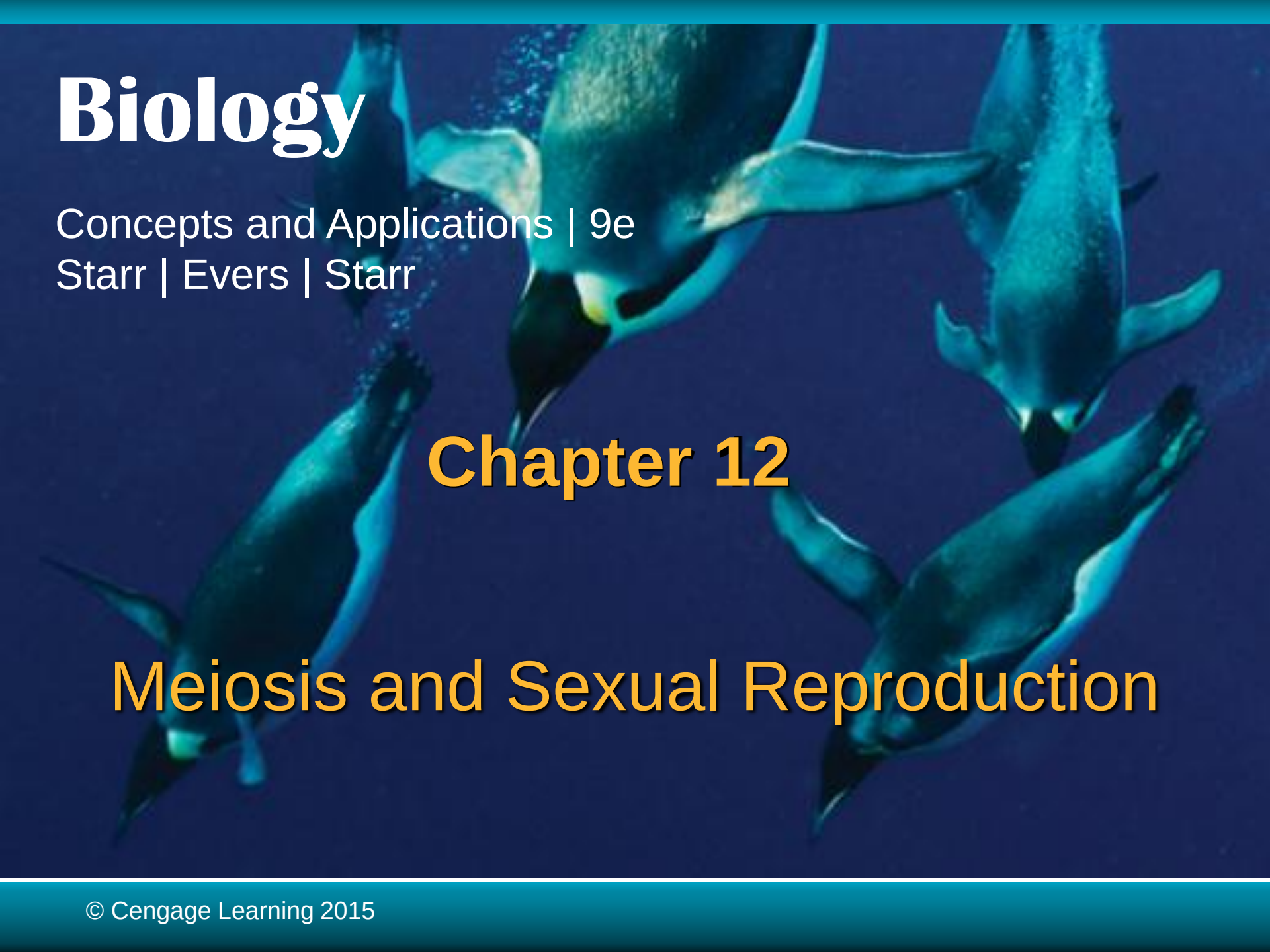


Biology

Concepts and Applications | 9e
Starr | Evers | Starr

Chapter 12

Meiosis and Sexual Reproduction

12.1 Why Sex?

- In *asexual reproduction*, a single individual gives rise to offspring that are identical to itself and others
- In *sexual reproduction,* two individuals mix their genetic material

Why Sex? (cont'd.)

Introducing Alleles

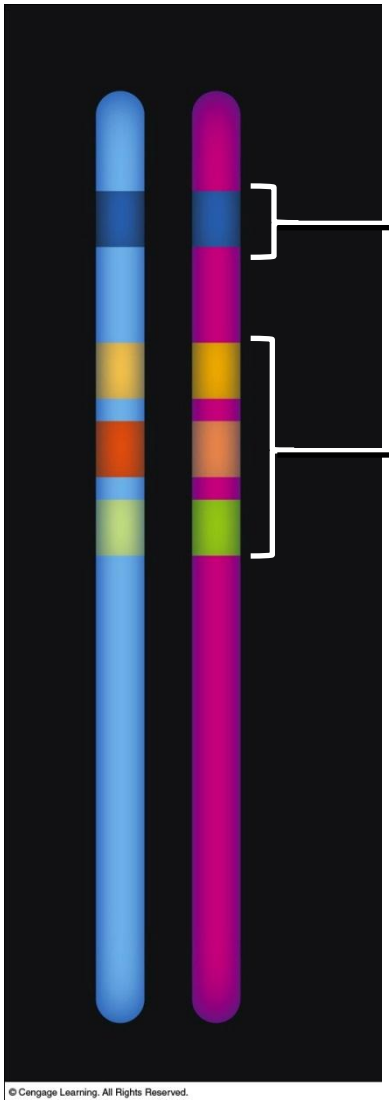
- Somatic (body) cells of sexually-reproducing eukaryotes contain pairs of homologous chromosomes:
  - One from the mother and one from the father
- Homologous chromosomes:
  - Carry genes (one from the mother and one from the father) of the same characteristics
- Different forms of the same gene are called alleles

Introducing Alleles (cont'd.)

- Paired genes on homologous chromosomes may vary in DNA sequences as *alleles*
  - Arise by mutation
  - Are the basis of differences in shared traits
- Offspring of sexual reproducers inherit new combinations of parental alleles
  - Results in new combinations of traits

Introducing Alleles (cont'd.)

A



B

Genes occur in pairs on homologous chromosomes.

The members of each pair of genes may be identical, or they may differ slightly, as alleles.

On the Advantages of Sex

- Sex mixes up the genes of two parents, so offspring have unique combinations of traits
- Diversity offers a better chance of surviving environmental change than clones

Red Queen Hypothesis

- In reference to Lewis Carroll's book *Through the Looking Glass*
  - Queen of Hearts tells Alice, "It takes all the running you can do, to keep in the same place"
- Organisms must constantly adapt and evolve in an ever-changing environment
  - Used to explain the evolution of sexual reproduction

12.2 Why Is Meiosis Necessary for Sexual Reproduction?

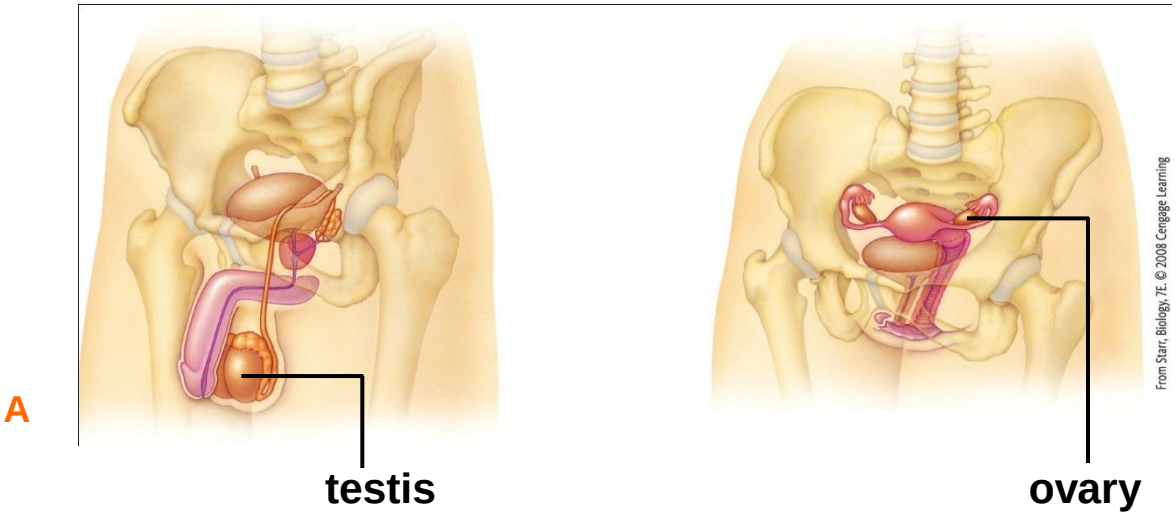
- Asexual reproduction produces clones
- Sexual reproduction mixes up alleles from two parents
  - Involves the fusion of gametes, mature reproductive cells
- Meiosis: a nuclear division mechanism that occurs in reproductive cells of eukaryotes

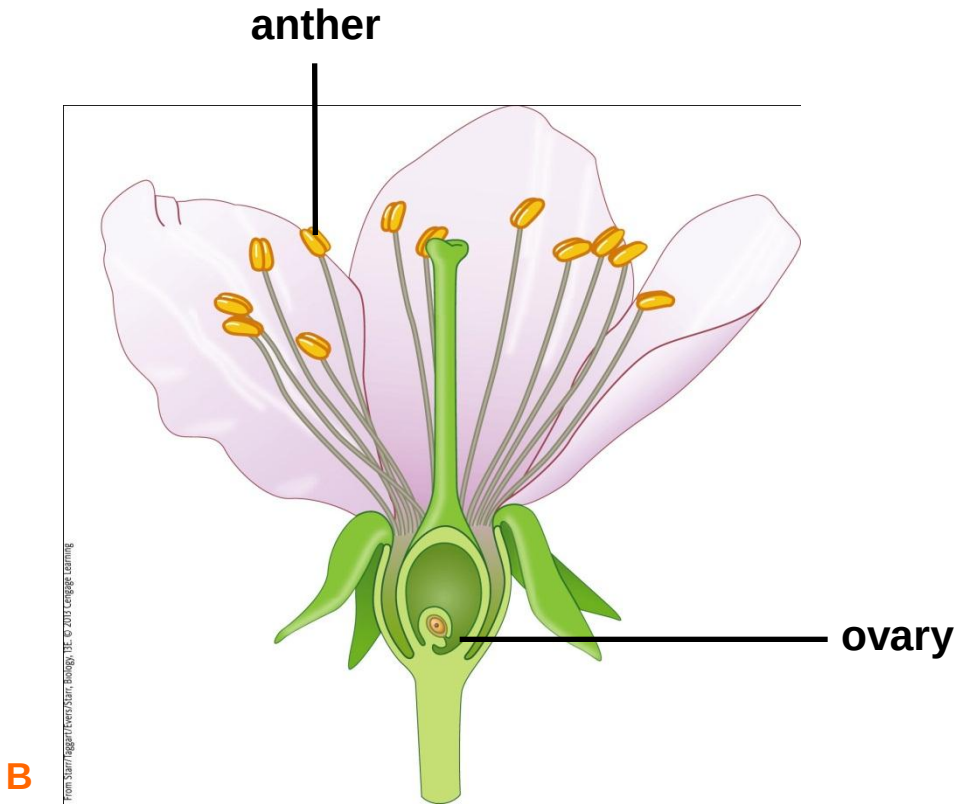
Meiosis Halves the Chromosome Number

- Gametes are specialized cells that are the basis of sexual reproduction
- Derive from germ cells: immature reproductive cells
- All gametes are haploid (*n*), but they differ in other details
- Gamete formation differs among plants and animals

Meiosis Halves the Chromosome Number (cont'd.)

Francis Leroy, Biocosmos/Science Photo Library/Science Source

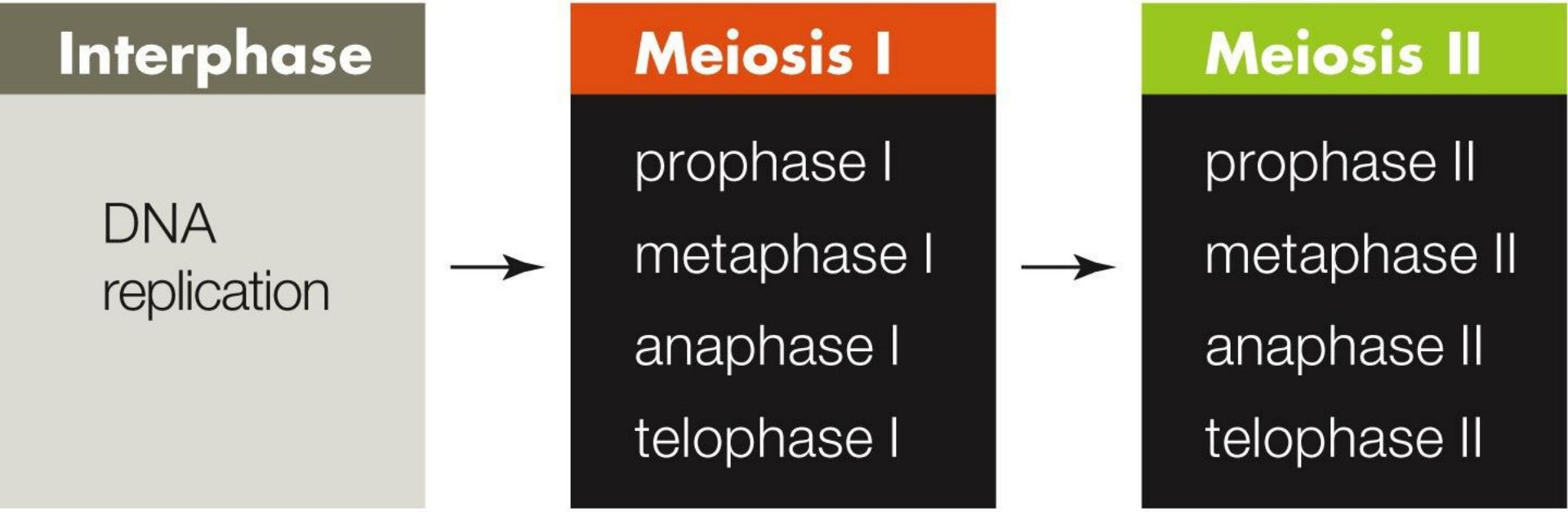




Meiosis Halves the Chromosome Number (cont'd.)

- Haploid germ cells form by meiosis
- Gametes form when these cells divide by mitosis

Meiosis Halves the Chromosome Number (cont'd.)



Meiosis Halves the Chromosome Number (cont'd.)

- In males, the diploid germ cell develops into sperm
- In females, a diploid germ cell becomes an egg

Meiosis Halves the Chromosome Number (cont'd.)

- Occurs in the gametes – mature reproductive cells
  - Gametes are haploid (*n*)
  - Their chromosome number is half of the diploid (2*n*) number
- Meiosis is a nuclear division

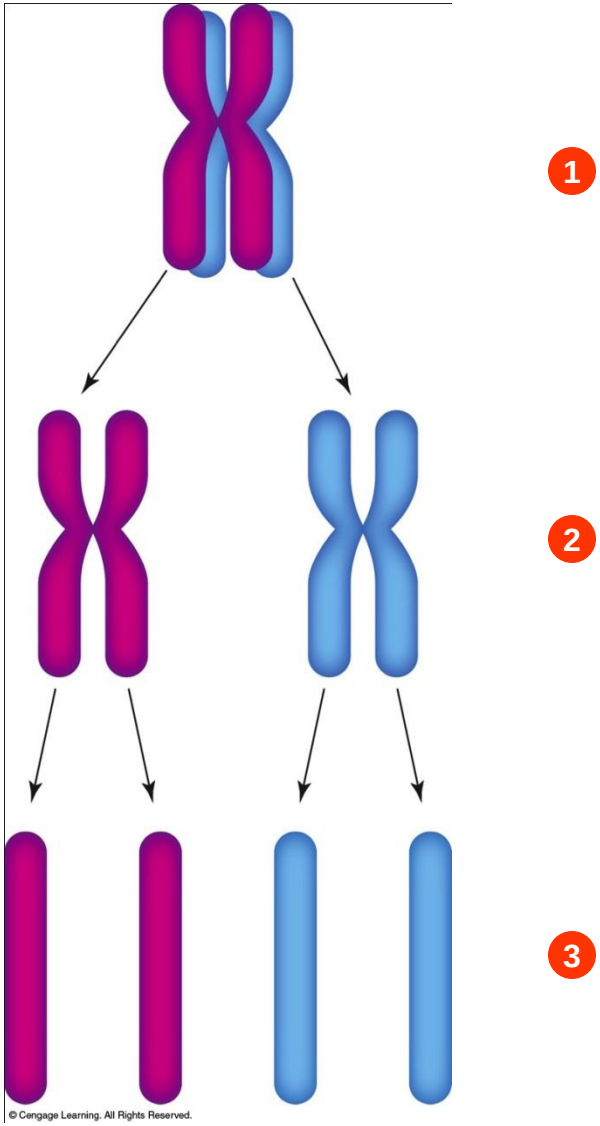
Meiosis Halves the Chromosome Number (cont'd.)

- Nuclear division that halves the chromosome number in the reproductive cells
  - Ensures that offspring have the same number of chromosomes as the parents

Meiosis Halves the Chromosome Number (cont'd.)

- DNA replication occurs prior to meiosis:
  - The nucleus is diploid (2*n*) with two sets of chromosomes, one from each parent
  - During meiosis, chromosomes of a diploid nucleus become distributed into four haploid nuclei
- Meiosis halves diploid (2*n*) chromosome to the haploid (*n*) number for forthcoming gametes

Meiosis Halves the Chromosome Number (cont'd.)



Fertilization Restores the Chromosome Number

- Haploid gametes form by meiosis
- The diploid chromosome number is restored at fertilization
- Two haploid gametes fuse a zygote is formed
- A zygote is a cell formed by the fusion of two gametes
  - The first cell of a new individual

Fertilization Restores the Chromosome Number (cont'd.)

- If meiosis did not precede fertilization, the chromosome number would double with every generation
- Chromosome number changes can have drastic consequences in animals
- An individual's set of chromosomes is like a fine-tuned blueprint that must be followed exactly to have normal functions

12.3 What Happens to a Cell During Meiosis?

- Meiosis I: Prophase I
  - Homologous chromosomes condense, pair up, and swap segments
  - Spindle microtubules attach to chromosomes as the nuclear envelope breaks up

What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis I: Metaphase I
  - The homologous chromosome pairs are aligned midway between spindle poles

What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis I : Anaphase I
  - The homologous chromosomes separate and begin heading toward the spindle poles

What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis I: Telophase I
  - Two clusters of chromosomes reach the spindle poles
  - A new nuclear envelope forms around each cluster, so two haploid (*n*) nuclei form

3D ANIMATION: Meiosis

What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis II: Prophase II
  - The chromosomes condense
  - The nuclear envelope breaks up
  - Spindle microtubules attach to each sister chromatid

What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis II: Metaphase II
  - The (still duplicated) chromosomes are aligned midway between poles of the spindle

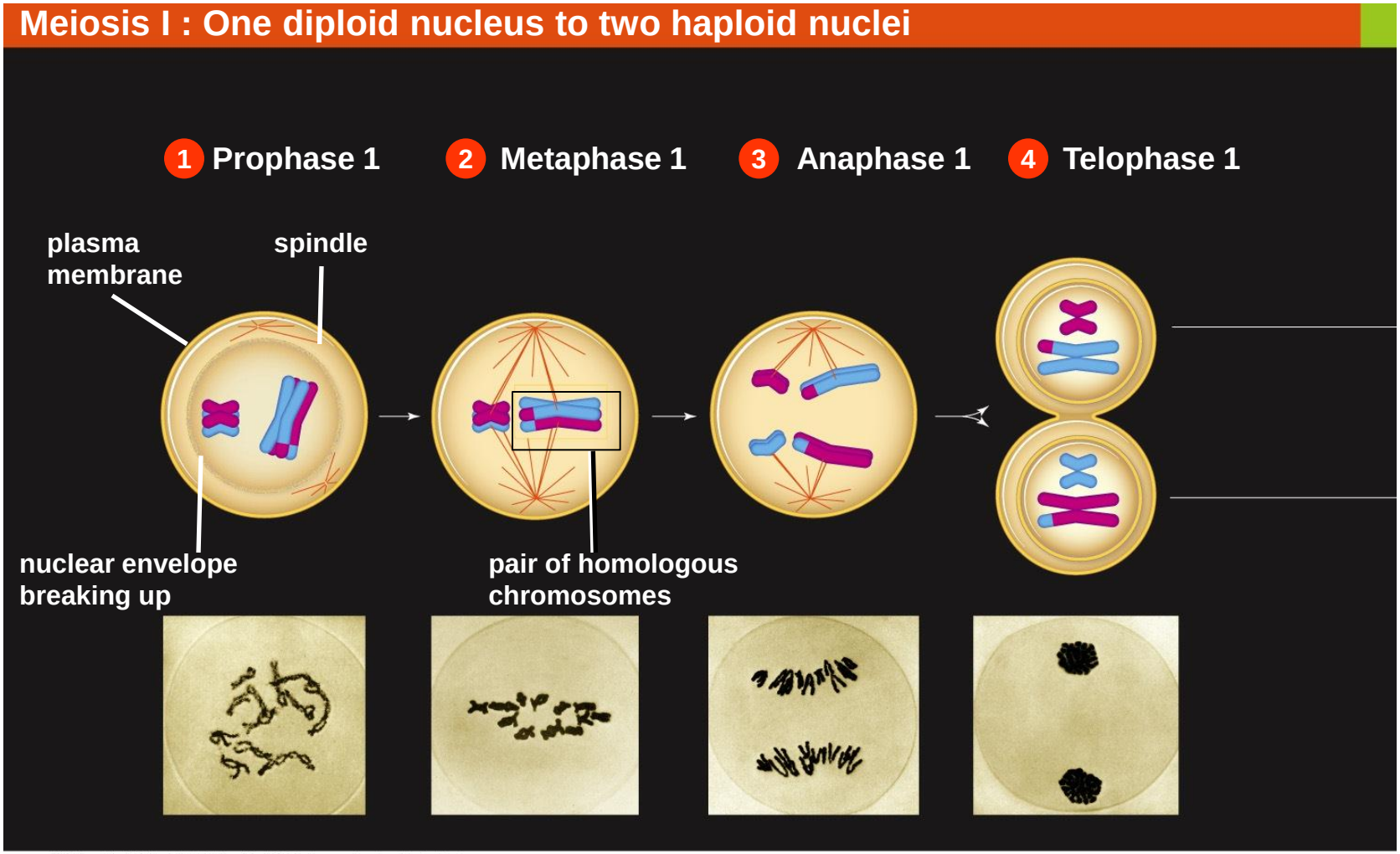
What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis II: Anaphase II
  - All sister chromatids separate
  - The (now unduplicated) chromosomes head to the spindle poles

What Happens to a Cell During Meiosis? (cont'd.)

- Meiosis II: Telophase II
  - A complete set of chromosomes clusters at each spindle pole
  - A new nuclear envelope encloses each cluster
  - Four haploid (*n*) nuclei form

What Happens to a Cell During Meiosis? (cont'd.)



CREDITS: (4) Bottom photos, With thanks to the John Innes Foundation Trustees, computer enhanced by Gary Head; Top art, © Cengage Learning.

12.4 How Meiosis Introduces Variations in Traits

- Two events in meiosis introduce novel combinations of alleles into gametes:
  - Crossing over in prophase I
  - Segregation of chromosomes into gametes
- Along with fertilization, these events contribute to the variation in combinations of traits among the offspring of sexually reproducing species

Crossing Over in Prophase I

- Chromatids of homologous chromosomes condense and align along their length and exchange segments
  - Introduces novel combinations of traits among offspring

ANIMATION: Crossing over

Please wait, loading

To play movie you must be in Slide Show Mode

PC Users: Please wait for content to load, then click to play

Mac Users: **CLICK HERE**

Chromosome Segregation

- When homologous chromosomes separate in meiosis I, one of each chromosome pair goes to each of the two new nuclei
- For each chromosome pair, the maternal or paternal version is equally likely to end up in either nucleus

Chromosome Segregation (cont'd.)

- Human gametes have 23 pairs of homologous chromosomes
  - Each time a human germ cell undergoes meiosis the four gametes that form end up with one of 8,388,608 (or 223) possible combinations of homologous chromosomes
- Crossing over increases these combinations

Chromosome Segregation (cont'd.)

- The chance that the maternal or paternal version of any chromosome will end up in a particular nucleus is 50 percent – Why?
  - Due to the way the spindle segregates the homologous chromosome during meiosis I
    - In prophase I, chromosomes are attached to spindle poles
    - Each homologous partner becomes attached to opposite spindle poles

ANIMATION: Random alignment

Please wait, loading

To play movie you must be in Slide Show Mode

PC Users: Please wait for content to load, then click to play

Mac Users: **CLICK HERE**

12.5 Are the Processes of Mitosis and Meiosis Related?

- There are striking parallels between the four stages of mitosis and meiosis II
- Many more similarities exist at the molecular level
- Meiosis may have evolved by remodeling the existing mechanisms of mitosis or for repairing damaged DNA

ANIMATION: Mitosis step-by-step

To play movie you must be in Slide Show Mode

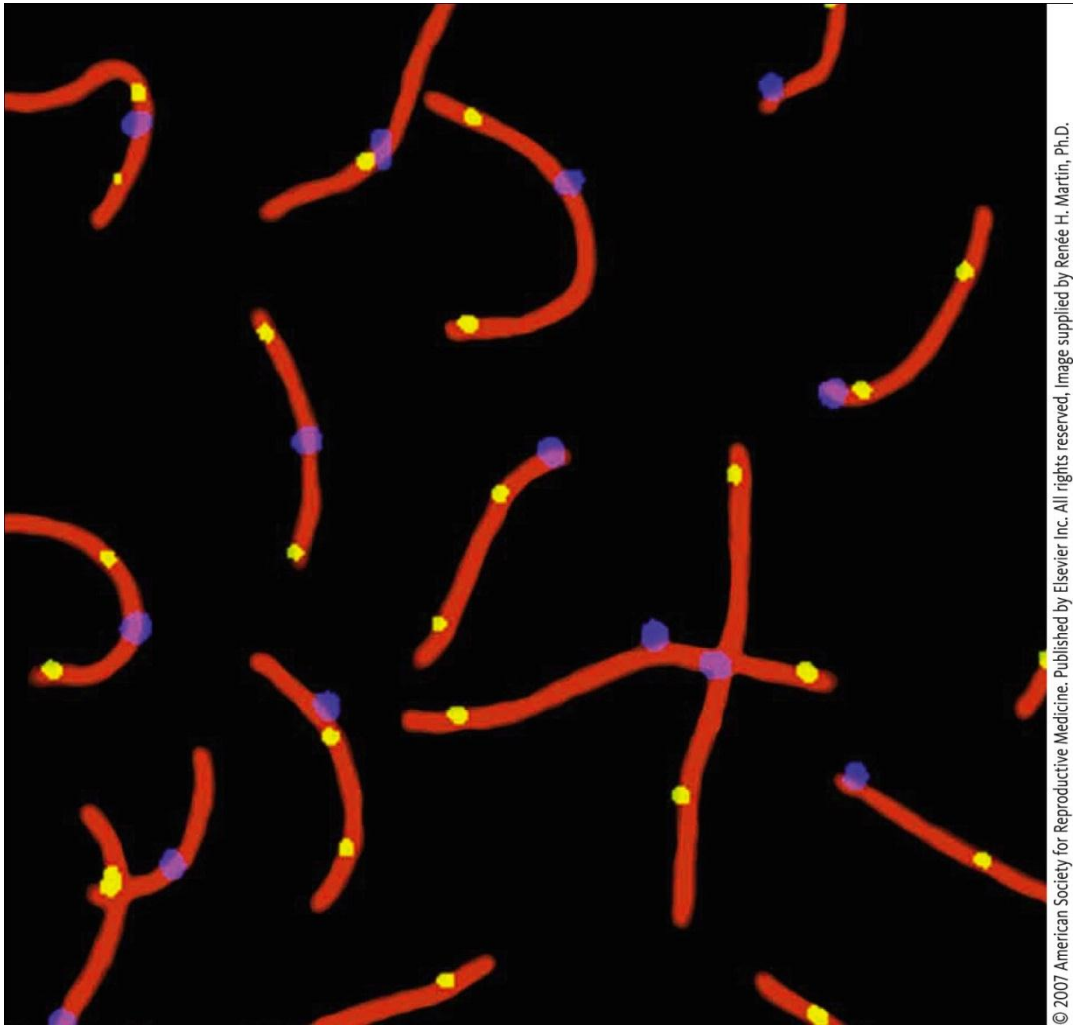
PC Users: Please wait for content to load, then click to play

Mac Users: **CLICK HERE**

Are the Processes of Mitosis and Meiosis Related? (cont'd.)

- Evidence for this hypothesis includes a host of shared molecules
  - Includes the products of the BRCA genes made by all eukaryotes
- By fixing the problems with DNA (mismatched base pairs), these molecules maintain integrity of cell's chromosomes

Are the Processes of Mitosis and Meiosis Related? (cont'd.)



12.6 Application: How To Survive 80 Million Years Without Sex

- In nature, there are a few all-female species of fishes, reptiles, and birds but not mammals
  - Females have been reproducing themselves for 80 million years through cloning themselves
- Asexual reproduction is a poor long-term strategy because it lacks crossing over that leads to genetic diversity

How To Survive 80 Million Years Without Sex (cont'd.)

© Wim van Egmond/Visuals Unlimited/Corbis.

How To Survive 80 Million Years Without Sex (cont'd.)

- Bdelloid rotifers: microscopic animals found in fresh water
  - Males are not present within the species
  - Females reproduce by asexual cloning
  - Have diversified into 360 species
  - Can import genes from bacteria, fungi, protists, and even plants
  - About 10 percent of their active genes have been pilfered from other organisms