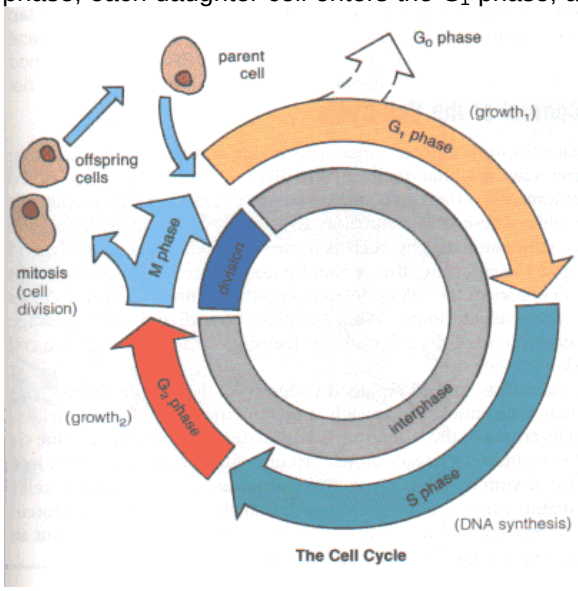
Chapter 9 – The Cell Cycle

1. **Cell Cycle** – model developed to describe and understand the continuous sequence of events in the life of a cell
   The Cell Cycle focuses on DNA synthesis and cell reproduction. **Used by eukaryotic cells only**
   Starts with the formation of a new cell and continues until that cell divides into two daughter cells

2. **Cell Division** – the process of producing two cells from one cell
   Unicellular organisms reproduce through cell division
   Multi-cellular organisms use it for growth, repair, and maintenance
   Before the cell splits, exact copies of the chromosomes are made inside the nucleus
   Each new cell receives, theoretically, the exact same copy of genetic instructions

3. **Phases of the Cell Cycle**
   Interphase – the time between divisions. The cell spends most of its life in this phase. 3 "sub" phases
      G_1 (Growth 1) phase – the time of cell growth just following cell division
         New cells are metabolically active, especially in protein and RNA synthesis
         Varies in length from a few hours to several days or more. May be affected by hormones
         G_0 (Extended Growth) phase – these cells don't divide, but still are important
            Adult nerve cells are in G_0 phase – that's why brain damage can't be repaired
            Much of stems, roots, leaves, and flowers are in G_0 phase
               Only the tips of these parts undergo the entire cell cycle
      S (synthesis) phase – an exact copy of the DNA is made, doubling the DNA in the nucleus
         Begins with the initiation of DNA synthesis and ends with its completion
         Usually lasts between 3 – 6 hours
      G_2 (Growth 2) phase – period of growth and metabolism occurring after the S phase
         Proteins, RNA, and other macromolecules are synthesized, but in smaller numbers
         Since S phase replicated the DNA, G_2 has twice the DNA has G_1
         Usually lasts 2 – 5 hours
   The M phase - occurs after G2, involves the actually splitting of the cell
      The only phase in which the chromosomes are visible with a light microscope
      Mitosis – nuclear division in which the replicated chromosomes separate to form two nuclei
         The phases of Mitosis are described in A Closer Look - M Phase
      Chromatin – genetic material as they would appear under normal conditions
         During Mitosis, chromatins become visible
      Cytokenesis – the splitting of the cytoplasm
      After mitosis, the cell splits into two daughter cells, completing the M phase
      After the M phase, each daughter cell enters the G_1 phase, and the cycle continues



The Cell Cycle

4. **Speed of the Cell Cycle** – different types of cells divide at different rates
   In animals, nerve, muscle, and red blood cells do not divide (they stay in the G_0 phase)
   In animals, skin and bone marrow cells divide very rapidly, as often as every 8 hours
   "Trigger" protein – determines how fast a cell matures and when it divides
      Animals cells acummulate this protein during the G1 phase

When enough of the protein is present, the cell proceeds into the S phase
Hormones, cell size, and cell's position influences the amount of trigger protein production

5. **DNA structure** – carries the genetic instructions for cell function, and are copied during the S phase

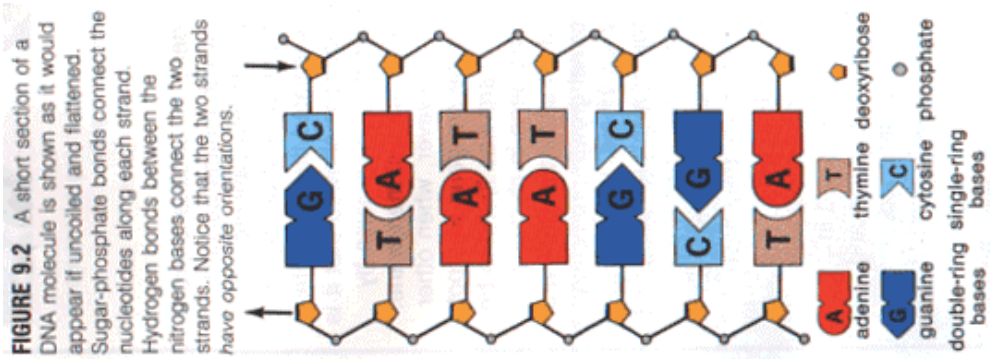


FIGURE 9.2 A short section of a DNA molecule is shown as it would appear if uncoiled and flattened. Sugar-phosphate bonds connect the nucleotides along each strand. Hydrogen bonds between the nitrogen bases connect the two strands. Notice that the two strands *have opposite orientations.*

6. **A Closer Look – The S Phase** – DNA is replicated in this phase.
   DNA polymerases – enzymes. They unwind, separate, read, build, and correct the strands of DNA
      Only works in 1 direction, so they must work from opposite ends of the DNA molecule
   DNA is split into 2 "half" strands, that pick up other nucleotides
      Since A can only bind to T and C to G, each strand serves as a template for new DNA
   The DNA polymerases move along the original strand, adding proper types of new molecules
      One strand is the leading strand – the DNA polymerases reads the code continuously
      The other strand is the lagging strand – the DNA reads the code in small, discontinued, segments
      For more information, see **Replication Forks**
   The phosphate of one nucleotide bonds covalently to the sugar of the next nucleotide
   The new DNA molecule contains one strand of the original, and 1 strand of new molecules
   Semiconservative Replication – each of the two new molecules conserves one strand of the original
   Shown is only a very small strand of DNA. For replication on a large scale, see **Replication Forks**

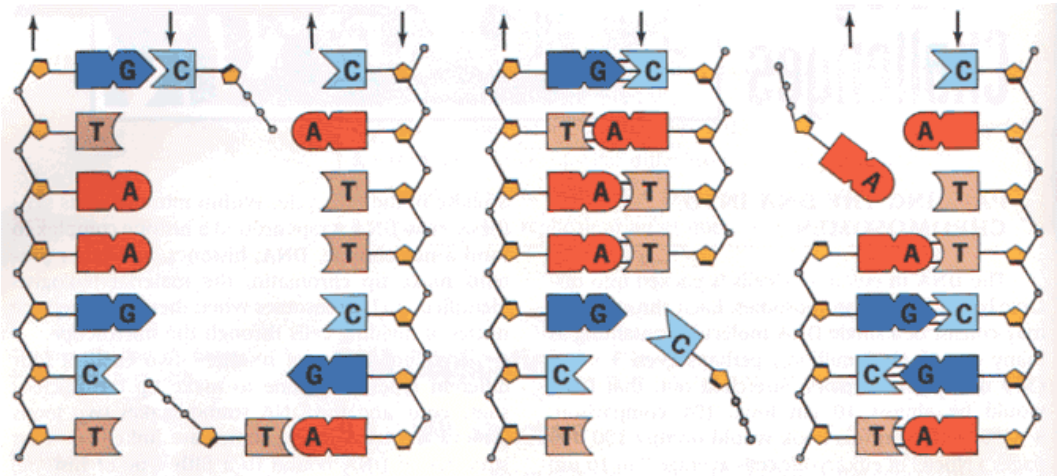


FIGURE 9.3 Two strands of DNA are separated by enzyme action. New nucleotides begin to pair with those of the original strands. Notice that the new nucleotides carry extra phosphates.

FIGURE 9.4 New nucleotides continue to be brought into place. The energy of their extra phosphates is used to bond these new arrivals to the preceding nucleotides.

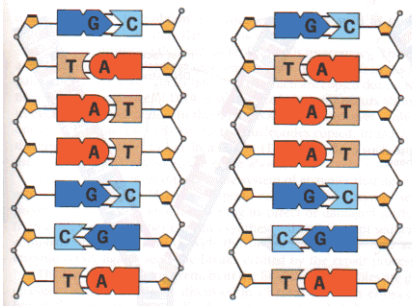


FIGURE 9.5 Two new fragments of double-stranded DNA are completed. Compare them to one another and to the original in Figure 9.2. Has the replication been exact?

7. **Replication Forks** – Places where replication occurs simultaneously
   The process described in section 6 is only for a very small fragment of DNA
   Since the entire DNA molecule is very long, if it had to be "read" and "built" from one end to the other, it will take a long time. Replication occurs simultaneously at many sites called replication forks

   At each one of these forks, synthesis such as described in section 6 takes place
   These forks move along the double stranded molecule in 1 direction as new DNA is synthesized
   However, replication takes place differently among each strand
      On the leading strand, synthesis at a fork is continuous in 1 direction (see picture)
      On the lagging strand, synthesis occurs in the opposite direction, in discontinuous segments
         The segments are joined together by other enzymes to the completed DNA strand

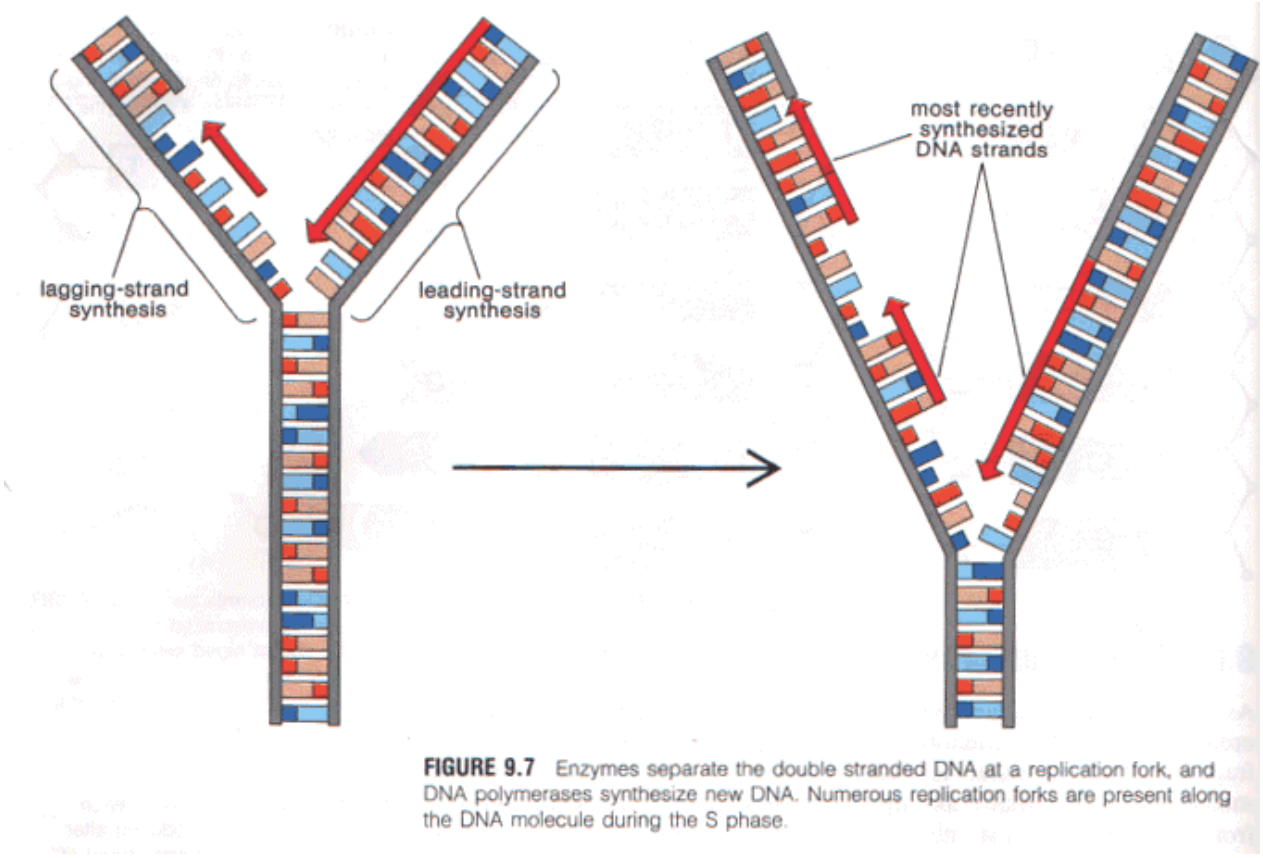
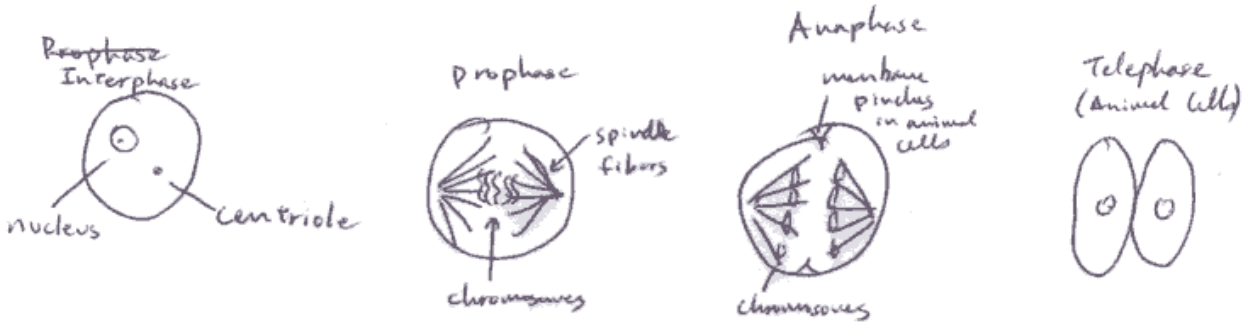


FIGURE 9.7 Enzymes separate the double stranded DNA at a replication fork, and DNA polymerases synthesize new DNA. Numerous replication forks are present along the DNA molecule during the S phase.

8. **Correcting Replication Errors** – DNA polymerases can make mistakes, and most are correct
   DNA polymerases can skip, add, or put the wrong nucleotide in a certain position
   Of the billions of DNA molecules synthesized, there are bound to be mistakes
      UV radiation and chemicals can damage nucleotides
   There are 6×10^9 nucleotides. An error occurs 1 in 1000. In the end, only 1 error every 10^6 nucleotides
   A system of enzymes detect the damaged area, which is then removed and replaced
      The information needed to restore strand 1 is taken from strand 2
      DNA ligase – enzyme that seals the breaks created by the repair process
   Mutations – errors that are not detected/corrected. Provides the variations for natural selection
      Most mutations are harmful, with others being fatal, some have no effect, and some are good
      Lethal mutations are not significant unless they occur on a very large scale
      Skin Cancer is a mutation where the UV light damages nucleotides

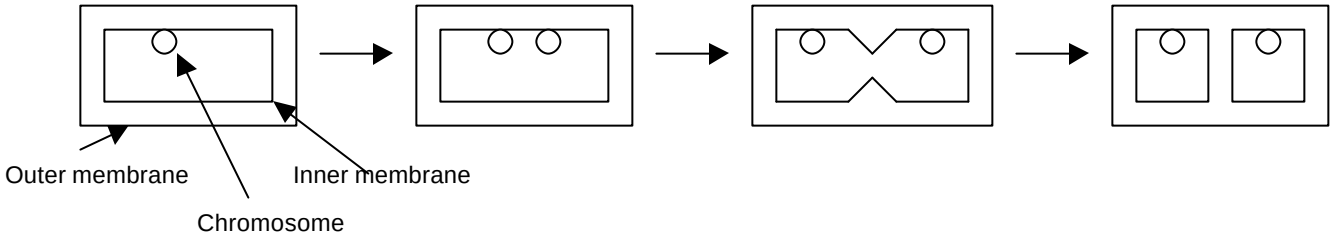
9. **A Closer Look – the M phase** – In the M phase, the cell actually divides. Occurs after the S and G_2 phase
   Also known as **mitotic cell division**.
   As mitosis occurs, the chromosomes condense and thicken, and can be seen under a light microscope
   Centrioles are replicated and move towards opposite ends of the cell, creating two poles
      Spindle fibers form between the poles
   Each chromosome is a double (replicated) structure joined at the centromere
   Centromere – the place where the two replicated chromosomes are attached
   Chromatids – the two attached replicas of the chromosome until they separate
   Phases of Mitosis – split into prophase, metaphase, anaphase, and telophase

Prophase – chromosomes condense, nuclear membrane and centrioles disappear
Metaphase –chromosomes set in a plane across the center of cell, perpendicular to spindle fibers
Anaphase – centromeres divide. Microtubules pull chromatids to opposite ends of the cell
Telophase – Chromosomes gather at opposite sites of the cell, nuclear membrane reforms
Mitosis ends when the two new nuclei are formed
Cytokenesis – dividing of cytoplasm, occurs simultaneously with mitosis



10. Differences between plant and animal mitosis
Since plants have cell walls that can't pinch, a cell plate forms that divides the cell in two
Animal cells duplicates a pair of centrioles
Cell division occurs earlier in animals cells (anaphase) than in plant (telophase)

11. **Prokaryotes** – Bacteria - reproduce through binary fission, some can reproduce every 20 minutes
Chromosomes duplicate, membrane grows, pinches inward, splits cell in half
Limiting factors – factors that restrict the size of a population. For bacteria, it's the lack of food



12. **Other Information** – facts you should know, but don't belong in a specific topic
Chromosomes are very long when stretched out. E. Coli chromosomes are 500 times longer than the cell
Daughter Cells – the two new cells that were once the single parent cell
Replication – the process of making an exact copy of something, in this case, DNA and chromosomes
Homeostasis – the maintenance of a stable internal environment
Cancer – cells that divide until the offspring cells form a ball, or tumor, which affects tissue functions
Metastases – cancerous cells that form additional tumors throughout the body
Oncogene – special tumor genes that are shown to help cause cancer
Environmental mutagens such as radiation and chemicals are known to cause cancer
Some viruses also cause cancer, but there is no direct proof
Enzymes usually have the "ase" ending on their names
When the cytosol splits, it pinches in and then splits. The pinch is known as **cleavage furrow**
Histones – proteins that are embedded in DNA