms.
- Two haploid gametes combine in fertilization to restore the diploid state in the zygote.
- Meiosis and mitosis are preceded by the duplication of chromosomes. However,
  - meiosis is followed by two consecutive cell divisions and
  - mitosis is followed by only one cell division.
- Because in meiosis, one duplication of chromosomes is followed by two divisions, each of the four daughter cells produced has a haploid set of chromosomes.

8.13 Meiosis reduces the chromosome number from diploid to haploid

- **Interphase**: Like mitosis, meiosis is preceded by an interphase, during which the chromosomes duplicate.
- **Meiosis I – Prophase I** – events occurring in the nucleus.
  - The nuclear membrane dissolves.
  - Chromatin tightly coils up.
  - Homologous chromosomes, each composed of two sister chromatids, come together in pairs in a process called **synapsis**.
  - During synapsis, chromatids of homologous chromosomes exchange segments in a process called **crossing over**.
  - The chromosome tetrads move toward the center of the cell.
  - Each pair, with four chromatids, is called a tetrad.
  - Nonsister chromatids exchange genetic material by crossing over.

Figure 8.13_left

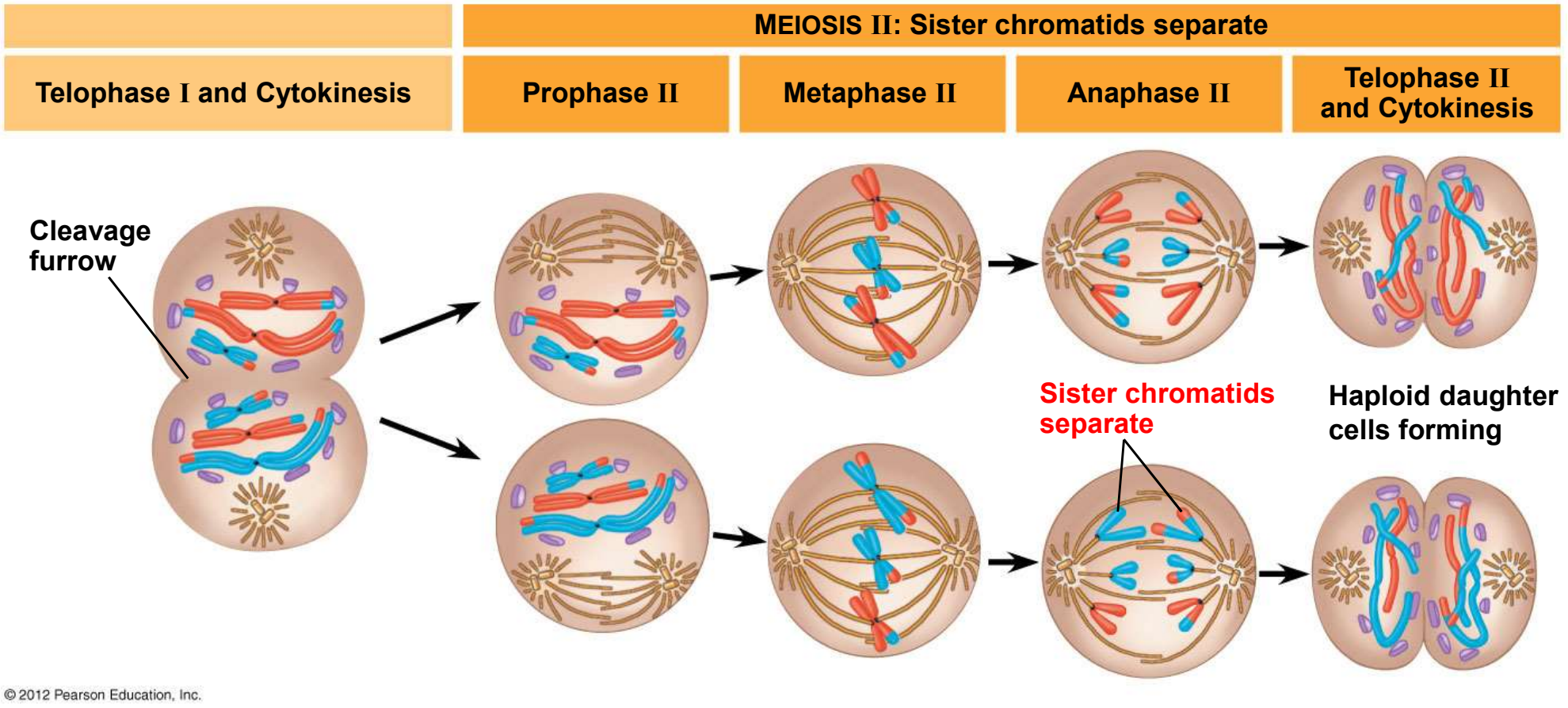


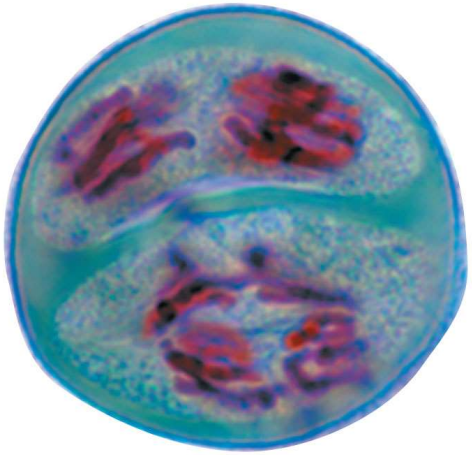
8.13 Meiosis reduces the chromosome number from diploid to haploid

- **Meiosis I – Metaphase I** – Tetrads align at the cell equator.
- **Meiosis I – Anaphase I** – Homologous pairs separate and move toward opposite poles of the cell.
- **Meiosis I – Telophase I**
  - Duplicated chromosomes have reached the poles.
  - A nuclear envelope re-forms around chromosomes in some species.
  - Each nucleus has the haploid number of chromosomes.
  - Usually, cytokinesis occurs along with telophase.
- Meiosis II follows meiosis I without chromosome duplication.
- Each of the two haploid products enters meiosis II.

- **Meiosis II – Prophase II**
  - A spindle forms and moves chromosomes toward the middle of the cell.
  - Chromosomes coil and become compact (if uncoiled after telophase I).
  - Nuclear envelope, if re-formed, breaks up again.
- **Meiosis II – Metaphase II** – Duplicated chromosomes align at the cell equator.
- **Meiosis II – Anaphase II**
  - Sister chromatids separate and
  - Individual chromosomes move toward opposite poles.
- **Meiosis II – Telophase II**
  - Chromosomes have reached the poles of the cell.
  - A nuclear envelope forms around each set of chromosomes.
  - With cytokinesis, four haploid cells are produced.

Figure 8.13_right

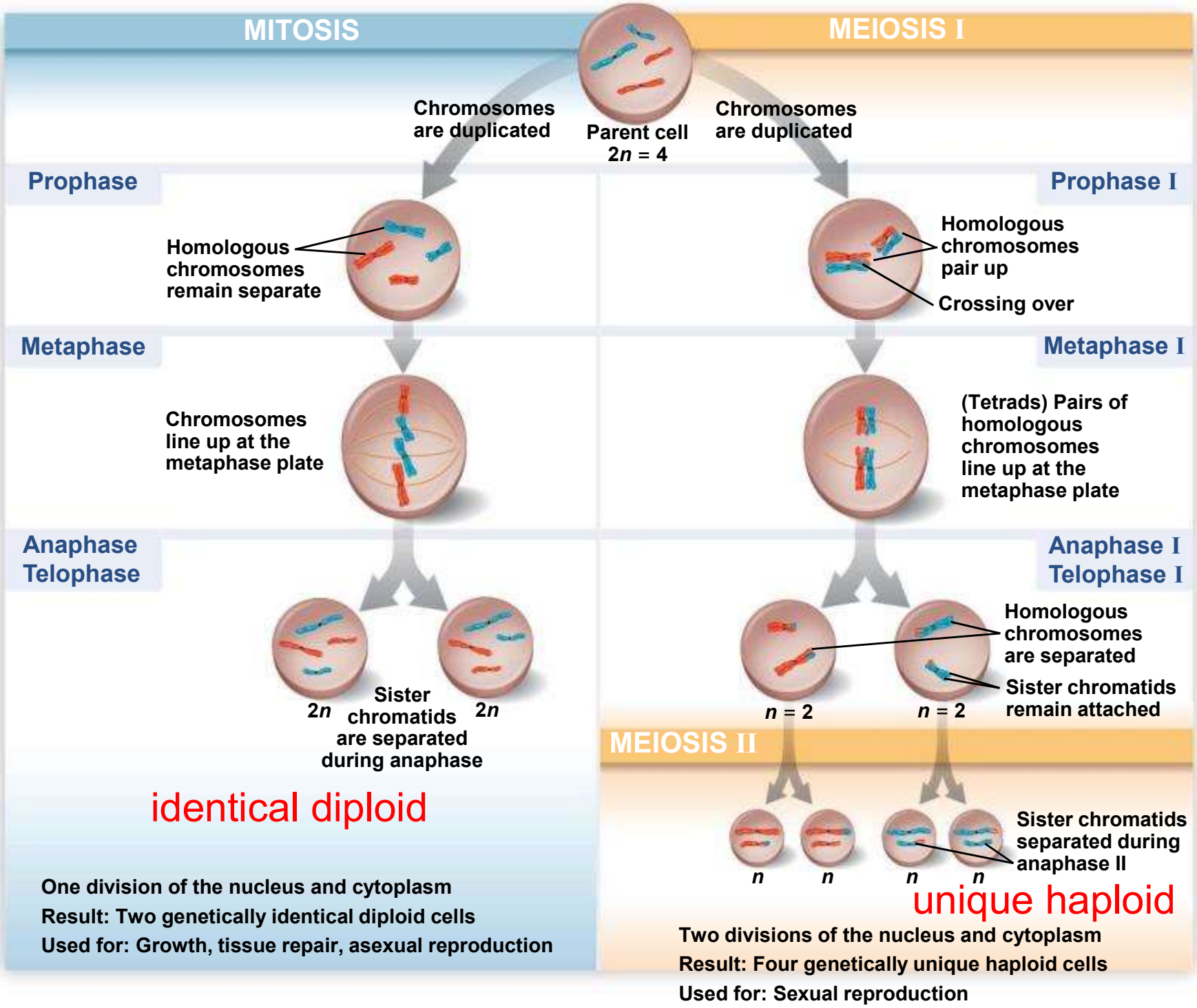




Two lily cells undergo meiosis II

8.14 Mitosis and meiosis have important similarities and differences

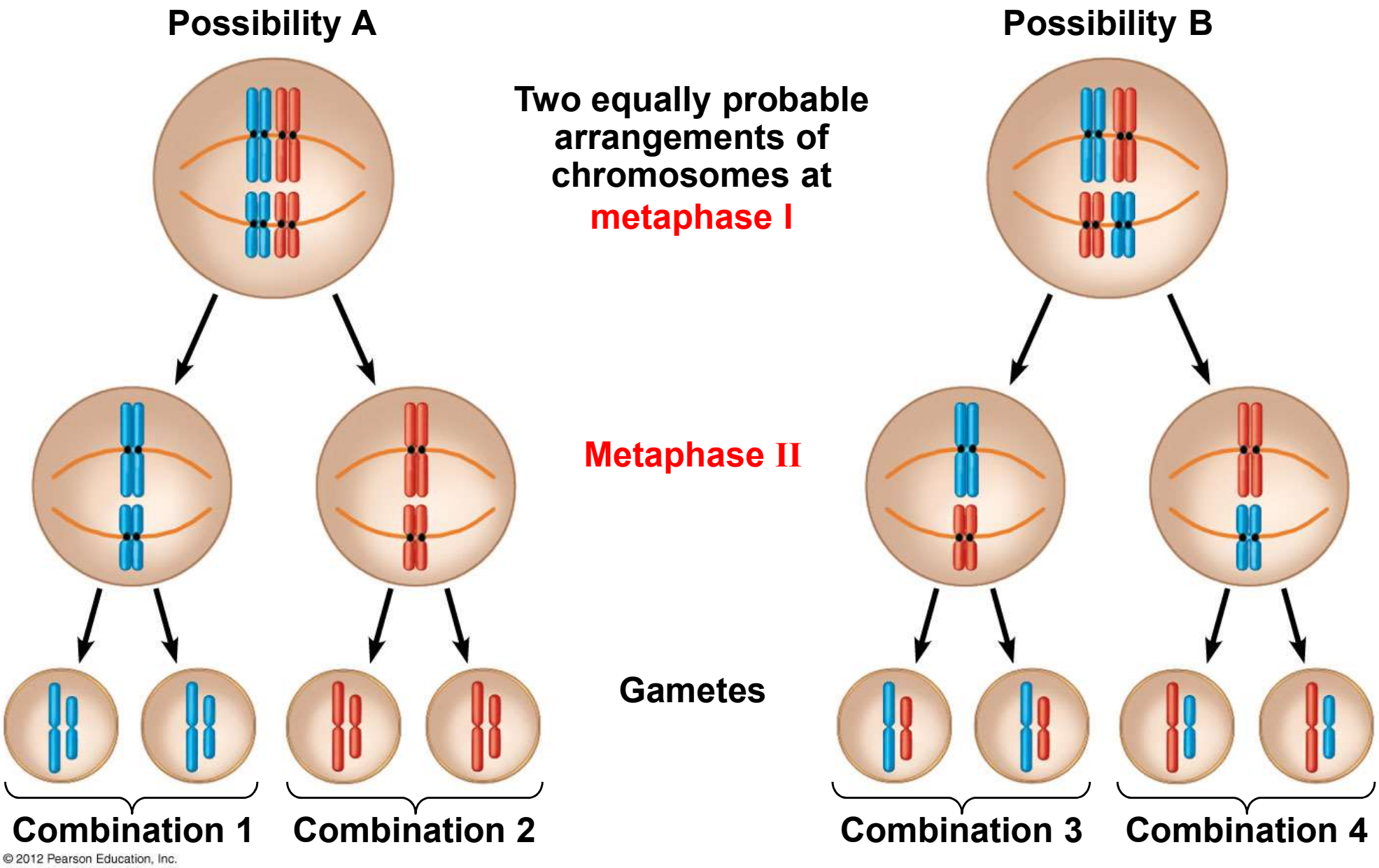
- Mitosis and meiosis both
  - begin with diploid parent cells that
  - have chromosomes duplicated during the previous interphase.
- However the end products differ.
  - Mitosis produces two genetically identical diploid somatic daughter cells.
  - Meiosis produces four genetically unique haploid gametes.

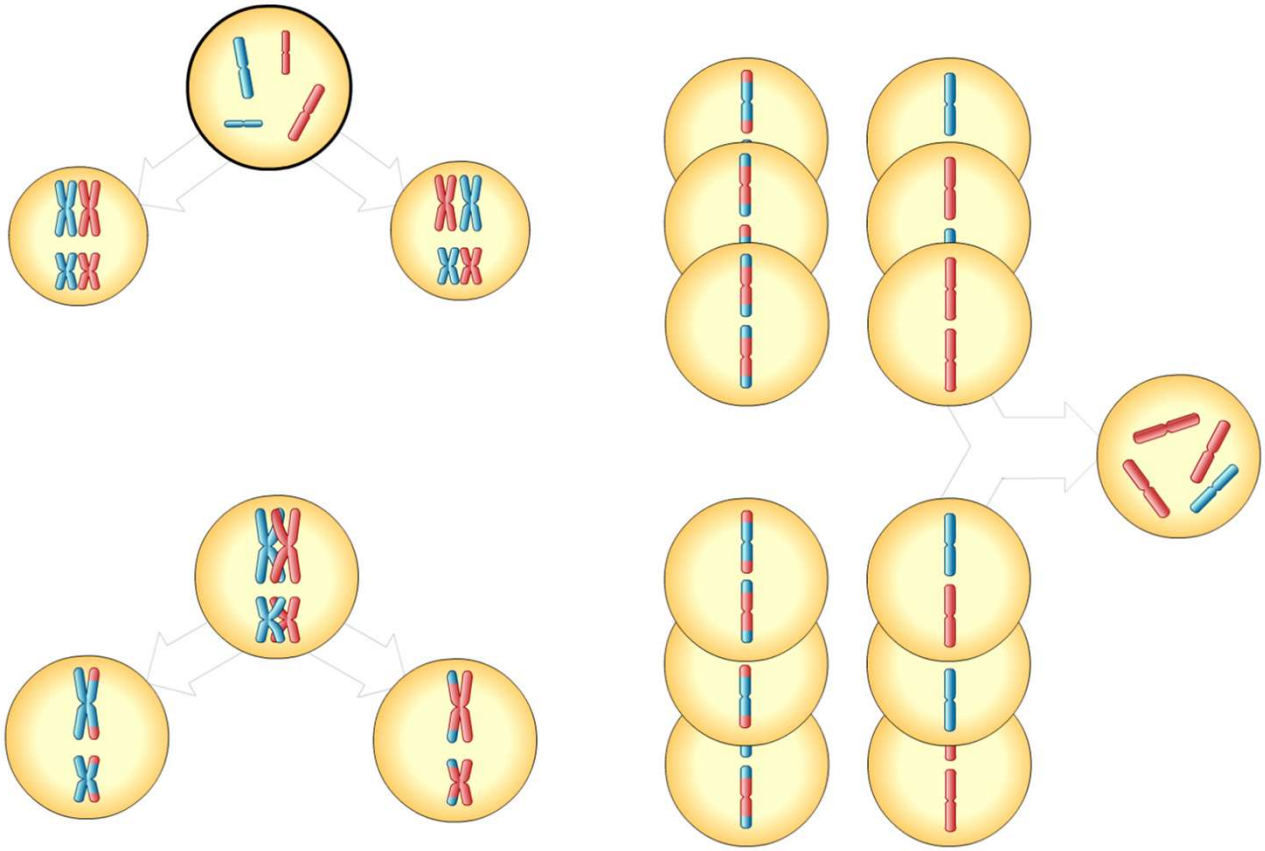

MITOSIS
MEIOSIS I
Chromosomes are duplicated
Parent cell
2n = 4
Chromosomes are duplicated
Prophase
Homologous chromosomes remain separate
Prophase I
Homologous chromosomes pair up
Crossing over
Metaphase
Chromosomes line up at the metaphase plate
Metaphase I
(Tetrads) Pairs of homologous chromosomes line up at the metaphase plate
Anaphase Telophase
2n
Sister chromatids are separated during anaphase
2n
Anaphase I Telophase I
Homologous chromosomes are separated
Sister chromatids remain attached
n = 2
n = 2
MEIOSIS II
Sister chromatids separated during anaphase II
n
n
n
n
identical diploid
unique haploid
One division of the nucleus and cytoplasm
Result: Two genetically identical diploid cells
Used for: Growth, tissue repair, asexual reproduction
Two divisions of the nucleus and cytoplasm
Result: Four genetically unique haploid cells
Used for: Sexual reproduction

8.15 Independent orientation of chromosomes in meiosis and random fertilization lead to varied offspring

- Genetic variation in gametes results from
  - independent orientation at metaphase I and
  - random fertilization.
- Independent orientation at metaphase I
  - Each pair of chromosomes independently aligns at the cell equator.
  - There is an equal probability of the maternal or paternal chromosome facing a given pole.
  - The number of combinations for chromosomes packaged into gametes is 2^n where n = haploid number of chromosomes
- Random fertilization – The combination of each unique sperm with each unique egg increases genetic variability.

Figure 8.15_s3





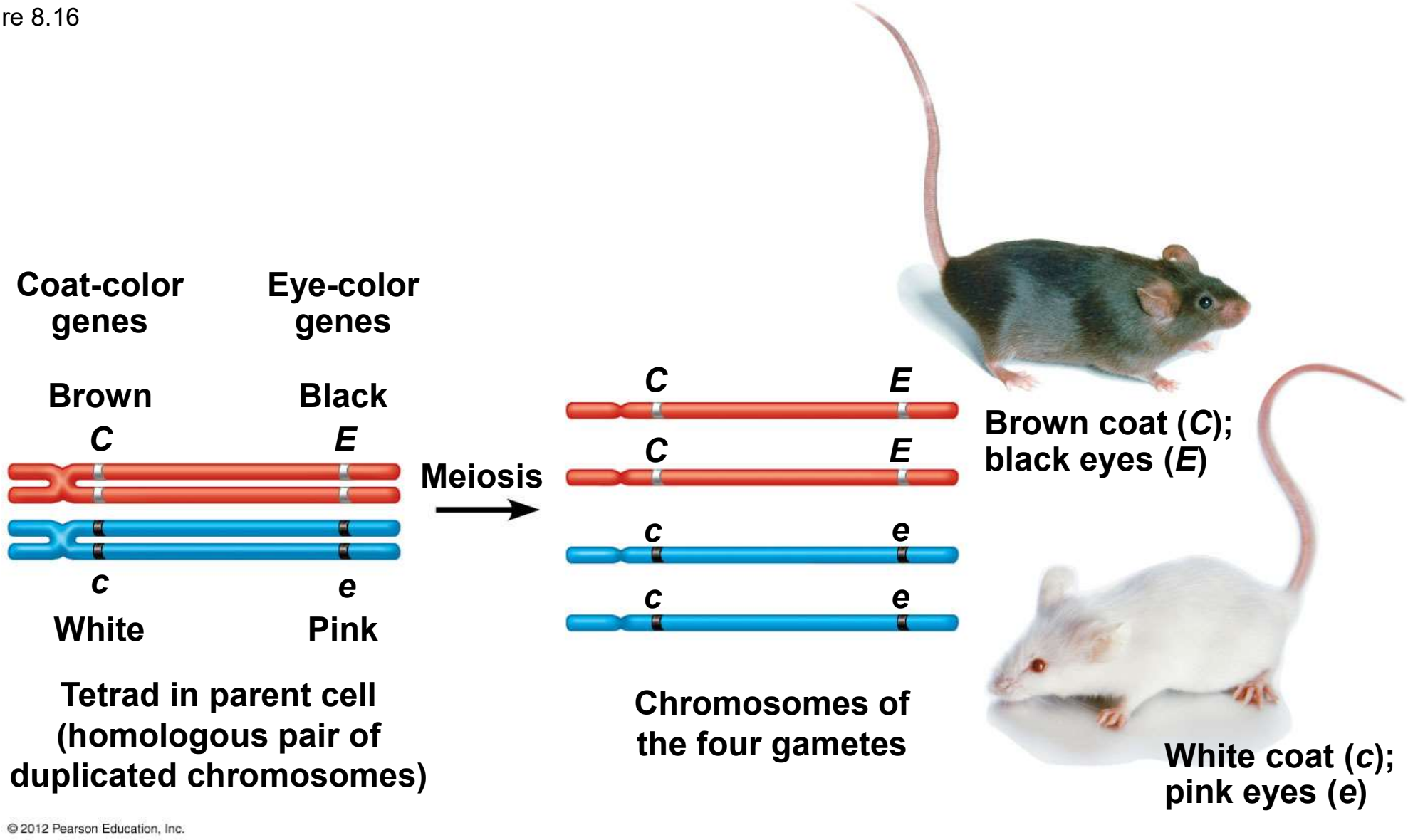
Animation: Genetic Variation

Right click on animation / Click play

8.16 Homologous chromosomes may carry different versions of genes

- Separation of homologous chromosomes during meiosis can lead to genetic differences between gametes.
  - Homologous chromosomes may have different versions of a gene at the same locus.
  - One version was inherited from the maternal parent and the other came from the paternal parent.
  - Since homologues move to opposite poles during anaphase I, gametes will receive either the maternal or paternal version of the gene.

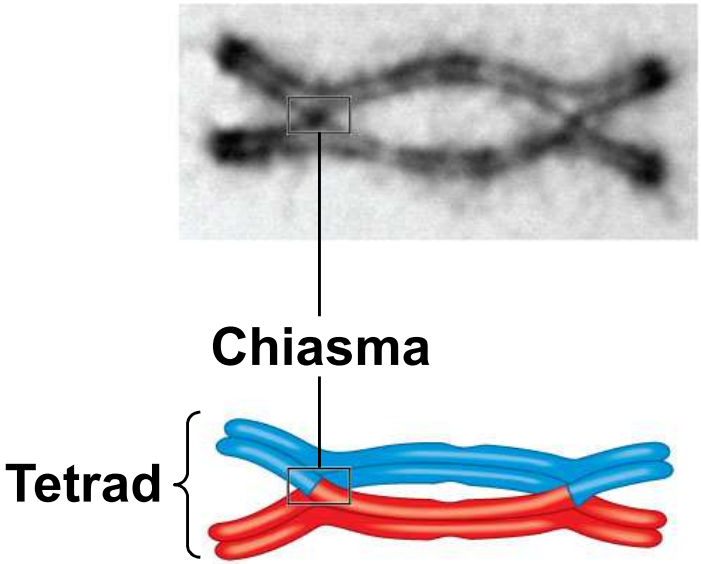
Figure 8.16

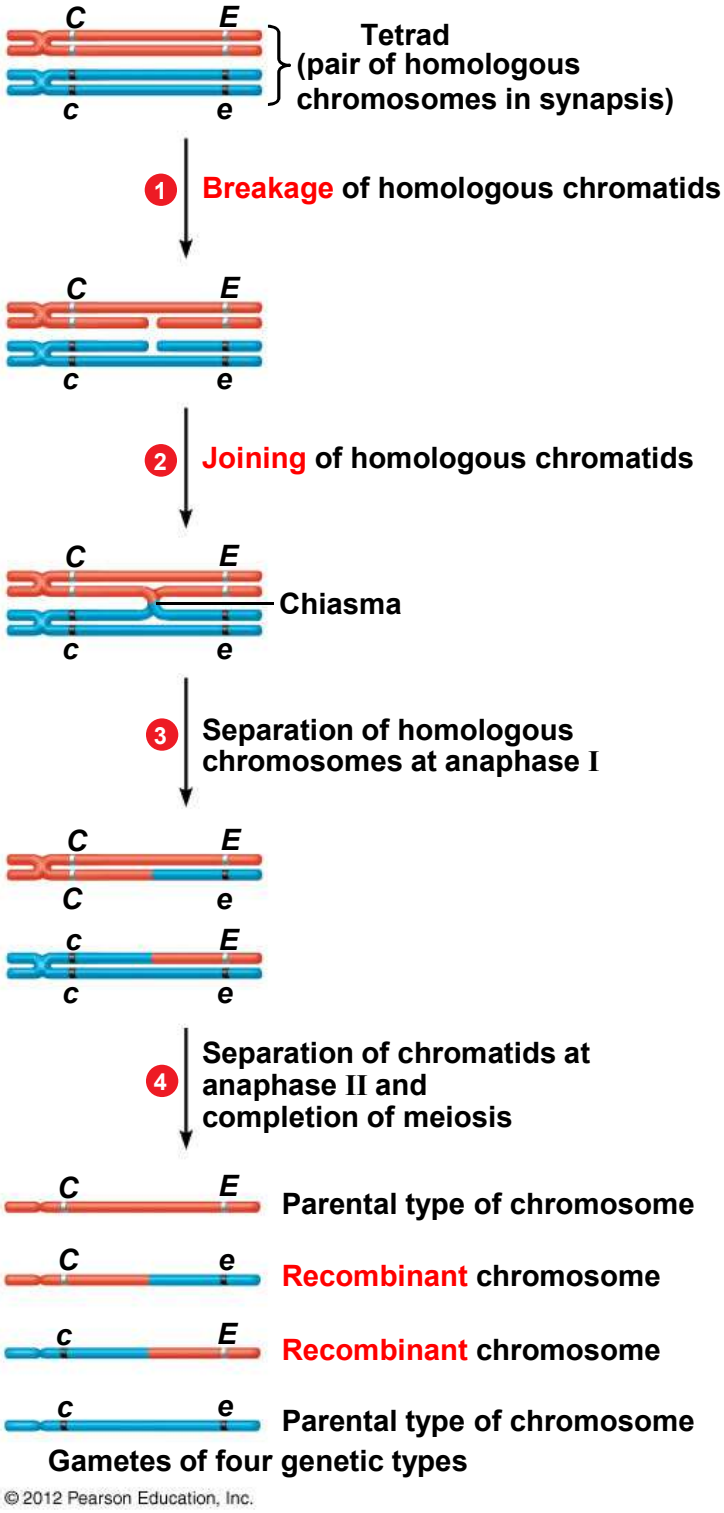


8.17 Crossing over further increases genetic variability

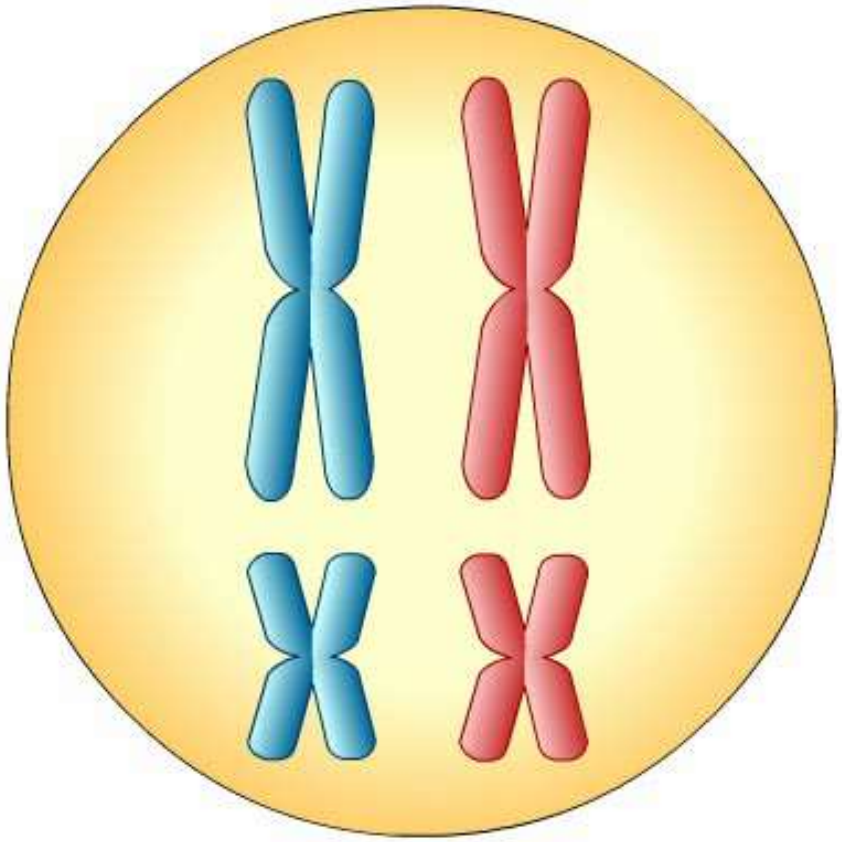
- **Genetic recombination** is the production of new combinations of genes due to crossing over. 基因重組
- **Crossing over** is an exchange of corresponding segments between separate (nonsister) chromatids on homologous chromosomes.
  - Nonsister chromatids join at a **chiasma** (plural, *chiasmata*), the site of attachment and crossing over.
  - Corresponding amounts of genetic material are exchanged between maternal and paternal (nonsister) chromatids.

Figure 8.17B





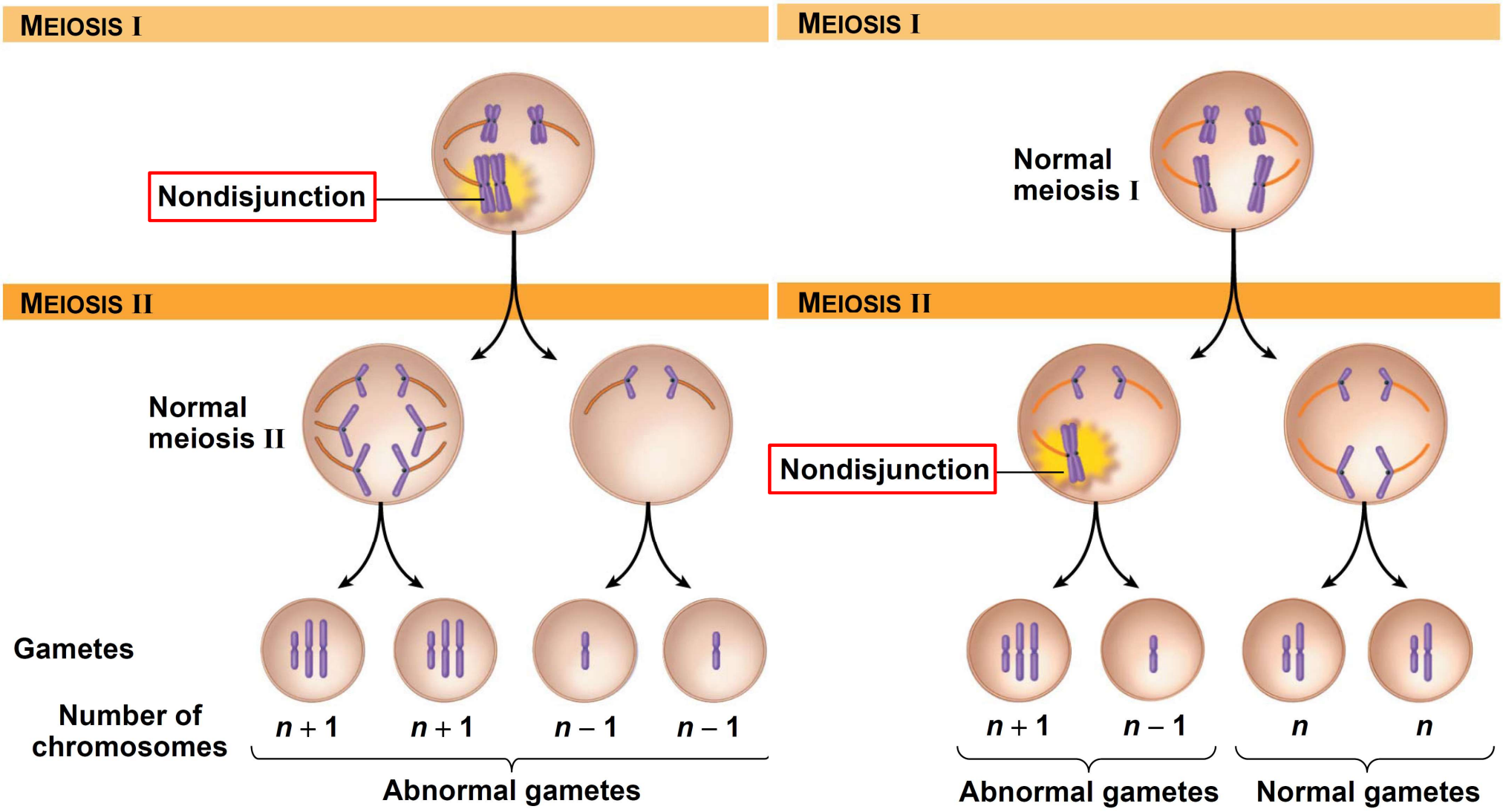
Animation: Crossing Over



ALTERATIONS OF CHROMOSOME NUMBER AND STRUCTURE

8.18 Accidents during meiosis can alter chromosome number

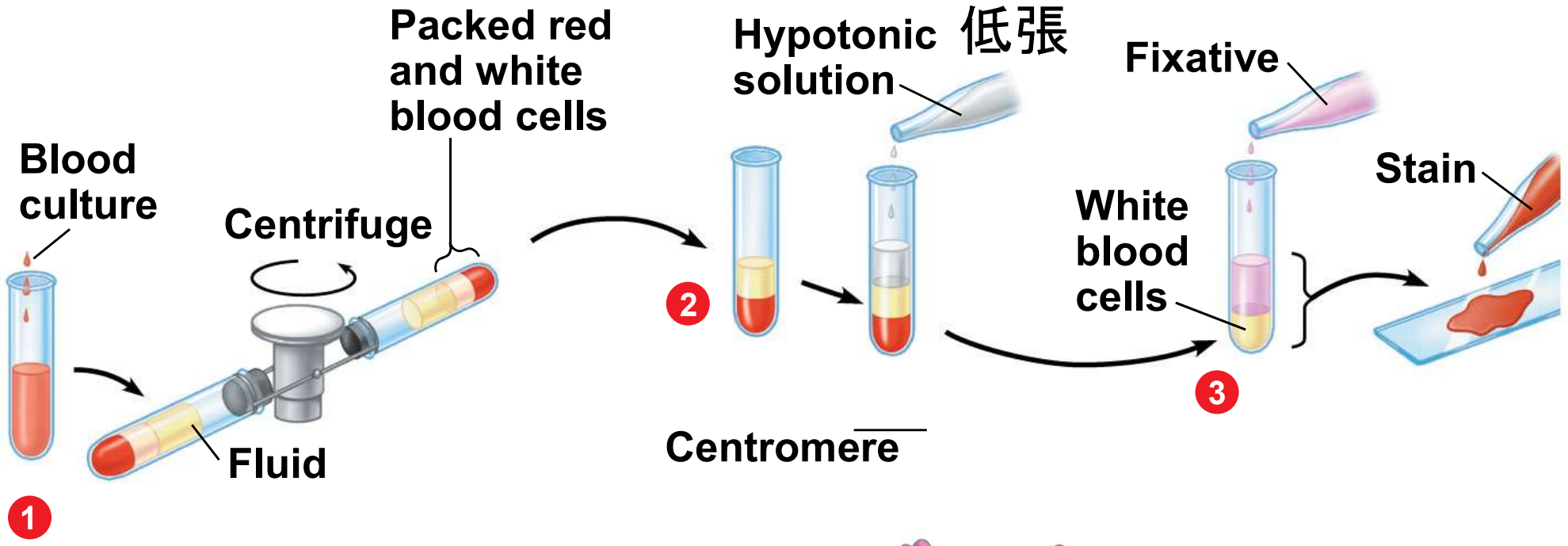
- **Nondisjunction** is the failure of chromosomes or chromatids to separate normally during meiosis. This can happen during
  - meiosis I, if both members of a homologous pair go to one pole, or
  - meiosis II, if both sister chromatids go to one pole.
- Fertilization after nondisjunction yields zygotes with altered numbers of chromosomes.

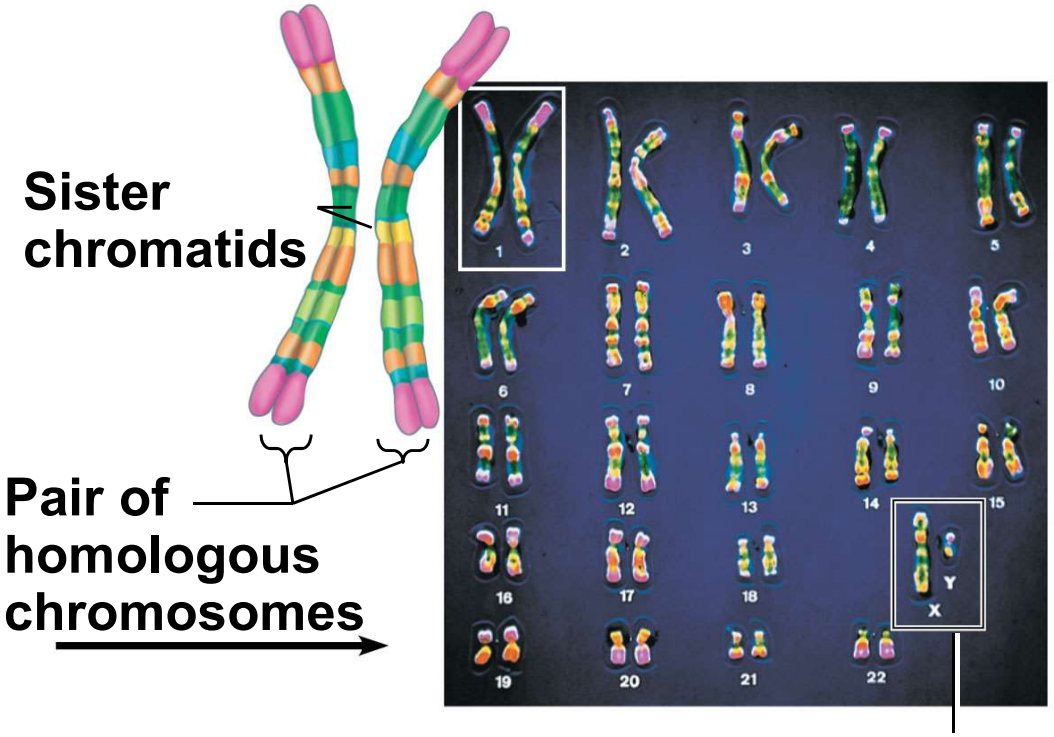

MEIOSIS I
Nondisjunction
MEIOSIS II
Normal meiosis II
Gametes
Number of chromosomes
n + 1
n + 1
n – 1
n – 1
Abnormal gametes
MEIOSIS I
Normal meiosis I
MEIOSIS II
Nondisjunction
n + 1
n – 1
n
n
Abnormal gametes
Normal gametes

8.19 A karyotype is a photographic inventory of an individual's chromosomes

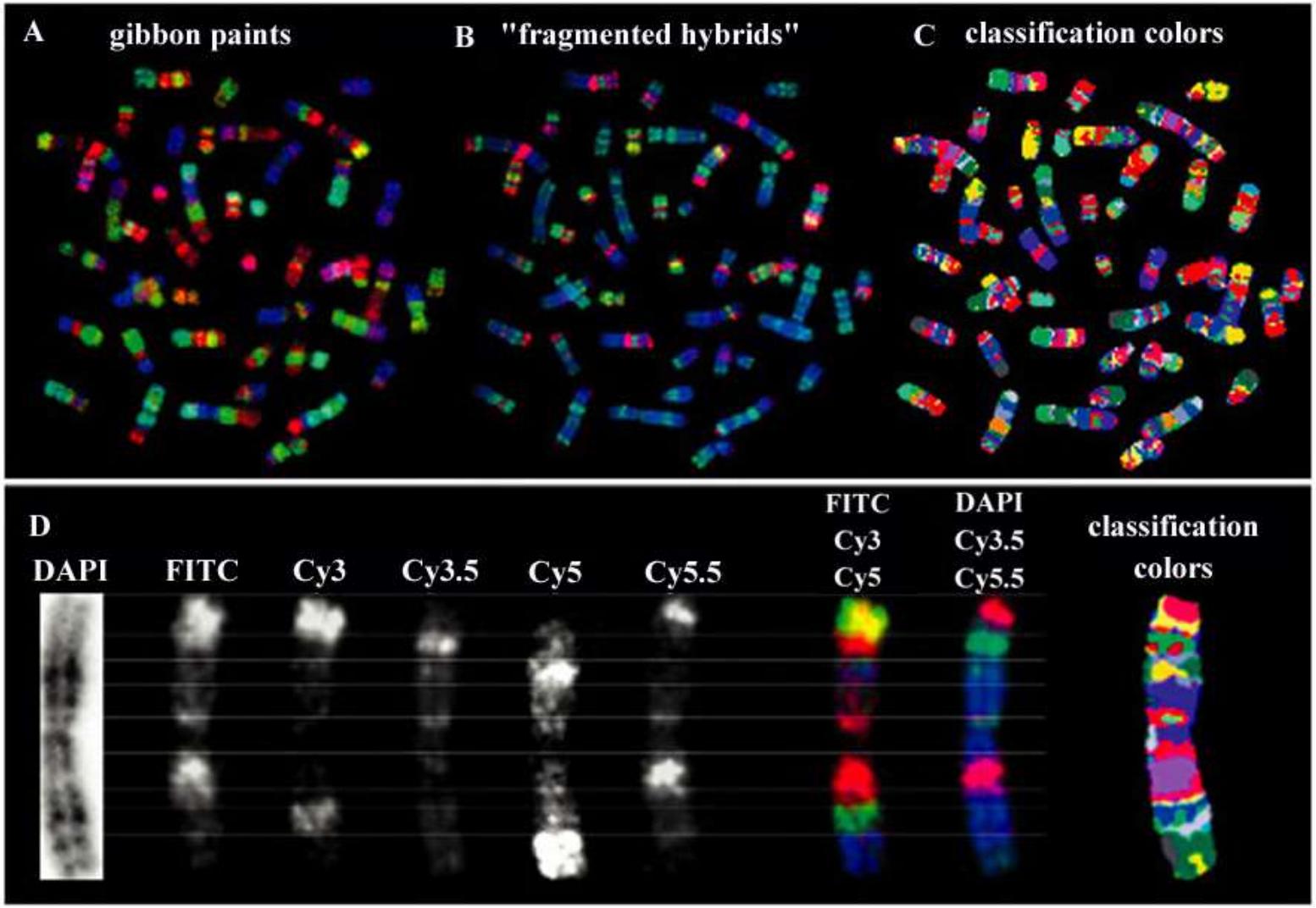
- A **karyotype** is an ordered display of magnified images of an individual's chromosomes arranged in pairs.
- Karyotypes 染色體組型
  - are often produced from dividing cells arrested at metaphase of mitosis and
  - allow for the observation of
    - homologous chromosome pairs,
    - chromosome number, and
    - chromosome structure.

Human Genome Resources
https://www.ncbi.nlm.nih.gov/projects/genome/guide/human/





Chromosome bar codes: structural abnormalities



Further characterize the chromosome translocation, intra-chromosome rearrangement

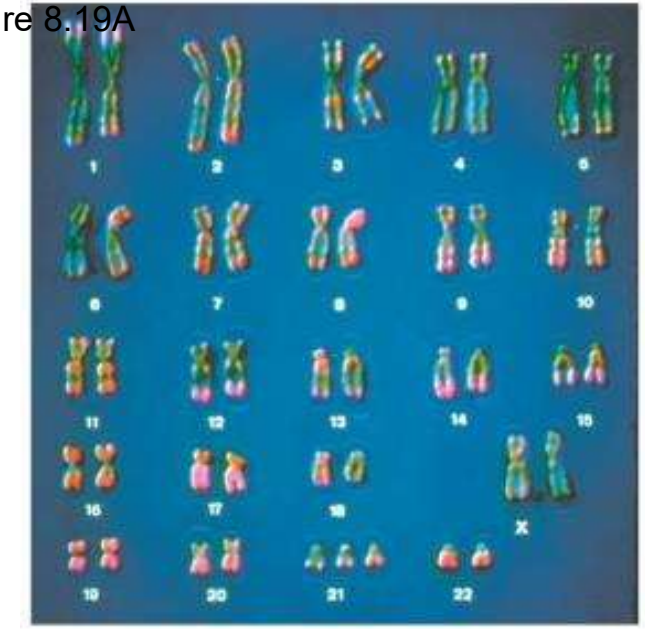
http://www.chrombios.com/cms/website.php?id=/en/index/aboutfish/barcodes.htm&sid=0k2ohofofue8tm1jdre7ab5o91

https://www.nature.com/scitable/topicpage/karyotyping-for-chromosomal-abnormalities-298

8.20 An extra copy of chromosome 21 causes Down syndrome

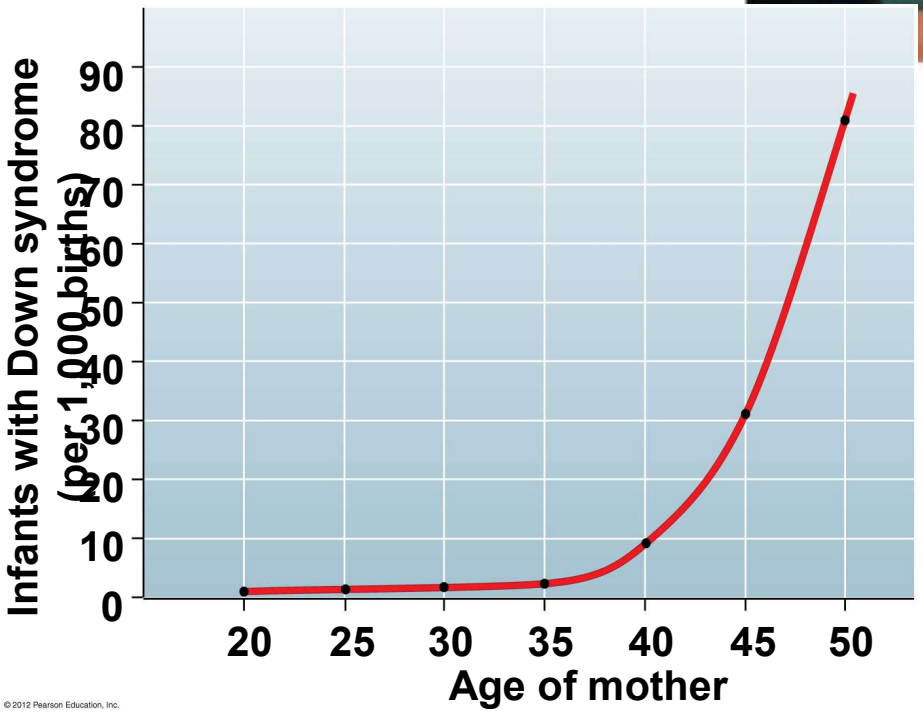
- **Trisomy 21**
  - involves the inheritance of three copies of chromosome 21 and
  - is the most common human chromosome abnormality.
- **Trisomy 21,** called **Down syndrome,** produces a characteristic set of symptoms, which include: 唐氏症
  - characteristic facial features,
  - short stature,
  - heart defects,
  - susceptibility to respiratory infections, leukemia, and Alzheimer's disease, and
  - varying degrees of developmental disabilities.
- The incidence increases with the age of the mother.

Figure 8.19A



Trisomy 21

A person with Down syndrome



唐氏症篩檢：血液、超音波、
羊膜穿刺 (Amniocentesis)、非侵入性產前染色體篩檢 (NIPT, NonInvasive Prenatal Testing)
檢測母血中的胎兒游離DNA、僅能知道染色體套數與否異常，但無法知道染色體結構，無法完全取代羊膜穿刺染色體檢查。

8.21 Abnormal numbers of sex chromosomes do not usually affect survival

TABLE 8.21 | ABNORMALITIES OF SEX CHROMOSOME NUMBER IN HUMANS

Sex Chromosomes	Syndrome	Origin of Nondisjunction	Frequency in Population
XXY	Klinefelter syndrome (male)	Meiosis in egg or sperm formation	1/1,000 live male births
XYY	None (normal male)	Meiosis in sperm formation	1/1,000 live male births
XXX	None (normal female)	Meiosis in egg or sperm formation	1/1,000 live female births
XO	Turner syndrome (female)	Meiosis in egg or sperm formation	1/2,500 live female births

- Sex chromosome abnormalities tend to be less severe, perhaps because of
  - the small size of the Y chromosome or
  - X-chromosome inactivation.
- The following table lists the most common human sex chromosome abnormalities. In general,
  - a single Y chromosome is enough to produce "maleness," even in combination with several X chromosomes, and
  - the absence of a Y chromosome yields "femaleness."

8.22 EVOLUTION CONNECTION: New species can arise from errors in cell division

- Errors in mitosis or meiosis may produce polyploid species, with more than two chromosome sets.
- The formation of polyploid species is
  - widely observed in many plant species but
  - less frequently found in animals.

Gray tree frog, tetraploid

Olympic gender test

2012 London: testosterone (睪酮素) level (female <3 nmol/L serum; male 7 to 30)

2016, no restriction for transition from female to male gender; for female events, Trans-athletes do not need reassignment surgery but testosterone level must have been <10 nmol/L for over 12 months. http://www.topendsports.com/events/summer/gender-testing.htm

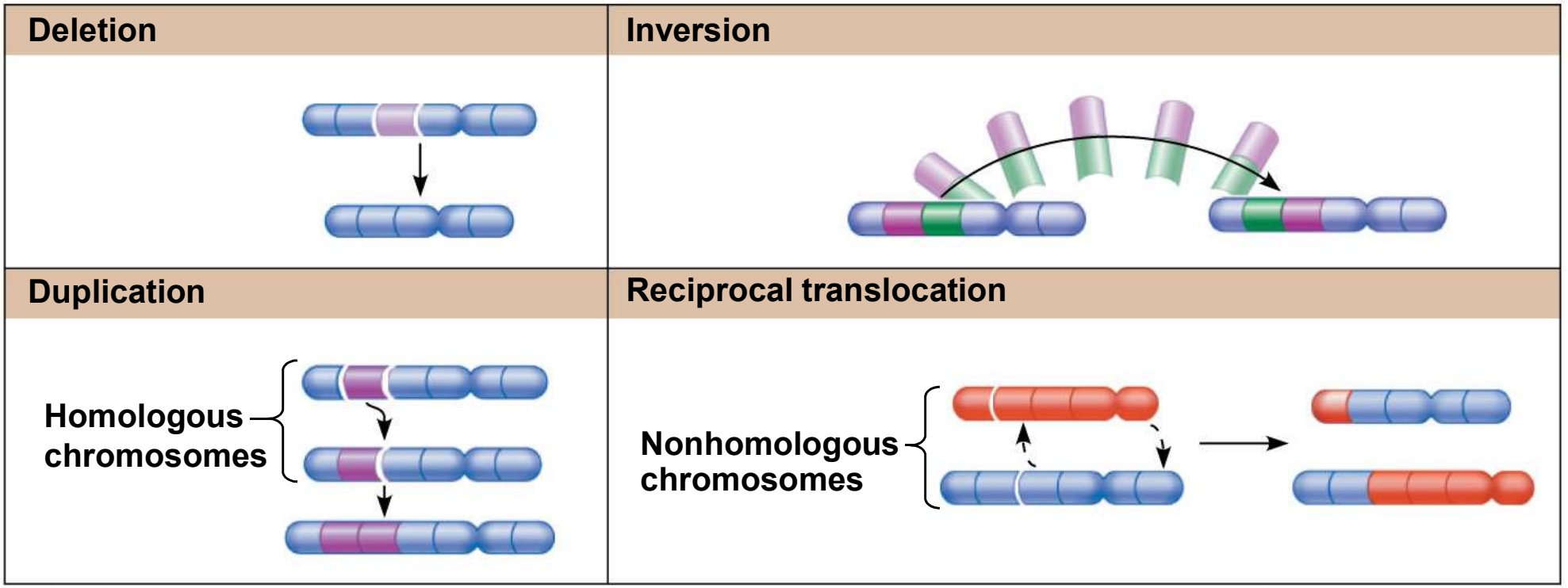
8.23 Alterations of chromosome structure can cause birth defects and cancer

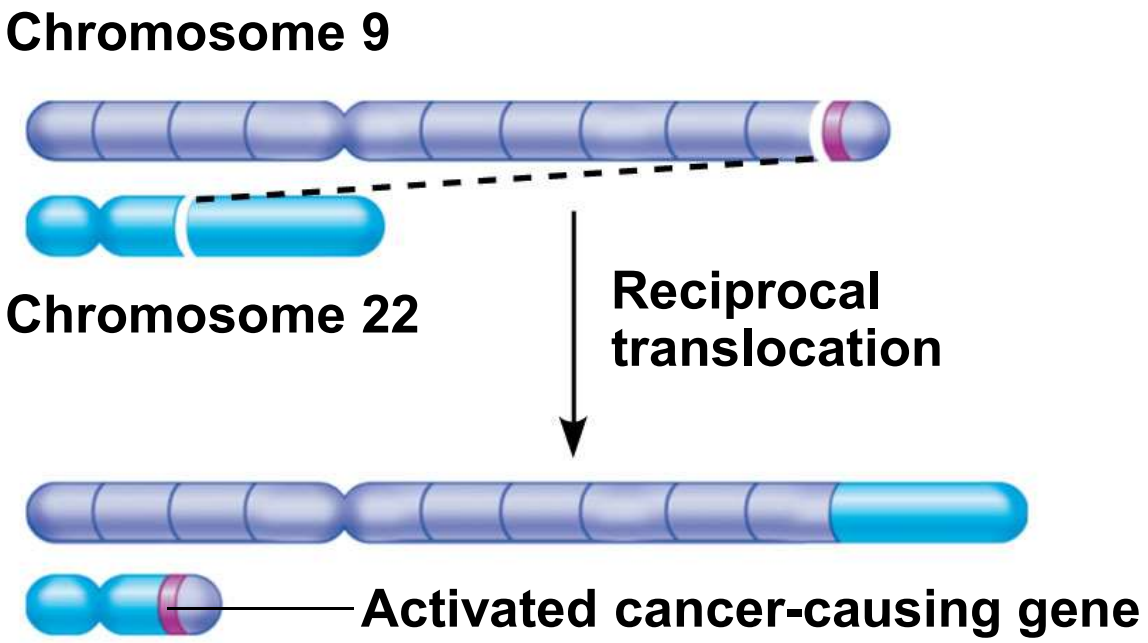
- Chromosome breakage can lead to rearrangements that can produce
  - genetic disorders or,
  - if changes occur in somatic cells, cancer.
- These rearrangements may include
  - **a deletion**, the loss of a chromosome segment,
  - **a duplication**, the repeat of a chromosome segment,
  - **an inversion**, the reversal of a chromosome segment, or
  - **a translocation**, the attachment of a segment to a nonhomologous chromosome that can be reciprocal.

8.23 Alterations of chromosome structure can cause birth defects and cancer

- Chronic myelogenous leukemia (CML) 慢性骨髓性白血病
  - is one of the most common leukemias,
  - affects cells that give rise to white blood cells (leukocytes), and
  - results from part of chromosome 22 switching places with a small fragment from a tip of chromosome 9.
- Such an exchange causes cancer by activating a gene that leads to uncontrolled cell cycle progression.
- Because the chromosomal changes in cancer are usually confined to somatic cells, cancer is not usually inherited.

Figure 8.23A





You should now be able to

1. Compare the parent-offspring relationship in asexual and sexual reproduction.
2. Explain why cell division is essential for prokaryotic and eukaryotic life.
3. Explain how daughter prokaryotic chromosomes are separated from each other during binary fission.
4. Compare the structure of prokaryotic and eukaryotic chromosomes.
5. Describe the stages of the cell cycle.
6. List the phases of mitosis and describe the events characteristic of each phase.
7. Compare cytokinesis in animal and plant cells.
8. Explain how anchorage, cell density, and chemical growth factors control cell division.
9. Explain how cancerous cells are different from healthy cells.
10. Describe the functions of mitosis.
11. Explain how chromosomes are paired.

12. Distinguish between somatic cells and gametes and between diploid cells and haploid cells.
13. Explain why sexual reproduction requires meiosis.
14. List the phases of meiosis I and meiosis II and describe the events characteristic of each phase.
15. Compare mitosis and meiosis noting similarities and differences.
16. Explain how genetic variation is produced in sexually reproducing organisms.
17. Explain how and why karyotyping is performed.
18. Describe the causes and symptoms of Down syndrome.
19. Describe the consequences of abnormal numbers of sex chromosomes.
20. Define nondisjunction, explain how it can occur, and describe what can result.
21. Explain how new species form from errors in cell division.
22. Describe the main types of chromosomal changes. Explain why cancer is not usually inherited.