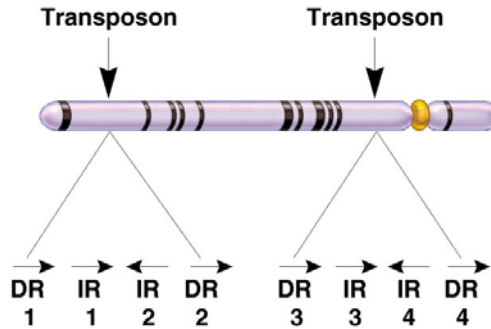


- C1. At the molecular level, sister chromatid exchange and homologous recombination are very similar. Identical (sister chromatid exchange) or similar (homologous recombination) segments of DNA line up and then cross over. Due to the molecular similarities of the two processes, one would expect that the same types of proteins would catalyze both events. At the genetic level, the events are different, however. Sister chromatid exchange does not result in the recombination of alleles because the chromatids are genetically identical. Homologous recombination usually results in a new combination of alleles after a crossover has taken place.
- C2. Branch migration will not create a heteroduplex during sister chromatid exchange because the sister chromatids are genetically identical. There should not be any mismatches between the complementary strands. Gene conversion cannot take place because the sister chromatids carry alleles that are already identical to each other.
- C3. Breakage would have to occur at the arrows labeled 2 and 4. This would connect the *A* allele with the *B* allele. The *a* allele in the other homologue would become connected with the *b* allele. In other words, one chromosome would be *AB* and the homologue would be *ab*.
- C4. The steps are described in Figure 17.6.
- The ends of the broken strands would not be recognized and degraded.
 - RecA protein would not recognize the single-stranded ends, and strand invasion of the homologous double helix would not occur.
 - Holliday junctions would not form.
 - Branch migration would not occur without these proteins. And resolution of the intertwined helices would not occur.
- C5. The two molecular mechanisms that can explain the phenomenon of gene conversion are mismatch DNA repair and gap repair synthesis. Both mechanisms could occur in the double-stranded break model.
- C6. Usually, the overall net effect is not to create any new mutations in particular genes. However, homologous recombination does rearrange the combinations of alleles along particular chromosomes. This can be viewed as a mutation, since the sequence of a chromosome has been altered in a heritable fashion.
- C7. A recombinant chromosome is one that has been derived from a crossover and contains a combination of alleles that is different from the parental chromosomes. A recombinant chromosome is a hybrid of the parental chromosomes.
- C8. It depends on which way the breaks occur in the DNA strands during the resolution phase. If the two breaks occur in the crossed DNA strands, nonrecombinant chromosomes result. If the two breaks occur in the uncrossed strands, the result is a pair of recombinant chromosomes.
- C9. Gene conversion occurs when a pair of different alleles is converted to a pair of identical alleles. For example, a pair of *Bb* alleles could be converted to *BB* or *bb*.
- C10. Holliday model—proposes two breaks, one in each chromatid, and then both strands exchange a single strand of DNA. Double-stranded break model—proposes two breaks, both in the same chromatid. As in the Holliday model, single-strand migration occurs between both homologues. The double-stranded break model also proposes strand degradation and gap repair synthesis. Finally, the double-stranded break model generates two Holliday junctions, not just one.
- C11. Gene conversion is likely to take place near the breakpoint. According to the double-stranded break model, a gap may be created by the digestion of one DNA strand in the double helix. Gap repair synthesis may result in gene conversion. A second way that gene conversion can occur is by mismatch repair. A heteroduplex may be created after DNA strand migration. This heteroduplex may be repaired in such a way as to cause gene conversion.
- C12. The RecA protein binds to single-stranded DNA and forms a filament. The formation of the filament promotes the sliding of the filament along another DNA region until it recognizes homologous sequences. This recognition process may involve the formation of triplex DNA. After recognition has occurred, RecA protein mediates the movement of the invading DNA strand and the displacement of the original strand.
- C13. No, it could involve mismatch repair, but it could also involve gap repair synthesis. The double-stranded break model involves a migration of DNA strands and the digestion of a gap. Therefore, in this gap region, only one chromatid is providing the DNA strands. As seen in Figure 17.6, the top chromosome is using the top DNA strand from the bottom chromosome in the gap region. The bottom chromosome is using the bottom DNA strand from the bottom chromosome. After DNA synthesis, both chromosomes may have the same allele.
- C14. RecG and RuvABC bind to Holliday junctions. They do not necessarily recognize a DNA sequence but, instead, recognize a region of crossing over (i.e., a four-stranded structure).

- C15. First, gene rearrangement of V, D, and J domains occurs within the light- and heavy-chain genes. Second, within a given B cell, different combinations of light and heavy chains are possible. And third, imprecise fusion may occur between the V, D, and J domains.
- C16. The function of the RAG1 and RAG2 proteins is to recognize the recombination signal sequences and make double-stranded cuts. In the case of V/J recombination, a cut is made at the end of one V region and the beginning of one J region. The NHEJ proteins recognize these ends and join them together. This is a form of DNA splicing. This creates different combinations of the V, J, (D), and constant regions, thereby creating a large amount of diversity in the encoded antibodies.
- C17. One segment (which includes some variable sequences and perhaps one or more joining sequences) of DNA is removed from the κ light-chain gene. One segment (which may include one or more joining regions and the region between the joining regions and constant region) is removed during pre-mRNA splicing.
- C18. Integrase is an enzyme that recognizes the attachment site sequences within the λ DNA and the *E. coli* chromosome. It brings the λ DNA close to the chromosome and then makes staggered cuts in the attachment sites. The strands are exchanged, and then integrase catalyzes the covalent attachment of the strands to each other. In this way, the λ DNA is inserted at a precise location within the *E. coli* chromosome.
- C19. The ends of a short region would be flanked by direct repeats. This is a universal characteristic of all transposable elements. In addition, many elements contain inverted repeats or LTRs that are involved in the transposition process. In transposons, one might also look for the presence of a transposase gene, although this is not an absolute requirement since the transposase gene is missing in incomplete elements. In retroviral elements, one might also locate a reverse transcriptase gene, but this may not be present.
- C20. In Figure 17.15, the TE has transposed prior to DNA replication. The transposon is single stranded at both locations. DNA replication (i.e., gap repair synthesis) copies the single-stranded elements into double-stranded elements. Therefore, the end result is two double-stranded TEs at two distinct locations.
- C21. Direct repeats occur because transposase or integrase produces staggered cuts in the two strands of chromosomal DNA. The transposable element is then inserted into this site, which temporarily leaves two gaps. The gaps are filled in by DNA polymerase. Since this gap filling is due to complementarity of the base sequences, the two gaps end up with the exact same sequence. This is how the two direct repeats are formed.
- C22. Retroelements have the greatest potential for proliferation because the element is transcribed into RNA as an intermediate. Many copies of this RNA could be transcribed and then copied into DNA by reverse transcriptase. Theoretically, many copies of the element could be inserted into the genome in a single generation.
- C23. Transposable elements are mutagens since they alter (disrupt) the sequences of chromosomes and genes within chromosomes. They do this by inserting themselves into genes.
- C24. Keep in mind that each type of transposase recognizes only the inverted repeats of a particular type of transposable element. The mosquitoes must express a transposase that recognizes the Z elements. This explains why the Z elements are mobile. This Z element transposase must not recognize the inverted repeats of the X elements; the inverted repeats of the X elements and Z elements must have different sequences. This same group of mosquitoes must not express a transposase that recognizes the X elements. This explains why the X elements are very stable.
- C25. A. Viral-like retroelements and nonviral-like retroelements.
B. Insertion sequences, composite transposons, and replicative transposons.
C. All five types have direct repeats.
D. Insertion sequences, composite transposons, and replicative transposons.
- C26. A transposon is excised as a segment of DNA, and then it transposes to a new location via transposase. A retroelement is transcribed as RNA, and then reverse transcriptase makes a double-stranded copy of DNA. Integrase then inserts this DNA copy into the chromosome. All transposable elements have direct repeats. Transposons that move as DNA have inverted repeats, and they may encode transposase (as well as other genes). Retroelements do not have inverted repeats, but they may or may not have LTRs. Autonomous retroelements encode reverse transcriptase and integrase.
- C27. A. As shown in solved problem S2, a crossover between direct repeats will excise the region between the repeats. In this case, it will excise a large chromosomal region, which does not contain a centromere, and will be lost. The remaining portion of the chromosome is shown here. It has one direct repeat that is formed partly from DR-1 and partly from DR-4. It is designated DR-1/4.



B. A crossover between IR-1 and IR-4 will cause an inversion between the intervening region. This is a similar effect to the crossover within a single transposable element, as described in solved problem S2. The difference is that the crossover causes a large chromosomal region to be inverted.



C28. An autonomous element has the genes that are necessary for transposition. For example, a cut-and-paste transposon that was autonomous would also have the transposase gene. A nonautonomous element does not have all the genes that are necessary for transposition. However, if a cell contains an autonomous element and a nonautonomous element of the same type, the nonautonomous element can move. For example, if a *Drosophila* cell contained two P elements, one autonomous and one nonautonomous, the transposase expressed from the autonomous P element could recognize the nonautonomous P element and catalyze its transposition.

C29. At a frequency of about 1 in 10,000, recombination occurs between the inverted repeats within this transposon. As shown in solved problem S2, recombination between inverted repeats causes the sequence within the transposon to be reversed. If this occurred in a strain that expressed the *H2/rH1* operon, the promoter would be flipped in the opposite direction, so that the *H2* gene and the *rH1* gene would not be expressed. The *H2* flagellar protein would not be made, and the *H1* repressor protein would not be made. The *H1* flagellar protein would be made because the expression of the *H1* gene would not be repressed. A strain expressing the *H1* gene could also “switch” at a frequency of about 1 in 10,000 by the same mechanism. If a crossover occurred between the inverted repeats within the transposable element, the promoter would be flipped around again, and the *H2* and *rH1* gene would be expressed again.

C30. The formation of deletions and inversions is illustrated in the answer to conceptual question C27. A deletion occurs when there is recombination between the direct repeats in two different elements. The region between the elements is deleted. An inversion can happen when recombination occurs between inverted repeats between two different elements. This occurs when the inverted repeats are in the opposite orientation. A translocation can result when recombination occurs between transposable elements that are located on different (nonhomologous) chromosomes. In other words, the TEs on different chromosomes align themselves and a crossover occurs. This will produce a translocation, as shown here.

