(Preparing for) **Tuesday's lecture:**

Budgeting homework time (60 min): Chapter 1, has a cover page, section 1.1 is 660 words, and section 1.2 on Drs. Griffith and Avery is 1725 words in length. While this is about 2300 words in total, thus the reading would be estimated to take 12 minutes. Yet careful reading and notetaking takes time and it has four data figures. While the Trifectas are easy to prepare for, Table 1.1 may be more difficult.

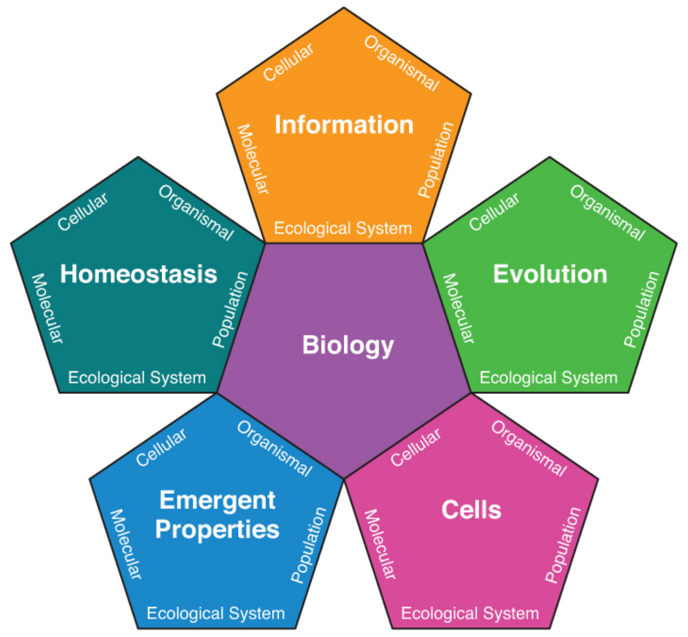
1. _______ **For Tuesday's lecture,** start **Chapter 1: Heritable Material** by reviewing the cover page and reading the short section 1.1: "What is biological information?" No notes needed.

2. _______ **Now slowly carefully read** section 1.2: "What is the heritable material?" and take careful handwritten notes in your lecture notebook.

3. _______ **Try to answer some Integrating Questions** and **Review Questions**.

4. _______ (Trifecta): **Prepare to explain (aloud) <u>Figures 1.2, 1.3, 1.4</u> and Table <u>1.1</u> in class** (Purpose, Methods, Findings).

Integrating Concepts in Biology



Chapter 1:
Heritable Material

1.1 What is biological information?
1.2 What is the heritable material?

by A. Malcolm Campbell, Laurie J. Heyer, & Christopher Paradise

Chapter 1: Heritable Material

What defines you as a human being? Why is every human different, even “identical” twins? Your body contains 10 to 50 trillion cells. Each cell contains instructions for the processes and functions of a human body. The information to carry out these functions is encoded in your deoxyribonucleic acid (DNA), half of which you inherited from each of your parents. What evidence supports the claim that DNA is the heritable material? How does DNA relay its information to the next generation? For many years, scientists mistakenly thought that protein was the heritable material. However, over many years of clever and now famous experiments, the evidence mounted in favor of DNA and against protein as the carrier of genetic information. One of the most famous discoveries in science was the double helix structure of DNA. DNA’s structure helps explain how your DNA replicates itself to produce the next generation. Chemical modifications to DNA can lead to differences among individuals, including some we can observe and some that make us sick. In Chapter 1, you will explore and interpret the original data from experiments that led to our current understanding of DNA as heritable information. Genetic information defines you as a human being and differentiates you as an individual. The five sections of Chapter 1 focus on information at the molecular level.

Dog breeds vary in phenotype, but they are all the same species. A is courtesy Kevin G. Smith, Davidson, NC. B - D are courtesy Abbye W. Stooksbury, Marietta, GA.

you are here		Big Ideas of biology				
		Information	Evolution	Cells	Homeostasis	Emergent Properties
levels of the biological hierarchy	molecules	1	4	7	10	13
	cells	2	5	8	11	14
	organisms I	3	6	9	12	15
	organisms II	16	19	22	28	25
	populations	17	20	23	29	26
	ecological systems	18	21	24	30	27

What defines you as a human being? Why is every human different, even “identical” twins? Your body contains 10 to 50 trillion cells. Each cell contains instructions for the processes and functions of a human body. The information to carry out these functions is encoded in your deoxyribonucleic acid (DNA), half of which you inherited from each of your parents. What evidence supports the claim that DNA is the heritable material? How does DNA relay its information to the next generation? For many years, scientists mistakenly thought that protein was the heritable material. However, over many years of clever and now famous experiments, the evidence mounted in favor of DNA and against protein as the carrier

Four Breeds of One Species

Slight differences in genetic information leads to different phenotypes.

Opening Figure

courtesy Kevin G. Smith and Abbye W. Stooksbury

1.1 What is biological information?

- Context: Introduce the Big Idea of Information as a critical part of life.
- Major themes: Heritable information provides continuity of life, and non-heritable information is transmitted within and between biological systems.
- Bottom line: Biological information takes many forms and is transmitted to others.

Biology Learning Objective

- Categorize different forms of biological information.

Biology is the study of life. You have learned this definition, but what does *life* really mean? If you look up the word *life,* Webster's dictionary tells us life is the quality that distinguishes a vital functional being from a dead body. In other words, life is not death. Frankly, this definition of life is not very informative; biology is the study of a quality that is not death. Most people mistakenly think of biology (and science in general) as a compilation of facts or a vocabulary list. In reality, science is a process of discovery based on observation and experimentation. Through the science of biology in this book, you will discover information that exists in nature and decipher information that characterizes the quality of life. Professional biologists are not paid to memorize facts already discovered. As a biologist, a student of life, your charge is to discover different layers of information represented in living organisms, regardless of their size or complexity. You will explore the Big Idea of Information at different levels of biological organization that are assembled into the quality that distinguishes life from death.

If you look up the word **information** in a dictionary, you will find many definitions, but two are particularly relevant: 1) communication or reception of knowledge; 2) signal representing data that justifies a change. One aspect of biological information is the transmission of knowledge to other living beings. Sharing ideas is commonplace for humans, and most people consider the communication of knowledge to be a uniquely human trait. But restricting information to human communication is a misconception (Figure 1.1). Information can be conveyed between monkeys, dogs, bees, plants, predators and their prey, and even bacteria. A very famous example of information as communicated knowledge is called within and between biological systems.

- Bottom line: Biological information takes many forms and is transmitted to others.

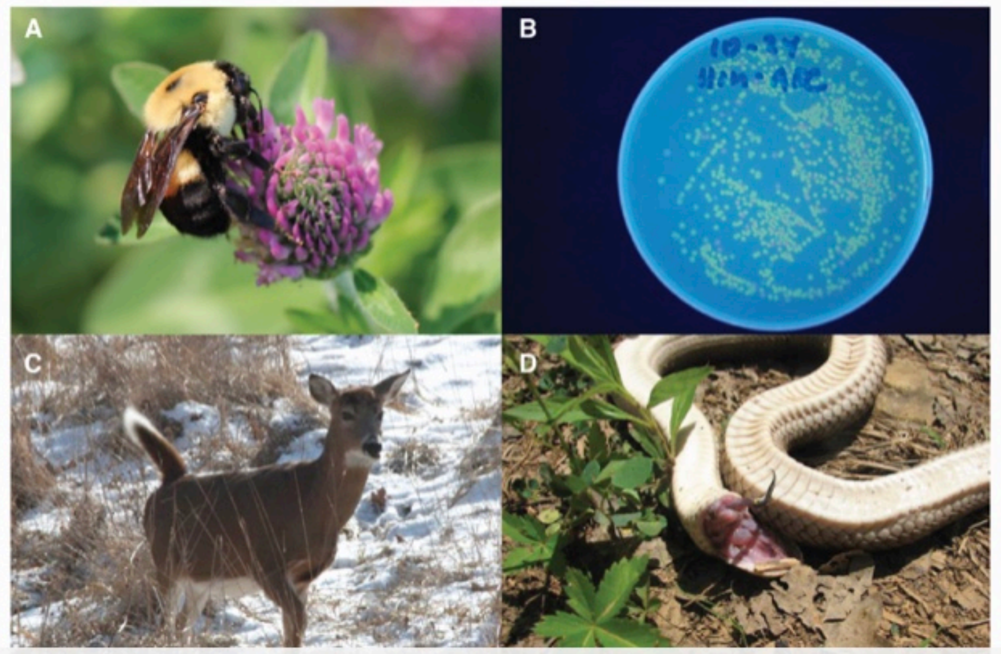
Biology Learning Objective

- Categorize different forms of biological information.

Biology is the study of life. You have learned this definition, but what does *life* really mean? If you look up the word *life,* Webster's dictionary tells us life is the quality that distinguishes a vital functional being from a dead body. In other words, life is not death. Frankly, this definition of life is not very informative; biology is the study of a quality that is not death. Most people mistakenly think of biology (and science in general) as a compilation of facts or a vocabulary list. In reality, science is a process of discovery based on observation and experimentation. Through the science of biology in this book, you will discover information that exists in nature and decipher information that characterizes the quality of life. Professional biologists are not paid to memorize facts already discovered. As a biologist, a student of life, your charge is to discover different layers of information represented in living organisms, regardless of their size or complexity. You will explore the Big Idea of Information at different levels of biological organization that are assembled into the quality that distinguishes life from death.

If you look up the word **information** in a dictionary, you will find many definitions, but two are particularly relevant: 1) communication or reception of knowledge; 2) signal representing data that justifies a change. One aspect of biological information is the transmission of knowledge to other living beings. Sharing ideas is commonplace for humans, and most people consider the communication of knowledge to be a uniquely human trait. But restricting information to human communication is a misconception (Figure 1.1). Information can be conveyed between monkeys, dogs, bees, plants, predators and their prey, and even bacteria. A very famous example of information as

If you look up the word **information** in a dictionary, you will find many definitions, but two are particularly relevant: 1) communication or reception of knowledge; 2) signal representing data that justifies a change. One aspect of biological information is the transmission of knowledge to other living beings. Sharing ideas is commonplace for humans, and most people consider the communication of knowledge to be a uniquely human trait. But restricting information to human communication is a misconception (Figure 1.1). Information can be conveyed between monkeys, dogs, bees, plants, predators and their prey, and even bacteria. A very famous example of information as communicated knowledge is called "The Hundredth Monkey" that became popularized in a book by the same name. In this 1950s study of monkeys on a Japanese island, the investigators introduced a new food item, sweet potatoes, to see what the troop of monkeys would do. One monkey used the ocean water to wash sand off of the potato, and the new behavior spread to most of the young monkeys and a few of the older adults. As the young monkeys began to reproduce, they taught their offspring, and the food washing behavior spread throughout the troop as the older monkeys died out. The young monkeys began to use the ocean for bathing and hunting seafood as well, which was an unexpected consequence (i.e., an **emergent property**) of the learned behavior. *{Connections: Emergent property is a Big Idea of Biology addressed in this textbook .}*



Information also means signal representing data that justifies a change. Signals come in many forms and scales; short days means winter season, a white stripe on a black fur coat warns you about a skunk, bitter taste indicates poisonous food, chemical odors signal the presence of a potential mate or predator, and loud sounds attract a mate or deter an enemy. Much of life concerns detecting and interpreting signals produced by organisms, which is why Information is one of the five Big Ideas of this book. Six chapters in this book focus on the core concept of information and how signals are transmitted ... stimulate a change in molecules, cells, organisms, populations, or ecological

Figure 1.1 Non-human biological

Define Information

To be considered information:

1. data must be stored for later use
2. its content has to be communicated
3. it has to be implemented and/or interpreted at some point in time.

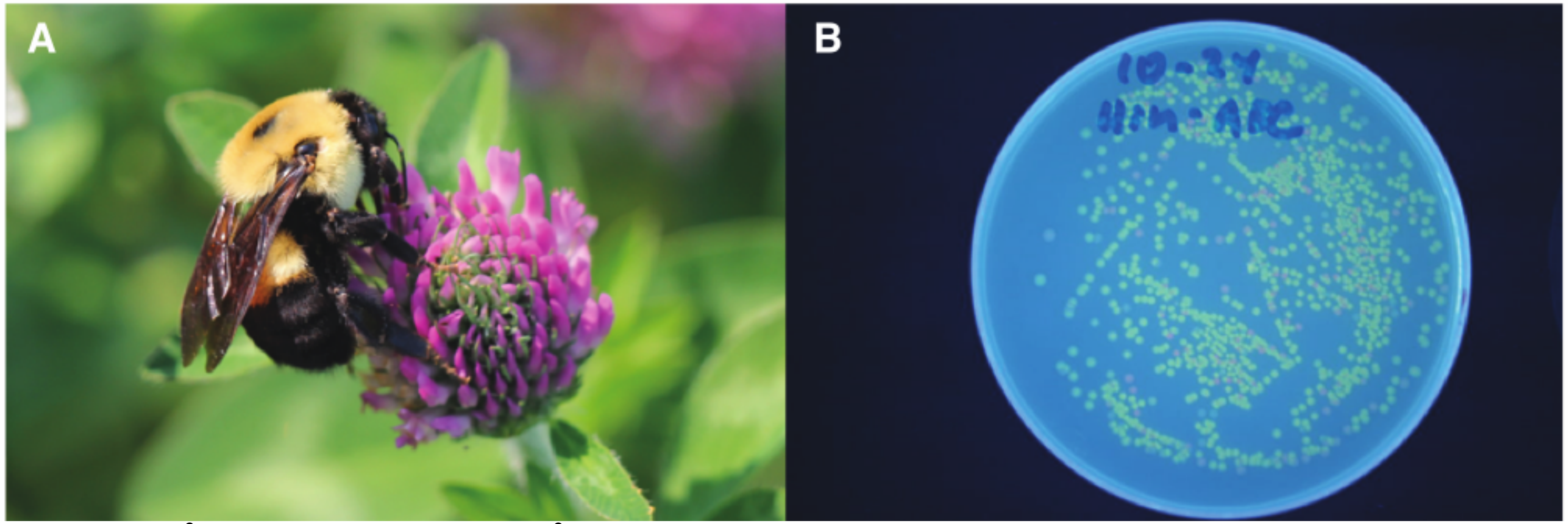
DNA, firefly examples?

Biological Information

Fig. 1.1

courtesy Chris Paradise, Todd Eckdahl, and Travis Mohrman

Biological Information



inter-species

molecular communication among individuals

Fig. 1.1

courtesy Chris Paradise, Todd Eckdahl, and Travis Mohrman

Biological Information

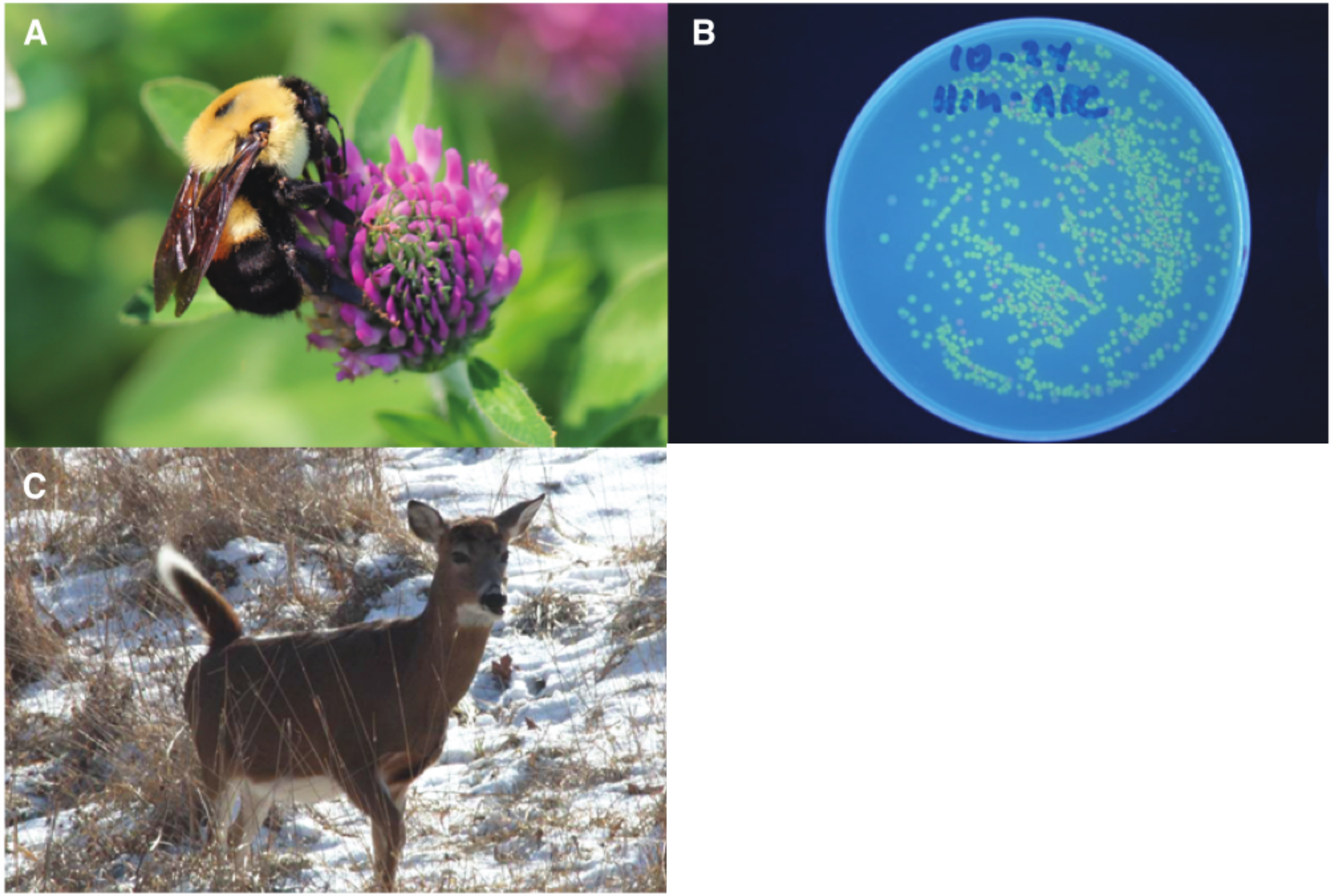


Fig. 1.1

courtesy Chris Paradise, Todd Eckdahl, and Travis Mohrman

Biological Information

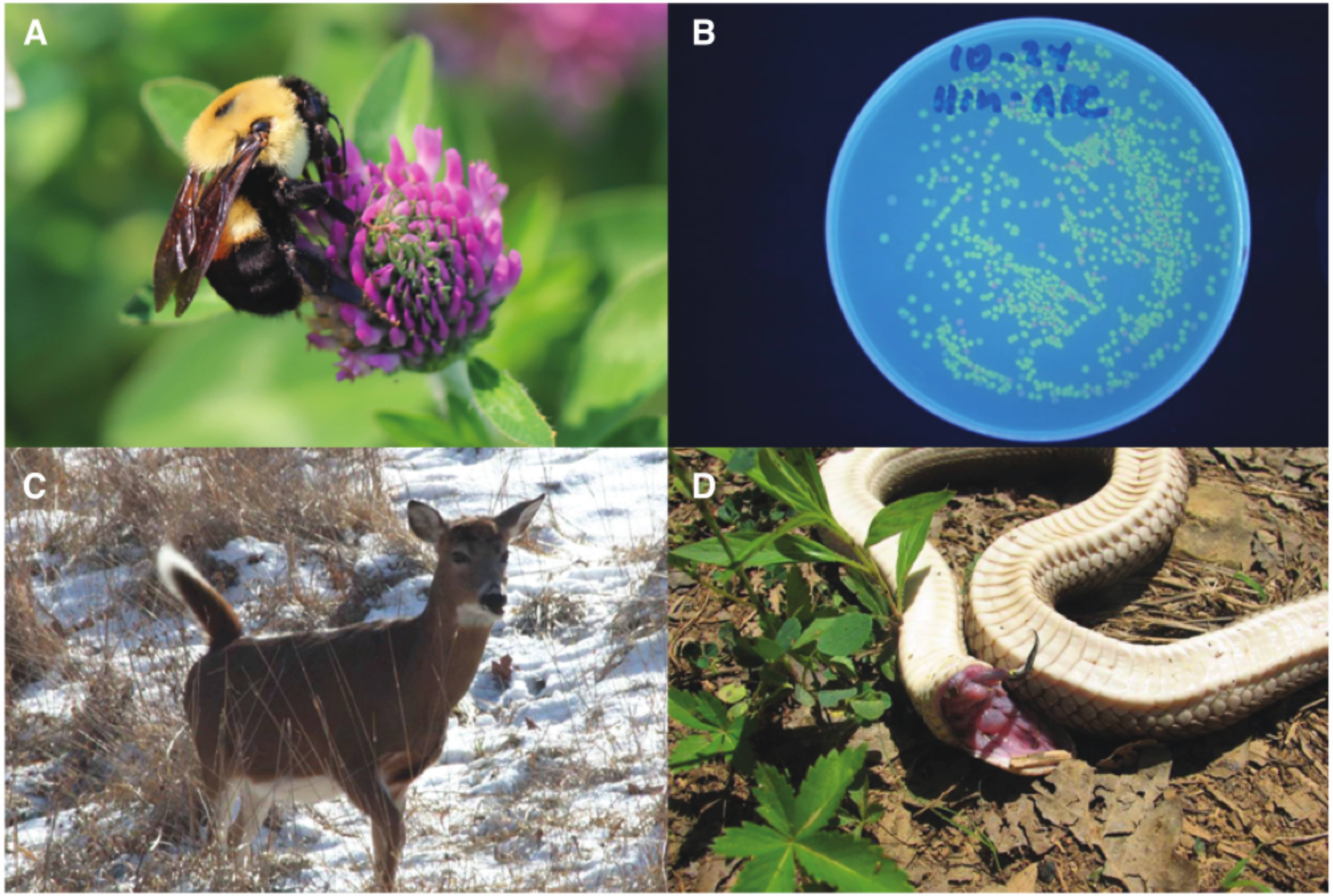


Fig. 1.1

courtesy Chris Paradise, Todd Eckdahl, and Travis Mohrman

1.2 What is the heritable material?

- Context: Genetic information is passed from one generation to the next.
- Major themes: Heritable information provides continuity of life and information can be expressed and regulated without loss of content.
- Bottom line: DNA probably is the heritable material, not proteins.

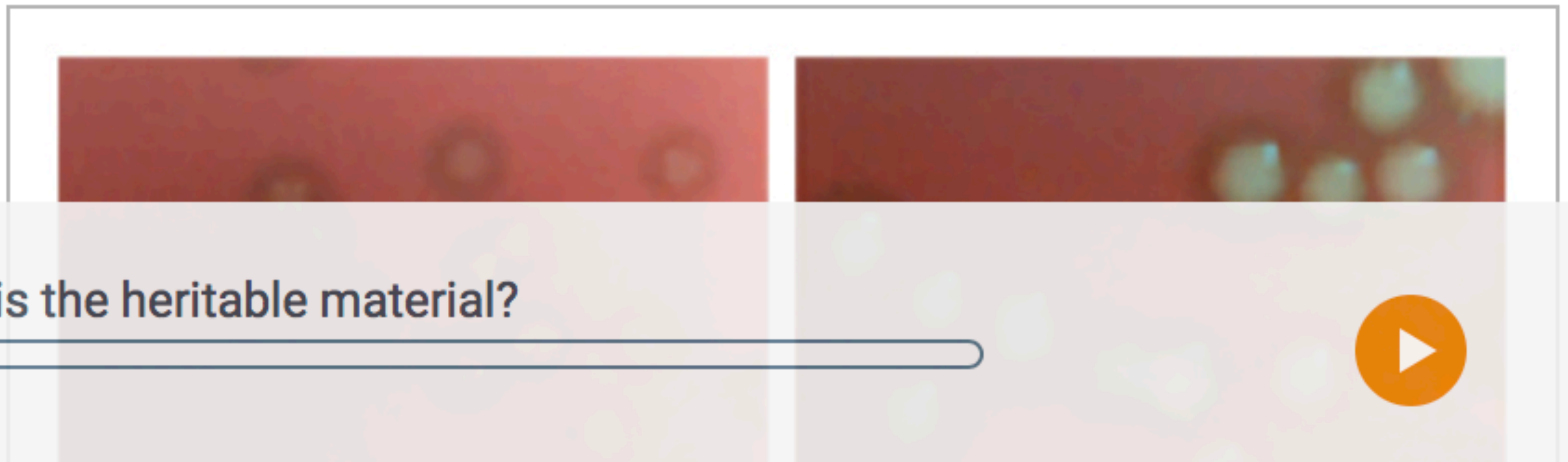
Biology Learning Objectives

- Interpret data showing that DNA is the heritable material and protein is not.
- Evaluate experimental design and analyze data from research on DNA as molecular information.

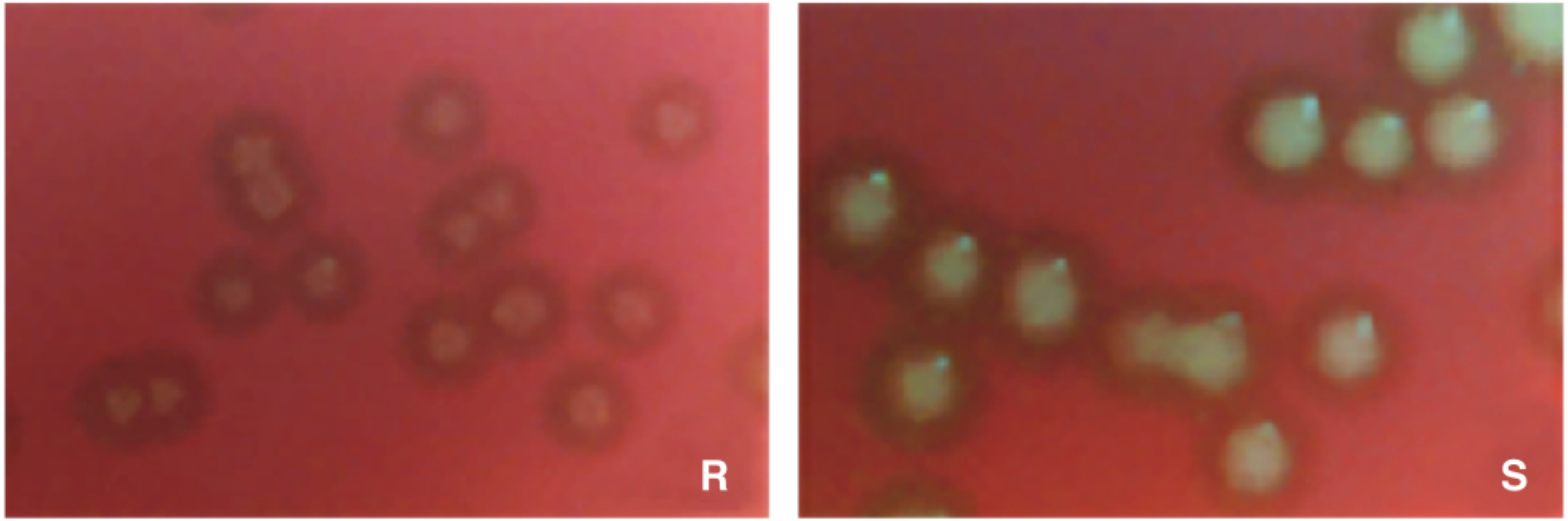
Science attempts to understand the physical world by answering questions through experimentation. For example, why do children often look like their parents? Why do adults give rise to the same species? Our first case study centers on the question, “What is the heritable material that is passed from one generation to the next?”

Sometimes, great science arises from an astute observation and a simple question. Dr. Fred Griffith was a medical officer in the British Ministry of Health during the 1920s. One of the major health threats at that time was pneumonia caused by the bacterium *Streptococcus pneumoniae*. Between 1920 and 1927, Griffith collected samples from patients and performed experiments on 278 isolates of pneumonia bacteria. At that time, the way to diagnose pneumonia consisted of two procedures: 1) inject a mouse with a patient’s saliva or mucus to see if the mouse died of pneumonia; and 2) spread the saliva or mucus on a Petri dish containing red growth media and examine any **colonies** that grew (Figure 1.2).

While conducting these tests, Griffith noticed *S. pneumoniae* could be classified into two **strains**, which he called rough (R) and smooth (S). These two strains of bacteria could be distinguished visually. He first performed many experiments to make sure he had not contaminated his samples. He also discovered an interesting **correlation**:



Trifecta (purpose, methods, findings)



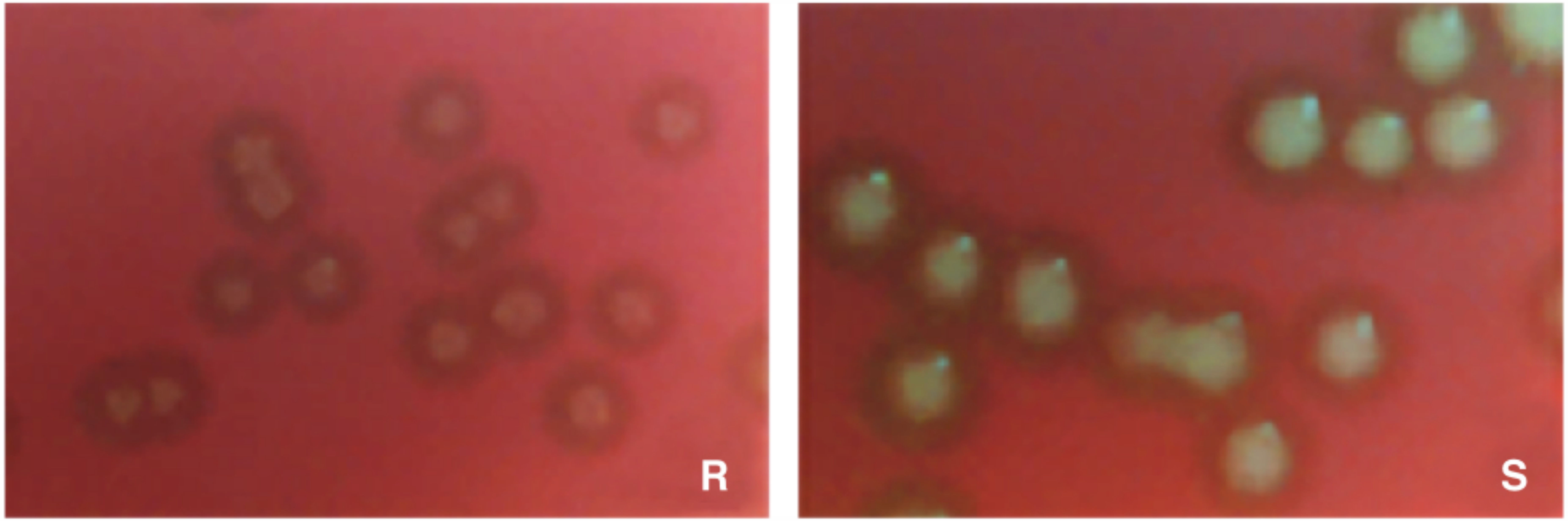
Griffith, 1928

Fig. 1.2

from Belanger et al. 2004

Photographs of Pneumococcus Strains

R strain → S strain



harmless lethal

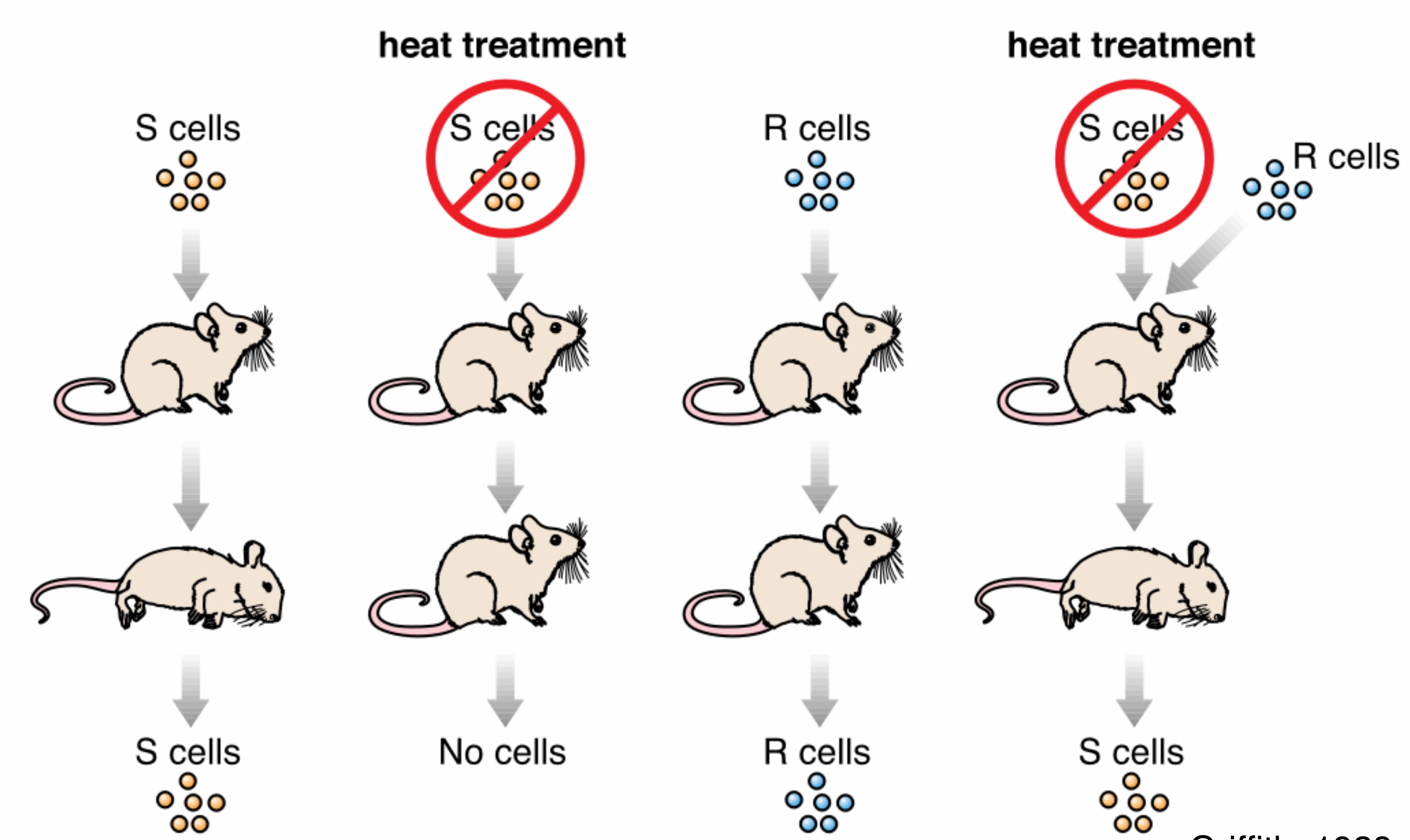
Griffith, 1928

Fig. 1.2

from Belanger et al. 2004

Griffith's work in the 1920s was fighting pneumonia

Trifecta (purpose, methods, findings)



Griffith, 1928

Fig. 1.3

Griffith's Experiments

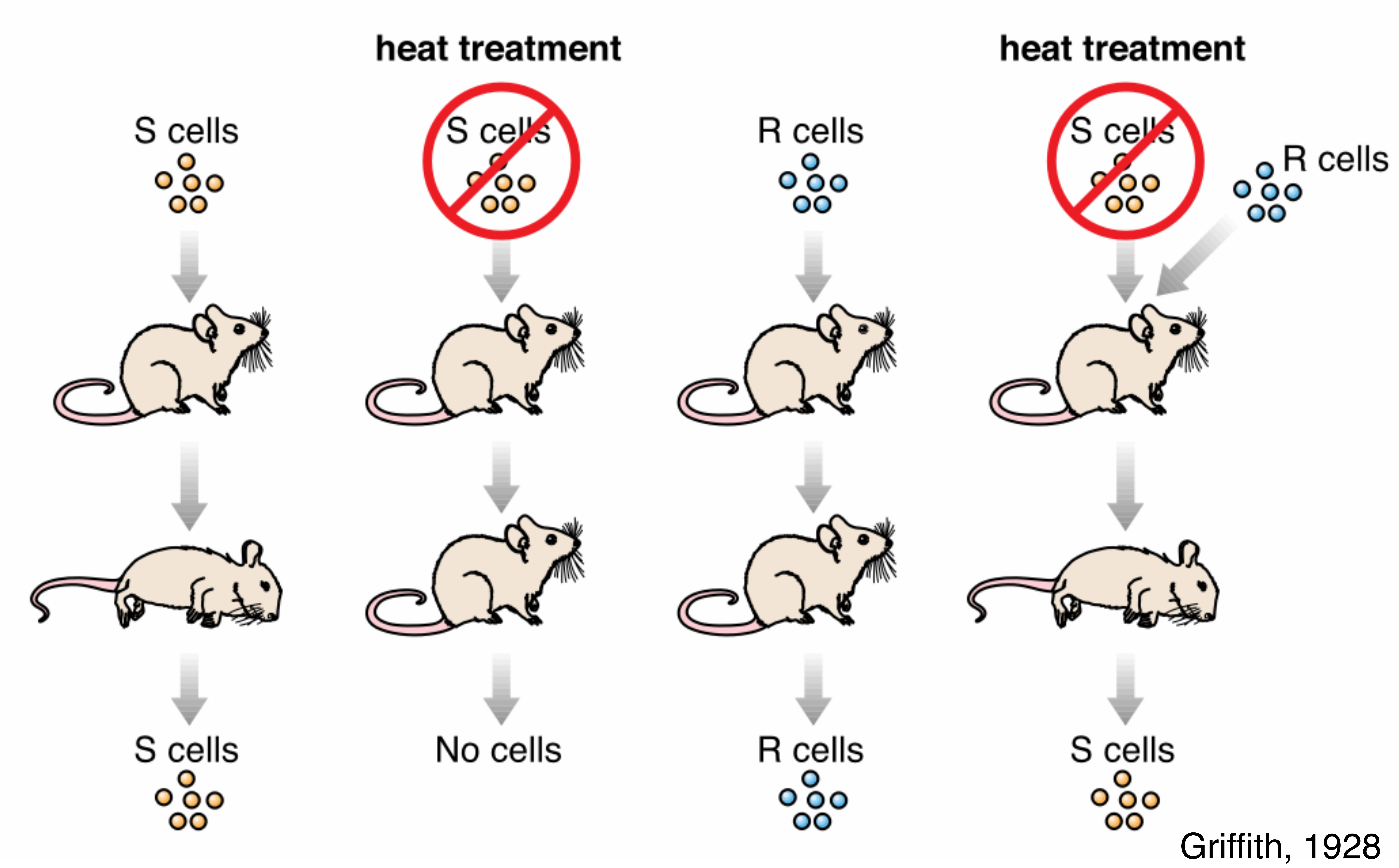


Fig. 1.3

Integrating Questions

1. Identify the positive and negative controls in Figure 1.3. Is it always clear when to call a control either positive or negative?
2. Which of the four experiments demonstrates the existence of an “S factor?” Can you use Griffith’s data to determine whether DNA or protein is the heritable material?

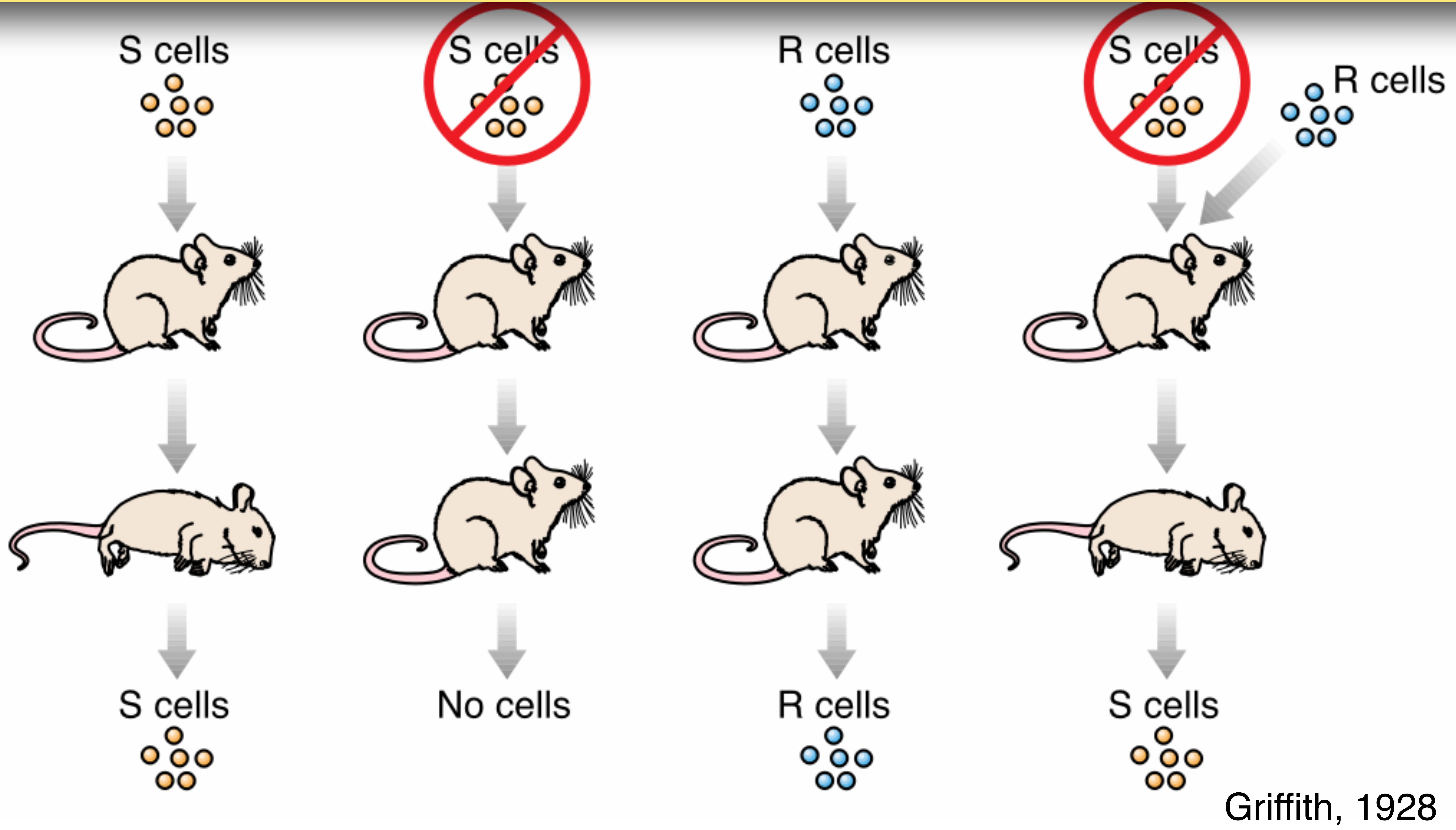


Fig. 1.3

VOLUME XXVII JANUARY, 1928 No. 2

THE SIGNIFICANCE OF PNEUMOCOCCAL TYPES.

BY FRED. GRIFFITH, M.B.

(A Medical Officer of the Ministry of Health.)

(From the Ministry's Pathological Laboratory.)

CONTENTS.

Avery worked in the 1940s to learn what was the transforming factor (genetic material)

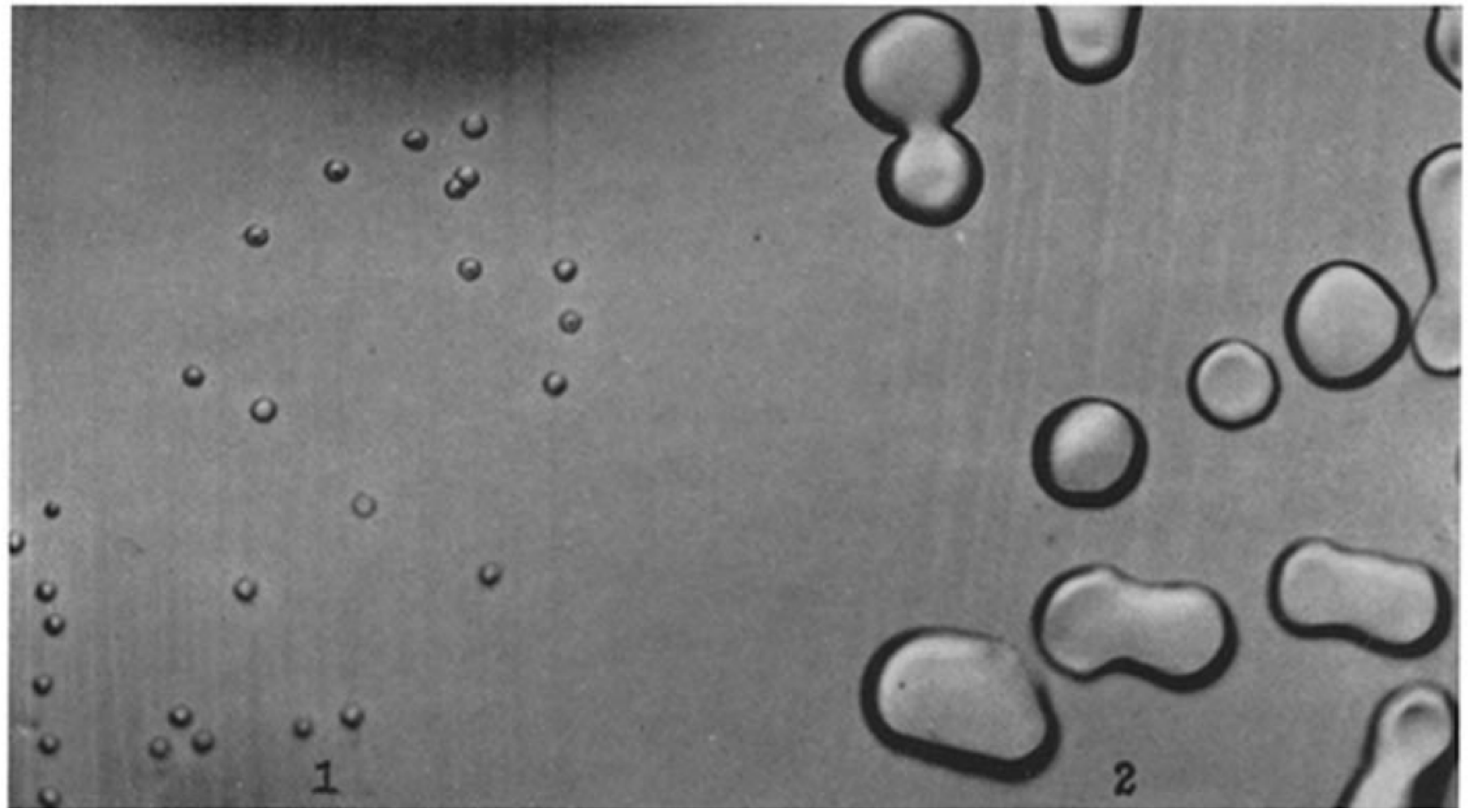
STUDIES ON THE CHEMICAL NATURE OF THE SUBSTANCE INDUCING TRANSFORMATION OF PNEUMOCOCCAL TYPES

Induction of Transformation by a Desoxyribonucleic Acid Fraction Isolated from Pneumococcus Type III

By OSWALD T. AVERY, M.D., COLIN M. MacLEOD, M.D., and MACLYN McCARTY,* M.D.

(*From the Hospital of The Rockefeller Institute for Medical Research*)

Plate 1



The photograph was made by Mr. Joseph B. Haulenbeek.

Fig. 1. Colonies of the R variant (R36A) derived from Pneumococcus Type II. Plated on blood agar from a culture grown in serum broth in the absence of the transforming substance. ×3.5.

Fig. 2. Colonies on blood agar of the same cells after induction of transformation during growth in the same medium with the addition of active transforming principle isolated from Type III pneumococci. The smooth, glistening, mucoid colonies shown are characteristic of Pneumococcus Type III and readily distinguishable from the small, rough colonies of the parent R strain illustrated in Fig. 1. ×3.5.

JOURNAL OF BACTERIOLOGY, Dec. 2004, p. 8164–8171 Vol. 186, No. 24
0021-9193/04/$08.00+0 DOI: 10.1128/JB.186.24.8164–8171.2004

Pyruvate Oxidase Is a Determinant of Avery's Rough Morphology

Aimee E. Belanger,* Melissa J. Clague, John I. Glass,† and Donald J. LeBlanc‡

Lilly Research Laboratories, Eli Lilly and Company, Indianapolis, Indiana

Received 13 July 2004/Accepted 10 September 2004

In pioneering studies, Avery et al. identified DNA as the hereditary material (A. T. Avery, C. M. MacLeod, and M. McCarty, J. Exp. Med. 79:137–158, 1944). They demonstrated, by means of variation in colony morphology, that this substance could transform their rough type 2 *Streptococcus pneumoniae* strain R36A into a smooth type 3 strain. It has become accepted as fact, from modern textbook accounts of these experiments, that smooth pneumococci make capsule, while rough strains do not. We found that rough-to-smooth morphology conversion did not occur in rough strains R36A and R6 when the ability to synthesize native type 2 capsule was restored. The continued rough morphology of these encapsulated strains was attributed to a second, since-forgotten, morphology-affecting mutation that was sustained by R36A during strain development. We

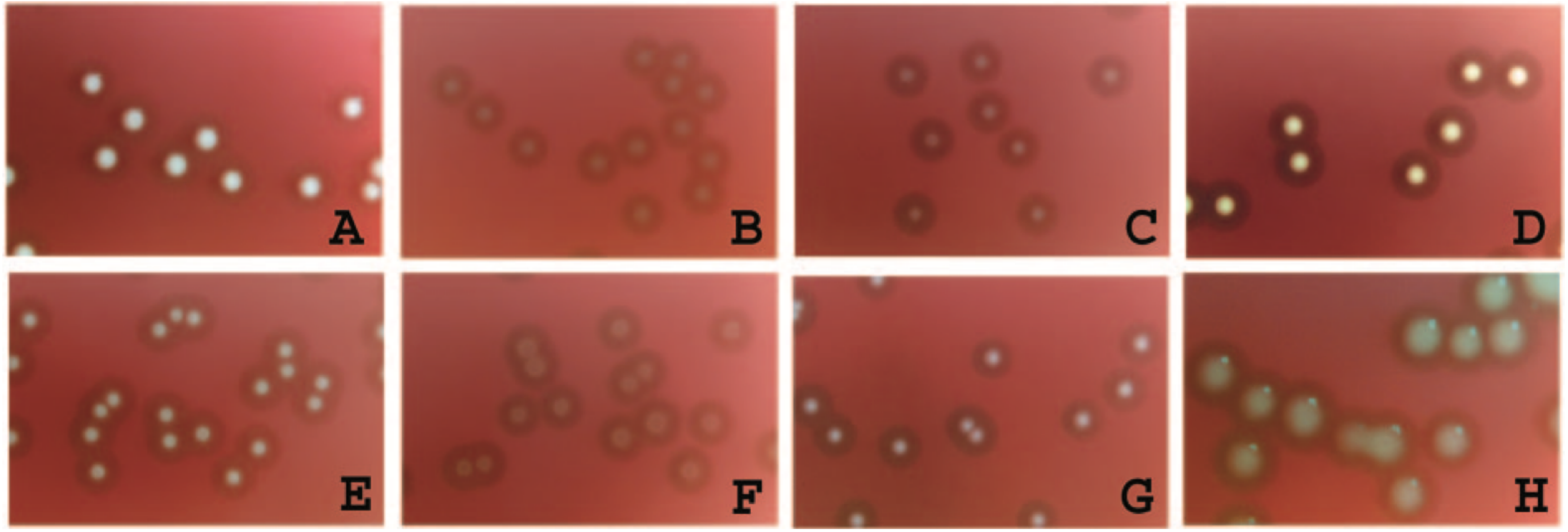


FIG. 3. Colony morphology of various *S. pneumoniae* strains grown on blood agar. (A) D39; (B) R6; (C) AB2; (D) AB7; (E) AB28; (F) R36A; (G) AB14; (H) AB15.

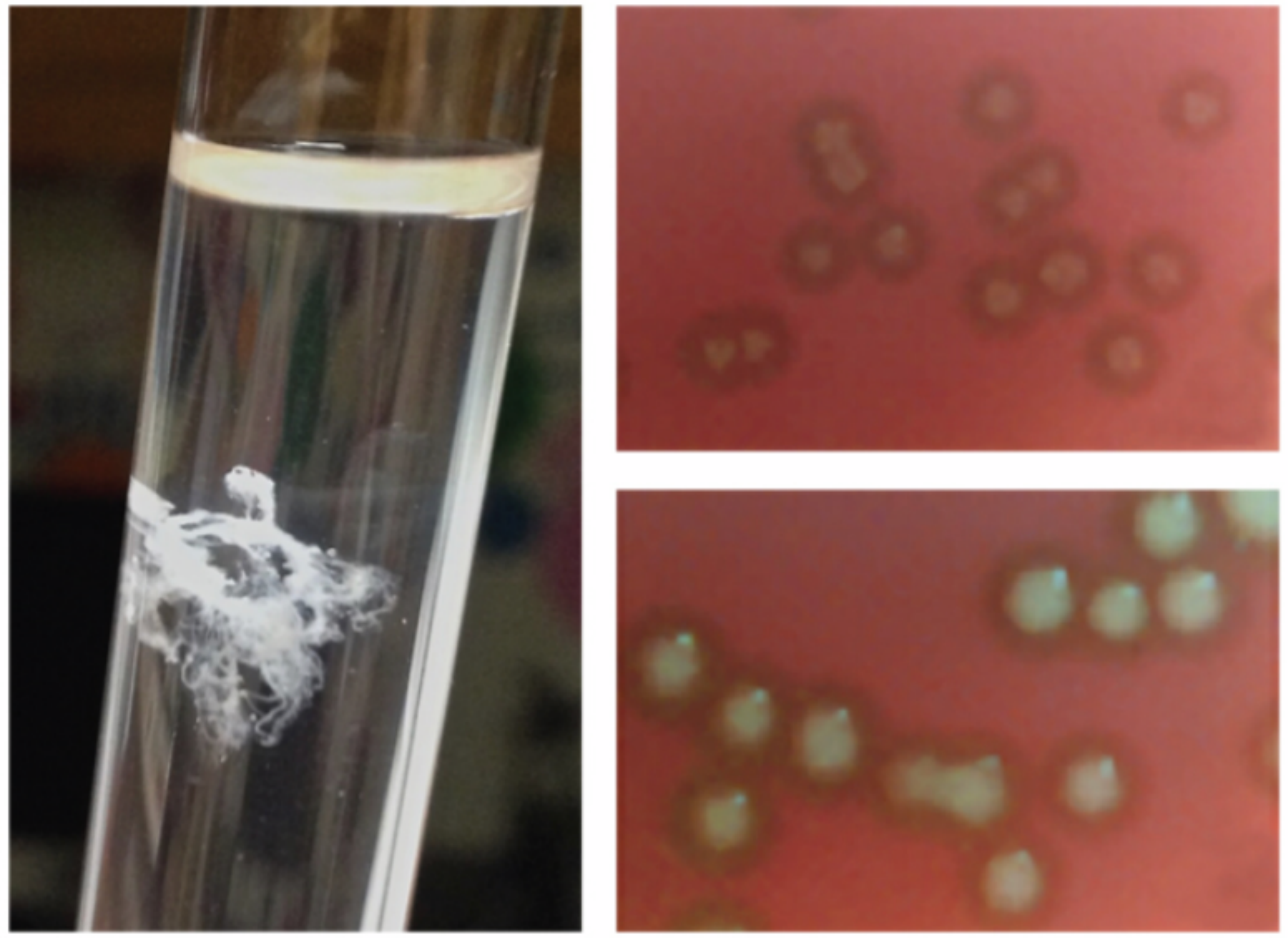
Integrating Questions

6. Where is the S-factor in Avery's protocol? Hypothesize what the white stringy material is in Figure 1.4A. (You may have performed a similar procedure during a lab at some point in your education.)
7. If the heritable material was isolated from mostly cytoplasm in the absence of cell wall/membrane, what is the likely source of heritable material? Apply Avery's protocol to hypothesize what Griffith was washing off from his cell wall/membrane material.

medical degree.

Avery addressed the open question Griffith left hanging: Is protein really the heritable material? Avery and his collaborators developed a **robust protocol** to convert R cells to S cells that worked better than Griffith's protocol:

1. Grind up S cells in buffer to extract all soluble material (10 mL).
2. Add 50 mL ethanol to the extract. Mix and store in a refrigerator for 8 hours. A white fluffy web of stringy material will appear that looks like a tangle of silk thread (Figure 1.4A).
3. The next morning, **centrifuge** the mixture (60 mL) to **pellet** the white stringy material. Pour off the ethanol, and allow the white pellet to dry.
4. Dissolve the pelleted material in 10 mL buffer.
5. Add the sterile solution from step 4 to R cells and incubate at 37° C for a day.
6. The next day, spread the cells from step 5 onto agar plates, and look for the transformation from R to S colonies (see Figure 1.4B). These S cells could have been injected into mice to demonstrate lethality, but out of concern for the animals, investigators in the 1940s had stopped using live mice for the pneumonia test.



A B

Figure 1.4 The heritable material produces S cells from R cells. **A,** Modern photograph of transforming factor precipitate. Note the wiry white strands in the tube. **B,** Photographs showing the original R cells (top) that were transformed into S cells (bottom). A. Original photo. Photo by Abagael Slattery, Davidson, NC B. From Belanger, Aimee E. *et al.* 2004. Figures 3A and 3B. Belanger, Aimee E. *et al.* 2004. Pyruvate oxidase is a determinant of Avery's rough morphology. Journal of Bacteriology. 186: 8164 – 8174.

Trifecta (purpose, methods, findings)

Table 1.1 Comparison of four independent preparations of transforming factor *vs* purified DNA.

sample #	% nitrogen, N	% phosphorus, P	N/P ratio
37	14.21	8.57	1.66
38B	15.93	9.09	1.75
42	15.36	9.04	1.69
44	13.40	8.45	1.58
pure DNA	**15.32**	**9.05**	**1.69**

*from Avery, *et al.*, 1944. Table I.

Avery, 1944

Table 1.1

Avery's Transforming Factor

Table 1.1 Comparison of four independent preparations of transforming factor *vs* purified DNA.

sample #	% nitrogen, N	% phosphorus, P	N/P ratio
37	14.21	8.57	1.66
38B	15.93	9.09	1.75
42	15.36	9.04	1.69
44	13.40	8.45	1.58
pure DNA	**15.32**	**9.05**	**1.69**

*from Avery, *et al*., 1944. Table I.

Avery, 1944

Table 1.1

Avery's Transforming Factor

Table 1.1 Comparison of four independent preparations of transforming factor *vs* purified DNA.

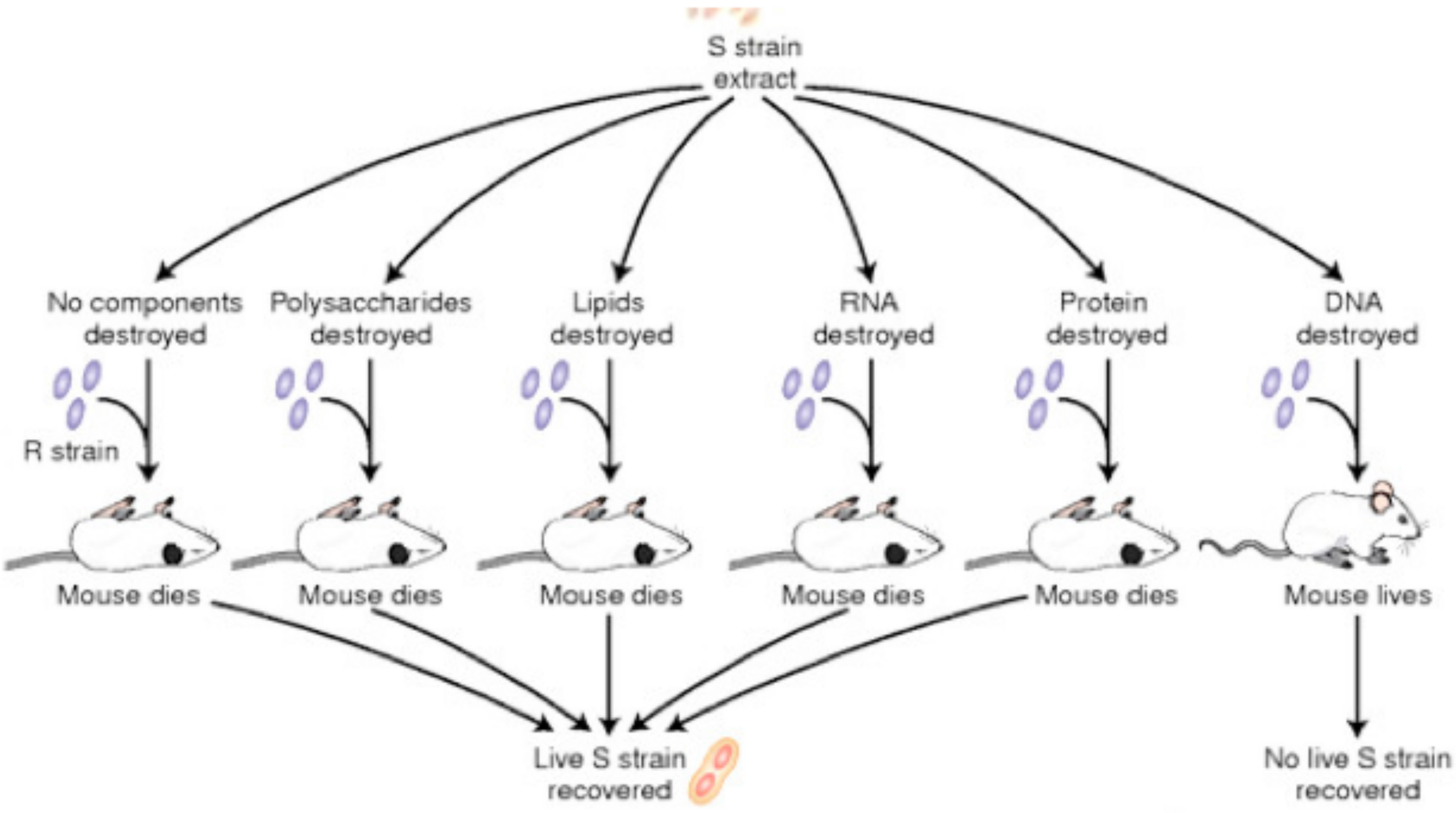
sample #	% nitrogen, N	% phosphorus, P	N/P ratio
37	14.21	8.57	1.66
38B	15.93	9.09	1.75
42	15.36	9.04	1.69
44	13.40	8.45	1.58
pure DNA	**15.32**	**9.05**	**1.69**

*from Avery, *et al.*, 1944. Table I.

nitrogen/phosphorous ratios of transforming factor ≈ DNA

Table 1.1

Avery's experiments (1944)



Q. How do these findings by Avery help you determine which chemical is the heritable material?