INVESTIGATION 6

WHAT IS THE RELATIONSHIP BETWEEN DNA AND CANCER?

INTRODUCTION

DNA is the chemical found in the nucleus of cells that makes up chromosomes. It is important to all cells, and to all organisms, because:

1. it is responsible for passing genetic information to new cells during the process of cell division,
2. it is responsible for passing genetic information from one generation to the next during reproduction, and
3. it provides the instructions for building proteins, which in turn carry out the major functions of a cell.

In short, an organism (be it an amoeba or a human being) could do nothing without DNA. It could not carry out its normal functions, could not replace worn-out cells, and could not reproduce. Because of the importance of DNA to the field of biology, scientists worked for decades (and continue to work) to learn how DNA does what it does. However, they could not come up with answers to basic questions about DNA functioning without first knowing its structure (see inset box). Thanks to the work of James Watson, Francis Crick, Linus Pauling, and many other scientists, we now know that DNA is a double helix (spiral) molecule, consisting of two complementary strands of sugar-phosphate groups with bases attached. The sequence of bases (A, G, C, and T) provide all the genetic information needed to carry out the cell's activities.

A mutation is a permanent change in the DNA. A mutation can arise spontaneously without apparent cause, or in response to radiation, ultraviolet light, certain chemicals, or viruses. Some mutations involve the substitution of one base pair for another, for example inserting a G-C where there should be a T-A pair. In other cases, one or more base pairs can be added to, or removed from, the chain. Sometimes huge segments are altered, rearranged, or misaligned. Mutations can lead to cell death, to alterations in the way a cell functions, or in some cases to cancer.

The word "cancer" evokes fear in a great many people. This may be because treatment is difficult, there may be no cure, and the disease seems to strike without warning. Cancer is a malfunction in the process of cell division, and older individuals tend to be afflicted. One-half million Americans die each year from cancer of one sort or another. A third of all cancers have been attributed to the use of tobacco.

The large, highly charged alpha particles emitted from radon and two of its decay products have the ability to cause serious DNA damage. The alpha particle may strike the DNA molecule and cause actual structural damage. The charged alpha particle may also produce chemical damage to the water molecules surrounding cells and their DNA. This chemical damage, however, is beyond the scope of this lesson.

DNA structure, function, and replication can easily be affected by the radiation emitted from inhaled radon and its decay products. These deleterious effects are usually confined to the respiratory tract. Exposure, then, to elevated levels of radon and its decay products over time will increase a person's risk of developing lung cancer during his or her lifetime.

OBJECTIVE

To investigate the interrelationships between DNA, mutation, and cancer, and to evaluate these interrelationships within the context of radiation and radon.

PROCEDURE

Examine the illustrations, complete the analysis, and answer the questions below.

UNRAVELLING THE CODE

In the early part of the 1950s two young scientists working in England, James Watson and Francis Crick, pieced together a very important biological puzzle. They unravelled the complicated structure of the DNA molecule. Their work marked a turning point in the study of genetics and molecular biology. Watson and Crick's discovery was of tremendous importance to the field of biology, and it was also important to these two young men! As Crick wrote in 1974, "Rather than believe that Watson and Crick made the DNA structure, I would rather stress that the structure made Watson and Crick. After all, I was almost totally unknown at the time and Watson was regarded, in most circles, as too bright to be really sound."

When Watson and Crick began their work on DNA in Cambridge, England, several parts of the puzzle had already been assembled. For example, it was known that DNA contained nucleotides attached to a sugar phosphate group. X-ray studies had revealed a helix (coil) shape. Some of Linus Pauling's work had shown that proteins are sometimes coiled in this way and held in shape by hydrogen bonding between the coils. There were also data suggesting that the nucleotides containing thymine (T) were about as numerous as those containing adenine (A). Furthermore, the number of nucleotides containing guanine (G) approximately equaled those containing cytosine (C). Using all of this information, Watson and Crick set about to construct a model that fit everything that was known about DNA and that could explain how DNA could carry such vast amounts of genetic information and also exactly copy itself, as needed.

According to Watson and Crick's model, DNA is a double stranded helix, shaped like a twisted ladder. The sides of the ladder are long strands of repeating sugar-phosphate groups. The rungs of the ladder consist of paired bases, of which there are four kinds: A, G, C, and T. A can only pair with T, and C can only pair with G. The complementary pairs are connected across the rungs by hydrogen bonds. The sequence of bases along each strand provides the genetic code, much like a four-letter alphabet.

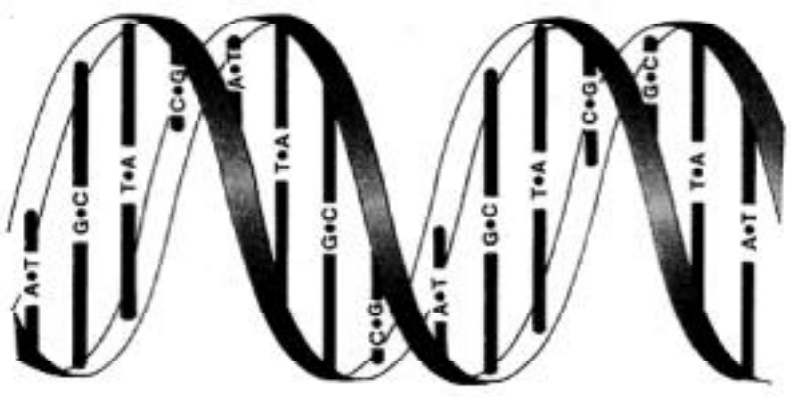

Figure 1. Model illustrating the structure of DNA. The sequence of bases provides the genetic code.

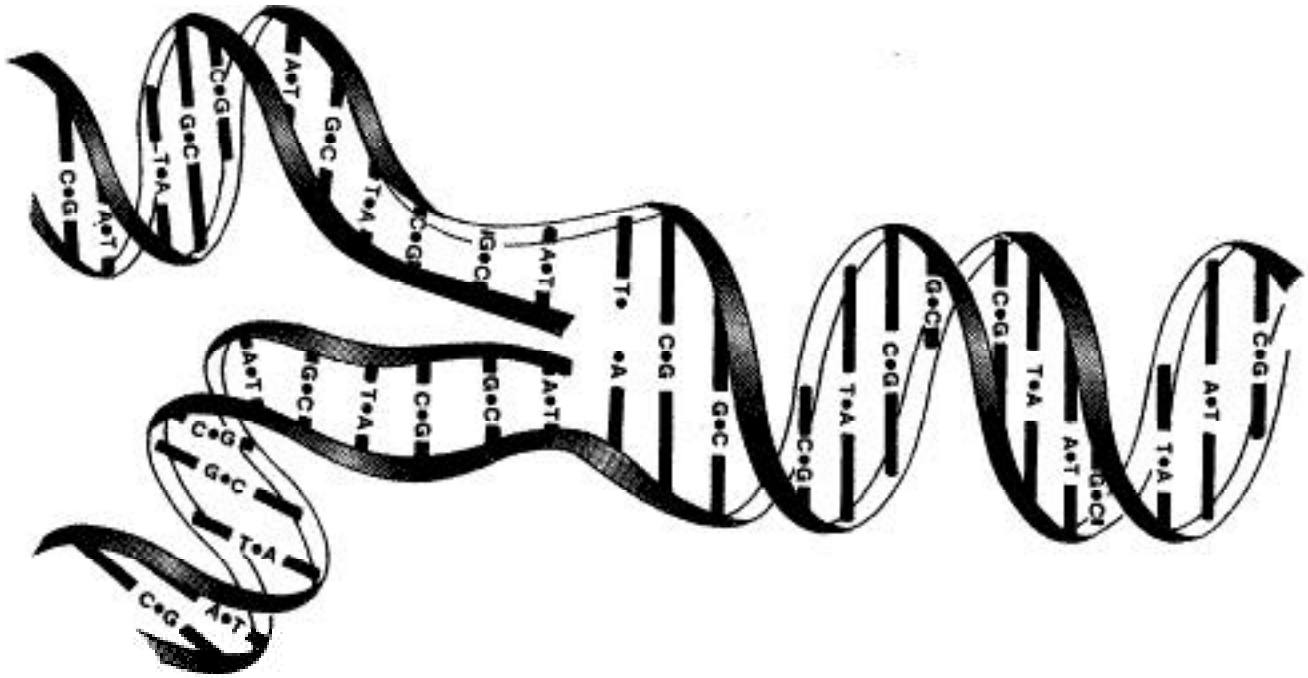

Figure 2. Schematic illustration of a double strand of DNA copying itself in preparation for cell division. The two new strands of DNA will be identical (assuming mutations do not occur) and one will go into each of the two new cells that are formed.

ANALYSIS

1. Figure 2 shows a diagram of DNA reproducing itself in preparation for cell division. Describe in detail what is occurring in this illustration.

2. As the two DNA strands unwind in the early stages of the duplication process, the opposite sides are not the same. They are *complementary*. Explain what this means, and why it is an important aspect of the DNA structure.

3. Why was Watson and Crick's work so important?

4. How is the process of mutation related to DNA and genetic coding?

CONCLUSIONS

5. Scientists have concluded that the link between exposure to alpha radiation and development of lung cancer involves the DNA in the cells of the respiratory system. Why do you think scientists have drawn this conclusion? What reasoning has gone into this conclusion?

6. Different cells reproduce at different rates. Cells of the nervous system are never replaced. Red blood cells last a few months before being replaced by new red blood cells. Cells in the intestines live only a few days. How is the rate of cell division related to mutation and development of cancer?

7. Cancer is out-of-control cell division. It involves a change in the DNA structure that causes an alteration of the normal DNA regulating mechanisms. The malignant (cancerous) cells no longer respond to normal regulatory signals. Cancer most often strikes older individuals. List three reasons why you think this is the case. Explain your rationale in each case.