

Cross-Curricular Discussion

After students have had a chance to review the article "[The difference makers](#)," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students.

Chemical and Biological Sciences

Discussion Questions:

1. What are some of the important molecular and functional differences between DNA and RNA?

[DNA and RNA have extremely similar molecular structures, but DNA is double-stranded while RNA is most often single-stranded. Instead of the base thymine, which is used in DNA, RNA has uracil which has a slightly different molecular structure. DNA is generally used to store genetic information, because of its greater chemical stability. RNA is generally used to make temporary copies of genes (messenger RNA) that encode proteins, or to make specialized RNA structures such as ribosomal RNA, transfer RNA or small interfering RNAs.]

2. What are some of the important differences between DNA replication and RNA replication?

Explain how retroviruses and retrotransposons replicate. [DNA is generally double-stranded. During replication, a number of enzymes pull the two strands apart and add complementary DNA nucleotides to each strand, producing two complete copies of double-stranded DNA. Cellular RNA is generally single-stranded. Cells generally do not replicate RNA (they just make RNA copies of DNA), but many viruses store their genes as RNA and must replicate that genetic material. Some use enzymes to assemble RNA nucleotides on one existing RNA strand, analogous to DNA replication. Retroviruses and retrotransposons use reverse transcriptase or retrotransposase enzymes to make a DNA copy of their RNA genes, then insert that DNA copy into a host's genome, wait for the host's genome to replicate and make more RNA copies from the DNA copies in the host genome.]

Extension Prompts:

3. How could transposons and viruses have originally developed? [Perhaps a transposon got so good at jumping within the genes of a host that it became the first virus, able to jump to the genes of another host. Or perhaps a virus inserted its genes into a host's genome and was able to replicate successfully within the same genome rather than constantly hopping into new hosts as a virus. Perhaps the very first transposon or virus came into existence when a natural mechanism of DNA copying or splicing went awry, leading to a small region of the genome with the ability to replicate independent of the rest of the genome. Anything that can make lots of copies of itself can win out in the long run over things that cannot.]

- 4. Would evolution still happen if there were no transposons, retrotransposons or retroviruses messing with the genome?** [Yes, but it would probably be slower, relying on ordinary mutations that arise during DNA replication when cells divide or genetic recombination of chromosomes in a new generation.]
- 5. Why do transposons appear to have been important for the evolution of the immune system?**
[The human immune system can make trillions of different antibodies (which also serve as B-cell receptors) and T-cell receptors to detect and fight trillions of different possible pathogens or other targets. However, the human genome contains only around 20,000 protein-encoding genes, and they have to take care of a lot more than just the immune system. The immune system uses a transposon-like ability to hop/splice/transform DNA to turn a small number of immune system genes into a vast number of sequences for antibodies and T-cell receptors. This process is called V(D)J recombination, because it uses gene segment hopping and splicing to mix and match various V gene segments, D gene segments and J gene segments to create a wide variety of possible complete V-D-J gene sequences for antibodies or for T-cell receptors. For more information, see the chapter "The Immune System" in Campbell's Biology.]
- 6. The X-Men comics and movies never explain how the same "mutant gene" or "X-gene" can give different superpowers to different people. How could transposons help to explain that?** [If the "mutant gene" were a very active transposon, it could hop to different places (or even several places) each time it is passed from parent to child, causing new mutations in each generation. People without the very active transposon would be "normal" and much less likely to have mutations. Of course, in the real world the mutations generally would not be as cool, and in fact many of them would be harmful.]

Chemical and Biological Sciences Question Bank

What are some of the important molecular and functional differences between DNA and RNA?

What are some of the important differences between DNA replication and RNA replication? Explain how retroviruses and retrotransposons replicate.

How could transposons and viruses have originally developed?

Would evolution still happen if there were no transposons, retrotransposons or retroviruses messing with the genome?

Why do transposons appear to have been important for the evolution of the immune system?

The X-Men comics and movies never explain how the same "mutant gene" or "X-gene" can give different superpowers to different people. How could transposons help to explain that?

Engineering and Experimental Design

Discussion Questions:

1. **How are transposons analogous to computer viruses?** [A computer virus inserts into computer code and causes changes to operating systems, just as transposons insert into genetic code and cause changes in an organism's genome (though the changes are often inconsequential). Computer viruses make copies of themselves; some will fill a computer's entire memory with copies of themselves.]
2. **If someone were suffering from a disease that involved hyperactive retrotransposons, what sort of treatment might be developed?** [A retrotransposase inhibitor might prevent the retrotransposons from making DNA versions from their RNA copies. Other normal cellular functions do not typically use retrotransposase or reverse transcriptase, so such an inhibitor should not interfere with other functions. Inhibitors that target enzymes involved in splicing transposon copies into the genome might also be useful.]

Extension Prompts:

3. **What are some ways in which you could deliberately use transposons for practical applications?** [Examples include: Inducing lots of mutations to accelerate evolution, for example to force bacteria to become good at consuming oil spills. Letting transposons randomly hop into different places in a genome, then learning about the natural function of those places in the genome by seeing what phenotypic changes result in the organism. Using hyperactive transposons as a sort of natural polymerase chain reaction (PCR) to make lots of copies of a gene of interest. Using transposons as a vector to deliver a gene of interest into a particular organism.]
4. **How would you actually implement some of those various applications of transposons?** [Help students think through the steps that would be required for each of their ideas.]

Engineering and Experimental Design Question Bank

How are transposons analogous to computer viruses?

If someone were suffering from a disease that involved hyperactive retrotransposons, what sort of treatment might be developed?

What are some ways in which you could deliberately use transposons for practical applications?

How would you actually implement some of those various applications of transposons?