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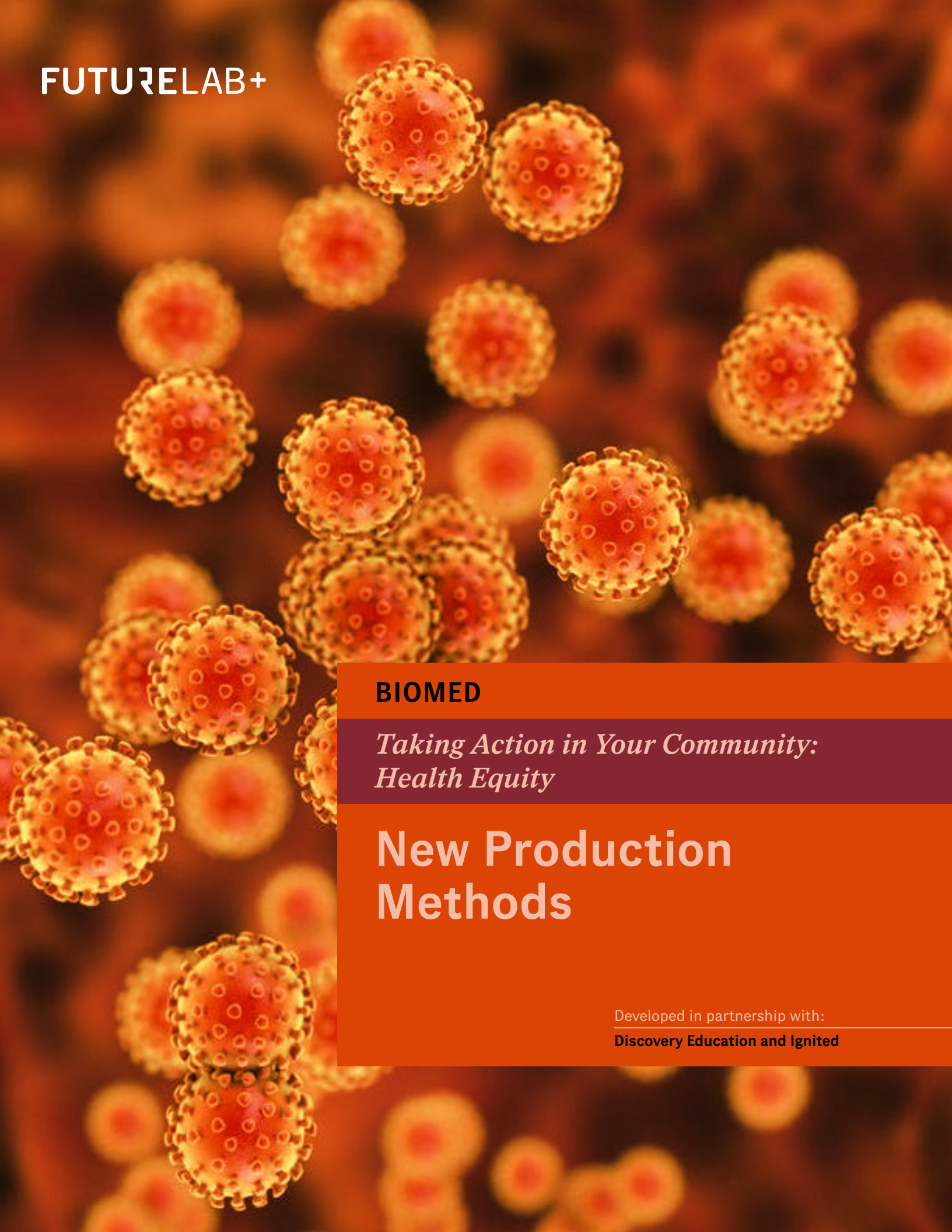


BIOMED

Taking Action in Your Community: Health Equity

New Production Methods

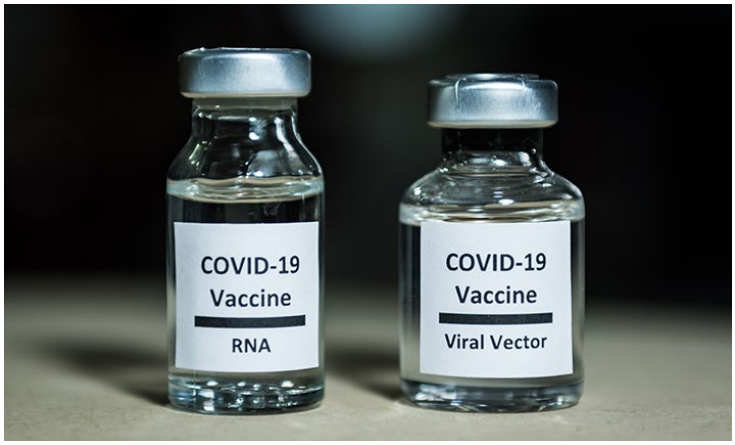
Developed in partnership with:

Discovery Education and Ignited

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →



Cover Image
Coronavirus particles, (illustration).

This document is separated into two sections, For Teachers [T] *and* Student Resources [S]*, which can be printed independently.*

Select the appropriate printer icon above to print either section in its entirety.

Follow the tips below in the Range field of your Print panel to print single pages or page ranges:

Single Pages (use a comma): T3, T6

Page Range (use a hyphen): T3–T6

BIOMED / TAKING ACTION IN YOUR COMMUNITY: HEALTH EQUITY

New Production Methods

ACTIVITY DURATION

Four class sessions
(45 minutes each)

DRIVING QUESTION

How do vaccines activate our adaptive immune system?

ESSENTIAL QUESTIONS

What are the differences between a DNA molecule and a messenger RNA molecule?

Are all viruses made of DNA molecules?

OVERVIEW

The best way to protect people from serious infections is to trigger a first response from their immune system by exposing their body cells to the pathogen without causing any symptoms. This is called immunization and is done by giving weakened virus or genetic material from the virus to the person. Novel methods based on viral genetic material will give a better response and therefore a stronger immunity to that pathogen. These vaccines have been found to improve protection by 15% against serious diseases compared to traditional vaccines.

In this lesson, students learn about the adaptive immune system and the role vaccines play in our adaptive immune system. They will take the role of a microbiologist to explore different vaccine types and how they work in the body. Students will summarize their learning by exploring differences in new vaccine development with COVID-19.

OBJECTIVES

Students will be able to:

Identify components and the function of the human adaptive immune system.

Apply knowledge of vaccines to compare different types of vaccines.

BACKGROUND INFORMATION

In this lesson, preparation of novel vaccine methods using genetic material are being reviewed. Students should have basic knowledge of genetics terminology. Familiarity with some common terms such as DNA and messenger RNA would provide an additional advantage.

Materials

- **Functions of the Adaptive Immune System Capture Sheet**
- **Functions of the Adaptive Immune System Key**
- **Microbiologist Tasks Concept Map**
- **Why Are There Different Types of Vaccines? Research and Discovery**
- **DNA and RNA Modeling Capture Sheet**
- **Colored Pencils**
- **Design Journal**

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

Students will be given the responsibility to choose the vaccine type they want to investigate. This will require them to be self aware in order to gauge their interest in a vaccine. They will also need to practice social management skills as they work in small groups and display proper relationship skills throughout the activities.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Instruction in this lesson provides for many small group interactions. This allows for culturally and linguistically diverse students to receive peer support and scaffolding during the lesson. The content included has implications for many communities that are historically underserved and undereducated in the purpose and types of vaccines. The lesson provides information about the work of a microbiologist which helps students understand this work as a possible career path.

ADVANCING INCLUSIVE RESEARCH

Our immune systems keep us alive by evolving and adapting as they come into contact with new pathogens. Because of our wide geographic dispersal, humans' immune systems evolve in different ways. Some groups may have immunity to diseases that others might not have. In order for scientists to develop therapies that help all people, they must work from clinical trials that have as diverse a participant pool as possible.

COMPUTATIONAL THINKING PRACTICES

As they examine new production methods for therapies, students utilize the computational thinking strategies of decomposition, abstraction, and developing algorithms to examine how the immune system works throughout the body. They create organizational tools that both simplify and break down what happens during immune reactions.

CONNECTION TO THE PRODUCT LIFE CYCLE

This lesson focuses on the immune response that occurs when our bodies detect pathogens. This reaction is studied during the **development** phase of the product life cycle.

Have you ever wondered…

Is the common cold a DNA or RNA virus?

The rhinovirus, which is the virus causing symptoms like cough, sneezing, sore throat, and runny nose, has all its genetic information coded in a single-stranded RNA sequence.

Can the DNA of viruses combine with the human genome?

Did you know that 8% of our genome is actually viruses inserted into our genes? The cause might be thousands of years of our ancestors being infected by different types of viruses.

Why are most people immune to the chickenpox virus after they have already had it?

The cells from the immune system, called B lymphocytes, produce antibodies against the chickenpox virus during the first infection. If the virus enters the body of a person again, the immune system will recognize the virus immediately and kill it. No symptoms will appear during the second infection. This person is considered immune.

Why would you use DNA or RNA for vaccines?

Human cells produce an mRNA sequence from the DNA molecule within their nucleus. Then they synthesize the protein coding for that mRNA. The protein is not destroyed as it is not recognized as "foreign" by the immune system. However, if a portion of viral RNA or DNA would be inserted manually within human cells, it would be recognized as "foreign" and destroyed. If the same virus enters the body again during a second infection, it would be killed rapidly. This would make the person immune.

MAKE CONNECTIONS!

How does this connect to the larger unit storyline?

The DNA and mRNA present in human cells are the genetic blueprint of complex proteins associated with various biological activities within cells. Recently, scientists have developed new vaccines based on viral genetic material capable of recruiting cells into producing a protein belonging to a virus. The protein or viral toxin serves as an antigen to trigger an immune reaction and therefore, provide protection against infection by this virus. These vaccines are powerful tools against novel viruses, such as coronavirus, to help curb the pandemic.

How does this connect to careers?

Vaccine researchers read scientific literature and work on how viruses infect cells and understand how they make people sick.

Product development engineers keep updated with novel techniques, communicate data from their findings with colleagues, and create more efficient processes.

Clinical trial participant recruiters are responsible for developing advertising materials according to the criteria of the study.

How does this connect to our world?

The human race is constantly battling pathogens from various origins. Biotechnology has permitted us to understand how viruses operate and to create novel vaccines based on the genetic material of these viruses. These vaccines are safer than traditional vaccines and more efficient at protecting people from infections.

Day 1

Procedure

LEARNING OUTCOMES

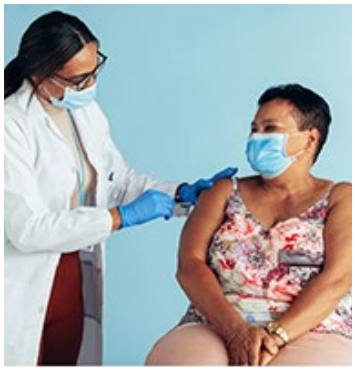
Students will be able to:

Model the adaptive immune system and identify key components.

Whole Group (20 minutes)	
1	Write the phrase "adaptive immune system" on the board. Ask students to consider what that phrase means by breaking down the individual words, using a simple *Stand and Share* strategy. Then invite students to *Turn to Your Partner* to share their thinking and come up with a one-sentence definition.
2	Define for students that the function of adaptive immune responses is to destroy invading pathogens and any toxic molecules they produce in our bodies. Ask students to revisit their definition and this new definition and consider it in the context of vaccines. What role could vaccines play in our adaptive immune system?
3	Ask students to imagine they are receiving or watching someone receive a shot. Injections need to go beyond the fatty tissue of our skin and penetrate our muscle. This is why your arm is sometimes sore! Muscle contains and recruits immune cells called dendritic cells which take up invaders, or antigens, quickly and stick them on their surface. Tell students: we are now going to travel inside the body to see what happens next!
4	Distribute the *Functions of the Adaptive Immune System Capture Sheet*. Explain to students they will be watching different components of the adaptive immune system interacting in the body. As they watch the video *The Adaptive Immune System—Vaccine Makers Project*, students should match the function with the correct name from the capture sheet. Provide time for students to read the definitions and then play the video. You may want to play the video more than once.
5	Review the correct responses and clarify with students that our adaptive immune system components carry out specific functions. This helps our body destroy invading pathogens and any toxic molecules they produce. This information will help us better understand how medicines work along with our immune system to keep us healthy.

COMPUTATIONAL THINKING IN ACTION

Here, students are using the computational thinking strategy of decomposition to explore how different components of the immune system fight disease throughout the body.



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Day 1

Continued

Procedure

COMPUTATIONAL THINKING IN ACTION

Here, students are using the computational thinking strategy of decomposition to explore how different components of the immune system fight disease throughout the body.

CONCEPT MAPS

Concept maps use visual descriptions to help us communicate concepts that may be difficult to understand through narrative text alone. Visual system diagrams or concept maps are two means of adding cultural value to the messages you are sharing. A concept map is a type of diagram that shows various relationships among concepts.

Small Group (25 minutes)

1 Organize students into groups of three to four and ask students to create a graphic organizer, such as a *flowchart* or *concept map*, that models the adaptive immune system.

Teacher Note > *The graphic organizers may be created using the linked digital tools, but may also be handmade by student groups.*

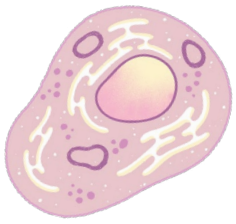
2 Invite students to consider creating an analogy of the different components and how they work together. For example, they might compare immune system components to different superheroes or villains.

3 After students have worked on their model for 15 minutes, have them pair up to compare and discuss their models.

4 Summarize with students using the following guiding questions as an exit slip or class discussion.

How representative is your model of the real immune system?

Why is an adaptive immune system needed?



Days 2–3

Procedure

LEARNING OUTCOMES

Students will be able to:

Examine the responsibilities of a microbiologist.

Investigate different vaccine types and how they work in the body.

INDUSTRY AND CAREER CONNECTION

In this activity, students will be tasked with using a microbiologists' soft skills of resilience and openness to learning new methods. They will need to display an analytical mind as they will be placed in pairs to watch a video and filter in relevant information required to complete the table. They will also develop time management skills as they will complete the assigned task in the available time. Students will need to demonstrate communication skills as they work in groups.

Individual (10 minutes)

1. Let students read the article from the U.S. Bureau of Labor Statistics about the responsibilities of a *Microbiologist*.

2. Give students the *Microbiologist Tasks Concept Map* and ask them to fill in the boxes around with the different tasks assigned to a microbiologist (minor tasks in smaller boxes), as well as the main responsibility.

3. Clarify with students that an adaptive immunity is an immunity that occurs after exposure to an antigen either from a pathogen or a vaccination. Ask students to turn to a partner and discuss why they think different approaches are needed to make vaccines for different illnesses. Anticipated response is that because of all the different types of antigens, we need different types of vaccines. Students will research more about the different vaccine types in small groups.

Small Group (35 minutes)

1. Assign small groups of two to three students. Invite groups to select a type of vaccine based on their interest, using the *Why Are There Different Types of Vaccines? Research and Discovery Capture Sheet*. This will lead to a selection of one of the following vaccine types: inactivated vaccines, live-attenuated vaccines, messenger RNA (mRNA) vaccines, subunit, DNA vaccine, and non-replicating viral vector vaccines.

2. Review the resources provided on the capture sheet. Invite students to begin their research and fill in their responses in the provided table.

3. Ask each group to write their group name and vaccination type on a notecard and collect their cards. Group the cards into sets of two different types of vaccines. Assign groups with different vaccines together. Have groups use the Types of Vaccines Infographics resource from the capture sheet to compare and contrast their two vaccines.

4. Invite students to support their ideas using the *PMI Strategy*. The PMI strategy challenges students to locate evidence to support their claims

Day 4

LEARNING OUTCOMES

Students will be able to:

Investigate the structure and function of DNA and RNA.

Explore differences in new vaccine development with COVID-19.

Procedure

Small Group (30 minutes)

1 Encourage students to share what they already know about DNA and RNA using a poll, collaboration board, or *Kahoot* game. Example pre-assessment questions:

- Which of the nucleic acids has the base thymine?

  DNA, RNA

- Which of the nucleic acids has the base uracil?

  DNA, **RNA**

- Which of the nucleic acids can travel out of the nucleus?

  DNA, **RNA**

- Which of the nucleic acids is double-stranded?

  DNA, RNA

- Which sugar is found in RNA?

  ribose, deoxyribose, glucose, sucrose

- Which molecule of RNA carries amino acids to the ribosome?

  mRNA, rRNA, **tRNA**

- Which nucleotide is complementary to guanine?

  adenine, **cytosine**, thymine, uracil

- Which RNA is transcribed from DNA ACT?

  TGA, **UGA**, GTA, GUA

- Which of these monomers make up DNA and RNA?

  amino acids, fatty acids, monosaccharides, **nucleotides**

- Do DNA and RNA have a charge?

  No, they are neutral, Yes, positive, **Yes, negative**

2 Show one nucleotide from DNA and one nucleotide from RNA (*DNA & RNA Templates*). Share with students that nucleic acids are made of repeating units (monomers) called nucleotides. Each nucleotide has three parts: a sugar, a phosphate group, and a nitrogenous base. Label each part on the nucleotides you are sharing.

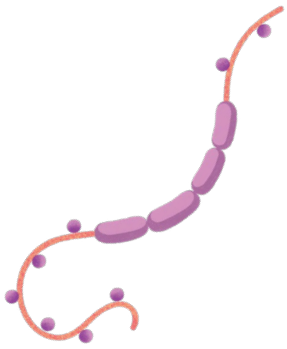
Continues next page >

Day 4

Continued

Procedure

3. Divide the class in half—one group will create a model of DNA and the other group will create a model of RNA, using the templates found at *DNA & RNA Templates*.
   - **a.** Sugar—blue
   - **b.** Phosphate—red
   - **c.** Guanine—green
   - **d.** Cytosine—yellow
   - **e.** Adenine—orange
   - **f.** Thymine—purple
   - **g.** Uracil—purple
4. Encourage students to compare and contrast their models by sharing observations in a whole-class discussion. Help students focus on the different sugars, nitrogenous bases, and number of strands.
5. Provide time for students to respond to the guiding questions and project connections in their **Design Journal**. They should capture the similarities and differences between DNA are RNA, and examine the role that mRNA plays in medicine.



Extension

Procedure

1. Students could research the following questions if time allows:
   - **a.** What charge do DNA and RNA have? Why?
   - **b.** How does the structure of deoxyribose and ribose differ?
   - **c.** The models show that adenine and guanine are larger than cytosine, thymine, and uracil. What makes some bases larger or smaller than others?
   - **d.** The model of DNA shows that adenine and thymine always pair with each other while cytosine and guanine always pair with each other. What force holds these nitrogenous bases together? Which pair are held together more tightly?
   - **e.** Erwin Chargaff studied DNA samples from numerous organisms and compared the amounts of adenine, cytosine, guanine, and thymine present. Suppose Chargaff found that 20% of the nucleotides in a DNA sample contain the nitrogenous base adenine. What percentage of the nucleotides contain the nitrogenous base cytosine?
   - **f.** A virologist finds that a viral genome contains 27.7% adenine, 21.3% uracil, 21.9% cytosine, and 29.1% guanine. Do you think the viral genome is single-stranded DNA, single-stranded RNA, double-stranded DNA, or double-stranded RNA? Defend your choice. *Source: Nucleotide composition of the Zika virus RNA genome and its codon usage*
2. Show the video *What is RNA?* and ask students to pay attention to the functions of DNA and RNA.
3. Encourage students to use the *Think-Pair-Share* strategy to develop an analogy for the functions of DNA and RNA. Encourage students to consider other pairs that work together to perform a job. Use a random calling strategy to have two or more groups share their analogy with the whole class. As an extension, students could then label DNA, mRNA, tRNA, and rRNA, and record their functions on a model using the *DNA and RNA Modeling Capture Sheet*.
4. Share with students that viruses carry very little within their capsid and rely mainly on the machinery inside a host cell to carry out its life functions.

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THINK-PAIR-SHARE STRATEGY

The Think-Pair-Share strategy promotes understanding for diverse learners through active reasoning and explanation. Because students are listening to and sharing ideas, this strategy encourages students to understand multiple perspectives.

Extension

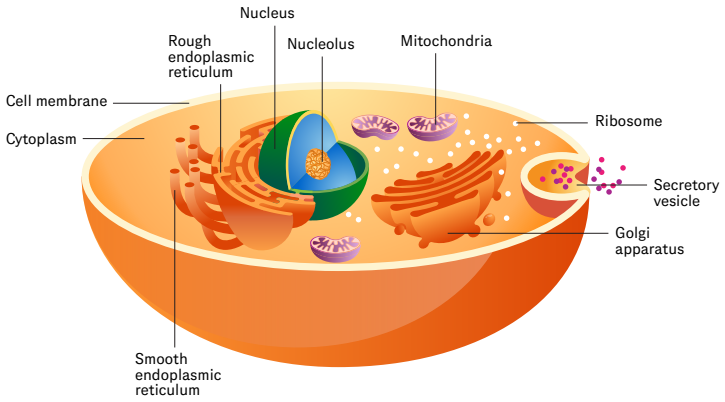
Continued

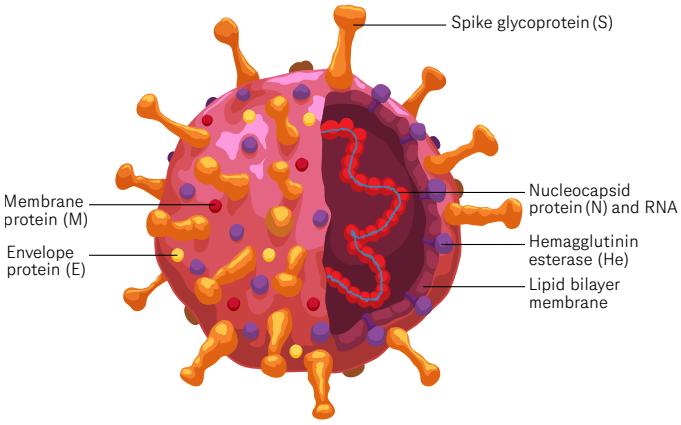
Procedure

5 Show students a model of a virus and a cell, such as the one below. Encourage students to identify similarities and differences and share them in a whole-class discussion.

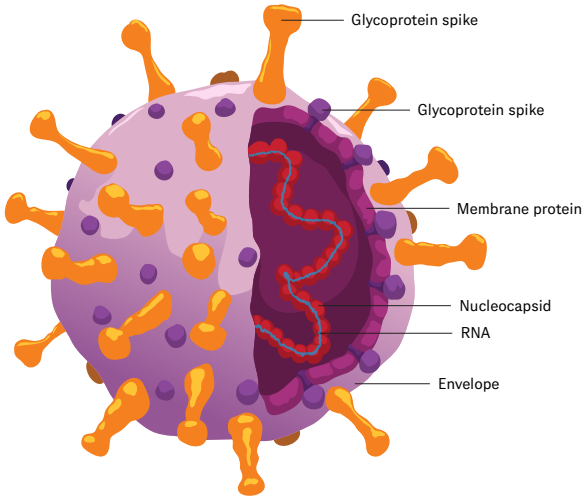
Help students focus on the presence of genetic material, the presence or absence of organelles, and the outer boundary of viruses and cells.

Eukaryotic Cell





Coronavirus



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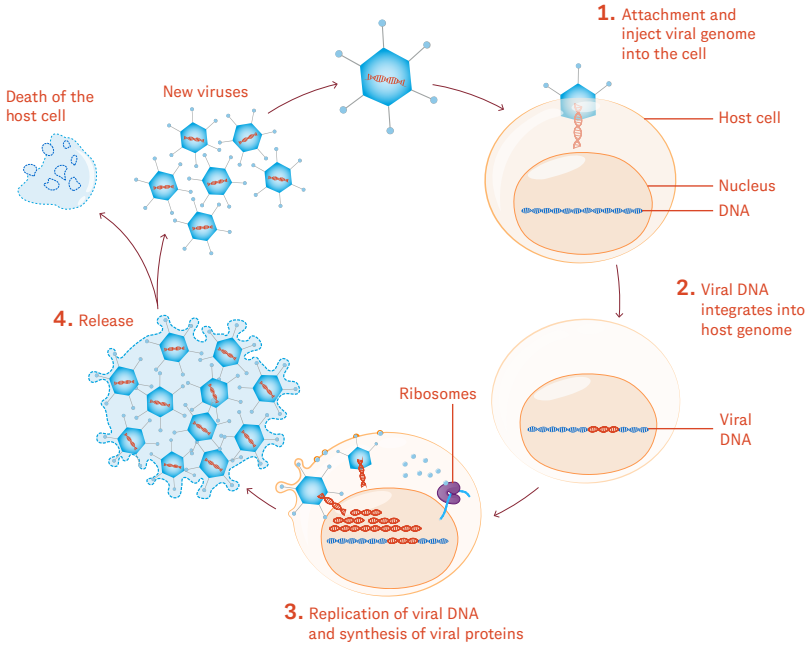
Extension

Continued

Procedure

6 Show a model such as the one below to students and ask them to compare how DNA viruses, RNA viruses, and retroviruses infect host cells. Ask student pairs to write a caption for each model. Encourage student pairs to share with at least one other pair to give and receive feedback on their captions.

Lifecycle of Viruses



Help students focus on the presence of genetic material, the presence or absence of organelles, and the outer boundary of viruses and cells.

7 Share with students that all vaccines have the same goal—to expose an individual's immune system to a virus so that it is prepared to fight if the individual is ever infected with the virus. Explain that traditional vaccines provide an individual with a weakened or shortened form of a virus. In contrast, DNA and RNA vaccines provide an individual with part of the virus' nucleic acids. Once the DNA or RNA is inside the host cell, the host cell transcribes or translates the viral nucleic acid to produce viral proteins that the immune system can prepare to fight against.

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Extension

Continued

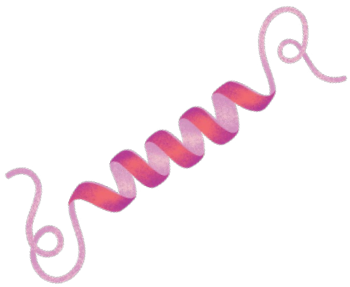
Procedure

8 Encourage student pairs to research two types of vaccines that were used during the COVID-19 pandemic, using the resources listed below. Each student will focus on one vaccine type and students will then compare and contrast the two vaccine types.

a. *How mRNA COVID-19 Vaccines Work*

b. *How Viral Vector COVID-19 Vaccines Work*

9 As an extension activity, invite students to listen to an episode of *Better Off*. In this episode, Harvard Chan School immunologist Sarah Fortune takes on common misconceptions about COVID-19 vaccines, and discusses the ways that mRNA technology could be used to create vaccines for diseases like TB and cancer. Students can use the *Sketchnote* strategy while listening and connect to their overall PBL project.



National Standards

Next Generation Science Standards

LS1.A: Structure and Function
All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins.

Science and Engineering Practices
Developing and using models
Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Crosscutting Concepts
Structure and Function
Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem.

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Career and Technical Education (CTE)

A3.1
Define and describe the structure and function of DNA ribonucleic acid (RNA) and proteins, explain the consequences of DNA mutations on proteins.

A9.3
Outline the steps in production and delivery of a product made through recombinant DNA technology.

Functions of the Adaptive Immune System Capture Sheet

ANSWER KEY — **Do not share with students**

Directions
Use the words provided and match them to their function in the adaptive immune system.

Word Bank

Antibodies	Dendritic
Antigen	T-Cells
B-Cells	

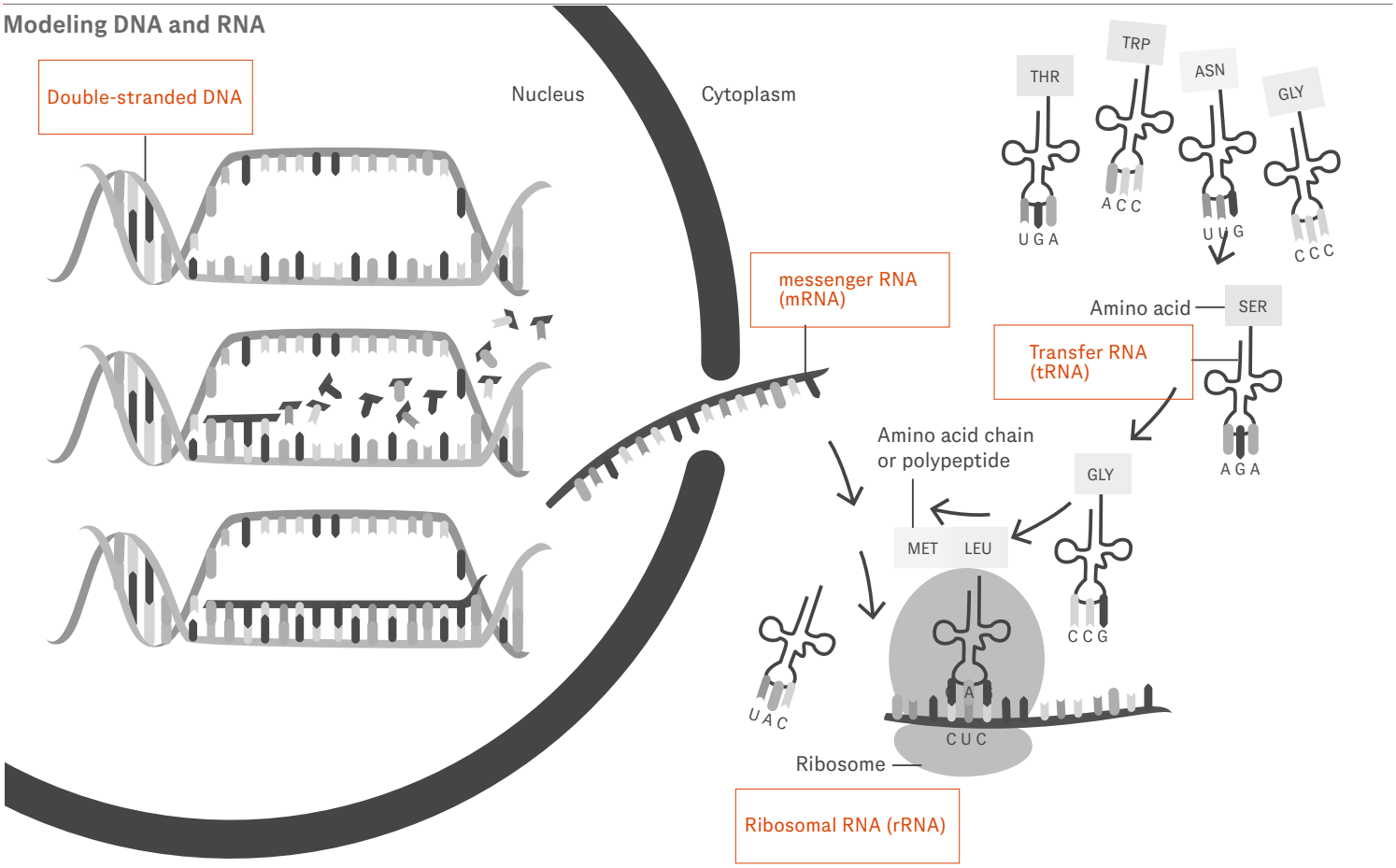
Component	Function in the Adaptive Immune System
Dendritic	Collects pieces of the invaders in the body and gives pieces of the invader to other cells
T-Cells	White blood cells that train other cells to form antibodies (establish immunological memory)
Antibodies	Protein produced by the body's immune system when it detects harmful substances
B-Cells	White blood cells that release antibodies to neutralize the enemy (fight infection)
Antigen	Molecule that is recognized by the body as a foreign substance

DNA and RNA Modeling Capture Sheet

ANSWER KEY — **Do not share with students**

Directions
Label DNA, mRNA, tRNA, and rRNA. Record their functions below.

Modeling DNA and RNA



1. DNA

the primary genetic material contained within the cell

2. mRNA

carries the genetic information copied from DNA in the form of a series of three-base codes, each of which specifies a particular amino acid

3. tRNA

helps decode a mRNA sequence into a protein by bringing amino acids to the ribosome for protein production

4. rRNA

works within the ribosome, binding the mRNA and tRNA to facilitate the process of translating mRNA's codon sequence into amino acids

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Functions of the Adaptive Immune System Capture Sheet

Directions
Use the words provided and match them to their function in the adaptive immune system.

Word Bank

Antibodies
Antigen
B-Cells
Dendritic
T-Cells

Component	Function in the Adaptive Immune System
	Collects pieces of the invaders in the body and gives pieces of the invader to other cells
	White blood cells that train other cells to form antibodies (establish immunological memory)
	Protein produced by the body's immune system when it detects harmful substances
	White blood cells that release antibodies to neutralize the enemy (fight infection)
	Molecule that is recognized by the body as a foreign substance

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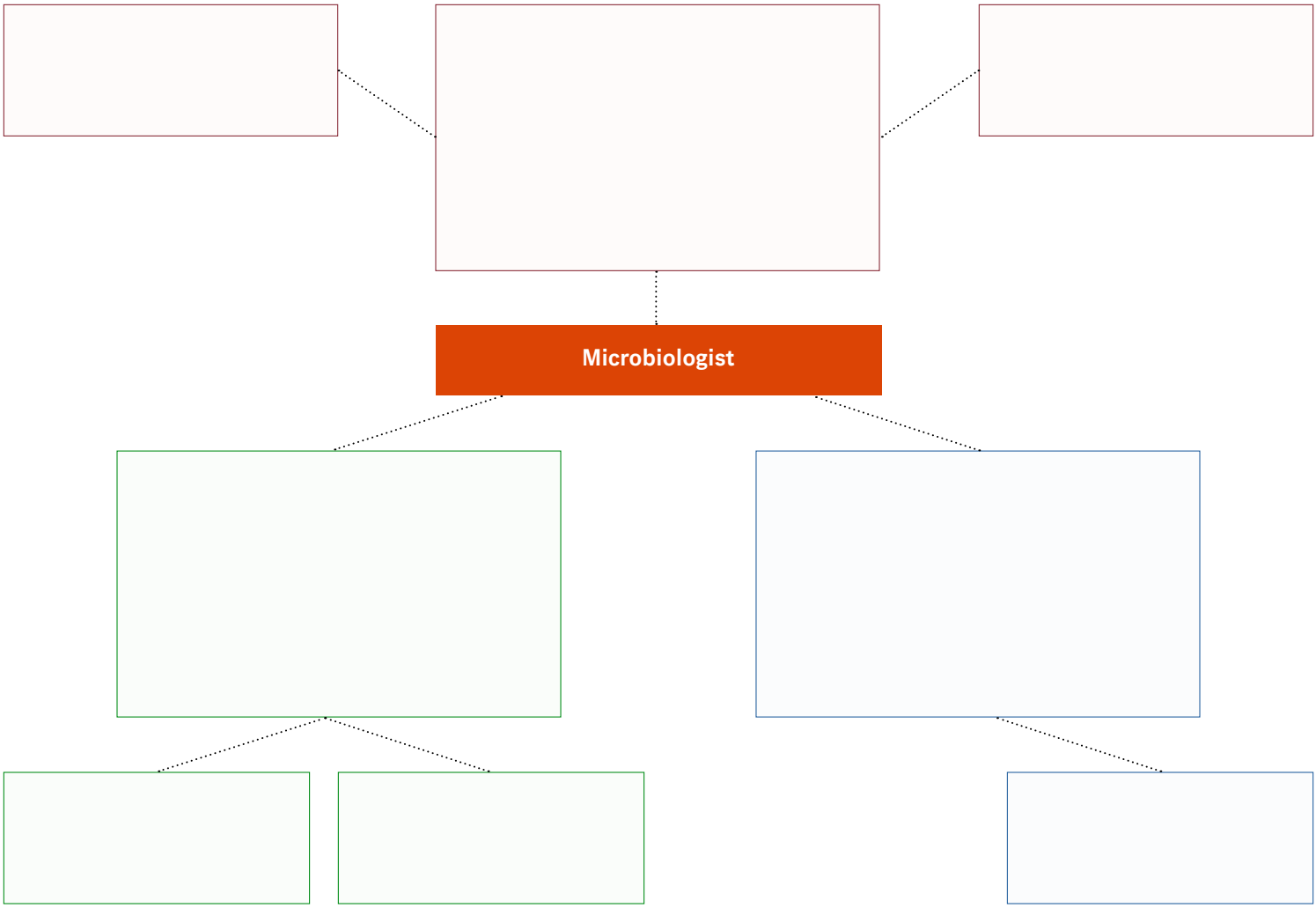
Microbiologist Tasks Concept Map

Directions

Consider the tasks of a microbiologist. Identify primary responsibilities in the larger boxes and minor or related responsibilities in the smaller boxes. Add additional boxes as needed.



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Why Are There Different Types of Vaccines?

Research and Discovery

Directions

Decide the type of vaccine you are most interested in exploring. Use the resources provided to get started.

I want to learn about vaccines that help prevent:

- deadly diseases from viruses that are spread to people from the saliva of infected animals—*inactivated*
- infectious bacterial diseases that cause uncontrollable coughing—*subunit*
- diseases caused by a virus that is spread through mosquito bites—*live attenuated*
- respiratory illnesses in humans caused by viruses—*mRNA*
- infectious diseases in animals—*DNA vaccine*
- a rare and deadly disease in people and nonhuman primates—*non-replicating viral vector vaccines*

Resources

Article	*Different Types of Vaccines*
Article	*Vaccine Types*
Article	*Understanding How Vaccines Work*
Infographic	*Types of Vaccines Infographics*
Glossary	*Vocabulary Cheat Sheet*

1. Record your research in the table below. You can write or create annotated drawings.

Topic	Research
How they are made	

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Why Are There Different Types of Vaccines?

Research and Discovery

Continued

Topic	Research
Model of how they work in the body	
Advantages	
Disadvantages	
Current use	

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Why Are There Different Types of Vaccines?

Research and Discovery

Continued

2. In your partner group, use the graphic organizer to compare and contrast your vaccine type with another type. Then write a summary of your findings.

Compare and Contrast	Vaccine #1 _____	Vaccine #2 _____
How are both vaccines alike?		
How are they different?		

Summarize

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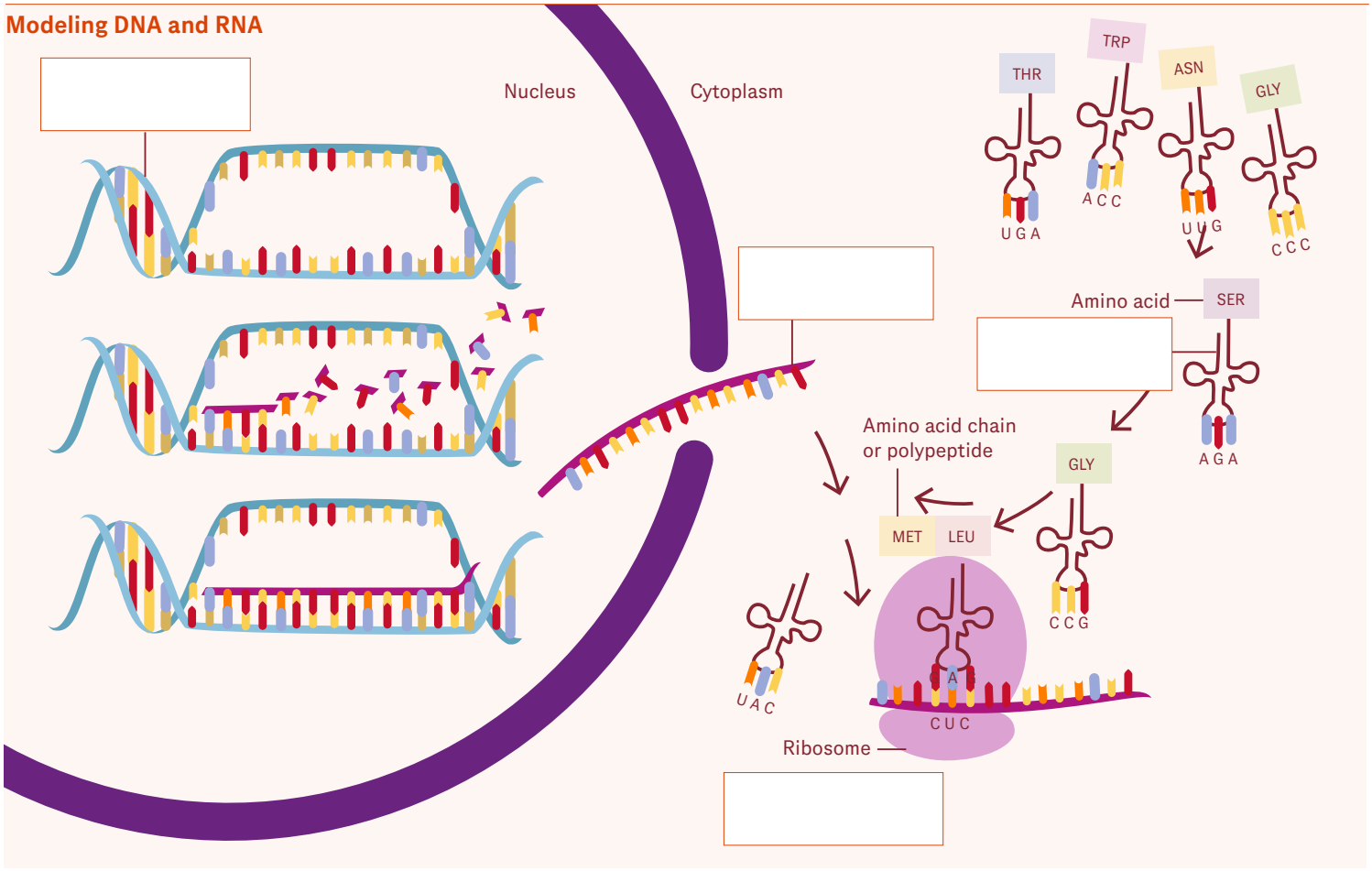
DNA and RNA Modeling Capture Sheet

Directions
Label DNA, mRNA, tRNA, and rRNA. Record their functions below.

Modeling DNA and RNA



1. DNA

2. mRNA

3. tRNA

4. rRNA