

DNA REPLICATION.

DEOXYRIBOSE,
PHOSPHATE,
ADENINE_A
THYMINE_T
CYTOSINE_C
GUANINE_G
HYDROGEN BOND_H

UNZIPPING AND
REPLICATION*
DNA POLYMERASE,
DIRECTION OF
SYNTHESIS_E
HYDROLYSIS_F

NUCLEOSIDE
TRIPHOSPHATES

DUPLICATE
STRANDS*

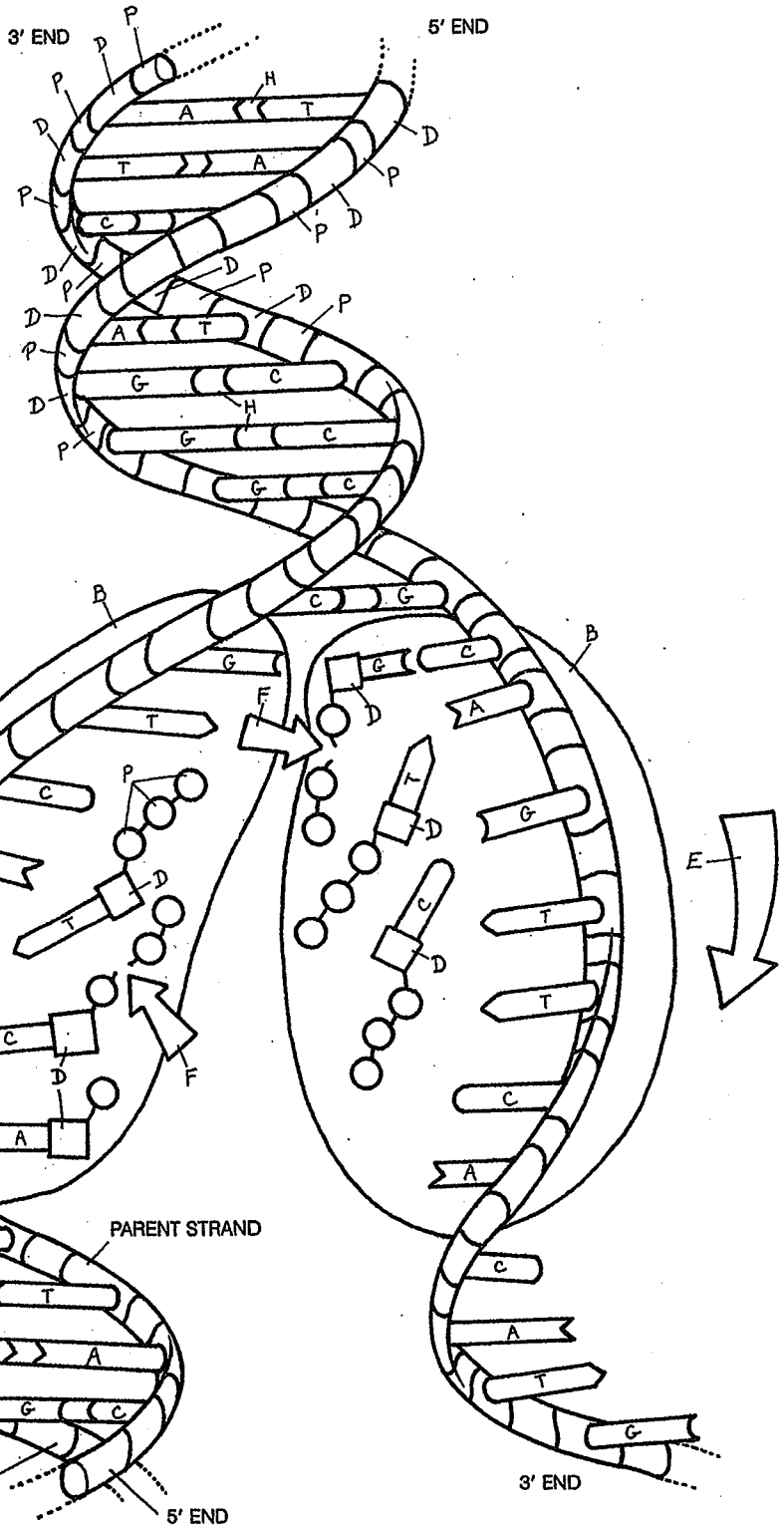
DAUGHTER STRAND

PARENT STRAND

3' END

5' END

3' END



DNA REPLICATION

This plate shows how the structure of DNA provides a method of exact replication. Although we cannot actually see these events at the molecular level, experiments with radioactive tracer atoms have provided very strong support for the idea that the events occur as illustrated in this plate.

Color the first seven titles and the corresponding structures in the upper portion of the plate only, using the same colors as in the previous plate.

The upper portion of the plate shows the DNA molecule in the double helix form prior to replication. The two strands of this "parent" DNA are held tightly together by *hydrogen bonds* between the bases in each pair.

Color the heading Unzipping and Replication, titles B, E, and F, and the structures in the center portion of the plate. Use a very light color for B.

For replication to occur, the two strands of the parent DNA must separate in much the same fashion as the two halves of a zipper unzip, exposing the bases in an unpaired condition. An enzyme, *DNA polymerase*, adds new nucleotides from the surrounding nucleoplasm to form "daughter" strands of DNA. Since the formation of the chemical bonds joining the nucleotides requires an input of energy, the cell must provide the nucleotides in the form of nucleoside triphosphates (base + sugar + three phosphates). Two of the three *phosphates* are *hydrolyzed* to provide the energy to add the nucleotide remaining to the growing daughter strand.

Since only *adenine* fits *thymine* and has opposite electrical charges in the correct places, only adenine is inserted into the growing daughter strand wherever a thymine is present in the parent strand, and vice versa. Similarly, only *guanine* is inserted into the growing daughter strand wherever a *cytosine* is present in the parent strand, and vice versa. This assures that each daughter strand is exactly complementary to the parent strand on which it is assembled and is an exact duplicate of the opposite parent strand. The two complete DNA molecules that result when the entire process is completed are exact duplicates of the original DNA molecule.

Molecules of DNA polymerase move along the parent strands, assembling new daughter strands as they go. They always assemble the new strand in the 5' to 3' direction, forming a covalent bond between the phosphate of the new nucleotide and the 3' oxygen atom of the deoxyribose on the growing end of the strand. This means that replication is in opposite *directions* on the two sides of the molecule. One strand, called the leading strand (left side of the plate), is assembled in a direction toward the "replication fork" (point of unzipping). The other strand, called the lagging strand (right side in the plate), is assembled in a direction away from the replication fork and must be done in segments. The segments are then connected by a different enzyme, DNA ligase, which also repairs DNA when it is damaged. Actually, numerous replication forks are started simultaneously at various points along a chromosome, usually in pairs running in opposite directions, so the leading strand also ends up being made in segments and needing DNA ligase to join the segments together.

Color the heading Duplicate Strands and the remainder of the plate.

The consequence of all these steps is that two exact duplicate strands of DNA are produced, each of them consisting of one of the original parent strands and a new daughter strand. The cell can now undergo cell division and provide each daughter cell with a complete copy of this DNA molecule.

In recent years one of the intriguing discoveries (not illustrated) has been that while one part of the DNA polymerase molecule functions as a polymerase, attaching nucleotides, another portion of the same molecule acts as an "exonuclease" (nucleotide-cutting-out enzyme) and performs a "proofreading" function. It is estimated that about one time in 10,000 to 100,000 the wrong base is added to a growing DNA strand. Somehow the exonuclease portion of the DNA polymerase molecule recognizes nearly all such mistakes and removes each erroneous base as fast as it is added so that another attempt to add the correct one can be made. The result is that there is an estimated error rate of only one in one billion base pairs copied.