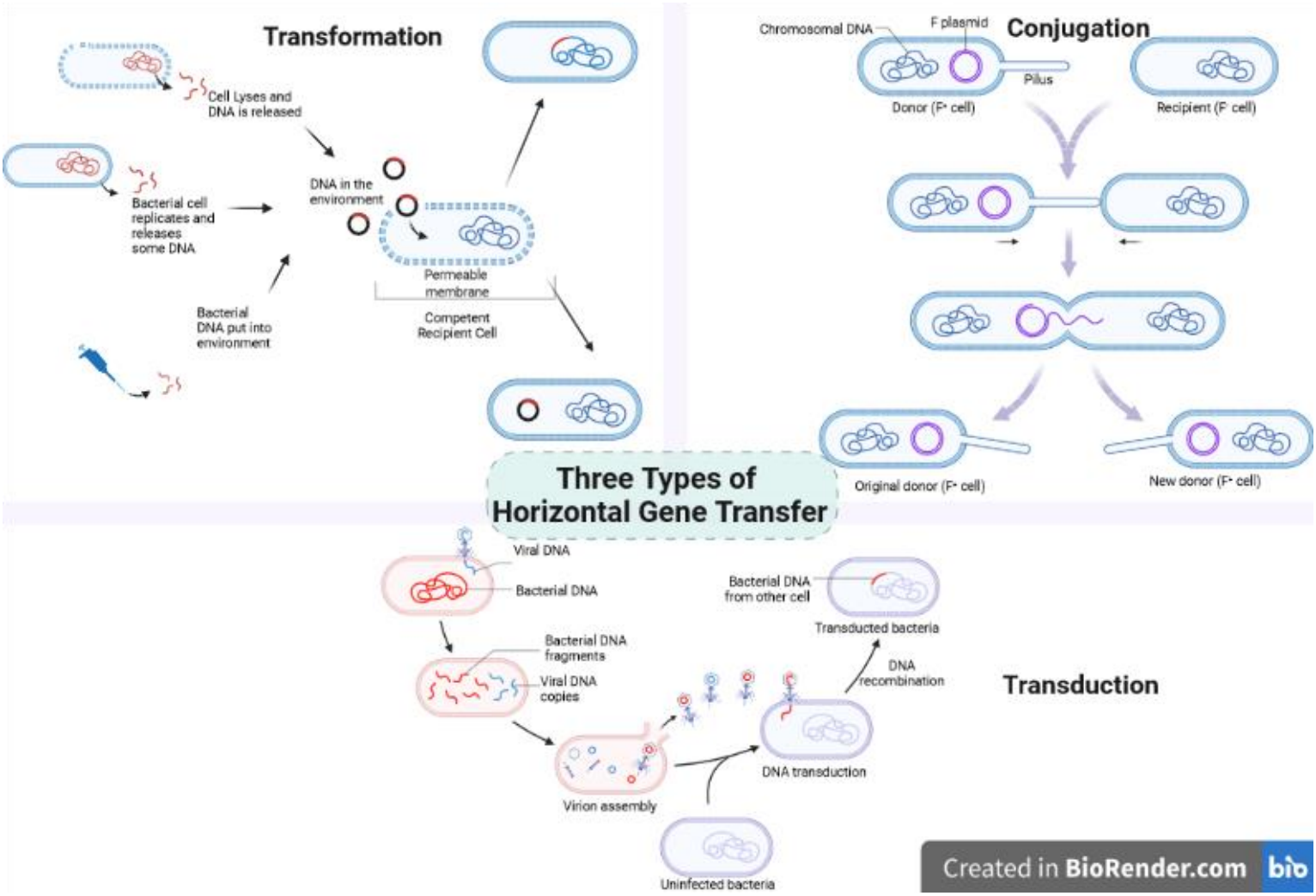
Horizontal Gene Transfer

Horizontal gene transfer is the process of a current living bacteria acquiring new genetic material. While eukaryotes get variation in genetic material from sexual reproduction, bacteria can only acquire new genetic material through horizontal gene transfer. Three types of horizontal gene transfer exist: conjugation, transformation, and transduction. It is important that you are able to know what each of these are and their requirements, how they differ from each other, and what types of problems you may see making use of each type of horizontal gene transfer.



Transformation:
Transformation is the process of a competent bacteria picking up DNA from its environment and integrating it into a chromosome or plasmid. The DNA in the environment could have come from a dead bacterial cell that lysed (exploded), a live bacterial cell which released a copy of its DNA, or a scientist who made the DNA and put it in a test tube. Because this DNA could have come from anywhere, the DNA is said to have come from the environment.

While it is common for bacterial cells to pick up genetic material from their environment, not all bacterial cells can do this. Only competent cells can undergo transformation. This means being competent is a requirement of a recipient cell to undergo transformation. Only competent cells have enough membrane permeability to take up DNA from their environment. These cells have large pores in their membrane that the DNA can fit through. In a lab, it is possible to induce competency, make a bacterial cell competent, so it can undergo transformation.

Conjugation:
Conjugation is the process of a bacterial cell giving another bacterial cell genetic information directly. How this works is the donor cell replicates part or all of its genetic material, then makes a tube between the two cells called a sex pilus. The newly made copy of DNA can move through the sex pilus as a single linear strand, then the recipient cell can integrate the DNA into a chromosome or plasmid. It is possible for a recipient cell to receive a copy of every gene the donor cell has, but this does not always occur. The sex pilus is very fragile and thin so it can break randomly at any time. If the sex pilus breaks, conjugation ends and the recipient cell does not receive any genes that were not yet transferred.

Only bacterial cells with a fertility factor can be a donor cell. Having a fertility factor gene is a requirement for a donor cell but any bacterial cell can be a recipient cell. This is because the fertility factor is a gene that allows a bacterial cell to make a sex pilus. When the fertility factor gene is stored on a plasmid, the plasmid is called the F^+ plasmid to denote it has a fertility factor in it. When the fertility factor gene is part of the chromosome, the cell is said to be a Hfr bacteria.

Because a chromosome is big, it is rare that a fertility factor in a chromosome is transferred to a recipient cell. Often, the sex pilus breaks before this part of the chromosome enters the recipient cell. Fertility factors on plasmids are more likely to be donated to recipient cell.

Transduction:
Transduction is the process of a bacterial cell receiving bacterial genetic information from a virus that infects it. Bacteriophages, a class of bacteria-infecting virus, first inserts itself into the bacteria to use the bacteria's machinery to replicate itself. To do this, the virus must insert its DNA into the host bacterial DNA. The location this insertion occurs is called an attachment site. In a typical infection, the bacterial cell replicates only this portion of the DNA and then packages only newly synthesized viral DNA up into viral capsids and then the newly formed viruses leave by popping the cell. Sometimes, the genes nearby the attachment site accidently get packaged up along with the viral DNA. When this occurs, the next time the virus infects a bacterial cell, these bacterial genes also get transferred.

A virus has a specific attachment site in the bacterial DNA. When only genes next to the attachment site are packaged up and get moved to the next cell the virus infects, specialized transduction has occured. In generalized transduction, any bacterial gene has a chance of being packaged up in the new virus. This means that only a few genes can be received from a specialized transduction from a specific virus, but any gene has a chance of being received during generalized transduction.

Another distinction of transduction is how fast the cycle of infection to viral release is. Some viruses will insert their DNA into a host and then use the bacterial cell to replicate it as fast as it can. This is said to be a virulent virus because it replicates so fast. It is in its lytic stage. Some viruses stay dormant longer after insertion. These are called temperate viruses. Staying dormant is part of the lysogenic stage. Some viruses stay in the lytic stage always while some move between the lytic and lysogenic stages and only replicate when the environment is favorable for infection. Many microbiology courses cover viral infections in more depth than genetics courses do.

Concluding Notes:
While it is important to know about the differences between each of the three types of horizontal gene transfer, they all share a few features in common. Bacterial cells only keep double stranded circular DNA. Any single stranded linear DNA that they acquire from horizontal gene transfer must be incorporated into a plasmid or chromosome and replicated so it is double stranded. Any DNA that is left linear or single stranded will be degraded.

Bacterial cells are prokaryotic; they normally are haploid and contain only one copy of each gene. Bacterial cells also only contain one circular chromosome but can have multiple smaller circular pieces of DNA called plasmids. When a bacterial cell receives a copy of a gene it already has, it may integrate the new copy into its chromosome or a plasmid. Horizontal gene transfer can make a bacterium a partial diploid, a cell that has one copy of most genes but has two copies of a few genes. These two copies can be identical but could also be different alleles for the same gene. Typically, the new allele will be stored in a plasmid. Both copies of the gene may be expressed and then alter survivability.

Learning Objectives:
- Understand what each type of horizontal gene transfer is, how it works, and the requirements for it.
- Be able to compare and contrast each of the types of horizontal gene transfer.
- Comprehend how interrupted mating experiments, gene mapping, and plating based problems can incorporate information about horizontal gene transfer.

Order of Activities:

1. Review your notes on each of the three types of horizontal gene transfer.
2. Read this article detailing horizontal gene transfer https://www.khanacademy.org/science/ap-biology/gene-expression-and-regulation/mutations-ap/a/genetic-variation-in-prokaryotes
3. Open the corresponding worksheet for this material and complete as much of the table as you can without using your notes. Hold onto this worksheet as you will come back to it again.
4. Watch the following videos to review types of horizontal gene transfer:
    a. Transformation: https://youtu.be/dKD19cXkWBw
    b. Transduction: https://youtu.be/uJH1G7MDC5E
    c. Conjugation: https://youtu.be/YycVGqBs1p0
5. Read about what it means to be a competent bacterial cell here: https://www.goldbio.com/articles/article/Introduction-to-Competent-Cells
6. Watch the following video and then explain to yourself which examples of transduction are virulent and which are temperate. https://www.britannica.com/video/154218/DNA-another-cell-conjugation-transduction-processes
7. Review how you filled out the horizontal gene transfer table in the worksheet. Change or add anything you need to make this a study review tool complete with all of the information about horizontal gene transfer you need. Then, move on to the thought questions below the table.
8. Discuss what you wrote with a partner or group if possible before checking your work using the answer key provided. This answer key provides information that will act as a foundation for other topics in genetics. While there is more information about horizontal gene transfer, make sure you understand at least the information provided in the key.
9. After reviewing any topic, it is a good idea to have a metacognition check. Ask yourself the following questions:
    - What are my emotional responses to learning this material? Which material am I frustrated with and need aid in understanding?
    - What difficulties have I had with the learning tasks? What specific tasks will I do to master this content?
    - Do I understand all of the learning goals? Can I explain each of them out loud to someone clearly and concisely?
    - How is what I learned related to other things I have learned in this class? How is it related to other classes, my career, and my life?
10. Closing: Think about which laboratory experiments could be done to test for each type of horizontal gene transfer.
    - How could plating be used to identify if horizontal gene transfer has occurred?
    - An interrupted mating experiment relies on which type of horizontal gene transfer?
11. If you would like to have more aid in learning this material, please reach out. There are numerous individuals who want to help you feel confident in your understanding. If your course has learning assistants or teaching assistant(s), you should reach out to them to review concepts you want to learn more about. Your professor is also a great resource to go to when you do not understand a topic. You can study with your peers or receive academic support through the LRC as well. If you would like help identifying how to receive the support you need, do not hesitate to contact the CU Denver Learning Resources Center at LRC@ucdenver.edu or stop by our front desk in the learning commons building.