Terms Introduced in This Chapter

After reading Chapter 3, you should be familiar with the following terms. These terms are defined in Chapter 3 and in the Glossary.

Amphitrichous bacterium
Archaea
Archaeans
Asexual reproduction
Autolysis
Axial filaments
Bacteria
Bacteria
Binary fission
Capsule
Cell
Cell membrane
Cell theory
Cell wall
Cellulose
Chitin
Chloroplast
Chromosomes
Cilium (pl., *cilia*)
Conjugation
Cytokinesis
Cytology
Cytoplasm
Cytoskeleton
Deoxyribonucleic acid (DNA)
Diploid cells
Endoplasmic reticulum (ER)
Endospore
Eucarya
Eucaryotic cells
Fimbriae (sing., *fimbria*)
Flagella (sing., *flagellum*)
Flagellin
Gene
Gene product
Generation time
Genotype (Genome)
Genus (pl., *genera*)
Glycocalyx
Golgi complex
Haploid cells
Life cycle
Lophotrichous bacterium
Lysosome
Meiosis
Metabolism
Microtubules
Mitochondria (sing., *mitochondrion*)
Mitosis
Monotrichous bacterium
Negative stain
Nuclear membrane
Nucleolus
Nucleoplasm
Nucleus (pl., *nuclei*)
Organelles
Peptidoglycan
Peritrichous bacterium
Peroxisome
Phagocyte
Phagocytosis
Photosynthesis
Pili (sing., *pilus*)
Plasmid
Plastid
Polyribosomes
Procaryotic cells
Protists
Protoplasm
Ribonucleic acid (RNA)
Ribosomes
Rough endoplasmic reticulum (RER)
Selective permeability
Sex pilus
Sexual reproduction
Slime layer
Smooth endoplasmic reticulum (SER)
Species (pl., *species*)
Specific epithet
Spirochetes
Sporulation
Taxa (sing., *taxon*)
Taxonomy
Tyndallization

Insight

Asexual Versus Sexual Reproduction

In ***asexual reproduction***, a single organism is the sole parent. It passes copies of all of its genes (i.e., its entire genome) to its offspring. Some single-celled eucaryotic organisms can reproduce asexually by mitotic cell division (mitosis; described later), a process by which their chromosomes are copied and allocated equally to two daughter cells. The genomes of the offspring are identical to the parent's genome. Procaryotic organisms reproduce asexually by a process known as binary fission (described later).

In ***sexual reproduction***, two parents give rise to offspring that have unique combinations of genes inherited from both parents. The alternation of meiosis (described later) and fertilization is common to all organisms that reproduce sexually. In sexual reproduction, a zygote (fertilized egg) is formed by the fusion of gametes.

Most **protists** can reproduce asexually. Some protists are exclusively asexual, whereas others can also reproduce sexually (involving meiosis and the fusion of gametes). Fungi (other than yeasts) reproduce by releasing spores, which are produced either sexually or asexually. Most yeasts reproduce asexually, either by simple cell division or by the process of budding. Budding, a type of mitosis, involves the formation of a small cell (called a bud), which then pinches off the parent cell. Some yeasts reproduce sexually.

Life Cycles

A ***life cycle*** can be defined as the generation-to-generation sequence of stages that occur in the reproductive history of an organism. The human life cycle (which is also the life cycle of most animals and some protists) involves production of haploid gametes by meiosis, fusion of gametes to produce a diploid zygote, and mitotic division of the zygote to produce a multicellular organism, composed of diploid cells. (***Haploid cells*** contain only one set of chromosomes, whereas ***diploid cells*** contain two sets of chromosomes.)

Another type of life cycle that occurs in most fungi and some protists, including some algae, involves fusion of haploid gametes to form a diploid zygote, meiosis to produce haploid cells, and then division of the haploid cells by mitosis to give rise to a multicellular adult organism that is composed of haploid cells. Gametes are then produced from the haploid organism by mitosis (rather than by meiosis). Thus, the only diploid stage is the zygote.

A third type of life cycle that occurs in plants and some species of algae is called alternation of generations. In this type of life cycle, there are both diploid and haploid multicellular stages. The multicellular diploid stage is called the sporophyte. Meiosis in the sporophyte produces haploid cells called spores. Unlike a gamete, a spore gives rise to a multicellular organism without fusing with another cell. A spore divides mitotically to generate a multicellular haploid stage called the gametophyte. The gametophyte makes gametes by mitosis. Fertilization results in a diploid zygote, which develops into the next sporophyte generation. Thus, the sporophyte and gametophyte generations take turns reproducing each other.

Eucaryotic Cell Reproduction

Eucaryotic cells may reproduce either by mitosis or meiosis. Mitosis results in two cells (called daughter cells), which are identical to the original cell (the parent cell). Meiosis results in four cells, each of which contains half the number of chromosomes as the parent cell.

Mitosis

The word mitosis comes from the Greek word *mito*, meaning “thread.” When cells are observed microscopically, threadlike structures can be seen during mitosis. Technically speaking, **mitosis** refers to nuclear division—the equal division of one nucleus into two genetically identical nuclei. Mitosis is preceded by replication of chromosomes, which occurs during a part of the cell life cycle known as interphase. During mitosis, the nuclear material of the parent cell shifts, reorganizes, and moves around, leading some people to refer to mitosis as “the dance of the chromosomes.” After mitosis occurs, the cytoplasm divides (a process known as ***cytokinesis***), resulting in two daughter cells. Either haploid or diploid cells can divide by mitosis.

Meiosis

Only diploid cells can undergo meiosis. As with mitosis, meiosis is preceded by replication of chromosomes. In **meiosis,** diploid cells are changed into haploid cells. Human diploid cells, for example, contain 46 chromosomes, whereas human haploid cells (sperm cells and ova) contain 23. Meiosis is the process by which gametes are produced. Many steps are involved in meiosis—too many to discuss in detail here. Suffice it to say that meiosis involves two divisions (called meiosis I and meiosis II). The end result is four daughter cells, each of which contains only half as many chromosomes as the parent cell. Recall that mitosis produces two daughter cells that are genetically identical to the parent cell.

The Origin of Mitochondria and Chloroplasts

Symbiosis is the living together or close association of two dissimilar organisms, usually two different species. In such a relationship, each party is referred to as a symbiont. Endosymbionts are organisms that live inside of other organisms, the latter of which are referred to as hosts.

Many scientists believe that the mitochondria and chloroplasts of eucaryotic cells were originally derived from bacterial endosymbionts—bacteria that once led a free-living, independent existence. The theory known as the serial endosymbiosis hypothesis proposes that, at some point in time—perhaps 1.5 billion years ago—certain bacteria were engulfed (phagocytized) by other procaryotic cells. At first, the engulfed bacteria continued to live an independent existence within the host cells. But, in time, an interdependence developed between the two organisms, and the endosymbionts developed into the organelles known as mitochondria and chloroplasts.

Most of the evidence for the serial endosymbiosis theory is based on similarities between these organelles and bacteria. Mitochondria possess a circular chromosome, a specific type of RNA, and ribosomes (which are very much like those of bacteria), and similar to bacteria, mitochondria arise only from preexisting mitochondria. Chloroplasts are very much like photosynthetic bacteria. They contain DNA and ribosomes quite similar to those found in bacteria, and they too arise independently of other organelles. This theory becomes even more plausible when one considers that many simple marine animals and protists existing today contain photosynthetic endosymbionts. Based on 16S rRNA sequence data, the most likely candidates to have evolved into mitochondria and chloroplasts are alpha purple bacteria and cyanobacteria, respectively. (See text for information on 16S sequences.)

Not all scientists agree with the serial endosymbiosis theory, however. Another theory—the autogenous hypothesis—states that mitochondria and chloroplasts, as well as other membranous structures found within eucaryotic cells, were derived from the cytoplasmic membrane. Undoubtedly, additional research will determine which of these hypotheses is correct.

Increase Your Knowledge

Technical information about the bacterial genomes that have been sequenced to date can be found at the web site of The Institute for Genomic Research—www.tigr.org. TIGR published the first complete microbial genomic sequence—that of *Haemophilus influenzae*—in 1995.

Critical Thinking

1. Draw a picture of a eucaryotic cell from memory, labeling as many structures as possible. Use the outline below to represent the cell membrane. When you are finished, compare your drawing to Figure 3-2 in the book.

2. Draw a picture of a procaryotic cell from memory, labeling as many structures as possible. Use the outline below to represent the cell membrane. When you are finished, compare your drawing to Figure 3-6 in the book.

Additional Chapter 3 Self-Assessment Exercises

(Note: Don't peek at the answers before you attempt to solve these self-assessment exercises.)

Matching Questions

A. plastids
B. mitochondria
C. ribosomes
D. endoplasmic reticulum
E. Golgi complex

_____ 1. Membrane-bound organelles where photosynthesis occurs.
_____ 2. The sites of protein synthesis in procaryotic cells.
_____ 3. Considered a "packaging plant," where proteins are packaged into membrane-bound vesicles.
_____ 4. Membrane-bound organelles where energy is produced by the Krebs cycle and electron transport chain.
_____ 5. Found in procaryotic cells as well as eucaryotic cells.

A. pili
B. cilia
C. eucaryotic flagella
D. capsules
E. procaryotic flagella

_____ 6. Short, hairlike projections used as organelles of locomotion by some eucaryotic cells.
_____ 7. Found on some bacteria; they serve an antiphagocytic function.
_____ 8. Found on some bacteria; they enable the bacteria to adhere to surfaces.
_____ 9. Composed of a protein called flagellin.
_____ 10. Long, whiplike structures having an internal organization that is described as a "9+2" arrangement of microtubules.

True/False Questions

_____ 1. The internal structure of procaryotic flagella is the same as the internal structure of eucaryotic flagella.
_____ 2. The internal structure of eucaryotic cilia is the same as the internal structure of eucaryotic flagella.
_____ 3. The production of endospores by bacteria is a reproductive mechanism.
_____ 4. Bacteria never have cilia and eucaryotic cells never have pili.
_____ 5. The 3-Domain System of classification is based on differences in the structure of transfer RNA (tRNA) molecules.
_____ 6. One way that archaeans differ from bacteria is that archaeans possess more peptidoglycan in their cell walls.
_____ 7. Chitin is found in the cell walls of algae, but is not found in the cell walls of any other types of microorganisms.
_____ 8. Tyndallization is a process that kills spores as well as vegetative cells.
_____ 9. Procaryotic cells do not contain endoplasmic reticulum, Golgi bodies, mitochondria, plastids, or membrane-bound vesicles.
_____ 10. In eucaryotic cells, ribosomal RNA (rRNA) molecules are manufactured in the nucleolus.

Answers to the Chapter 3 Self-Assessment Exercises in the Text

1. C
2. C
3. B
4. C
5. C
6. C
7. B
8. C
9. A
10. C

Answers to the Additional Chapter 3 Self-Assessment Exercises

Matching Questions

1. A
2. C
3. E
4. B
5. C
6. B
7. D
8. A
9. E
10. C

True/False Questions

1. False (eucaryotic flagella contain microtubules, whereas procaryotic flagella do not)
2. True
3. False (production of endospores is a survival mechanism)
4. True
5. False (the 3-Domain System is based on differences in the structure of ribosomal RNA [rRNA])
6. False (archaean cell walls do not contain peptidoglycan)
7. False (chitin is found in the cell walls of fungi)
8. True
9. True
10. True