The Function of DNA

You are one of a kind and like no other—unless you are an identical twin, of course! How is it that you are so unique? You have a set of traits, or distinguishing characteristics, such as hair color, eye color, face shape, and body type, that are passed from one generation to the next. Early scientists made these same observations. But a question remained: How are traits passed from one generation to the next?

FIGURE 2: Unique traits are observable among humans.

Analyze As you can see in Figure 2, humans have many observable traits that set us apart from each other. What are some traits you have?

Codes for Proteins

DNA, or deoxyribonucleic acid, is the molecule that stores the genetic information for all organisms. DNA is heritable, which means it can be passed from parent to offspring. This explains why offspring may look like their parents and why individual organisms within a species share many of the same characteristics. Scientists understood that traits were heritable long before they identified DNA and its key role in inheritance.

DNA does not act alone to pass on genetic information. The information from DNA is used to build another nucleic acid called RNA, or ribonucleic acid, and RNA in turn builds proteins. This concept is known as the central dogma of molecular biology. Recall that proteins play a crucial role in body functions. Enzymes help regulate chemical reactions. Other proteins provide structural support for cells. Proteins in the cell membrane transport nutrients across the membrane in response to changing conditions inside or outside the cell. Each protein has a unique structure and function in the cell, so proper coding is critical for building each protein.

Predict Kinesin is a motor protein that transports organelles and proteins around a cell. The structure of kinesin is crucial for its function. What might happen to the structure of kinesin if the DNA code was damaged?

Mechanism for Heredity

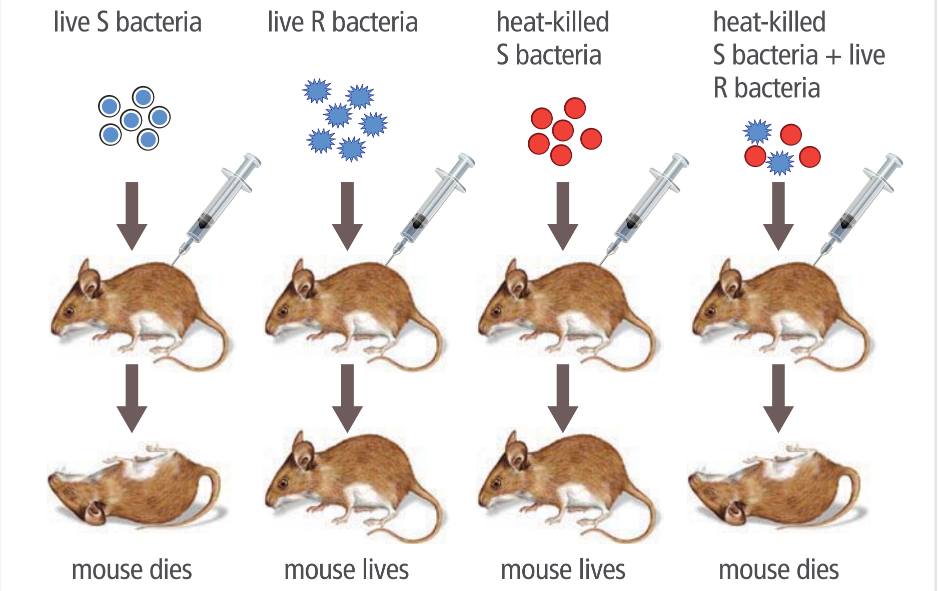
Genetics is the study of biological inheritance patterns and variation in organisms. Gregor Mendel, an Austrian monk, was an early contributor to our understanding of genetics. Mendel's revolutionary experimentation with breeding pea plants identified factors that controlled traits. He correctly predicted that traits can be inherited as discrete units passed from parents to offspring. However, it would take the work of several different scientists over many years to discover DNA and explain how it codes for the inheritance of individual traits. Results from experiments led by these scientists supported the conclusion that DNA is the molecule of inheritance.

Griffith's Experiments

In 1928, the British microbiologist Frederick Griffith was investigating two types of pneumonia-causing bacteria. One type, called *S*, has a smooth outer coating made from carbohydrates. The other type, called *R*, has a rough outer surface. As shown in Figure 3, when Griffith injected mice with both types of bacteria, only the S–type killed the mice. When Griffith injected mice with heat–killed S bacteria, they were unaffected. However, when he injected the mice with a combination of heat–killed S bacteria and live R bacteria, the mice died. Even more surprising, he found live S bacteria in a blood sample taken from the dead mice. Unable to identify the factor that transformed harmless R bacteria into disease-causing S bacteria, Griffith called the mystery material the *transforming principle*. This mystery would be a question for other scientists to explore.

Collaborate With a partner, discuss what further questions you would ask based on Griffith's experimental results.

FIGURE 3: Griffith's Experimental Design



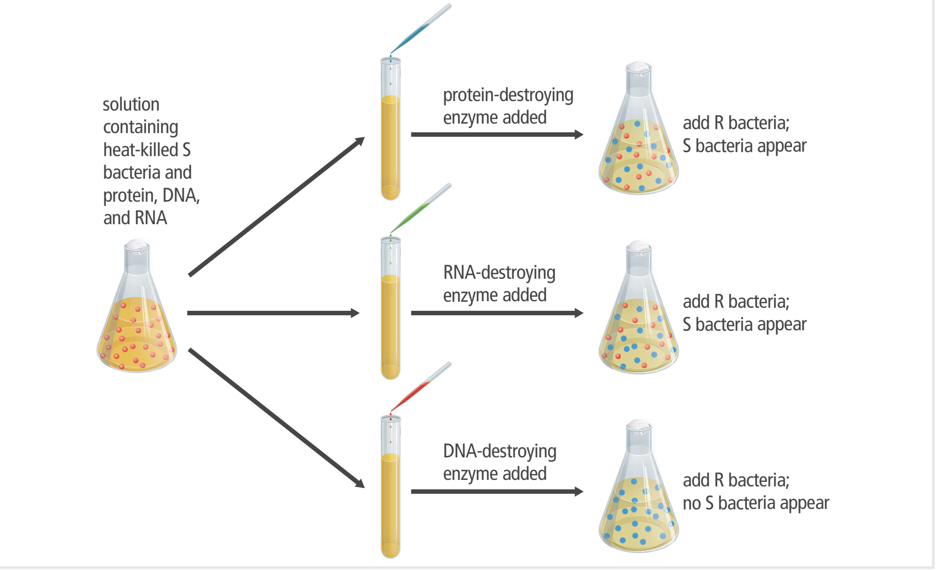
Analyze What evidence suggested that there is a transforming principle?

Avery's Experiments

Oswald Avery and his fellow scientists were intrigued by Griffith's transforming principle. Avery's team worked for more than 10 years to answer the question of what transformed the R strain. The scientists started with heat–killed S bacteria cells. They used a detergent to break down the bacteria, which resulted in an extract that contained only protein, DNA, and RNA molecules. Initial experiments showed that this extract contained the transforming principle.

Avery's team then used enzymes to break down each of the molecules separately. Once degraded, each sample was mixed with R-strain bacteria to test for transformation to S-strain. The results of this work are shown in Figure 4.

FIGURE 4: Avery's Experimental Design



Explain Why did Avery's group destroy each type of molecule before adding it to the solution containing R bacteria? What can you conclude from the results?

Avery and his group performed a chemical analysis of the molecule determined to be the "transforming principle." The table in Figure 5 shows the percentage of nitrogen and phosphorus and the ratio of nitrogen to phosphorus for four samples.

Data Analysis

FIGURE 5: Chemical analysis of the transforming principle

	% Nitrogen (N)	% Phosphorus (P)	Ratio of N to P
Sample A	14.21	8.57	1.66
Sample B	15.93	9.09	1.75
Sample C	15.36	9.04	1.69
Sample D	13.40	8.45	1.58
Known value for DNA	15.32	9.05	1.69

Analyze How does the data in the table support the claim that DNA is the transforming principle?

Avery's group also performed standard chemical tests that showed DNA was present in the extract and protein was not. They also used enzymes to destroy different molecules such as lipids and carbohydrates. Each time a molecule was destroyed, the transformation from R to S bacteria still occurred—until they destroyed DNA. When DNA was destroyed, the transformation did not occur.

In 1944, Avery and his group presented the evidence to support their conclusion that DNA must be the transforming principle, or genetic material. However, the scientific community remained skeptical as to whether the genetic material in bacteria was the same as that in other organisms. Despite Avery's evidence, some scientists insisted that his extract must have contained protein. Further testing remained to be done.

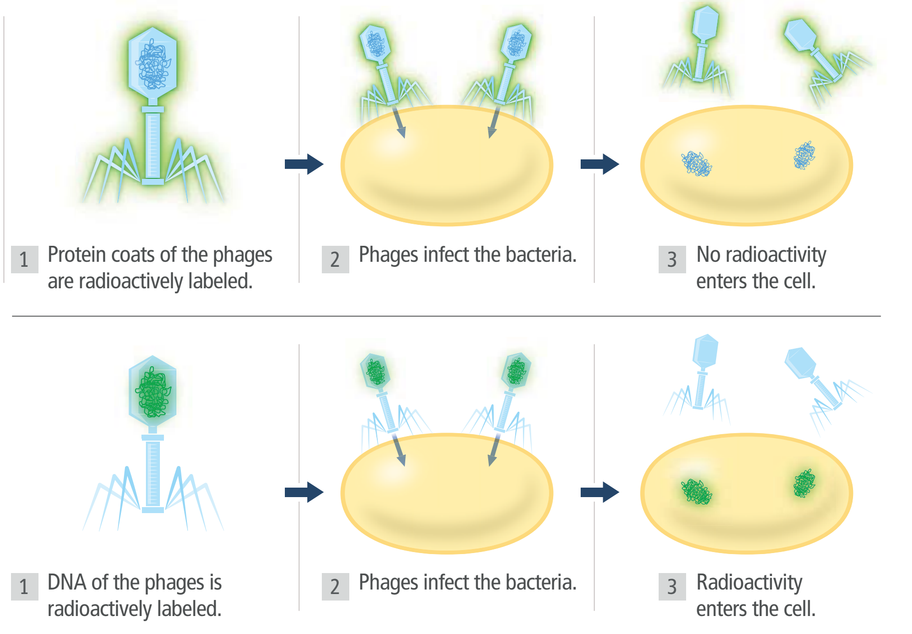
Hershey and Chase Experiments

In 1952, two American biologists, Alfred Hershey and Martha Chase, were researching different viruses that infect bacteria. These viruses, called bacteriophages, are made up of a DNA core surrounded by a protein coat. To reproduce, the bacteriophages attach themselves to bacteria and then inject material inside the cell. Hershey and Chase thought up a clever procedure that used the chemical elements found in protein and DNA. Protein contains sulfur but very little phosphorus, while DNA contains phosphorus but no sulfur. The researchers grew phages in cultures that contained radioactive isotopes of sulfur or phosphorus. Hershey and Chase then used these radioactively tagged phages in two experiments.

In the first experiment, bacteria were infected with phages that had radioactive sulfur atoms in their protein molecules. Hershey and Chase then used a kitchen blender and a centrifuge to separate the bacteria from the parts of the phages that remained outside the bacteria. When they examined the bacteria, they found no significant radioactivity.

In the second experiment, Hershey and Chase repeated the procedure with phages that had DNA tagged with radioactive phosphorus. This time, radioactivity was clearly present inside the bacteria.

FIGURE 6: Hershey and Chase's Experimental Design



Analyze Why did the Hershey and Chase experiments support the idea that DNA is the transforming principle?

Explain

1. Draw a table to summarize each experiment. Include information on how the experiments relate to one another, key data, and questions that remained after each experiment.
2. Develop an argument for why the data from each experiment either supported or did not support the conclusion that DNA is the molecule of inheritance.
3. Scientists often build on, and improve, the work of other scientists. This process may cover a long period of time. Explain how advances in technology affect this process of building scientific knowledge.