Egido, JE, AR Costa, C Aparicio-Maldonado, P Haas, and SJJ Brouns. 2022. Mechanisms and clinical importance of bacteriophage resistance. *FEMS Microbiology Reviews* 46(1): fuab048. The original text can be found at https://doi.org/10.1093/femsre/fuab048 under a CC BY-NC 4.0 license.

Translators
Azeeta Bance, Undergraduate Student, University of California, Berkeley, CA 94720, azeetabance@berkeley.edu
Ixchel Gonzalez Ramirez, Graduate Student, University of California, Berkeley, CA 94720, ixchel_gonzalezrmz@berkeley.edu

Intended Audience: High school and college students and beyond
Language: Visual art with accompanying text

The graphics were created in Adobe Illustrator using the graphics available in the paper as a starting point. The focus of this translation is on the heading "THE MULTISTEP PROCESS OF BACTERIOPHAGE INFECTION" and the subheading "Host phage defense systems." A short text description in simplified English is available as a reference to provide information beyond the image and a short glossary of relevant terms is also included. This translation was done as part of the Spring 2022 Breaking Language Barriers in Ecology and Evolution seminar (IB 84) led by Rebecca D. Tarvin at the University of California Berkeley.

Translation (see next page)

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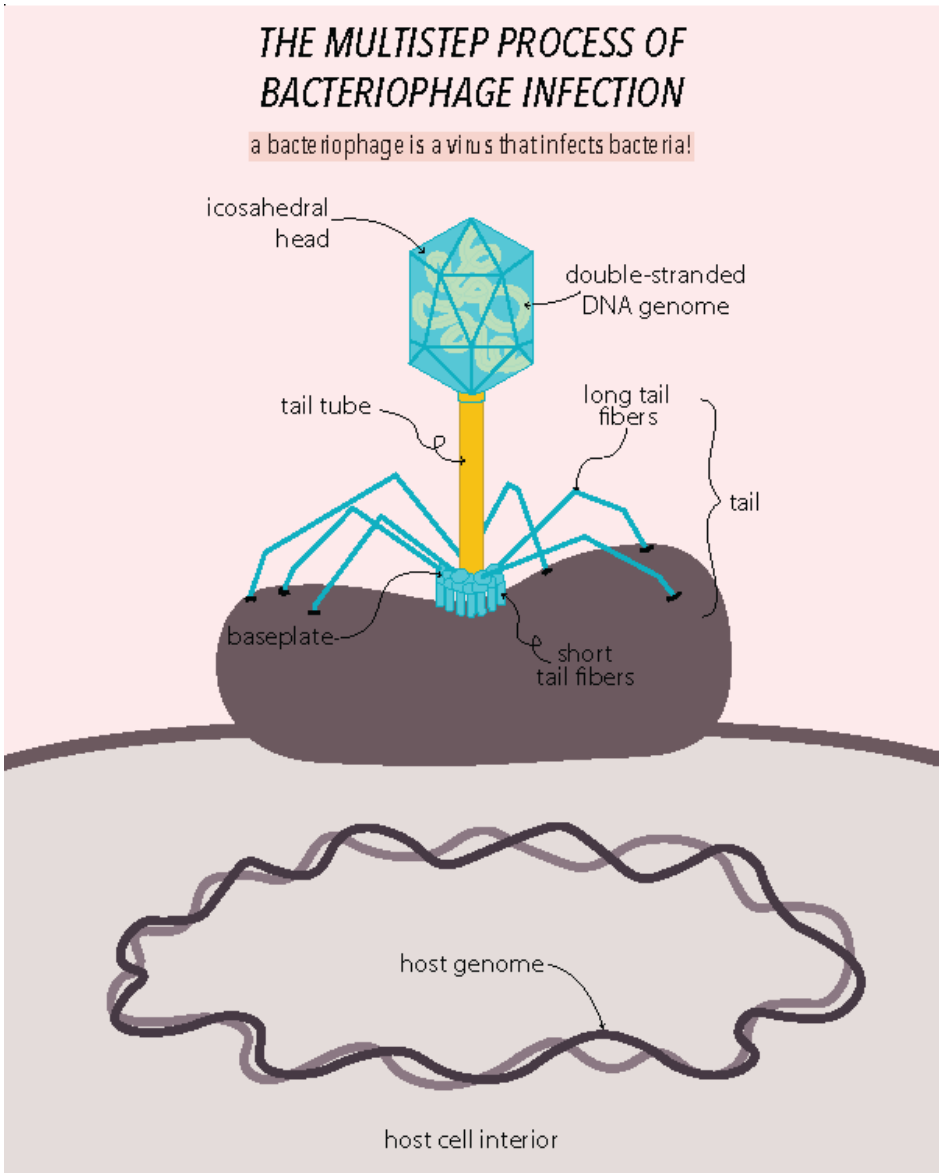

THE MULTISTEP PROCESS OF BACTERIOPHAGE INFECTION

The first step of phage infection is the phage recognizing specific protein receptors on the bacteria's surface. Once the phage positions itself properly, it injects its DNA content into the bacterial cell. From here, there are 2 main cycles that can occur, depending on the phage. The first cycle is called the lytic cycle. The phage will take control of the bacteria's cellular machinery and begin making copies of its own DNA. Once it has made enough copies of itself, the cell will burst open, releasing all of the newly produced phages and killing the bacterial cell. The new phages will go on to infect other bacterial cells. The second cycle is called the lysogenic cycle. In this cycle, the phage will insert its DNA into the bacteria's DNA. This fused structure is called a prophage. The bacterial cell will carry on like normal, but when it replicates, it will transmit the prophage rather than the normal bacterial DNA. This creates several daughter bacteria cells that are infected. Occasionally, a prophage will exit the bacterial DNA and initiate a lytic cycle. The remainder of the images will focus on host defense systems, which are mechanisms bacteria have evolved to protect themselves against mobile genetic elements, such as phages.

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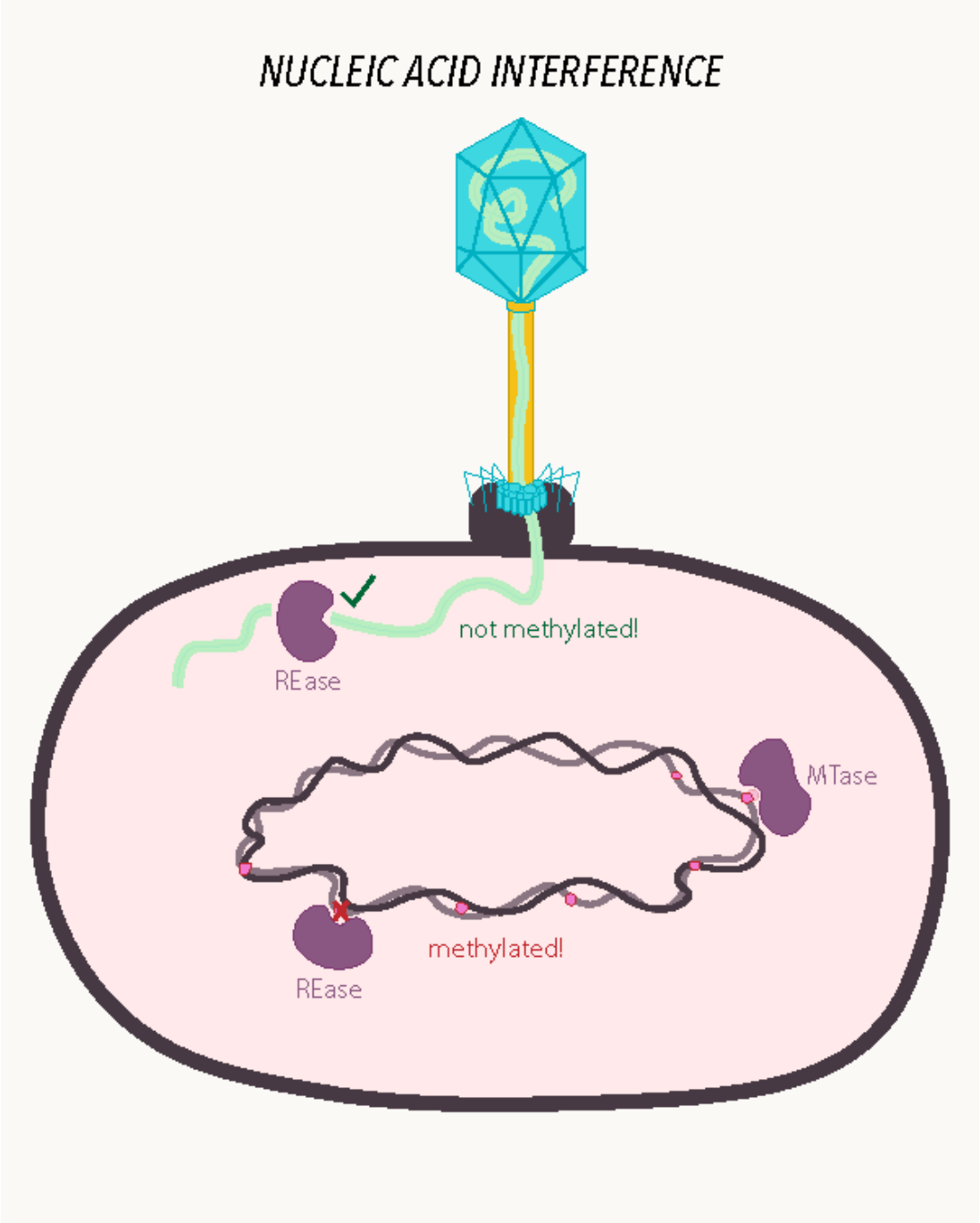

NUCLEIC ACID INTERFERENCE

An MTase will methylate the bacterial DNA, creating a distinction between the bacterial DNA and the phage DNA. REases will recognize DNA that is not modified (has no added methyl groups) and classify it as foreign. The REase will then proceed to cut the phage DNA into pieces, destroying it and preventing it from infecting the bacterial cell. In other words, the methylation of host DNA by MTases distinguishes self from nonself, allowing REases to kill foreign, potentially dangerous DNA that has entered the cell.

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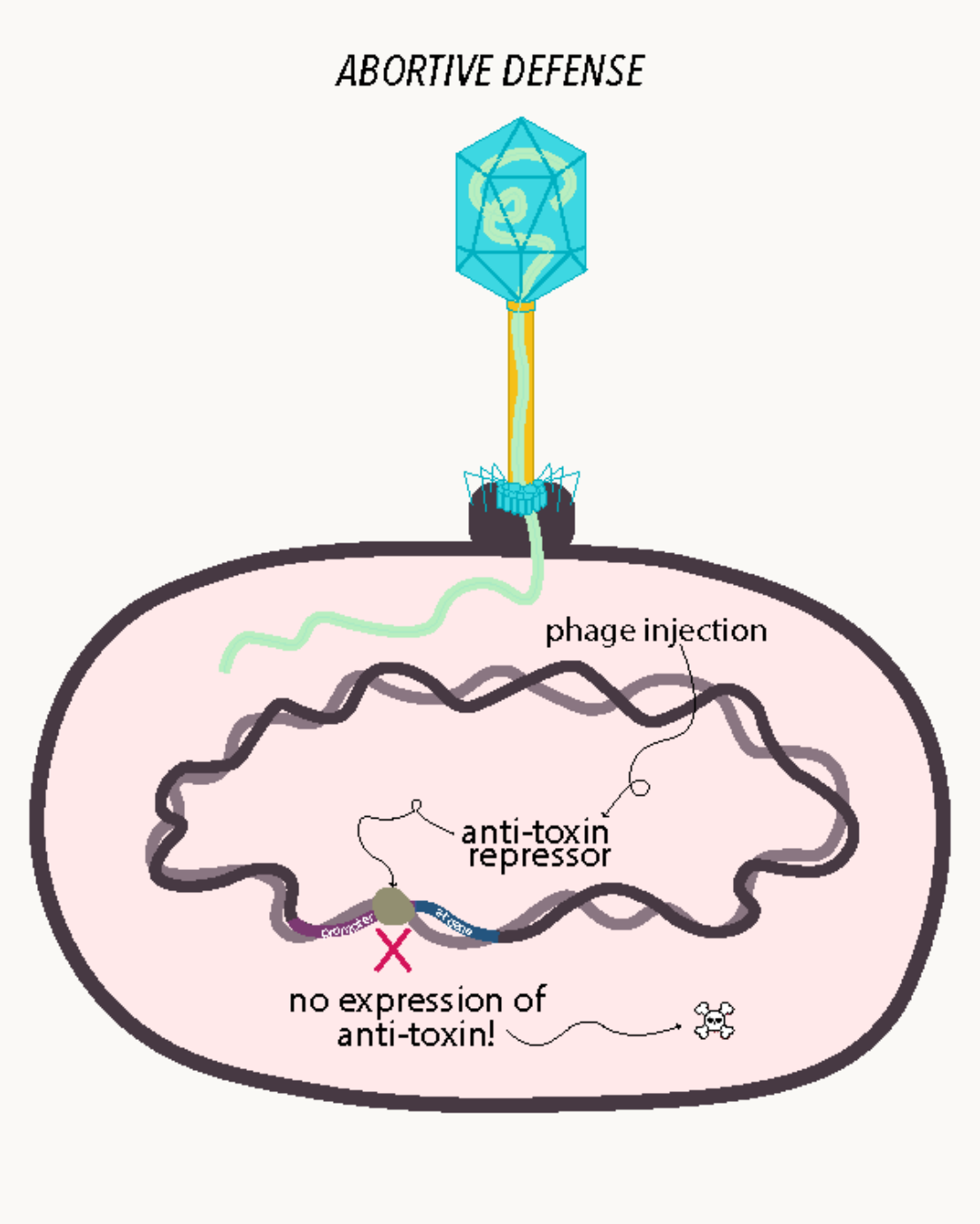

ABORTIVE DEFENSE

The bacterial cell can recognize the injection of phage DNA, which will lead to the repression of the antitoxin gene or the end of its transcription. As a result, the antitoxin gene is not expressed, meaning that no antitoxin is produced. Because there is no antitoxin to counteract the phage, the bacterial cell will die. However, this is beneficial because the phage cannot infect other cells since it no longer has any DNA to transmit.

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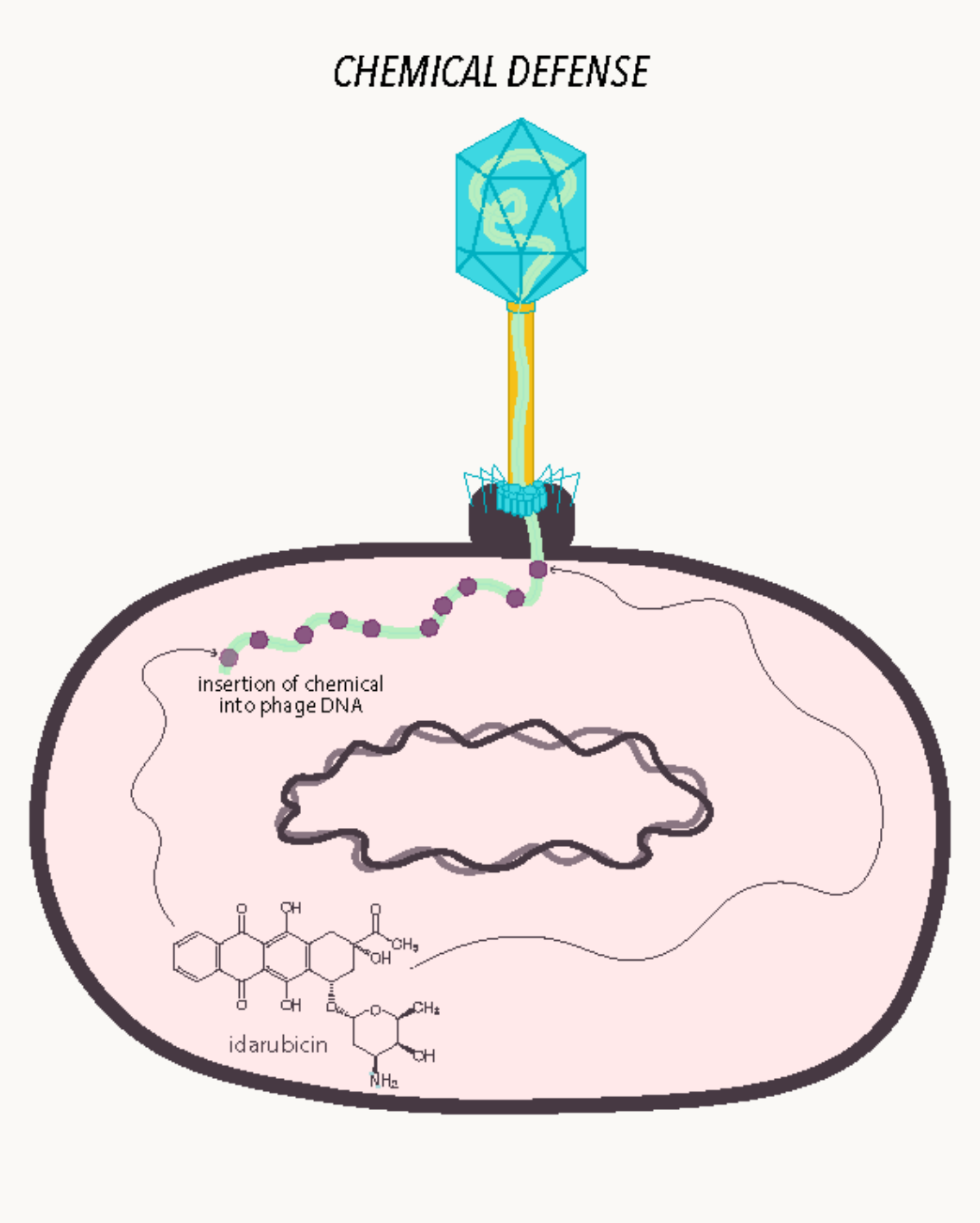

CHEMICAL DEFENSE

Chemicals present in the bacterial cell will be inserted into the phage's DNA. This messes up the nucleotide sequence of the phage's DNA, preventing it from assembling properly inside the bacterial cell. It also prevents the phage from accessing the proteins it needs to multiply, effectively rendering it useless.

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GLOSSARY

1. **Antitoxin**: an antibody that counteracts a toxin (in this case, the toxin is the phage)
2. **Antitoxin gene**: the gene that encodes for the antitoxin
3. **Antitoxin repressor**: the repressor for the antitoxin gene
4. **Bacteriophage (phage)**: a virus that infects bacteria
5. **Baseplate**: aids in host-cell recognition, attachment of the phage to the bacteria, and injection of DNA
6. **Binary fission**: the mechanism by which bacteria divide or replicate
7. **Cellular machinery**: components within a cell that allow it to function and carry out different tasks (e.g., ribosomes, which manufacture proteins, or RNA polymerase, which turns DNA into RNA during transcription)
8. **Daughter cells**: cells that result from the division of a single parent cell
9. **Double-stranded DNA (dsDNA) genome**: the set of genes that make up the phage
10. **Gene**: a small region of DNA that encodes a specific function; basic unit of heredity
11. **Host genome**: the set of genes that make up the bacteria cell that is being infected
12. **Icosahedral head**: protein shell of the phage that protects the genome
13. **Idarubicin**: a chemical produced by a specific type of bacteria (*Streptomyces* spp.) that inhibits certain dsDNA phages
14. **Methylate**: the process of adding methyl groups to some substance
15. **Methyl group**: small chemical groups composed of one carbon atom and three hydrogen atoms (CH_3)
16. **Methyltransferase (MTase)**: an enzyme in the bacterial cell that adds methyl groups to bacterial DNA at specific sites
17. **Mobile genetic elements**: a type of genetic material that can move around within a genome, or can be transferred from one species to another
18. **Nucleotides**: the basic structural unit that composes nucleic acids such as DNA; the unique combination of nucleotides in each organism is what creates diversity
19. **Prophage**: when the genetic material of a phage is incorporated into the genome of a bacterium
20. **Repression**: a mechanism that blocks genes from being expressed into proteins
21. **Repressor**: a protein that sits on top of a gene, physically blocking RNA polymerase from making RNA
22. **Restriction endonuclease (REase)**: an enzyme that cuts up DNA at specific sites
23. **Tail fibers (long and short)**: contain specific binding proteins that help phage recognize specific bacteria and attach
24. **Tail tube**: serves as a “pipe” during infection to make sure the phage DNA ends up in the bacteria
25. **Transcription**: making an RNA copy from a DNA sequence
26. **Translation**: making a protein from an RNA sequence