

## CHAPTER 2

### Guiding Question 2-1

**How do scientists study the natural world? Why do we say science is a “process” and that conclusions are always open to further study?**

#### Multiple Choice

1. The first step of the scientific process is a(n) \_\_\_\_\_.

- A. prediction
- B. hypothesis
- C. experiment
- D. peer review
- E. observation

Answer: E

Section: 2.1

Level: Easy

Bloom's Level: Remembering

2. A(n) \_\_\_\_\_ is a possible explanation for what is observed that is based on some previous knowledge.

- A. peer review
- B. prediction
- C. hypothesis
- D. theory
- E. anecdote

Answer: C

Section: 2.1

Level: Easy

Bloom's Level: Remembering

3. Which of the following lists the steps of the scientific process in the correct order?

- A. observe, create a testable prediction, form a hypothesis, experiment, support or refute the hypothesis
- B. observe, form a hypothesis, create a testable prediction, experiment, support or refute the hypothesis
- C. form a hypothesis, create a testable prediction, observe, experiment, support or refute the hypothesis
- D. create a testable prediction, form a hypothesis, observe, experiment, support or refute the hypothesis
- E. None of the above are correct.

Answer: B

Section: 2.1

Level: Easy

Bloom's Level: Remembering

4. Which of the following questions can be solved with empirical evidence?

- A. Do ghosts exist?
- B. What is the meaning of life?
- C. What is my cat thinking?
- D. What causes the changing of the seasons?
- E. Is the death penalty wrong?

Answer: D

Section: 2.1

Level: Easy

Bloom's Level: Understanding

5. Which is TRUE regarding the following statements?

(1) "Higher levels of greenhouse gases cause increased warming of the troposphere."

(2) "People who are good go to heaven when they die."

- A. Both statements are obviously wrong.
- B. Both statements have been proven true by long-standing scientific theories.
- C. Only statement (1) is a scientific hypothesis testable by scientific methods.
- D. Only statement (2) can generate falsifiable predictions.
- E. Neither statement is suitable for science.

Answer: C

Section: 2.1

Level: Easy/Medium

Bloom's Level: Applying

6. Which of the following statements is NOT falsifiable?

- A. Car exhaust contributes to ozone depletion.
- B. Iced wings of a plane contribute to some plane crashes.
- C. Dogs become tired when they are hungry.
- D. People should not litter because it is wrong to do so.
- E. All of the above are falsifiable statements.

Answer: D

Section: 2.1

Level: Medium

Bloom's Level: Applying/Analyzing

7. Which of the following hypotheses is NOT testable?

- A. CFCs are causing depletion of the ozone layer.
- B. Bacterial water pollution increases risk of infectious disease.
- C. Increased salt intake leads to high blood pressure.
- D. Reincarnation exists.
- E. Increased UV exposure increases the risk of skin cancer.

Answer: D

Section: 2.1

Level: Easy

Bloom's Level: Understanding

8. Peer review is \_\_\_\_\_.

- A. the process a scientist undergoes to analyze the results of the experiment
- B. a measure of how well the report is received by the general public
- C. a method for measuring the amount of ozone in the atmosphere
- D. a panel of editors who proofread the report after it is accepted for publication
- E. a process by which a group of scientists in the field evaluate the report and determine if it is of high enough quality to publish in a journal

Answer: E

Section: 2.1

Level: Easy

Bloom's Level: Remembering

9. Which of the following ensures that only quality scientific studies that have been well controlled and avoid bias appear in scientific journals?

- A. peer review
- B. funding agencies
- C. an independent variable
- D. anecdotal evidence
- E. the scientist responsible for the experiment

Answer: A

Section: 2.1

Level: Easy

Bloom's Level: Understanding

10. How does a peer-reviewed article compare to an Internet blog?

- A. Both are equally analyzed and evaluated by scientists in the field prior to publication.
- B. Any person can easily create and publish a peer-reviewed article.
- C. A peer-reviewed article is likely to contain opinions that are not supported by data.
- D. A blog must be written by a researcher and not a reporter.
- E. The study design and results are evaluated in a peer-reviewed article.

Answer: E

Section: 2.1

Level: Easy

Bloom's Level: Understanding

11. A(n) \_\_\_\_\_ is a hypothesis that has been widely accepted and extensively and rigorously tested.

- A. theory
- B. fact
- C. explanation
- D. definition
- E. proof

Answer: A

Section: 2.1

Level: Easy

Bloom's Level: Remembering

12. Which of the following is FALSE regarding a scientific theory?
- A. It can be modified over time as new information is discovered.
  - B. It is the result of a hypothesis being repeatedly supported by many lines of inquiry.
  - C. It has strong predictive powers that can explain observed phenomena.
  - D. It is an idea based only on observations.
  - E. It is a very well-supported hypothesis.

Answer: D

Section: 2.1

Level: Easy

Bloom's Level: Remembering

13. Cell theory states that all living organisms are made up of one or more cells. Which of the following statements is FALSE regarding this theory?

- A. All living organisms discovered so far have been made of one or more cells.
- B. A newly discovered organism is very likely to be made out of one or more cells.
- C. Cells are the basic units of structure for all known living organisms.
- D. No living organism will ever be discovered that is not made out of cells.
- E. All of the above are true.

Answer: D

Section: 2.1

Level: Easy/Medium

Bloom's Level: Understanding/Applying

14. Why can scientific opinions change over time?

- A. All conclusions in science are considered tentative and open to revision.
- B. Our understanding of a concept or process can change as scientists learn more.
- C. New evidence may be used to overturn a prevailing conclusion.
- D. All of these statements are true.
- E. None of these statements are true.

Answer: D

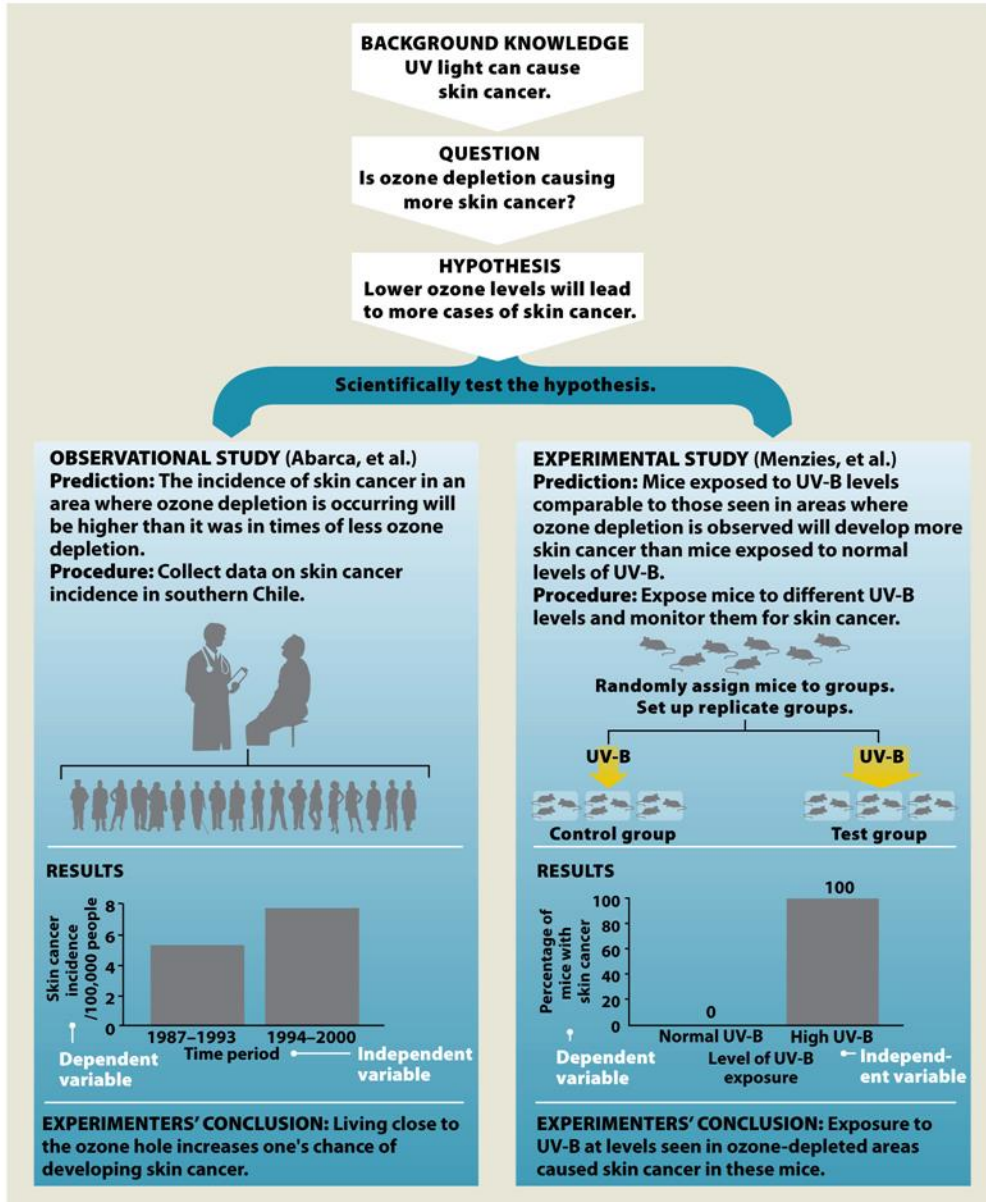
Section: 2.1

Level: Easy

Bloom's Level: Understanding

### Short Answer

15. Refer to Infographic 2.6. Taken together, do these two studies prove that lower ozone levels directly cause skin cancer in humans? Why or why not?



**Infographic 2.6**

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ANSWER: These studies provide support for the hypothesis that lower ozone levels will lead to more cases of skin cancer. When many different studies support a hypothesis from a diverse array of experimental approaches, a hypothesis has strong predictive power and can be promoted to the status of a scientific theory. However, the hypothesis can never be completely proven because new evidence could be obtained in the future that could cause the hypothesis to be refuted.

Section: 2.1

Level: Medium

Bloom's Level: Applying/Analyzing

16. How would you respond to someone who says, “The hole in the ozone layer being caused by CFCs is just a theory”?

ANSWER: The word “theory” in casual usage means “an idea.” In contrast, a “scientific theory” is a very well-supported hypothesis with strong predictive powers. It is very likely not going to be refuted by additional studies.

Section: 2.1

Level: Easy

Bloom’s Level: Applying

17. In this chapter it has been made clear that the process used to obtain a body of knowledge (facts and explanations) is more important than the body of knowledge itself.

Why is this?

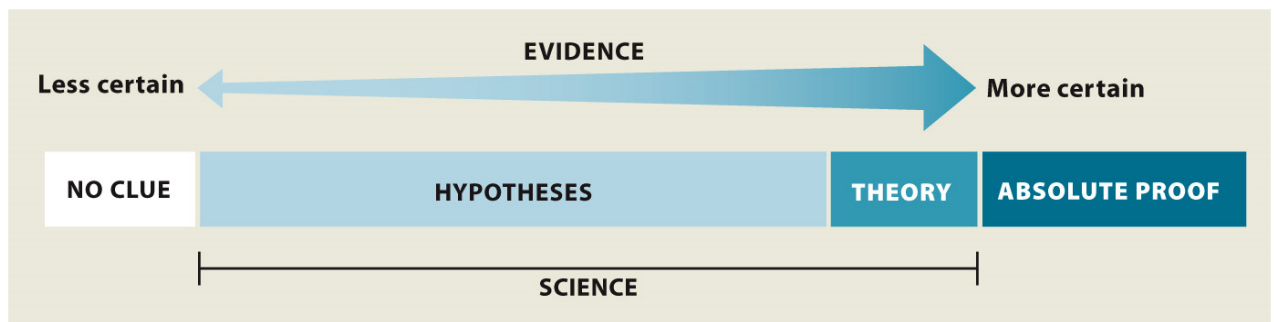
ANSWER: Facts may change as additional information is collected through the scientific process. Consequently, it is important that the entire process be open-ended and that the investigators be open-minded to change.

Section: 2.1

Level: Medium/Hard

Bloom’s Level: Analyzing

18. Refer to Infographic 2.4. Explain why in science *absolute* proof is not required.



Infographic 2.4  
Environmental Science for a Changing World, Second Edition  
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ANSWER: Since all scientific information is open to further investigation, it is not expected or required to have absolute proof in science.

Section: 2.1

Level: Easy

Bloom’s Level: Understanding

19. Describe the difference between a hypothesis and a scientific theory?

ANSWER: A hypothesis is a possible explanation for what we have observed that is based on some previous knowledge. A scientific theory is a widely accepted explanation of a natural phenomenon that has been extensively and rigorously tested scientifically.

Section: 2.1

Level: Easy/Medium

Bloom’s Level: Understanding/Applying

20. What criteria must be met for a hypothesis to be valid?

ANSWER: A valid hypothesis must be testable. It must be possible to create predictions from the hypothesis that we can objectively observe if we ran a test. Predictions based on a hypothesis also must be falsifiable. It must be possible to refute them by evidence.

Section: 2.1

Level: Medium

Bloom's Level: Analyzing

21. Is the following a valid hypothesis? Cancer patients who are prayed for will have better outcomes compared with patients with similar prognoses (likely outcomes) who are not prayed for.

ANSWER: Yes. Predictions from the hypothesis are testable and falsifiable.

Section: 2.1

Level: Easy

Bloom's Level: Understanding

22. Is the following a valid hypothesis? Natural disasters around the world are a result of a supernatural deity punishing humanity for our actions.

ANSWER: No. Predictions from the hypothesis are not testable nor are they falsifiable.

Section: 2.1

Level: Easy/Medium

Bloom's Level: Understanding/Applying

23. Scientists use the scientific method to investigate the natural world. The scientific method is based on gathering empirical evidence. What is empirical evidence, and why are empirical data a hallmark of good science?

ANSWER: Empirical evidence is information gathered by means of observation of physical phenomena. The same data can be objectively observed by anyone in the same place (using the same equipment). Phenomena that are not objectively observable cannot be empirically studied and are therefore not under the purview of science.

Section: 2.1

Level: Easy/Medium

Bloom's Level: Understanding/Applying

24. Describe the importance of peer-review to the scientific process.

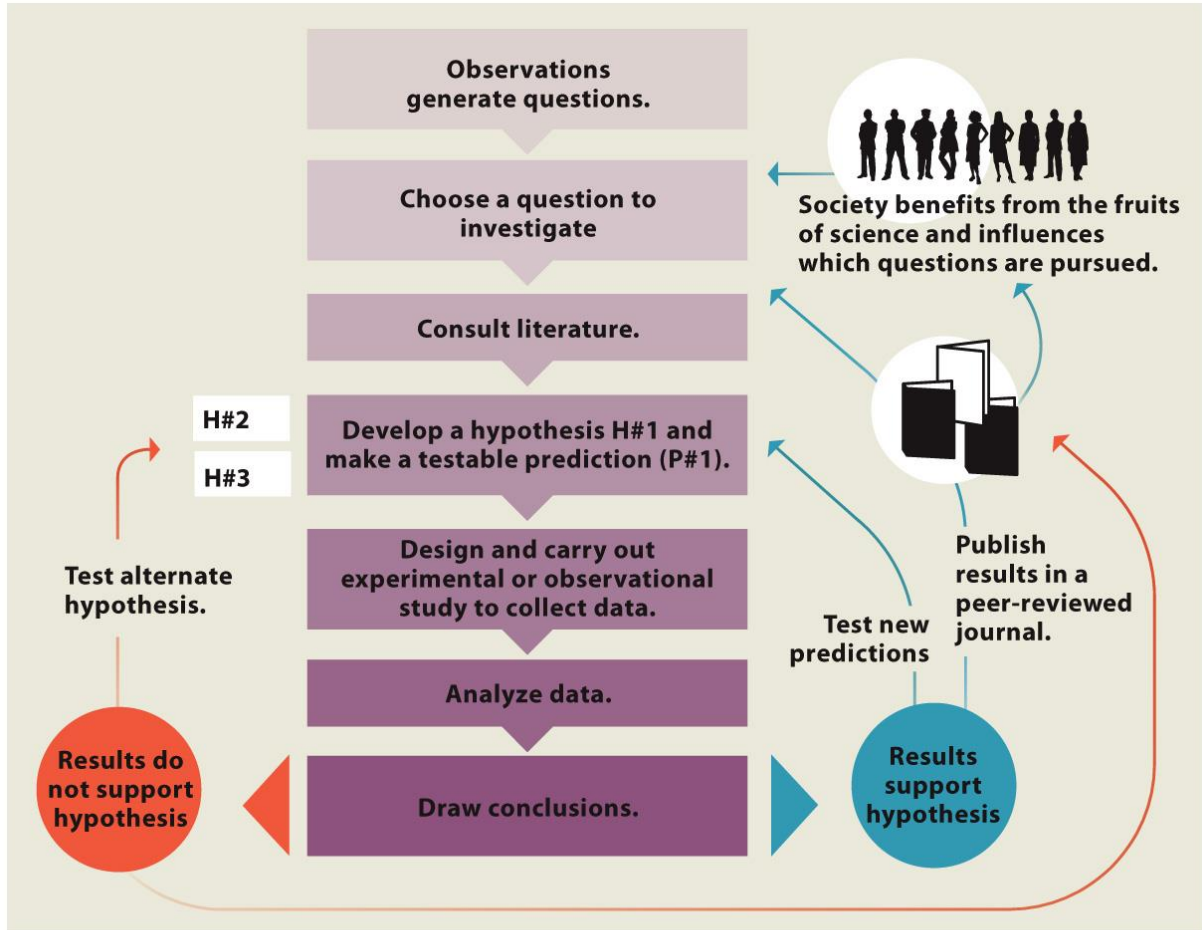
ANSWER: Prior to publication in a scientific journal, a study is first rigorously analyzed by peers in that scientific area who know well if the study is of acceptable quality. This ensures only quality scientific reports (without bias, well-controlled studies, etc.) appear in the scientific literature.

Section: 2.1

Level: Medium

Bloom's Level: Applying/Analyzing

25. Refer to Infographic 2.3. What are the possible outcomes after analyzing the data in the scientific method?



**Infographic 2.3**  
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ANSWER: The hypothesis is either rejected (develop and test alternate hypotheses), modified, or accepted (published in a peer-reviewed journal and used to test new predictions or hypotheses).

Section: 2.1

Level: Easy

Bloom's Level: Understanding



### Guiding Question 2-2

What is stratospheric ozone, and why are scientists worried about its depletion?

#### Multiple Choice

26. The ozone layer is located in the \_\_\_\_\_.

- A. stratosphere
- B. troposphere
- C. mesosphere
- D. thermosphere
- E. exosphere

Answer: A

Section: 2.2

Level: Easy

Bloom's Level: Remembering

27. What is the chemical formula for ozone?

- A. O<sub>2</sub>
- B. C<sub>2</sub>F<sub>2</sub>Cl<sub>2</sub>
- C. SF<sub>6</sub>
- D. O<sub>3</sub>
- E. CrO<sub>2</sub>Cl<sub>2</sub>

Answer: D

Section: 2.2

Level: Easy

Bloom's Level: Remembering

28. What's the difference between "good" and "bad" ozone?

- A. Good ozone forms gray smog, and bad ozone forms brown smog.
- B. Good ozone resides in the stratosphere and blocks UV-B radiation, whereas bad ozone occurs in the troposphere and is a pollutant.
- C. Good ozone resides in the troposphere and blocks UV-B radiation, whereas bad ozone occurs in the stratosphere and is a pollutant.
- D. Good ozone resides in the stratosphere and blocks most of the UV-A radiation, whereas bad ozone occurs in the troposphere and causes skin cancer.
- E. Good ozone is abbreviated O<sub>3</sub>; bad ozone is abbreviated O<sub>2</sub>.

Answer: B

Section: 2.2

Level: Easy

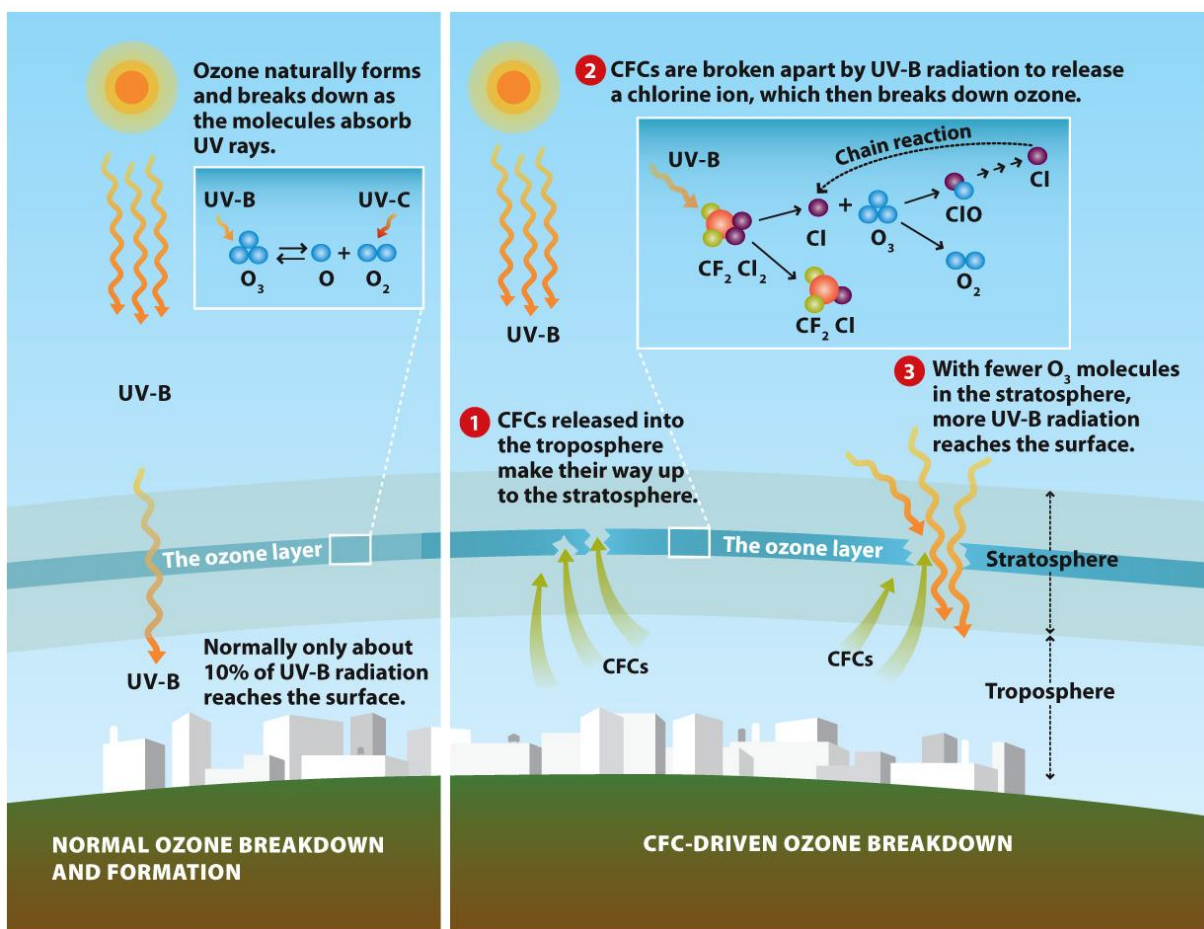
Bloom's Level: Understanding

29. Which form of ultraviolet (UV) radiation is important in the formation of ozone?

- A. UV-A
- B. UV-B
- C. UV-C
- D. all of the above
- E. none of the above

Answer: C  
Section: 2.2  
Level: Medium/Hard  
Bloom's Level: Analyzing

30. Refer to Infographic 2.5. What happens to the chlorine atom liberated from chlorine monoxide in the second portion of this figure?

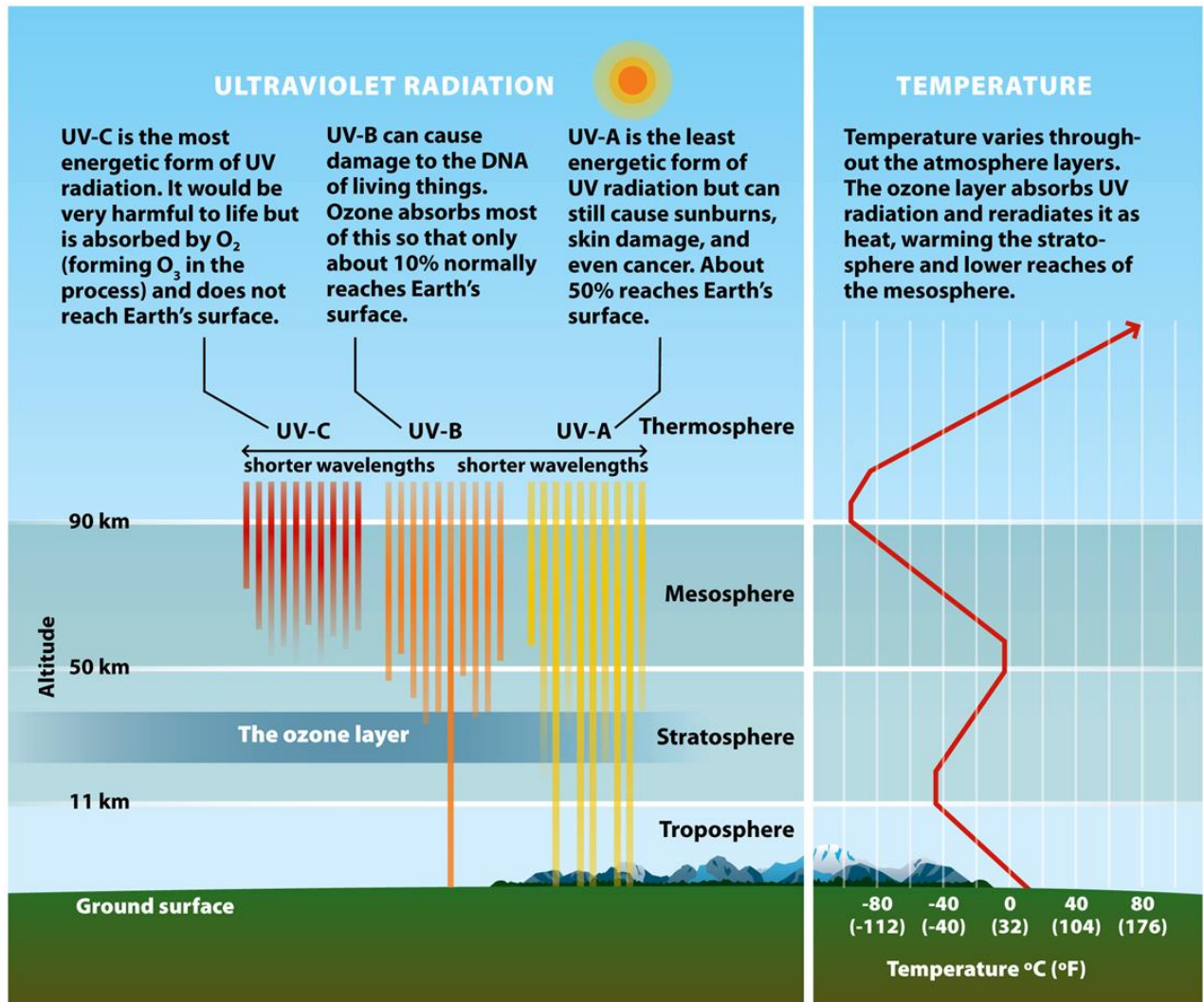


Infographic 2.5  
Environmental Science for a Changing World, Second Edition  
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- A. It escapes into the thermosphere above.
- B. It becomes inert.
- C. It sinks back down to the troposphere where it becomes a part of smog pollution.
- D. It breaks down many other ozone molecules.
- E. It bonds with one additional ozone molecule to make chlorine trioxide.

Answer: D  
Section: 2.2  
Level: Easy  
Bloom's Level: Understanding

31. Refer to Infographic 2.1. Why is it that the least energetic form of ultraviolet light, UV-A, causes sunburns and skin damage but the most energetic form, UV-C, is of no concern whatsoever?



**Infographic 2.1**  
*Environmental Science for a Changing World, Second Edition*  
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- A. Water vapor in the air filters all but UV-A.
- B. CFCs in the air filter all but UV-A.
- C. Radiation from the sun is mostly UV-A.
- D. UV-A radiation passes through the atmosphere easily, UV-B is absorbed by the stratospheric ozone layer, and UV-C is absorbed by oxygen,  $O_2$ .
- E.  $NO_x$  reacts with UV-B and UV-C.

Answer: D

Section: 2.2

Level: Easy/Medium

Bloom's Level: Understanding

32. Ozone-depleting chemicals are most efficient at the poles, both for Arctic and Antarctic regions. The major reason for this is:

- A. lots of CFCs are used in polar regions.
- B. tourists there pollute the atmosphere.
- C. very cold winters.
- D. all the ozone is formed over the equator and none reaches the poles.
- E. a lack of stringent air pollution laws at the poles.

Answer: C

Section: 2.2

Level: Hard

Bloom's Level: Analyzing

33. Where in the atmosphere is ozone found?

- A. the mesosphere and paleosphere
- B. just the troposphere
- C. just the stratosphere
- D. both the troposphere and stratosphere
- E. It is not found in the atmosphere at any level.

Answer: D

Section: 2.2

Level: Medium

Bloom's Level: Applying

34. Why should we care about ozone?

- A. It's a dangerous stratospheric pollutant.
- B. It protects the Earth's surface from UV-B radiation.
- C. It is used in the production of CFCs.
- D. It's a major pollutant in our rainwater.
- E. It protects the Earth from climate change.

Answer: B

Section: 2.2

Level: Easy

Bloom's Level: Understanding

### **Short Answer**

35. Which form of ultraviolet (UV) radiation is mostly absorbed by the ozone layer? What are the effects of this form of UV radiation on living things?

ANSWER: UV-B can cause damage to the DNA of living things. The ozone layer absorbs most of this so that only about 10% normally reaches Earth's surface.

Section: 2.2

Level: Medium

Bloom's Level: Analyzing

36. Why is the term "ozone hole" misleading?

ANSWER: Ozone is still present over Antarctica and the Arctic, but it is present in reduced quantities or concentration. A thinning of the ozone layer would be a more accurate description.

Section: 2.2

Level: Easy/Medium

Bloom's Level: Applying

37. Explain how the depletion of the ozone layer in the stratosphere is allowing more UV-B radiation to reach the Earth's surface.

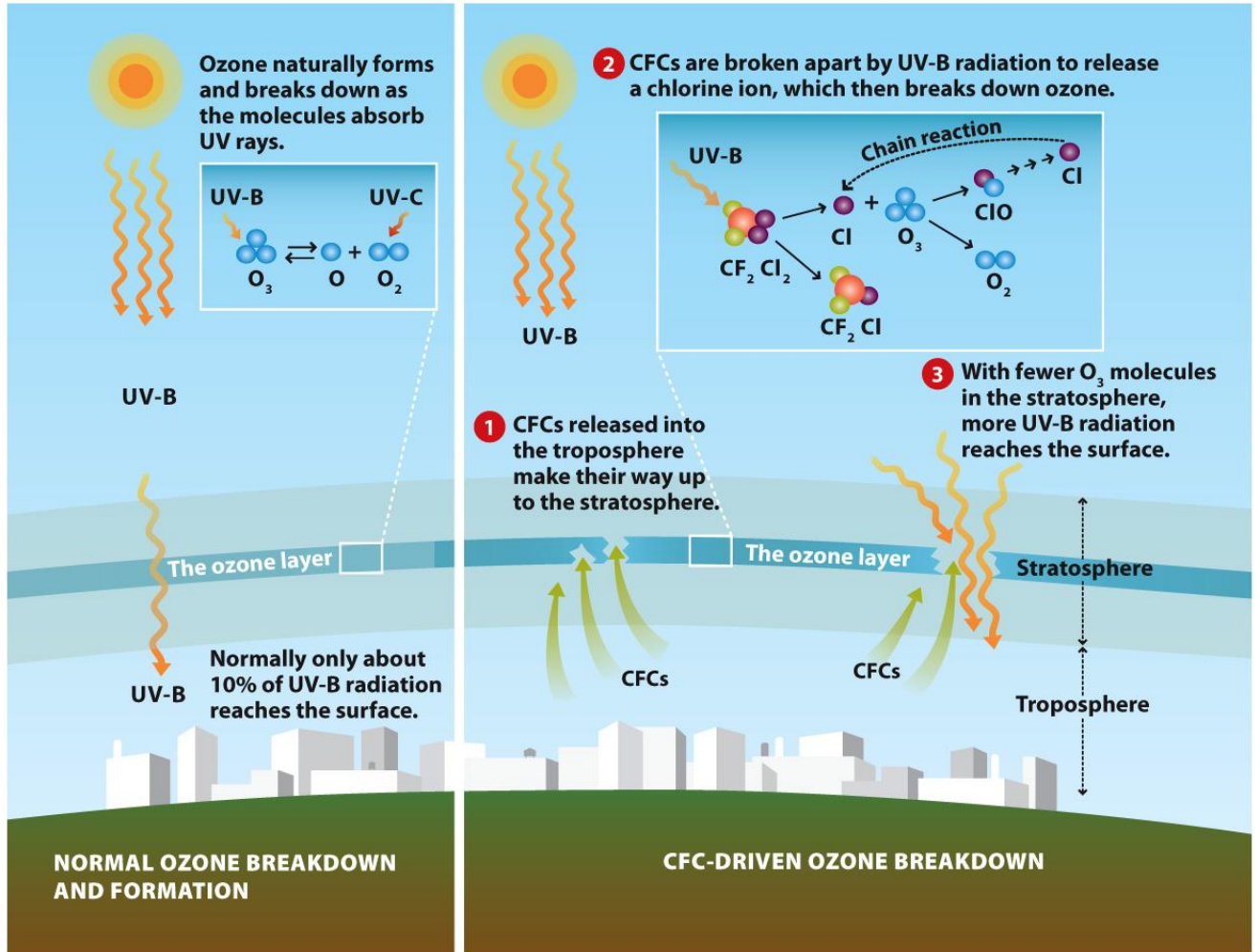
ANSWER: Ozone molecules in the stratosphere normally absorb UV-B rays. Depletion of ozone molecules in the stratosphere allows more UV-B rays to reach the surface of the Earth.

Section: 2.2

Level: Easy/Medium

Bloom's Level: Applying

38. Refer to Infographic 2.5. Explain chemically how CFCs in the stratosphere are damaging the ozone layer.



**Infographic 2.5**  
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ANSWER: CFCs in the stratosphere are broken apart by UV-B to release a chlorine atom, which then breaks down ozone molecules into  $O_2$  and  $ClO$ . This becomes a positive feedback mechanism (chain reaction) when the  $Cl$  is then reformed and able to catalyze additional breakdown reactions of even more ozone molecules (up to 100,000 ozone molecules).

Section: 2.2

Level: Medium

Bloom's Level: Applying

### Guiding Question 2-3

**What lines of evidence suggest that CFCs are causing the depletion of stratospheric ozone?**

#### Multiple Choice

39. Instruments are used to measure the level of ozone in the stratosphere. These measurements are \_\_\_\_\_.

- A. inferences
- B. observations
- C. conclusions
- D. explanations
- E. predictions

Answer: B

Section: 2.3

Level: Easy

Bloom's Level: Understanding

40. Scientists have concluded that increasing levels of \_\_\_\_\_ were causing the depletion of the ozone layer.

- A. methane
- B. smog
- C. particulates
- D. CFCs
- E. O<sub>3</sub>

Answer: D

Section: 2.3

Level: Easy

Bloom's Level: Remembering

41. Which of the following statements best describes the relationship between ozone in the stratosphere and the presence of CFCs?

- A. Ozone in the stratosphere is broken down by chemicals like CFCs, but as CFCs themselves are broken apart by UV radiation, ozone depletion slows.
- B. When CFCs come in contact with ozone in the troposphere, their reaction sometimes causes increased UV radiation to reach Earth's surface.
- C. Ozone naturally breaks down in the stratosphere, but substances like CFCs regulate its re-formation so that less harmful UV radiation reaches Earth's surface.
- D. Ozone from the stratosphere migrates down to the troposphere where it reacts with chemicals like CFCs to produce more oxygen.
- E. Ozone is formed naturally and is broken down in the stratosphere. However, CFCs cause additional ozone breakdown.

Answer: E

Section: 2.3

Level: Medium

Bloom's Level: Applying

42. Which of the following statements is TRUE of CFCs?
- A. A CFC is an industrial chemical that was once used as a refrigerant.
  - B. A CFC is a type of ultraviolet radiation between UV-A and UV-B.
  - C. CFCs are used to cook food at the McMurdo research station.
  - D. CFCs react with water to generate ozone.
  - E. Both B and C are true.

Answer: A

Section: 2.3

Level: Easy

Bloom's Level: Remembering

43. Which of the following provided support for Solomon's hypothesis that CFCs were contributing to ozone depletion?

- A. Ozone-poor air was shown to be lifting and mixing with the stratosphere.
- B. Increased  $\text{NO}_x$  levels were observed in the South Pole.
- C.  $\text{NO}_x$  levels were observed to be decreasing in the South Pole.
- D. High levels of ClO were observed in the stratosphere.
- E. Both C and D provide support.

Answer: E

Section: 2.3

Level: Medium/Hard

Bloom's Level: Analyzing/Evaluating

44. The multiple lines of evidence in support of the "CFC hypothesis" have elevated it to the status of \_\_\_\_\_.

- A. law
- B. theory
- C. proof
- D. fact
- E. rule

Answer: B

Section: 2.3

Level: Easy

Bloom's Level: Understanding

### Short Answer

45. Prior to Susan Solomon's experiments, the information available to NASA ozone-modeler Paul Newman led him to believe that the loss of ozone in the Antarctic spring was due to excess solar activity. What was the new information that Solomon discovered that led Newman to reject his hypothesis in favor of her polar cloud hypothesis? Is it possible that Solomon's hypothesis could be rejected in the future?

ANSWER: The level of ClO (chlorine monoxide) in the stratosphere measured by Solomon's team supported the hypothesis that UV-B breaks down CFCs, which in turn break down ozone molecules. All conclusions in science are tentative. The data supporting her hypothesis are strong, but new information could cause the hypothesis to be modified or even rejected.



Section: 2.3

Level: Hard

Bloom's Level: Analyzing/Evaluating

46. What kind of study, observational or experimental, was Susan Solomon's experiment that provided support for her hypothesis that CFCs were leading to depletion of ozone in the stratosphere?

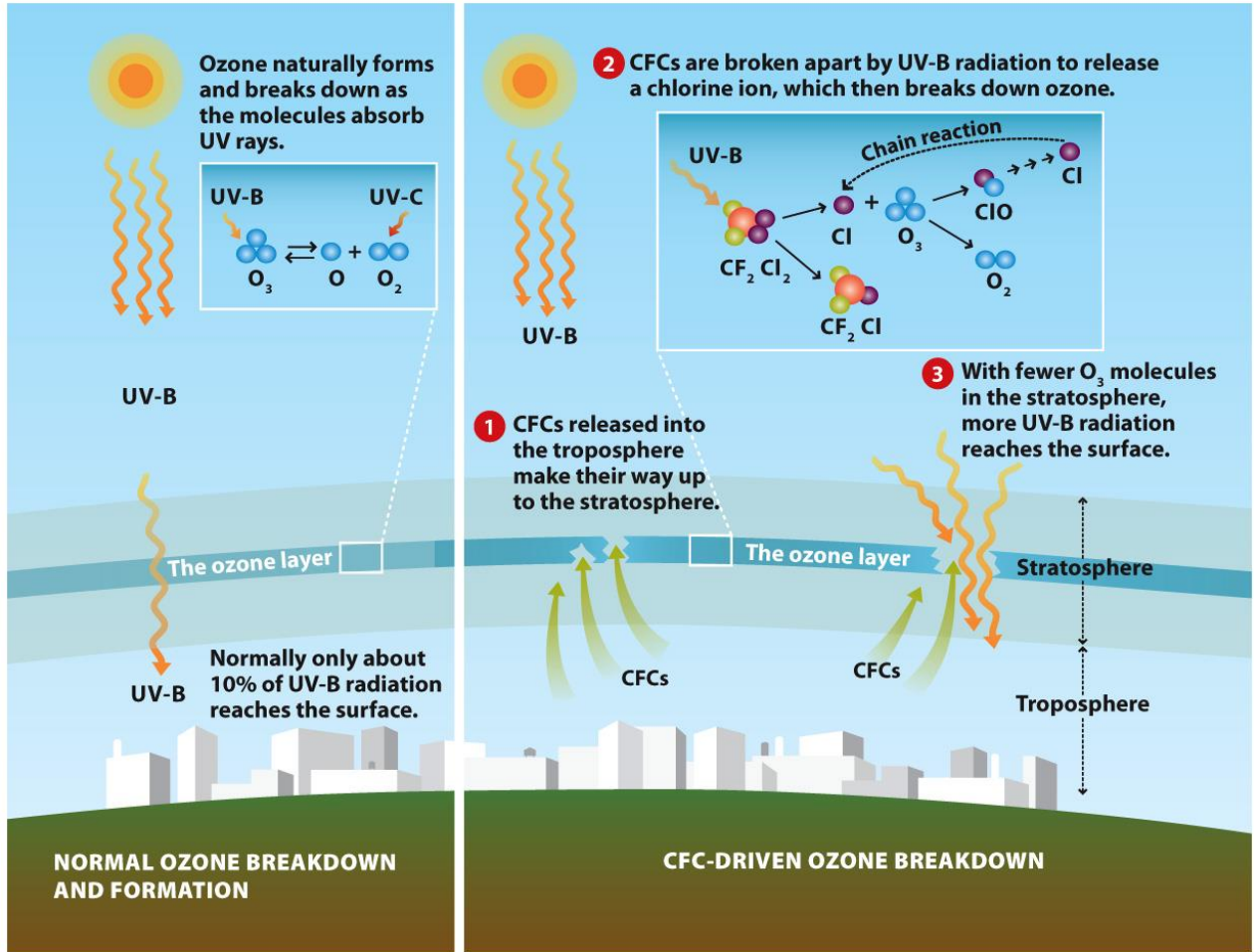
ANSWER: Solomon's experiment was an observational one. She hypothesized that ClO levels would be increased if ozone depletion came about because of CFCs. When atmospheric gases were collected, the levels of ClO were indeed elevated, in support of her hypothesis.

Section: 2.3

Level: Medium

Bloom's Level: Applying

47. Refer to Infographic 2.5. Does an increase or decrease in the concentration of chlorine monoxide (ClO) in the stratosphere support Solomon's hypothesis that free chlorine molecules (Cl<sub>2</sub>) from CFCs would break up into chlorine atoms that destroy ozone?



**Infographic 2.5**  
*Environmental Science for a Changing World, Second Edition*  
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ANSWER: An increase in ClO supports the hypothesis. It forms as an intermediate, in the destruction of ozone.

Section: 2.3

Level: Medium

Bloom's Level: Analyzing

### **Guiding Question 2-4**

**Why are both observational and experimental studies needed to investigate the natural world? How does statistics help researchers analyze the data they gather from these studies?**

#### **Multiple Choice**

48. Which type of study is appropriate for demonstrating the cause-and-effect relationship between an independent variable and a dependent variable?

- A. anecdotal
- B. observational
- C. experimental
- D. inferential
- E. natural

Answer: C

Section: 2.4

Level: Easy

Bloom's Level: Understanding

49. Which type of experiment collects data in the real world, without manipulating the subject of study?

- A. experimental
- B. anecdotal
- C. theoretical
- D. observational
- E. randomized

Answer: D

Section: 2.4

Level: Easy

Bloom's Level: Remembering

50. In an experimental study, what is TRUE about the independent variable?

- A. It shows a response.
- B. It is charted on the y-axis (vertical axis).
- C. It is what you manipulate.
- D. It is what you measure.
- E. It is the same for both the control and experimental groups.

Answer: C

Section: 2.4

Level: Easy

Bloom's Level: Understanding

51. In an experimental study, what is TRUE about the dependent variable?

- A. It is charted on the x-axis (horizontal axis).
- B. It only pertains to the experimental group.
- C. It is what you manipulate.
- D. It is a measured response.

E. It is what can be changed to see if it produces an effect.

Answer: D

Section: 2.4

Level: Easy

Bloom's Level: Understanding

52. When data are shown in a graph, the independent variable should be plotted on the \_\_\_\_\_.

A. vertical axis

B. x-axis

C. response

D. ordinate

E. y-axis

Answer: B

Section: 2.4

Level: Easy/Medium

Bloom's Level: Understanding/Applying

53. Scientists generally require a level of certainty of at least \_\_\_\_\_ to be sure their conclusions are correct.

A. 50%

B. 60%

C. 75%

D. 80%

E. 95%

Answer: E

Section: 2.4

Level: Easy

Bloom's Level: Remembering

54. Studying the effects of CFCs on ozone in the atmosphere is an example of which of the following?

A. manipulative study

B. experimental study

C. theoretical study

D. random study

E. observational study

Answer: E

Section: 2.4

Level: Easy/Medium

Bloom's Level: Applying

55. Susan Solomon used an observational study because:

A. the atmosphere is far too vast and complex to bring into the lab and manipulate in a controlled experimental study.

B. the use of human subjects is not legal in this country.

- C. she didn't use an observational study, she used an experimental study.
- D. her research was intended as a reconnaissance mission, and she later followed up with an experimental study.
- E. there is no such thing as an experimental study; she used the only type of study that can be used: an observational study.

Answer: A

Section: 2.4

Level: Medium

Bloom's Level: Applying

56. In the following example, what is the independent variable?

Hypothesis: Mice on a restricted low-caloric diet will live longer than mice that can eat as much as they want.

Experiment: A large population of genetically identical mice is divided into two groups. Half receive as much food as they care to eat each day. The other half receives 20% less food than a typical mouse eats each day. The day of death (lifespan) is recorded for all mice. All mice live in the same room, in the same type of cage, with access to water.

- A. amount of food available
- B. volume of water available
- C. genetically identical mice
- D. happiness of each mouse
- E. lifespan of each mouse

Answer: A

Section: 2.4

Level: Medium

Bloom's Level: Applying/Analyzing

57. A researcher wants to know how effective a new suntan lotion is at preventing skin cancer caused by UV radiation. She uses mice as test subjects to model the effects for humans. Which of the following is the best control for this experiment?

- A. Only mice in the control group are shaded during the experiment.
- B. Mice in the test group receive twice as much UV radiation as those in the control group.
- C. No suntan lotion is applied to mice in the control group; lotion is only applied to the test group.
- D. Mice in the test group are from a genetic line that increases their susceptibility to UV radiation.
- E. Mice in the control group are provided lotion in their drinking water to maximize effectiveness.

Answer: C

Section: 2.4

Level: Medium

Bloom's Level: Applying/Analyzing

58. When conducting an experimental study, scientists manipulate the \_\_\_\_\_ variable and measure the \_\_\_\_\_ variable to see if it is affected.

- A. dependent; independent
- B. independent; dependent
- C. observational; dependent
- D. experimental; independent
- E. observational; experimental

Answer: B

Section: 2.4

Level: Easy

Bloom's Level: Understanding

59. In an experiment examining the level of UV-B radiation on the incidence of skin cancer, the level of UV-B radiation would be the \_\_\_\_\_.

- A. independent variable
- B. dependent variable
- C. non-independent variable
- D. control variable
- E. extraneous variable

Answer: A

Section: 2.4

Level: Medium

Bloom's Level: Applying

60. The group in an experimental study that is manipulated such that it differs from the control group in only one way is the \_\_\_\_\_.

- A. confirmation group
- B. test group
- C. validation group
- D. placebo group
- E. independent group

Answer: B

Section: 2.4

Level: Easy

Bloom's Level: Remembering

### **Short Answer**

61. The observation of a decrease in stratospheric ozone didn't come from just a few readings. Explain the importance of replication within a study.

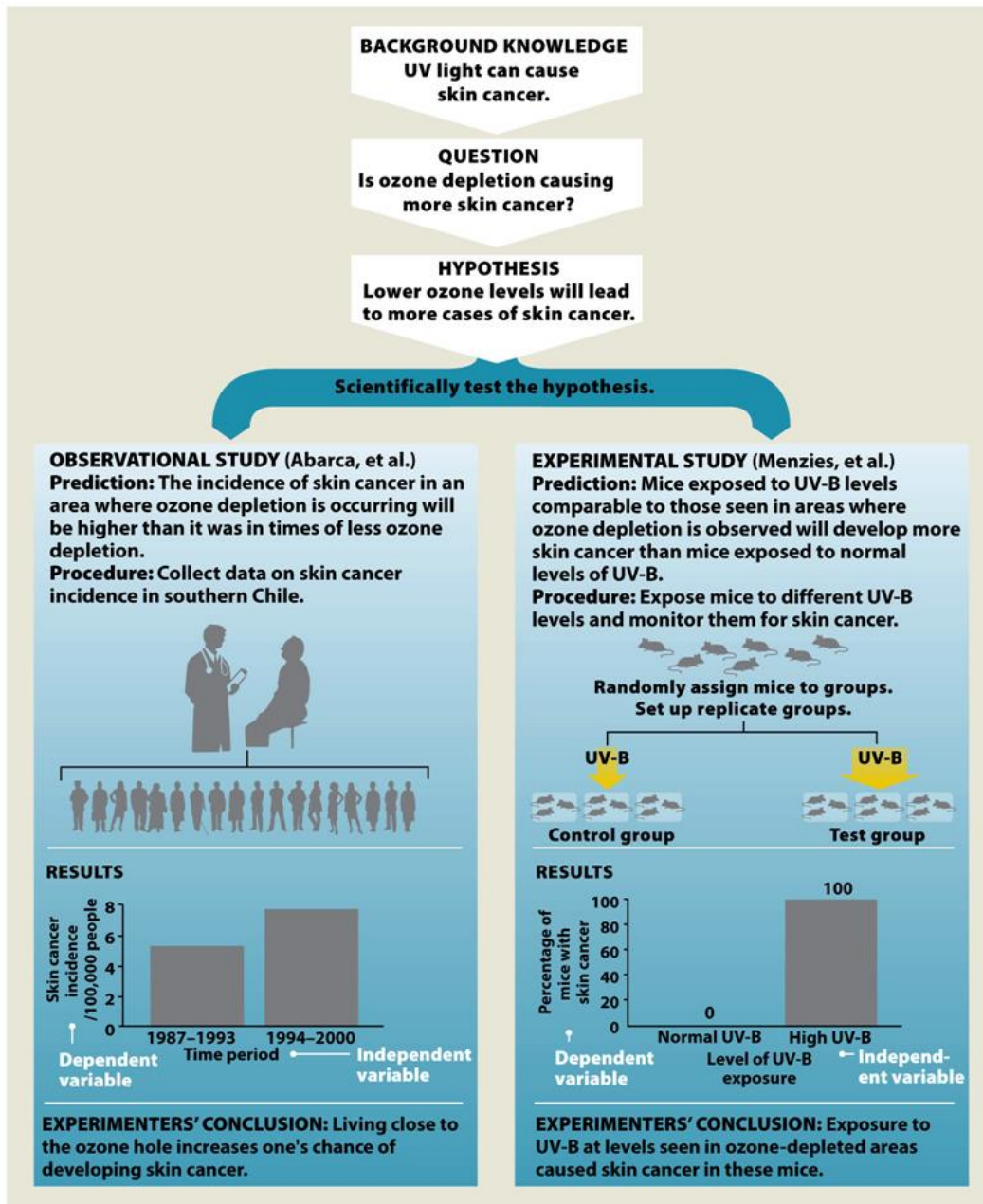
ANSWER: Many readings were taken at two different sites over more than a dozen seasons. This is a hallmark of good science because it decreases the chance that one reading was influenced by another factor (e.g., equipment error, unusual seasonal variation, etc.).

Section: 2.4

Level: Medium

Bloom's Level: Applying

62. Refer to Infographic 2.6. Which study depicted in the infographic provides stronger support for the stated hypothesis? Briefly explain why.



**Infographic 2.6**

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ANSWER: By manipulating the independent variable (UV-B levels), the experimental study (Menzies et al.) provides stronger support because it allows testing of a cause-and-effect relationship.

Section: 2.4

Level: Easy/Medium

Bloom's Level: Understanding/Applying

63. What is a correlation, and how does it differ from a cause-and-effect relationship? Give an example of each and note what type of study can provide that information.

ANSWER: In an *observational study*, data can provide a correlation between, for example, the presence of CFCs and ozone depletion. Both occur together and it suggests a cause-and-effect relationship. An *experimental study*, where variables can be directly manipulated and controlled, can be used to test a cause-and-effect relationship, for example, showing that elevated UV exposure increases the incidence of skin cancer in lab rats.

Section: 2.4

Level: Medium

Bloom's Level: Applying/Analyzing

64. In terms of manipulating variables, what is the difference between an observational study and an experimental study? Which type of study can test cause-and-effect relationships?

ANSWER: In an observational study, data are gathered in a real-world setting, without intentionally manipulating any variable. This can lead to correlative conclusions. In an experimental study, the independent variable is manipulated by the researcher to evaluate a cause-and-effect relationship.

Section: 2.4

Level: Easy

Bloom's Level: Understanding

65. The health and lifestyle of 10,000 nurses are tracked for a period of 30 years. It is discovered that of the nurses who smoked cigarettes for at least 10 years, 35% had lung cancer. Is this an observational or an experimental study? Does this study demonstrate that cigarettes cause lung cancer?

ANSWER: This is an observational study which shows a correlation between smoking and lung cancer. It is not an experimental study, where variables can be directly manipulated. It would be unethical to directly test this cause-and-effect relationship using human subjects.

Section: 2.4

Level: Hard

Bloom's Level: Analyzing/Evaluating

66. When it rains, you often notice people outside holding open umbrellas. You hypothesize that opening an umbrella causes rain to fall. What type of experiment can be used to test this? Explain what is meant by the phrase "correlation is not causation."

ANSWER: Although the appearance of rain and open umbrellas is correlated, it is not clear yet if one variable is causing the other to happen. We need an experimental study to test if rain is causing people to open umbrellas or if opening an umbrella causes rain to fall. "Correlation is not causation" means that just because two things happen at the same time does not mean that one is caused by the other.

Section: 2.4



Level: Medium

Bloom's Level: Applying

67. Suppose you were part of the team of Finnish researchers studying the effects of increased UV-B radiation. Design a simple observational experiment that could lead to data that support or refute your hypothesis.

ANSWER: There are lots of possibilities. One such possibility considers the observation that ozone has an impact on crop yield. Grow tomatoes, for example, in an area where UV-B radiation is currently high but where tomatoes have been grown for years in the past (when UV-B radiation levels were traditionally much lower). Try to control for as many growth factors as possible (i.e., same fertilizer as used in the past, same seed type, etc.). Compare crop yields now with yields from previous years. Look for trends.

Section: 2.4

Level: Hard

Bloom's Level: Creating

68. Explain the function of a control group in an experimental study.

ANSWER: A control group validates the experiment. The control group should be identical to the test group except for the independent variable. This allows conclusions to be drawn about the outcome by comparing the experimental group with the control group. Any differences are due to the independent variable.

Section: 2.4

Level: Easy

Bloom's Level: Understanding

69. Tests of significance help to determine if an event was due to chance or something else. The probability value is expressed as a  $p$ -value. What does it mean to have a  $p$ -value equal to 0.05?

ANSWER: The null hypothesis is that the result observed is due to chance. A  $p$ -value is the probability of obtaining a result at least as extreme as the one observed (assuming the null hypothesis is true). A  $p$ -value less than 0.05 means rejection of the null (by chance) hypothesis. This means the result is statistically significant. The smaller the  $p$ -value, the more strongly the test rejects the null hypothesis.

Section: 2.4

Level: Hard

Bloom's Level: Analyzing

70. Explain how scientists use probability to apply a level of certainty to their conclusions?

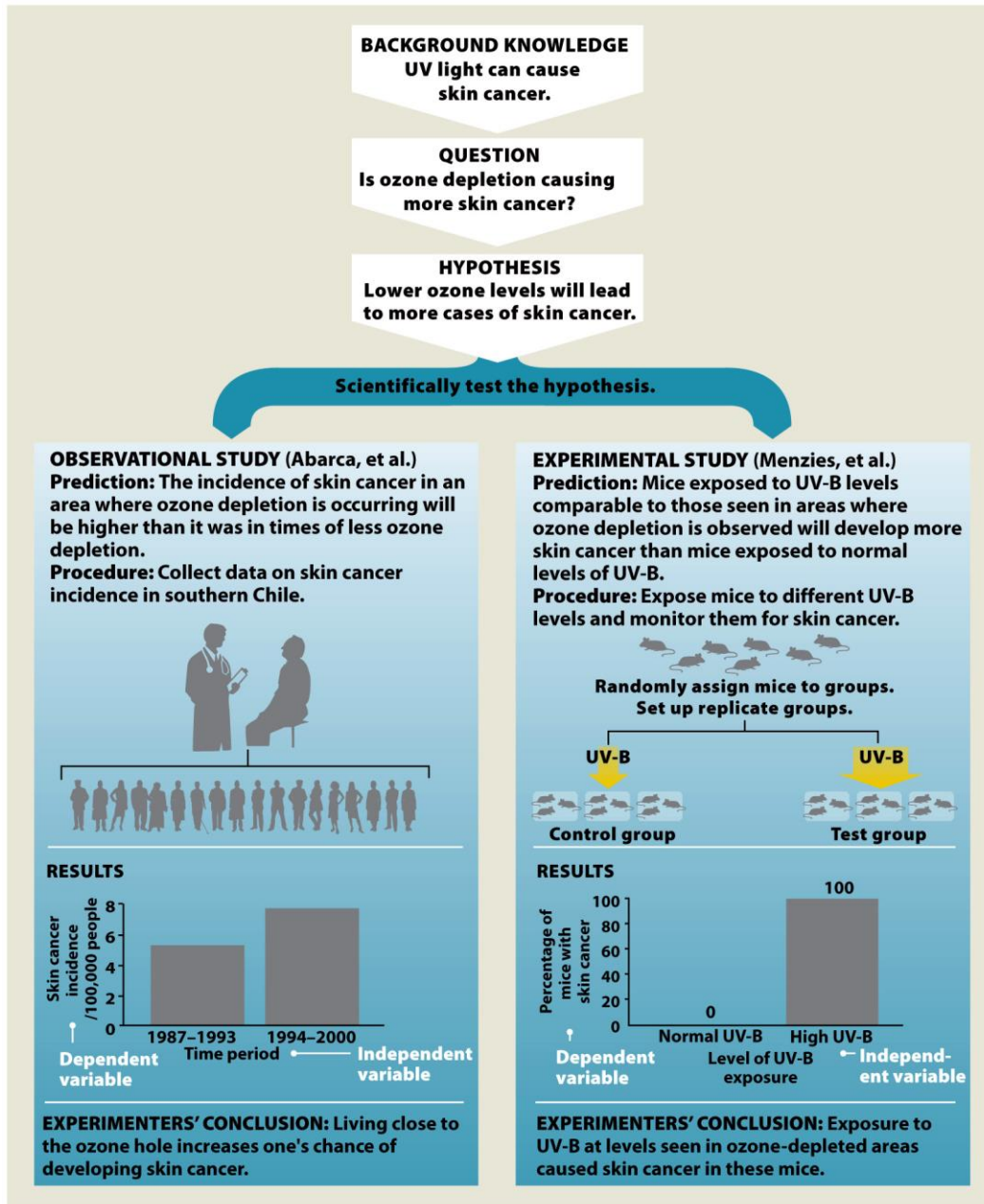
ANSWER: Scientists generally require a high level of certainty that their conclusions are correct. Normally scientists try to achieve 95% certainty that they are correct in their conclusions.

Section: 2.4

Level: Medium

Bloom's Level: Applying

71. Design an experimental study to test the hypothesis that lower ozone levels will lead to more cases of skin cancer in humans. Why is it unlikely that this experiment will be carried out? Why did Menzies et al. select rats as test subjects? Refer to Infographic 2.6.



**Infographic 2.6**

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ANSWER: Start with a large population of humans and divide them into two groups. Over the course of the experiment, the control group is exposed to normal levels of UV-B radiation, while the test group receives UV-B levels similar to that seen in areas where ozone depletion is observed. After a certain period of time, all human test subjects are

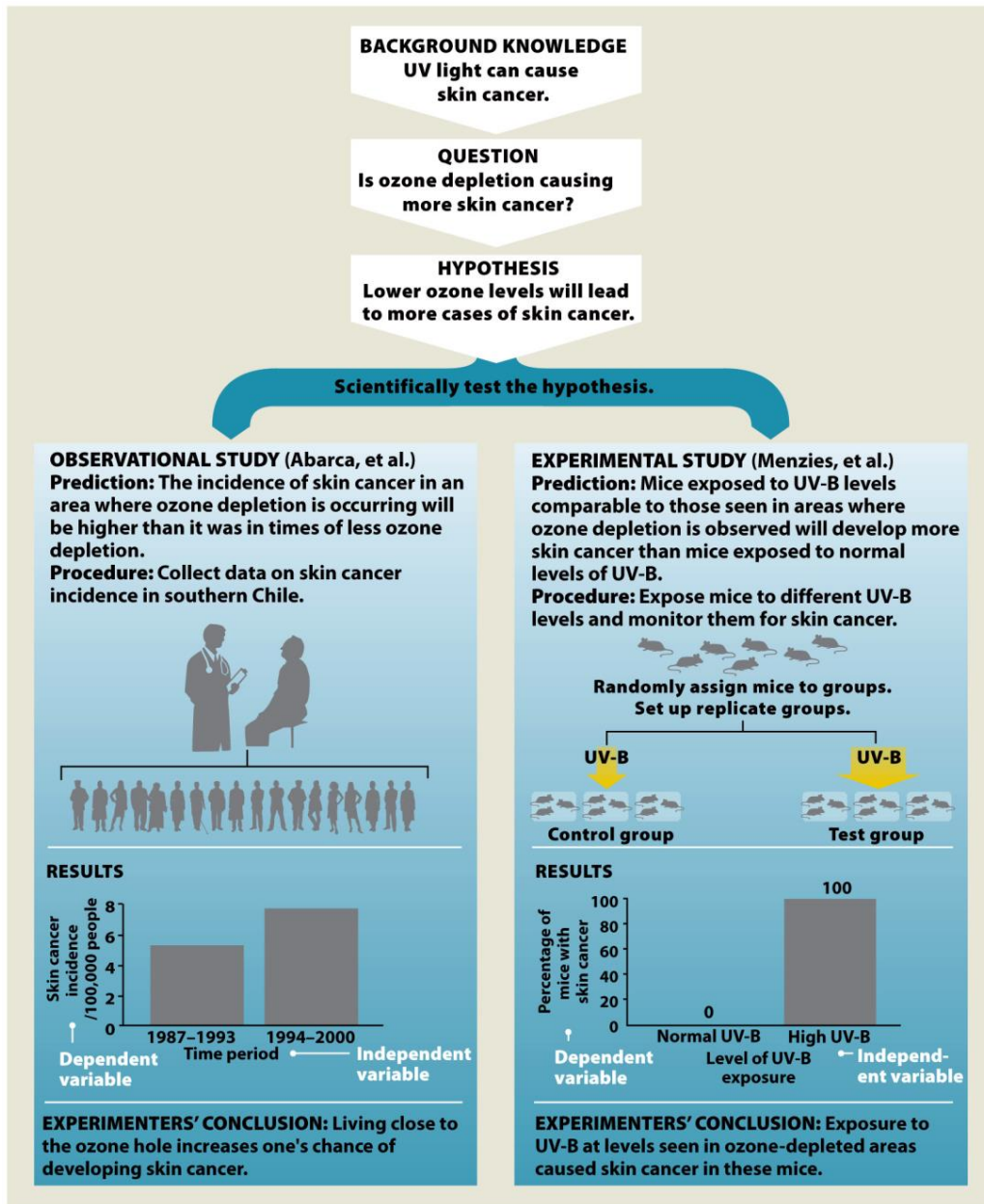
carefully observed for skin cancer. Going into the experiment, all test subjects are as similar as possible (e.g., none already had skin cancer, skin color is the same, age and sex are controlled for, no one has suntan lotion, etc.). This experiment will not be performed because it is unethical to do manipulative experiments that are likely to cause harm to humans. Instead, model animals with a similar physiology to humans, such as rats, are used; they can more quickly generate data that likely simulate the effect on humans.

Section: 2.4

Level: Hard

Bloom's Level: Evaluating/Creating

72. Refer to Infographic 2.6. In Menzies et al., what is the independent variable? What is the dependent variable? List as many qualities as possible that should be the same between mice in the two groups (control and test groups). Ideally, what should be the only difference between the two groups of mice?



**Infographic 2.6**

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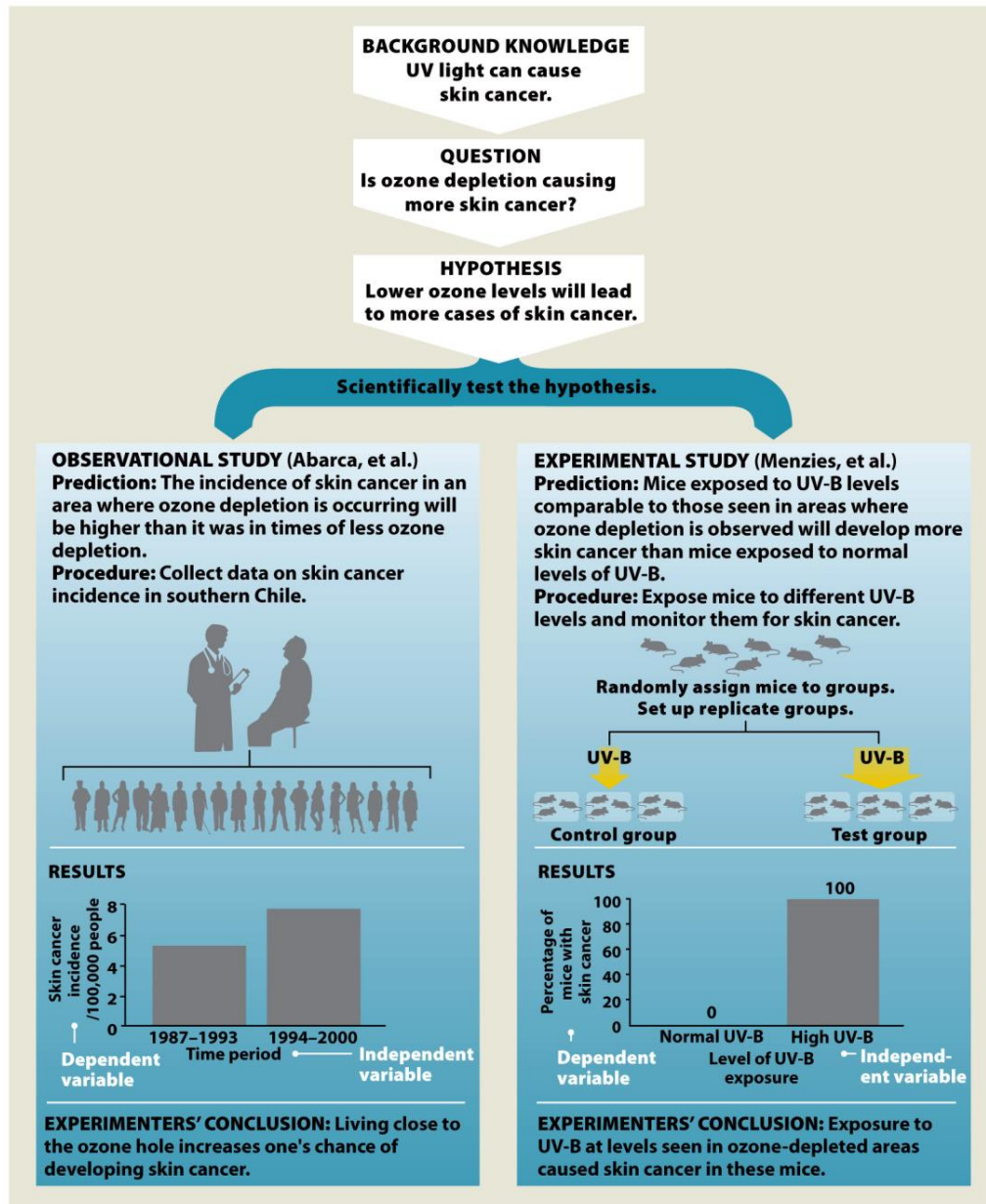
ANSWER: The independent variable is the level of UV-B radiation. The dependent variable is the incidence of skin cancer. Mice in both groups should be genetically identical (inbred line), radiation should be applied the same way, and skin cancer should be measured the same way. The mice should be the same age and same sex, or at least a balance across the groups, given the same diet, housed in the same conditions, etc. The only difference between the groups should be the independent variable.

Section: 2.4

Level: Medium/Hard

Bloom's Level: Analyzing/Evaluating

73. Refer to Infographic 2.6 In the observational study (Abarca et al.), explain why the time period is the independent variable and the incidence of skin cancer is the dependent variable.



**Infographic 2.6**

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ANSWER: The time period is the independent variable because this is the variable in the experiment that is manipulated by the investigator to see if it produces an effect. The incidence of skin cancer is the dependent variable because this is what is measured to see if it changes due to the conditions of the experiment.

Section: 2.4

Level: Medium

Bloom's Level: Applying/Analyzing

### **Guiding Question 2-5**

**How do approaches that use the precautionary principle and adaptive management help policy makers address environmental problems?**

#### **Multiple Choice**

74. An ongoing process that allows for altering policy strategies as new information is discovered or the situation itself changes is an example of \_\_\_\_\_.

- A. precautionary principle
- B. peer review
- C. adaptive management
- D. level of certainty
- E. innocent until proven guilty

Answer: C

Section: 2.5

Level: Easy

Bloom's Level: Remembering

75. The precautionary principle states that:

- A. once a theory is developed, it is not sound science to change this theory.
- B. human subjects must be used only when no harm is done to them.
- C. it is best to act in the face of uncertainty when there is a chance that serious consequences might occur.
- D. the Montréal Protocol is mandated by the United Nations because ozone depletion is such a serious problem.
- E. None of these answers is correct.

Answer: C

Section: 2.5

Level: Easy

Bloom's Level: Remembering

76. The \_\_\_\_\_ was an international treaty, eventually ratified by all countries in 2009, which dealt with the problem of ozone depletion.

- A. Quebec Protocol
- B. Montréal Protocol
- C. CFC Protocol
- D. Ozone Plan
- E. Global Clean Air Act

Answer: B

Section: 2.5

Level: Easy

Bloom's Level: Remembering

77. Which of the following statements about the Montréal Protocol is TRUE?

- A. The United Nations set a standard for phasing out ozone depletion, and each country must follow this standard.

- B. It is administered by the United Nations and outlines a series of deadlines for cutting back production of CFCs.
- C. All developed nations are required by the United Nations to participate in the Montréal Protocol due to the serious global nature of ozone depletion.
- D. The United Nations stated that no amendments can be made to this protocol.
- E. Once a developing nation has a per capita income of greater than \$20,000, that country is mandated to come into compliance with the Montréal Protocol.

Answer: B

Section: 2.5

Level: Easy

Bloom's Level: Remembering

### **Short Answer**

78. Describe the significance of the Montréal Protocol.

ANSWER: The Montréal Protocol was significant because it achieved international agreement to phase out CFCs in order to protect the ozone layer. The policies put in place by these nations were guided by science.

Section: 2.5

Level: Easy

Bloom's Level: Understanding

79. How can the Montréal Protocol be viewed as a model for reducing greenhouse gas emissions and avoiding a global catastrophe due to the recent changes in global climate attributed to human activities such as fossil fuel combustion?

ANSWER: The scientific consensus is that recent changes in global climate are being driven by human activities such as fossil fuel combustion and deforestation. These activities result in increased levels of greenhouse gases in the atmosphere, which then trap more heat (global warming). Scientists recommend that the levels of greenhouse gases (such as CO<sub>2</sub>) being added to the atmosphere must be reduced by all nations. This is similar to the Montréal Protocol in scope because it is a global environmental crisis and requires agreement across nations.

Section: 2.5

Level: Medium/Hard

Bloom's Level: Analyzing/Evaluating

80. Apply the precautionary principle to development of a new cancer-fighting drug. What needs to happen before the drug actually reaches consumers? Might some cancer patients be critical of applying the precautionary principle in this case? Why?

ANSWER: Before the new drug reaches consumers, it must first undergo years of intensive research to avoid any potential harm to the subjects who ultimately will consume the product. This seems like a good thing in terms of protecting the public, however, to a terminal cancer patient, this would be difficult because they do not have the luxury of waiting years for access to a drug that could potentially cure them.

Section: 2.5

Level: Hard

Bloom's Level: Evaluating



81. Explain what the precautionary principle is and how it was applied during the formation of the Montréal Protocol?

ANSWER: The precautionary principle is acting in the face of uncertainty when there is a chance that serious consequences might happen. The Montréal Protocol used the precautionary principle to outline a series of deadlines for reducing the production of CFCs before definitive studies were published explaining the harmful effects of CFCs on ozone.

Section: 2.5

Level: Medium

Bloom's Level: Applying

82. The manufacture and sale of CFCs was very profitable for the DuPont chemical company, and they and other industry scientists actively resisted their ban, using both political and scientific means. Considering that most of their products do not cause a global catastrophe and products must be sold in order to generate profit, it is in their interests to take an "innocent until proven guilty" approach to regulation of their products. What approach to environmental policy was used for the Montréal Protocol? Why is it required that scientists acknowledge any competing interests when they submit a manuscript for publication in a peer-reviewed journal?

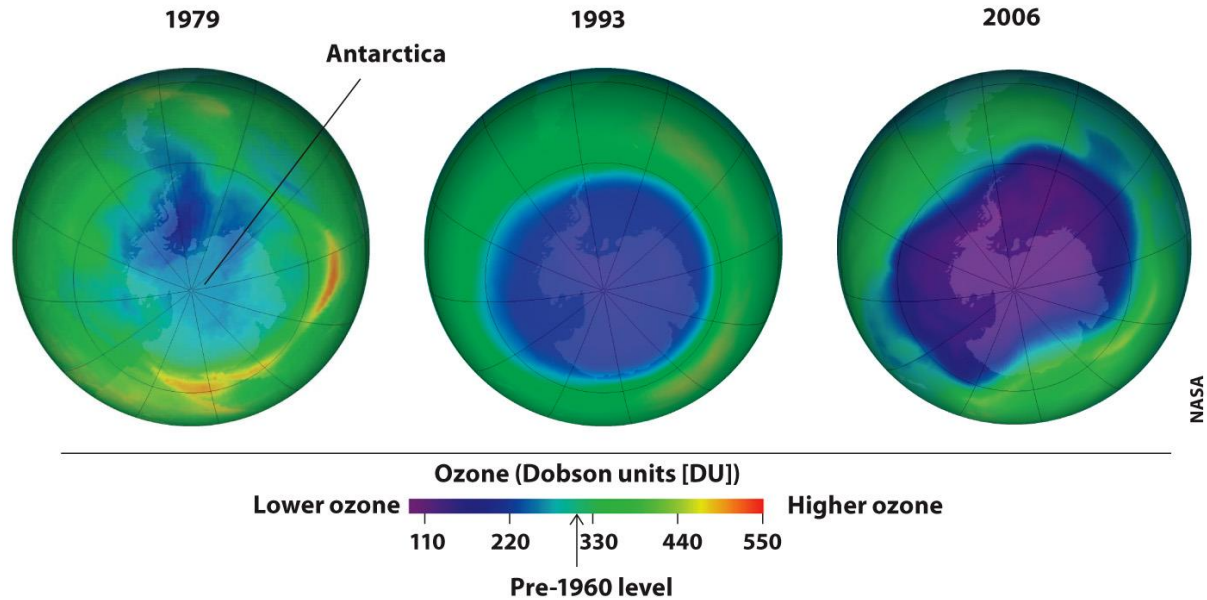
ANSWER: The precautionary principle states that we must act in a way that leaves a safety margin when the possibility for severe consequences is likely. This was applied to the Montréal Protocol. Society must demand policies based on quality science and be willing to follow its results and suggestions. For the science to be valuable, it must be free of competing interests and remain unbiased.

Section: 2.5

Level: Medium/Hard

Bloom's Level: Analyzing/Evaluating

83. Refer to the right-hand panel of Infographic 2.7. The Montréal Protocol and its amendments have phased out the use of CFCs worldwide. Still, the protective ozone layer over Antarctica continues to shrink. Please give several reasons why this occurs and why it will continue to occur for some time.



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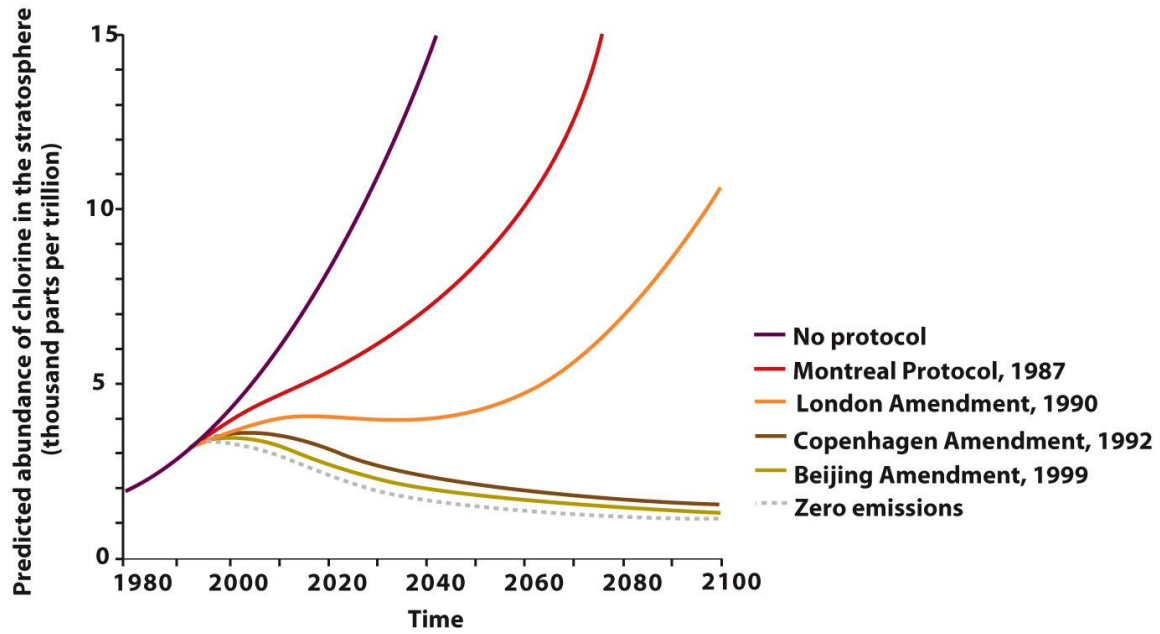
ANSWER: It takes time for ozone levels to return to normal despite the strides made in CFC reductions. Much of the CFCs released into the troposphere have not yet diffused up into the stratosphere. Also, in junkyards around the world CFCs are likely leaking from old refrigerators or auto air conditioners. There is some limited legal use of CFCs, as well.

Section: 2.5

Level: Medium

Bloom's Level: Analyzing

84. Refer to Infographic 2.7. Comparing the Beijing Amendment (1999) to no protocol, by what percent was chlorine in the stratosphere depleted in 2010?



Infographic 2.7  
*Environmental Science for a Changing World, Second Edition*  
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ANSWER: Beijing: 3.5 thousand parts per trillion Cl; compared with no protocol: 6.2.  
 % reduction =  $100 \times (6.2 - 3.5) / 6.2 =$  about 44% reduction.

Section: 2.5

Level: Medium

Bloom's Level: Analyzing

## Matching Questions

Please match each term in the left-hand column to the statement that it best exemplifies.

1. observations	An association between two variables that identifies one (the effect) occurring as a result of or in response to the other (the cause) (*11)
2. inferences	Molecule with three oxygen atoms that absorbs UV radiation in the stratosphere (*6)
3. atmosphere	Plan that allows room for altering strategies as new information comes in or the situation itself changes (*29)
4. troposphere	A formalized plan that addresses a desired outcome or goal (*27)
5. stratosphere	A body of knowledge (facts and explanations) about the natural world, and the process used to get that knowledge (*8)
6. ozone	Research that gathers data in a real-world setting without intentionally manipulating any variable (*17)
7. ultraviolet (UV) radiation	The group in an experimental study that is manipulated such that it differs from the control group in only one way (*20)
8. science	The mathematical evaluation of experimental data to determine how likely it is that any difference observed is due to the variable being tested (*25)
9. empirical evidence	Blanket of gases that surrounds Earth and other planets (*3)
10. correlation	Information detected with the senses or with equipment that extends our senses (*1)
11. cause-and-effect relationship	Researchers submit a report of their work to a group of outside experts who evaluate the study's design and results of the study to determine whether it is of high-enough quality to publish (*23)

12. scientific method	Region of the atmosphere that starts at ground level and extends upward about 7 miles (*4)
13. hypothesis	A widely accepted explanation of a natural phenomenon that has been extensively and rigorously tested scientifically (*24)
14. testable	The group in an experimental study that the test group's results are compared to; ideally, the control group will differ from the test group in only one way (*19)
15. prediction	Information gathered via observation of physical phenomena (*9)
16. falsifiable	Conclusions we draw based on observations (*2)
17. observational study	International treaty that laid out plans to phase out ozone-depleting chemicals like CFCs (*26)
18. experimental study	An idea or a prediction that can be proved wrong by evidence (*16)
19. control group	Acting in a way that leaves a safety margin when the data are uncertain or severe consequences are possible (*28)
20. test group	Procedure scientists use to empirically test a hypothesis (*12)
21. independent variable	Two things occur together, but it doesn't necessarily mean that one caused the other (*10)
22. dependent variable	A statement that identifies what is expected to happen in a given situation (*15)
23. peer reviewed	A possible explanation for what we have observed that is based on some previous knowledge (*13)
24. theory	Region of the atmosphere that starts at the top of the troposphere and extends up to about 31 miles; contains the ozone layer

	(*5)
25. statistics	The variable in an experiment that a researcher manipulates or changes to see if the change produces an effect. (*21)
26. Montréal Protocol	The variable in an experiment that is evaluated to see if it changes due to the conditions of the experiment (*22)
27. policy	Research that manipulates a variable in a test group and compares the response to that of a control group that was not exposed to the same variable (*18)
28. precautionary principle	Short-wavelength electromagnetic energy emitted by the Sun (*7)
29. adaptive management	A possible explanation that generates predictions for which empirical evidence can be collected to verify or refute the hypothesis (*14)