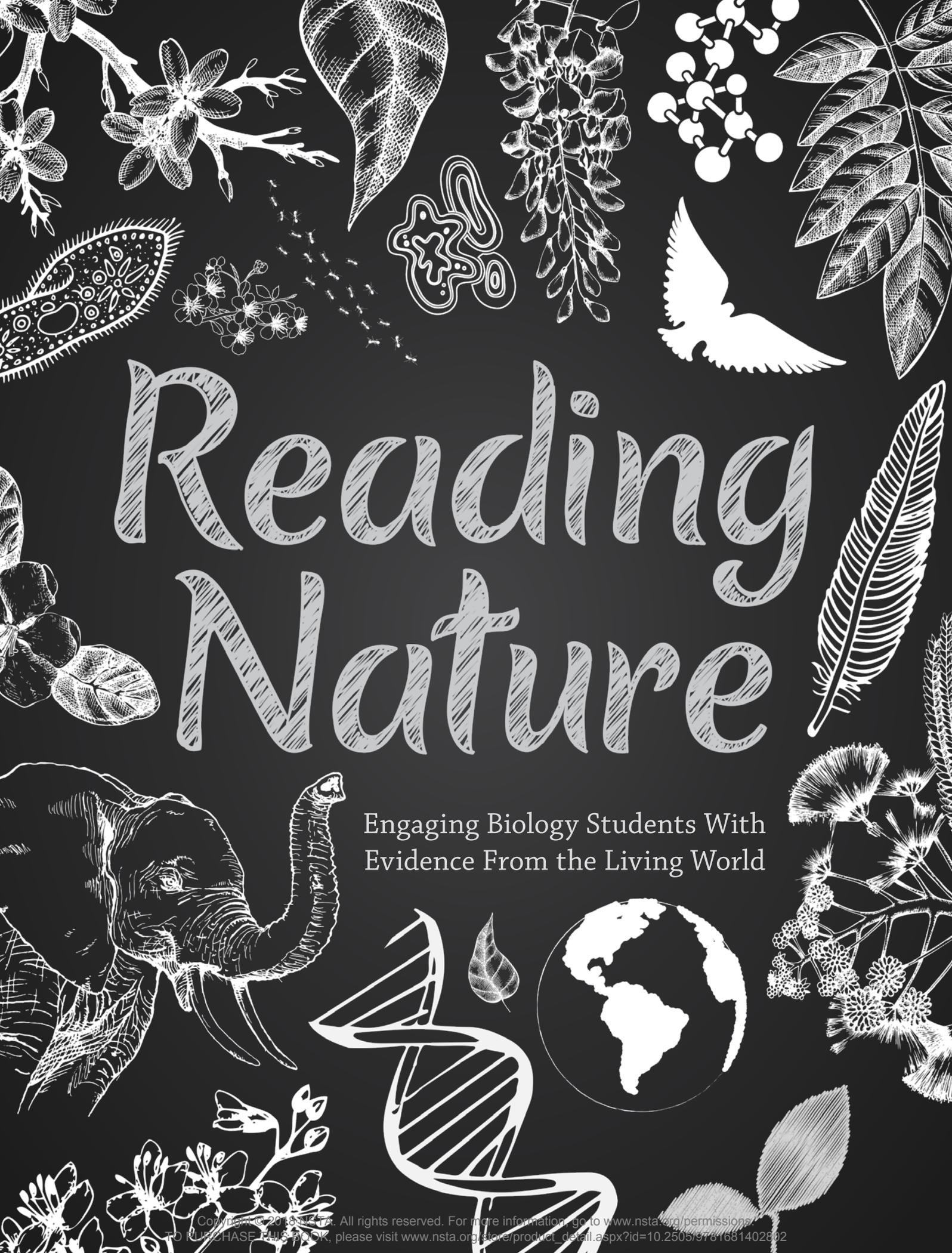


Reading Nature

Engaging Biology Students With
Evidence From the Living World

MATTHEW KLOSER
SOPHIA GRATHWOL

NSTApress
National Science Teachers Association



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Arlington, Virginia



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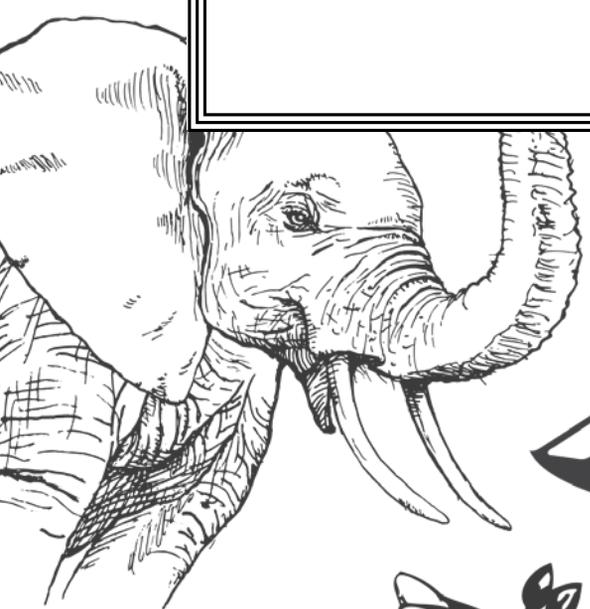
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This book is dedicated to all those who wonder about the world around them.



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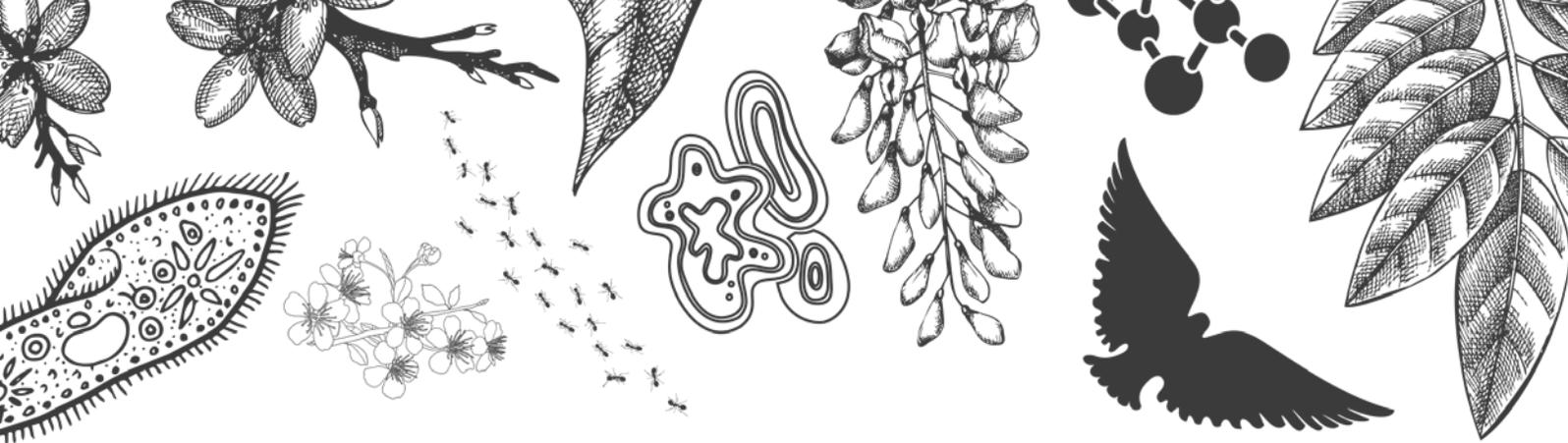
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Text 7	Meselson, M., and F. W. Stahl. 1958. The replication of DNA in <i>Escherichia coli</i> . <i>Proceedings of the National Academy of Sciences</i> 44 (7): 671–682.
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INTRODUCTION

It is a rare textbook, indeed, which supplies enough of the structure of the discipline to let students know that [they are] dealing with a model or a possibility and not with a literal truth or literal falsehood (Schwab 1978, p. 236).

My own science education is defined by a contradiction. My report cards and transcripts from kindergarten through high school were filled with straight As in science. I could solve physics problems, identify the different parts of a cell, and balance chemical equations. Yet I never really knew much about science. The science I mastered focused mostly on facts, a form of school science that so many of us have experienced. This version of science is not wholly ineffective, but it misrepresents what science truly is—a creative, social, and tentative endeavor that is based on puzzling questions, using a variety of methods, and justified by evidence that does not always paint a definitive picture.

At the heart of this contradiction lies the important role that traditional textbooks played in my science classes, especially in the life sciences. These voluminous texts posed no questions, except perhaps at the end of chapter reviews. They portrayed science as a static body of knowledge passed down from a nameless source. Lost in the extensive vocabulary were the ingenious experiments that contributed to what we know about the amazing phenomena of living things.

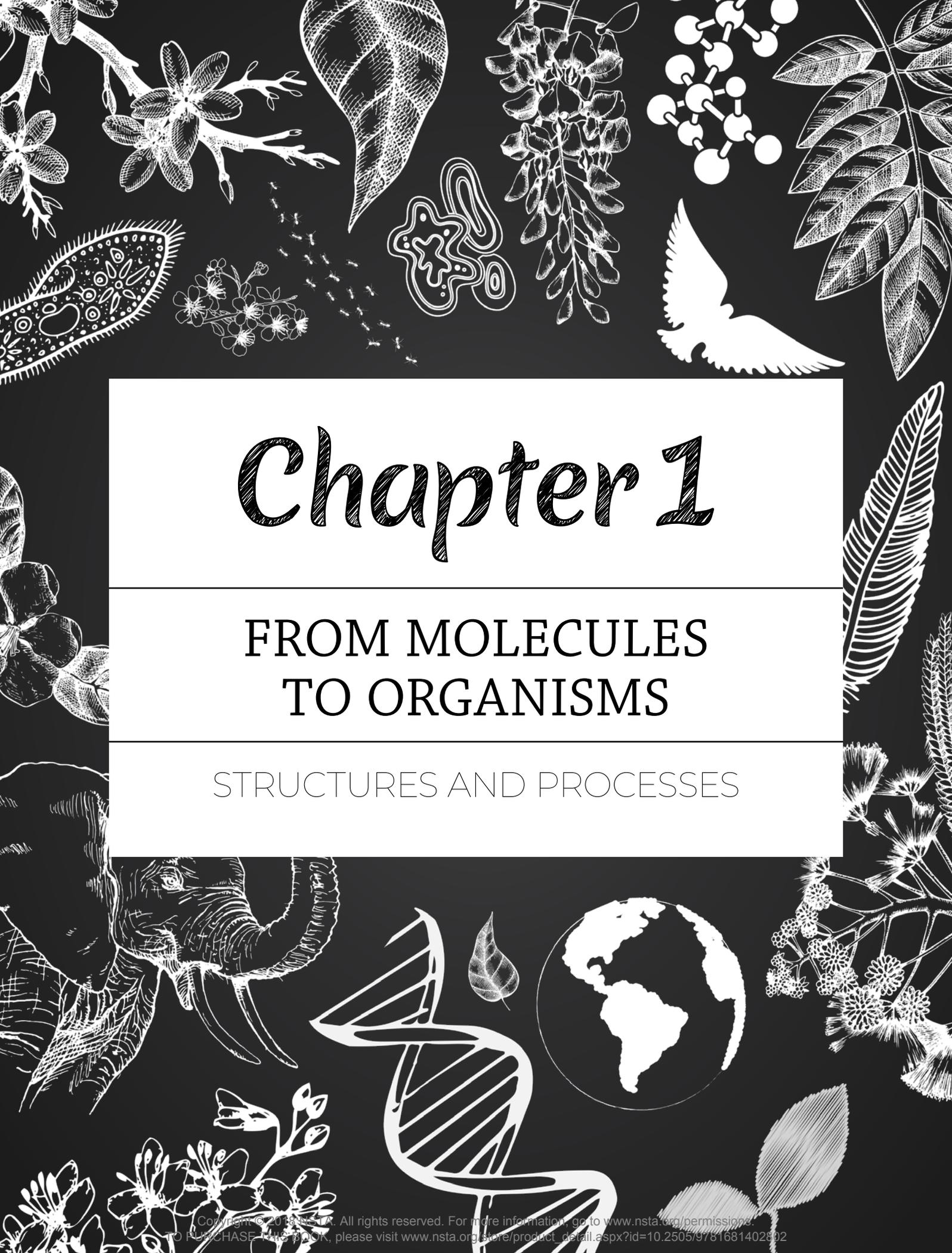
The need for new science texts is imperative. The release of the *Next Generation Science Standards* (NGSS Lead States 2013) and the literacy standards in the *Common Core State Standards for English Language Arts* (NGAC and CCSSO 2010) emphasize the importance of informational texts across subject areas that better reflect the enterprise of science. This book provides a set of resources for teachers who want to focus on core science ideas while trying to shed light on how the stated claims are justified and why they matter. To mirror the importance of raising questions in our science classrooms, the Teacher Guide is not written declaratively, but rather as a set of questions about the structure of the texts that comprise this book; the research literature about the use of alternative science text types; and most importantly, suggestions for how these accounts may be used in high school biology classrooms as active tools for inquiry. Ultimately, I hope that these texts can push a few more students to look at the living world and ask both “why?” and “how do we know?”

Matt Kloser, September 2017

INTRODUCTION

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Chapter 1

FROM MOLECULES TO ORGANISMS

STRUCTURES AND PROCESSES



Text 1

THE FLUID MOSAIC MODEL OF THE CELL MEMBRANE

1 What structure influences cell 2 membrane function?

3 The cell membrane is central to cell function. This outer
4 layer controls what molecules pass in and out of animal
5 and plant cells. [Q1] Given the microscopic nature of
6 the membrane, scientists have had to use creative ways
7 to identify its parts and structure. Over time, models of
8 the cell membrane have been improved through inves-
9 tigation that build on each other.

10 The Gorter-Grendel Model

11 In 1925, Evert Gorter and François Grendel did not have
12 powerful enough microscopes to determine the structure
13 of cell membranes. They devised a set of experiments to
14 indirectly determine a cell membrane's structure. Pre-
15 vious studies proved that the membrane was made of
16 lipids (molecules similar to a fat), but these experiments did not explain how the lipids were
17 arranged. Gorter and Grendel extracted the lipids from a known amount of red blood cells
18 from a variety of animals. Using a method previously developed by other scientists, Gorter
19 and Grendel dissolved the lipids for a given animal's red blood cells in a chemical called
20 benzene and placed this solution on a thin surface of water. This technique causes the for-
21 mation of a single layer of lipids. Using this method, Gorter and Grendel realized that they
22 could determine the thickness of a cell membrane based on the surface area of the cell and
23 the surface area covered by the extracted fatty substances. [Q2] Gorter and Grendel gathered
24 the following data from the red blood cells of animals, shown in Table 1.1 (p. 24).

ADAPTED FROM

Frye, L. D., and M. Edidin. 1970.
The rapid intermixing of
cell surface antigens after
formation of mouse-human
heterokaryons. *Journal of
Cell Science* 7 (2): 319–335.

Gorter, E., and F. J. E.
M. Grendel. 1925. On
bimolecular layers of lipids
on the chromocytes of
the blood. *The Journal of
Experimental Medicine* 41
(4): 439–443.

Table 1.1. Data from the red blood cells of animals

Animal	Sample	Total Cell Surface (sq. μ)	Surface Occupied by All of the Fatty Substances (sq. μ)	Ratio of Total Cell Surface to Surface Covered by Fatty Substances
Dog A	1	31.3	62	2.0:2.0
	2	6.2	12.2	
Sheep 1	1	2.95	6.2	2.1:2.2
	2	2.65	5.8	
Rabbit A	1	5.46	9.9	1.8:2.0
	2	0.27	0.54	
Guinea Pig A	1	0.52	1.02	2.0:1.9
	2	0.52	0.97	
Goat 1	1	0.33	0.66	2.0:2.1
	2	0.33	0.69	
Man	1	0.47	0.92	2.0:1.9
	2	0.47	0.89	

[Q3–Q4]

Although Gorter and Grendel's work contributed to scientists' understanding of the lipid bilayer (or two-layer-thick) cell membrane, their model was later found incomplete as it did not include the proteins that are embedded within the cell membrane. These proteins were found to have an important structural and functional role for cell function.

Are cell membranes rigid or moveable structures?

The Frye-Edidin Model

Gorter and Grendel's work did not address the presence of proteins and how they existed as part of the cell membrane. In 1970, Larry Frye and Michael Edidin predicted that if cells could change shape, then the proteins and lipids of the cell membrane must be able to move past each other. To test their prediction, they used techniques that labeled the proteins on the outside of a cell with fluorescent colors that could be seen under a microscope.

However, the scientists realized that proteins on a cell membrane would all be labeled with the same fluorescent color, making it difficult to distinguish whether or not they moved. They needed to tag the proteins with at least two distinct colors that could be watched for movement over time. To do this, the scientists used fluorescent labels that were dependent on an organism's immune system. The immune responses from two different organisms would allow cells from the organisms to be tagged uniquely. Thus, if Frye and Edidin were able

THE FLUID MOSAIC MODEL OF THE CELL MEMBRANE

63 to fuse, or combine, two cells from
64 different organisms, they would
65 have one big cell—half of which was
66 tagged with one fluorescent color,
67 while the other half was tagged with
68 a different fluorescent color. [Q5]

69 The scientists hypothesized that
70 if the initially separated fluores-
71 cent labels eventually resulted in
72 alternating, or “mosaic,” patterns
73 on the cell membrane, then move-
74 ment of proteins and lipids must
75 be possible. If the two fluorescent
76 tags remained separated, then they
77 could be confident that movement
78 does not take place.

79 To test their hypotheses, Frye and
80 Edidin used the Sendai virus to fuse
81 two different cells. They combined
82 human and mouse cells because the
83 immune system responses from the dif-
84 ferent organisms allowed proteins on the
85 cell surface to be tagged with two different
86 fluorescent colors. The scientists tagged the
87 proteins in the mouse membrane with a
88 green label and the proteins on the human
89 cell with a red label.

90 Frye and Edidin then took photographs
91 of the fused cells through their microscope
92 and looked at the position of the red and
93 green labels every few minutes. Their
94 results are shown in Figure 1.1.

95 After observing the mosaic cells through
96 their microscope, Frye and Edidin wanted
97 to know more about the mechanism for
98 this result. The scientists reasoned that if
99 the parts of the membrane were moving
100 past each other, then they would see changes in the movement rate related to changes in
101 temperature. They ran another experiment in which they placed different fused cells in
102 different temperatures. Their results are shown in Figure 1.2.

Figure 1.1. Relationship of the red and green fluorescent labels on the fused mouse and human cell membrane

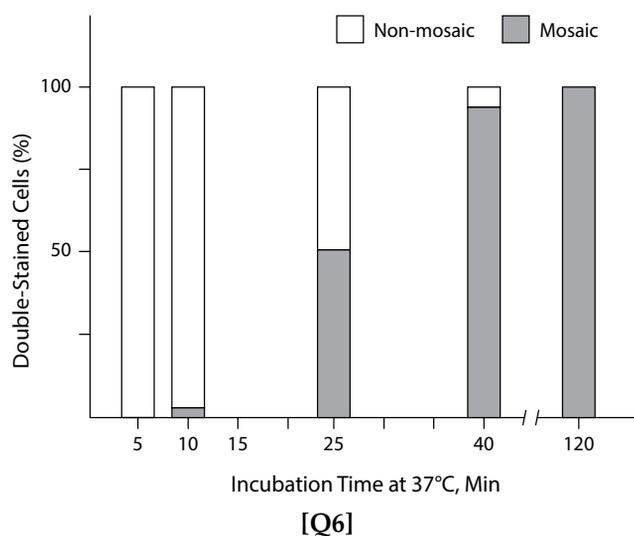
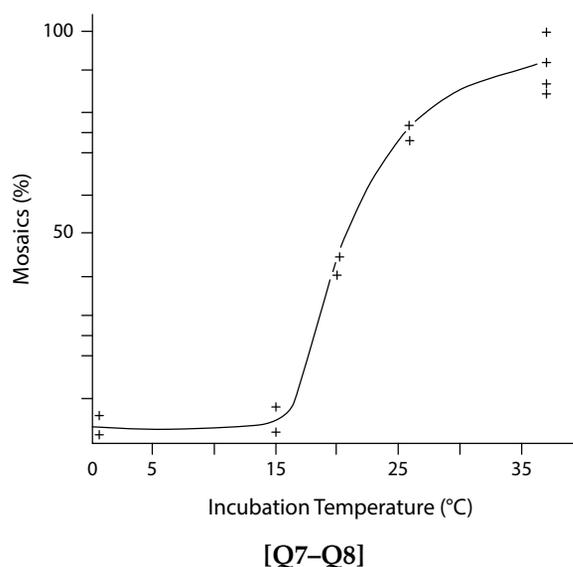


Figure 1.2. Effect of temperature on the appearance of mosaic cells



103 **Conclusions and Discussion**

104 Gorter and Grendel observed that the ratio of surface area covered by lipids to surface
105 area of the cell was very close to 2.1 for all the animals tested. They concluded that the cell
106 membrane structure was a bilayer—that is, a membrane two lipids thick. Because the cells
107 existed in a watery environment, they deduced that the polar, or water-loving, part of the
108 lipid existed on the outside of the membrane while the hydrophobic, or water-repelling,
109 tails were pointed toward the middle of the double-layered membrane.

110 Frye and Edidin’s results added more information that would help determine a model of
111 the cell membrane. The scientists observed that the fluorescent markers initially remained
112 on their own sides of the fused cells. But, over time, the colors mixed throughout each
113 fused cell and the percentage of mosaic cells rose as temperatures increased. This evidence
114 added explanatory power to Gorter and Grendel’s experiment, providing more details
115 about the composition and physiology of the cell membrane. It was not until 1972 that
116 Seymour Singer and Garth Nicolson used data from multiple experiments and multiple
117 scientists to create a detailed “fluid mosaic model” of the cell membrane that is still re-
118 ferenced today. The model uses the term “fluid” because the proteins and the lipids have
119 mobility and can move about like molecules in a liquid. The model is “mosaic” because the
120 proteins that form channels for particle movement into and out of the cell are distributed
121 throughout the bilayer. [Q9]

Group/Whole-Class Discussion Questions

- Q1:** Why is it important for molecules to be able to pass into and out of the cell?
- Q2:** In your own words, how does Gorter and Grendel's experiment help determine how many layers of lipids form the cell membrane? It may be helpful to draw a picture to explain your reasoning.
- Q3:** Why did the scientists use cells from different animals in their experiment?
- Q4:** What does the ratio of the surface area covered by fatty substances to the total surface area of the cell in each of the animal samples suggest about the structure of the cell membrane?
- Q5:** After the cells were fused and labeled with the two different colors, what evidence might suggest that the parts of the cell membrane could move easily? What evidence might suggest that the parts could not move easily?
- Q6:** What does the data in Figure 1.1 suggest about the structure of the cell membrane?
- Q7:** Why might temperature affect the movement of molecules in the cell membrane?
- Q8:** What conclusions can be drawn from the data in Figure 1.2?
- Q9:** What questions remain about the structure and function of the cell membrane?

Chapter

1

FROM MOLECULES TO ORGANISMS

Teacher Supplementary Materials

Reading Level (Flesch-Kincaid Scale): 11.5

Related *Next Generation Science Standards*

PERFORMANCE EXPECTATIONS

MIDDLE SCHOOL

- MS-LS1-2: Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.
- MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.

HIGH SCHOOL

- HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

SCIENCE AND ENGINEERING PRACTICES

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in Argument From Evidence
- Obtaining, Evaluating, and Communicating Information

DISCIPLINARY CORE IDEA

- Core Idea LS1: From Molecules to Organisms: Structures and Processes
 - » LS1.A: Structure and Function
 - » LS1.C: Organization for Matter and Energy Flow in Organisms

CROSCUTTING CONCEPTS

- Scale, Proportion, and Quantity
- Structure and Function

THE FLUID MOSAIC MODEL OF THE CELL MEMBRANE

Related *Common Core State Standards for English Language Arts*

- RH.9-10.8: Assess the extent to which the reasoning and evidence in a text support the author’s claim.
- RST.9-10.2: Determine the central ideas or conclusion of a text; trace the text’s explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of that text.
- RST.9-10.6: Analyze the author’s purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.
- RST.9-10.7: Translate information expressed visually or mathematically (e.g., in an equation) into words.

Supplementary Information

Using a case study to trace the history of our understanding of the cell membrane effectively highlights the longitudinal nature of scientific research. Text 1 addressed only two of the many experiments conducted to understand the cell membrane. Although scientists began discussing the structure and function of the cell in the 17th century, it took more than 200 hundred years to complete a viable model for the cell membrane. As technology improved, the depth of understanding increased. For instance, by the middle of the 20th century, micrographs of the cell confirmed the bilayer structure that Gorter and Grendel had proposed with their indirect experiment back in the 1920s. Yet with each contribution, questions remained open. Furthermore, contemporary research has identified even greater nuances that help refine the initial theory.

Students will gain a better grasp of the quest to understand the cell by studying background information about the scientists’ investigative techniques. Students are probably unfamiliar with the investigative technique of cell fusion via a virus. In Frye and Edidin’s experiment, the formation of a mouse-human heterokaryon (a cell with at least two different nuclei) was performed using the Sendai virus. The Sendai virus is responsible for highly contagious respiratory diseases in small mammals. However, it has been used to fuse cells together for purposes such as creating large amounts of antibodies.

Students will likely also be unfamiliar with immunofluorescence, the technique Frye and Edidin used for coloring proteins. The term *immunofluorescence* did not appear in the text. Instead, terms like *cell labeling* or *fluorescent tags* were used to convey the same meaning in more accessible language. This technique leverages the ability of an organism’s immune system to produce responses in order to fight disease. Antibodies are proteins used by the immune system to neutralize pathogens like bacteria and viruses, and they are specific to antigens—the disease-causing agent. Antibodies recognize particular structures of the antigen, bind to the antigen, and either neutralize it directly or destroy the invader with

Chapter

1

FROM MOLECULES TO ORGANISMS

assistance from other parts of the immune system. Scientists use this immune response to bind fluorescent markers to particular proteins on a cell surface. Then, using a special fluorescent microscope, they can identify specific parts of the cell that are present or absent based on the fluorescent pictures that appear.

A free full-text version of Frye and Edidin's paper is available online at: <http://jcs.biologists.org/content/joces/7/2/319.full.pdf>. While the text is likely beyond the grasp of students, the figures provide full-color images of the green and red marked cells as well as the fused cell and the intermixing of the fluorescent markers.

Group Tasks

SAMPLE CLAIMS-EVIDENCE-JUSTIFICATION CHART

Note: Students should receive a blank table with only the header titles (p. 17). The completed chart below represents only a sample of possible responses. Final charts may vary.

Claims	Summarized Evidence	Justification
The cell membrane is composed of a lipid bilayer, not a monolayer.	Across six different mammals' cells, the ratios of lipid surface area to surface area of the cell are all 2:1.	If the cell membrane were one lipid layer thick, then the surface area of the lipids laid out side-by-side would be equal to the surface area of the corresponding cell. Since the data shows that the ratio is 2:1, there is likely a double layer of lipids to cover the same surface area.
Components of the cell membrane are able to move within the cell membrane.	The fused mouse-and-human cells were initially 100% nonmosaic. After two hours, 100% of the combined cells were mosaic.	Lipids form a structure around cells based on their properties. Proteins are found within the lipid cell membrane. When proteins in a fused cell membrane are tagged with different fluorescent colors, the two colors are initially separated when viewed under a microscope. Over time, however, images from a microscope show that the colors begin to mix and form a 100% mosaic cell. The only way for mosaic cells to occur is for the proteins to have the ability to change position fluidly among the lipids.
Temperature affects the movement of cell membrane components.	When cells were placed in temperatures ranging from 0°C to 15°C, about 10% of the fused cells were mosaic. When cells were in temperatures ranging from 15°C to 35°C, approximately 100% of the fused cells were mosaic.	Temperature affects the movement of molecules. As more heat energy is added to a system, the molecules begin to move more quickly. For lipids, the increased movement leads to more mosaic cells in a short period of time, with nearly 100% of the cells at 35°C showing a mosaic pattern. Lower temperatures, therefore, should result in less movement and fewer mosaic cells.

THE FLUID MOSAIC MODEL OF THE CELL MEMBRANE

WHY ARE THE RESULTS OF THIS INVESTIGATION IMPORTANT?

The focus of this text is important for understanding both science concepts and how science works. Membrane structure and movement across membranes are crucial parts of cell and organ physiology. The fluid mosaic model is represented in almost every biology textbook as a graphical image. However, little to no evidence is ever given for how we know the membrane is fluid and mosaic in nature. Thus, this text provides some of that evidentiary basis. Importantly, this text also shows that big ideas require the findings of many different scientists and that new knowledge builds on old knowledge. The historical narrative that spans multiple decades is an important reminder of the cumulative nature of science.

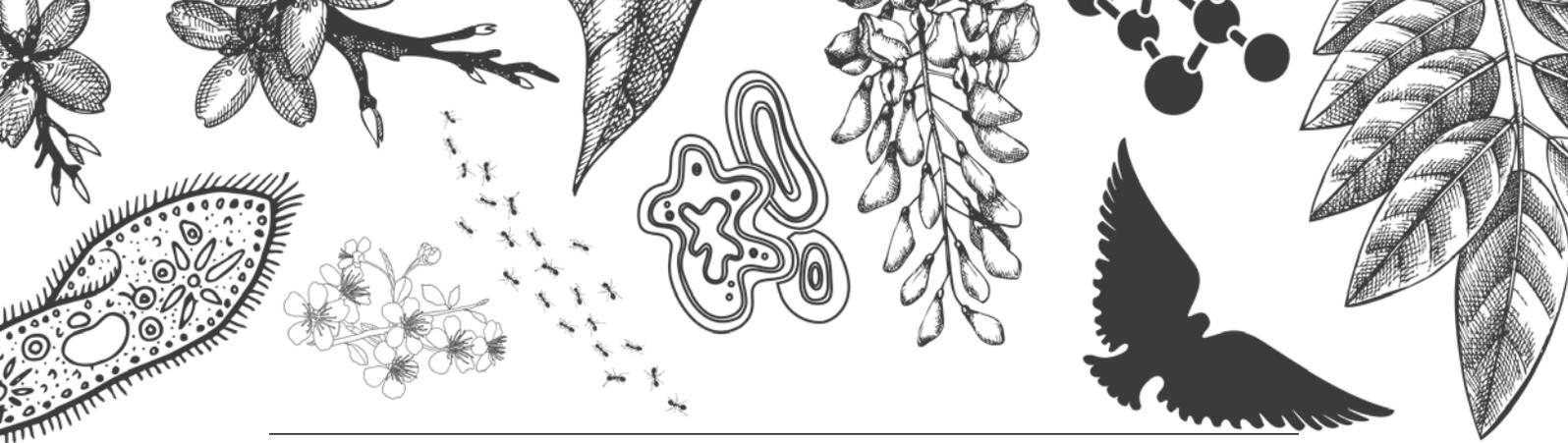
INVESTIGATION DESIGN TASKS**TASK A**

Frye and Edidin could not determine exactly how the parts of the cell membrane moved. They narrowed the possibilities to: (1) the components slid past each other or (2) the components were ejected from the membrane and then re-integrated into the membrane at a different point. If you were able to use their techniques of labeling cells and fusing cells, plus any other techniques that would work at the cellular level, how might you be able to determine which of the two mechanisms for movement is correct? When designing your investigation be sure to include the following:

- Your hypothesis—what you think will happen and why you think this will happen based on your prior knowledge of biology and previous studies.
- Your methods—the samples you will study, how you will study them (procedures), and the different conditions of the study (e.g., treatment and controls).
- Your analysis plan—what data you would compare to test your hypothesis and what results you would expect from the different conditions if your hypothesis was supported.

TASK B

Cystic fibrosis is a disease that occurs when there is a double mutation for the gene that codes the CFTR protein. The CFTR protein is found in the cell membrane and controls the flow of water and chloride ions in and out of the cell. People with cystic fibrosis have a malfunction in the protein that does not allow the free flow of these ions. For many people with cystic fibrosis, mucus will build up in the lungs because ions are not flowing freely across the cell membrane, causing infection and difficulty breathing. Currently there is no cure for cystic fibrosis. If you were a cellular biologist working on a cure, what possible solutions might you investigate and why might your approach(es) address the problems caused by cystic fibrosis?



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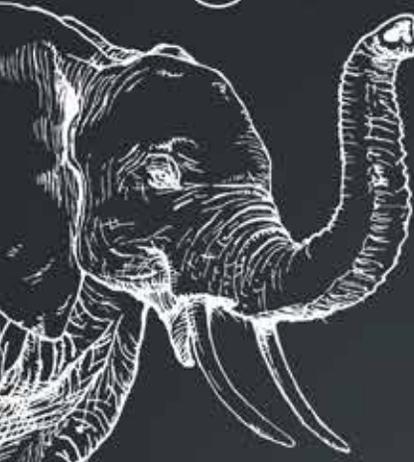
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