

### Guiding Question 2-1

**What kinds of questions are under the purview of science and why is science limited in this way? Why do we say science is a “process” and that conclusions are always tentative (nothing is ever proven)?**

1. 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 and inductions.  
E) It is a very well-supported hypothesis.  
Ans: D      Difficulty level: easy
2. A(n) \_\_\_\_\_ is a hypothesis that has been widely accepted, as well as extensively and rigorously tested.  
A) theory    B) fact    C) explanation    D) definition    E) proof  
Ans: A      Difficulty level: easy
3. 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 the above  
E) None of the above  
Ans: D      Difficulty level: easy
4. 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%  
Ans: E      Difficulty level: medium
5. 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 up of one or more cells.  
B) A newly discovered organism is very likely to be made up of one or more cells.  
C) Cells are the basic units of life for all known living organisms.  
D) Cells are the basic building blocks of life.  
E) No living organism will ever be discovered that is not made up of cells.  
Ans: E      Difficulty level: medium
6. 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  
Ans: B      Difficulty level: easy

7. Which is TRUE regarding the following statements: (1) “Higher levels of greenhouse gases cause increased warming of the troposphere,” and (2) “Earth is the only habitable planet in the solar system”?
- 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 that is testable by scientific methods.
  - D) Only statement (2) can generate falsifiable predictions.
  - E) Neither statement is suitable for science.

Ans: C      Difficulty level: easy

8. Which of the following question(s) 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?

Ans: D      Difficulty level: easy

9. 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.
  - E) All of the above are falsifiable statements.

Ans: D      Difficulty level: medium

10. Which of the following hypotheses is NOT testable?
- A) CFCs are causing depletion of the ozone layer.
  - B) Bacterial water pollution increases the risk of infectious diseases.
  - C) Increased salt intake leads to high blood pressure.
  - D) Reincarnation exists.
  - E) Increased UV exposure increases the risk of skin cancer.

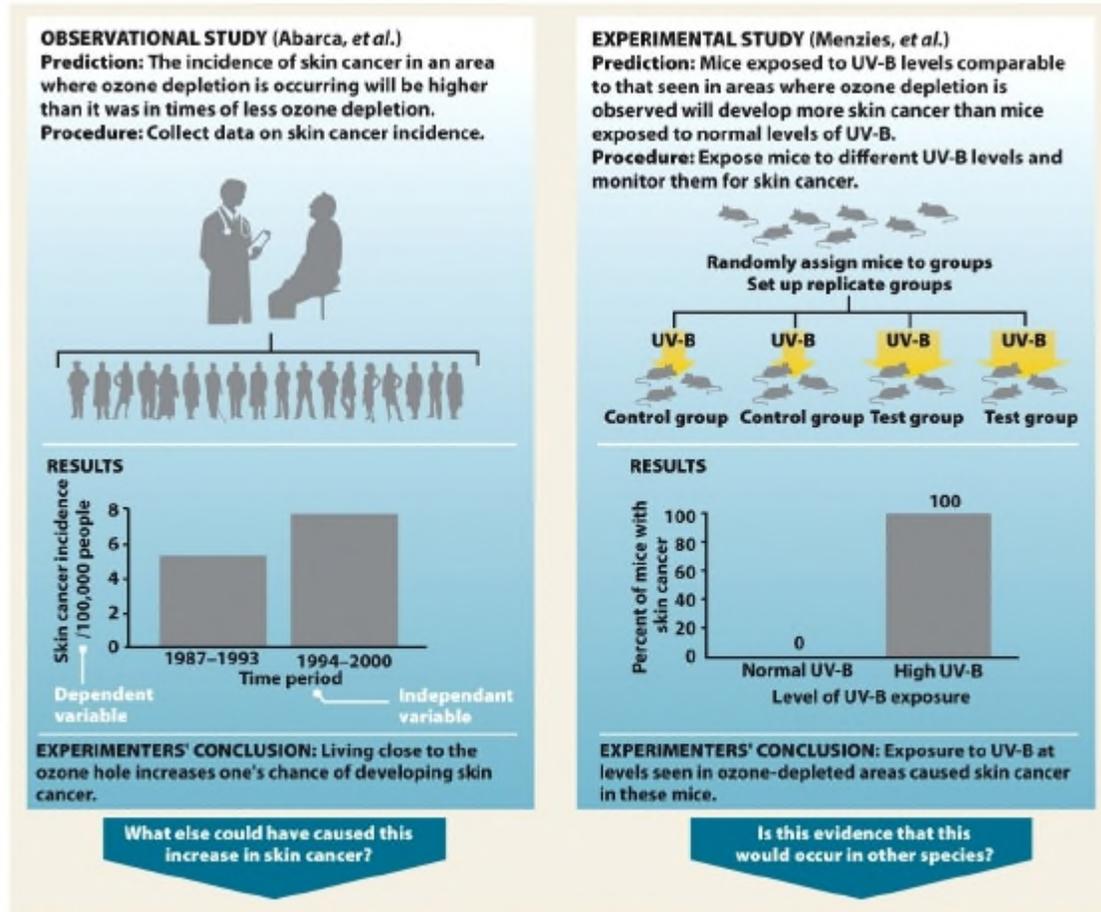
Ans: D      Difficulty level: easy

11. 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?

Ans: 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.

Difficulty level: hard

12. Refer to Infographic 2.5. Taken together, do these two studies prove that lower ozone levels directly cause skin cancer in humans? Why or why not?



Infographic 2.5 part 2  
 Environmental Science for a Changing World  
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Ans: 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 cannot ever be completely proven because new evidence could be obtained in the future that could refute the hypothesis.

Difficulty level: medium

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

Ans: 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 not likely to be refuted by additional studies.

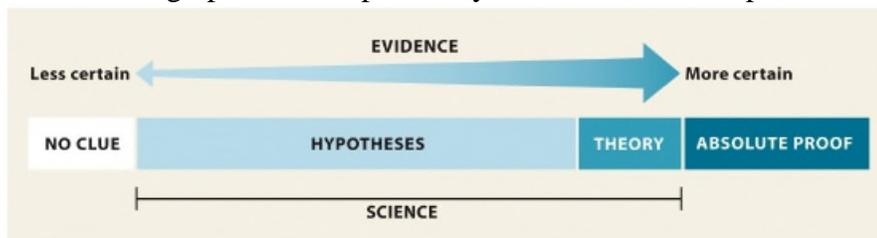
Difficulty level: easy

14. This chapter has 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?

Ans: 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.

Difficulty level: medium

15. Refer to Infographic 2.2. Explain why in science *absolute* proof is not required.



Infographic 2.2  
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Ans: Since all scientific information is open to further investigation, it is not expected or required to have absolute proof in science.

Difficulty level: easy

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

Ans: 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.

Difficulty level: medium

17. Describe the difference between a hypothesis and a scientific theory.

Ans: A hypothesis is a possible explanation for observations that are 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.

Difficulty level: medium

18. Prior to Susan Solomon's experiments, the information available to NASA ozone-modeller 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, which led Newman to reject his hypothesis in favour of her polar cloud hypothesis? Is it possible that Solomon's hypothesis could be rejected in the future?

Ans: 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 Solomon's hypothesis is strong, but new information could cause the hypothesis to be modified or even rejected.

Difficulty level: hard

19. What criteria must be met for a hypothesis to be valid?  
Ans: A valid hypothesis must be testable. It must be possible to create predictions from the hypothesis that we can objectively observe by running the test. Predictions based on a hypothesis must also be falsifiable. It must be possible to refute them with evidence.  
Difficulty level: medium
20. Is the following a valid hypothesis? Cancer patients who are prayed for will have better outcomes compared to patients with similar prognoses (likely outcomes) who are not prayed for.  
Ans: Yes. Predictions from the hypothesis are testable and falsifiable.  
Difficulty level: medium
21. Is the following a valid hypothesis? Natural disasters around the world are a result of a supernatural deity punishing humanity for our actions.  
Ans: No. Predictions from the hypothesis are neither testable nor falsifiable.  
Difficulty level: medium
22. 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 is empirical data a hallmark of good science?  
Ans: 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 studied empirically and are therefore not under the purview of science.  
Difficulty level: medium

### Guiding Question 2-2

**How are scientific hypotheses generated and tested? What are the two main types of scientific studies, and why do we need both types?**

23. 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  
Ans: C    Difficulty level: easy
24. Which type of experiment collects data in the real world without manipulating the subject of study?  
A) experimental    D) observational  
B) anecdotal    E) randomized  
C) theoretical  
Ans: D    Difficulty level: easy

25. 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 group.

Ans: C      Difficulty level: medium

26. 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.

Ans: D      Difficulty level: easy

27. Peer review is

- A) the process a scientist undergoes to analyze the results of an experiment.
- B) a measure of how well a 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 a report after it is accepted for publication.
- E) a process by which a group of field scientists evaluate a report to determine if it is of high enough quality to publish in a journal.

Ans: E      Difficulty level: easy

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

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

Ans: C      Difficulty level: easy

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

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

Ans: A      Difficulty level: easy

30. In the following example, what is the independent variable? Hypothesis: Mice on a restricted low-calorie 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 want 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
- Ans: A      Difficulty level: medium

31. A researcher wants to test the effectiveness of a new sunscreen for 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) Sunscreen is not applied to mice in the control group; sunscreen 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 sunscreen in their drinking water to maximize effectiveness.
- Ans: C      Difficulty level: medium

32. 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
- Ans: B      Difficulty level: easy

33. Inferences are
- A) recordings of multiple hypotheses in one location to create a revised theory.
  - B) information detected with the senses or with equipment that extends our senses.
  - C) explanations of what else might be true or what might have caused the observed phenomenon.
  - D) multiple data points collected at more than one testing site.
  - E) a body of knowledge and the process used to get that knowledge.
- Ans: C      Difficulty level: easy

34. 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

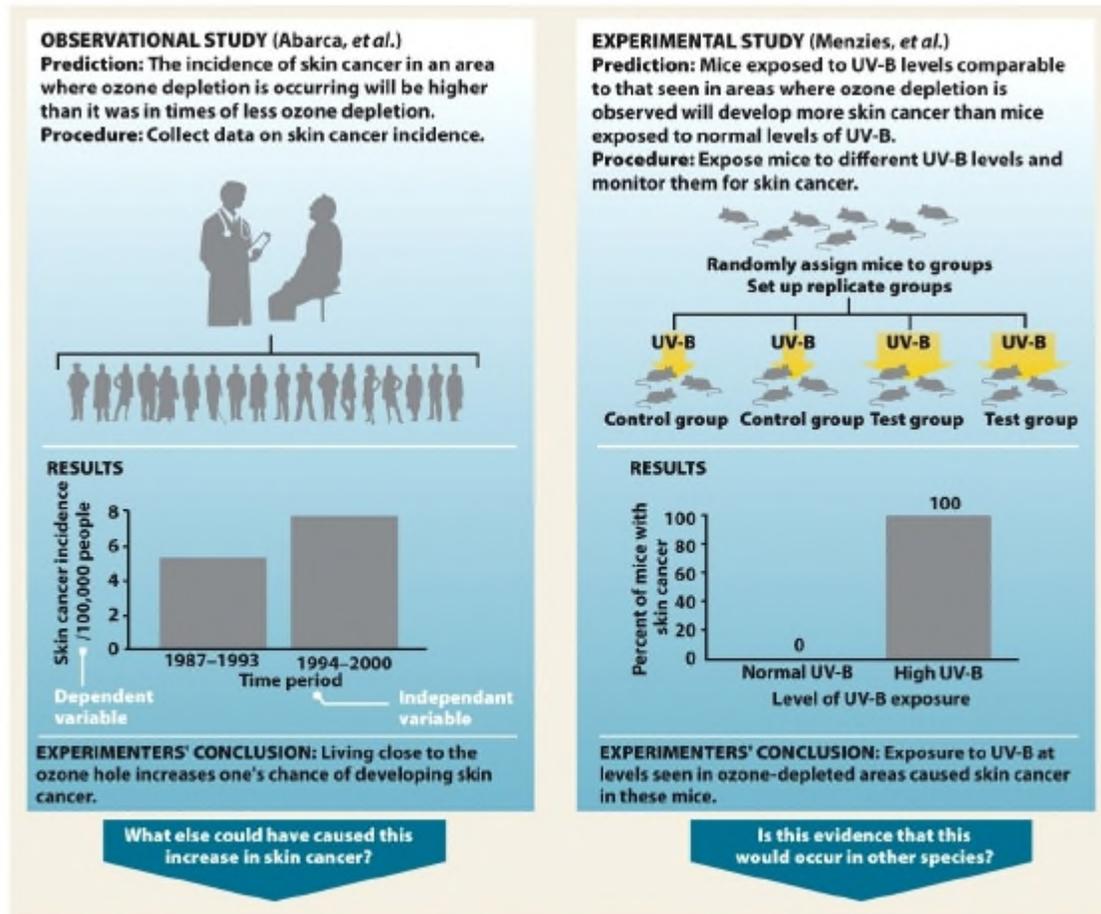
Ans: A      Difficulty level: medium

35. The group in an experimental study that is manipulated somehow 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

Ans: B      Difficulty level: easy

36. Refer to Infographic 2.5. Which study depicted in the Infographic provides stronger support for the stated hypothesis? Briefly explain why.



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Ans: 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.

Difficulty level: easy

37. 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.

Ans: In an *observational study*, data can provide a correlation between, for example, the presence of CFCs and ozone depletion. Occurring together, they suggest a cause-and-effect relationship. In an *experimental study*, variables can be directly manipulated and controlled, and 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.

Difficulty level: medium

38. 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?

Ans: In an observational study, the researcher gathers data in a real-world setting without manipulating any variable. This can lead to correlative conclusions. In an experimental study, the researcher manipulates the independent variable to evaluate a cause-and-effect relationship.

Difficulty level: medium

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

Ans: This is an observational study that 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.

Difficulty level: hard

40. 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.”

Ans: 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 whether opening an umbrella causes rain to fall.

Difficulty level: medium

41. 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 a conclusion.

Ans: There are many possibilities. Since ozone has an impact on crop yield, one experiment is to grow tomatoes in an area where UV-B radiation is high and where tomatoes have been grown previously (when UV-B radiation was much lower). Try to control as many growth factors as possible (e.g., use the same fertilizer, seed type, etc., that were used in the past). Compare current crop yields to those from previous years. Look for trends.

Difficulty level: medium

42. Was Susan Solomon's experiment, which provided support for her hypothesis that CFCs were leading to depletion of ozone in the stratosphere, observational or experimental?

Ans: Solomon's experiment was an observational one. She hypothesized that ClO levels would increase with ozone depletion from CFCs. When atmospheric gases were collected, the levels of ClO were indeed elevated, which supported her hypothesis.

Difficulty level: medium

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

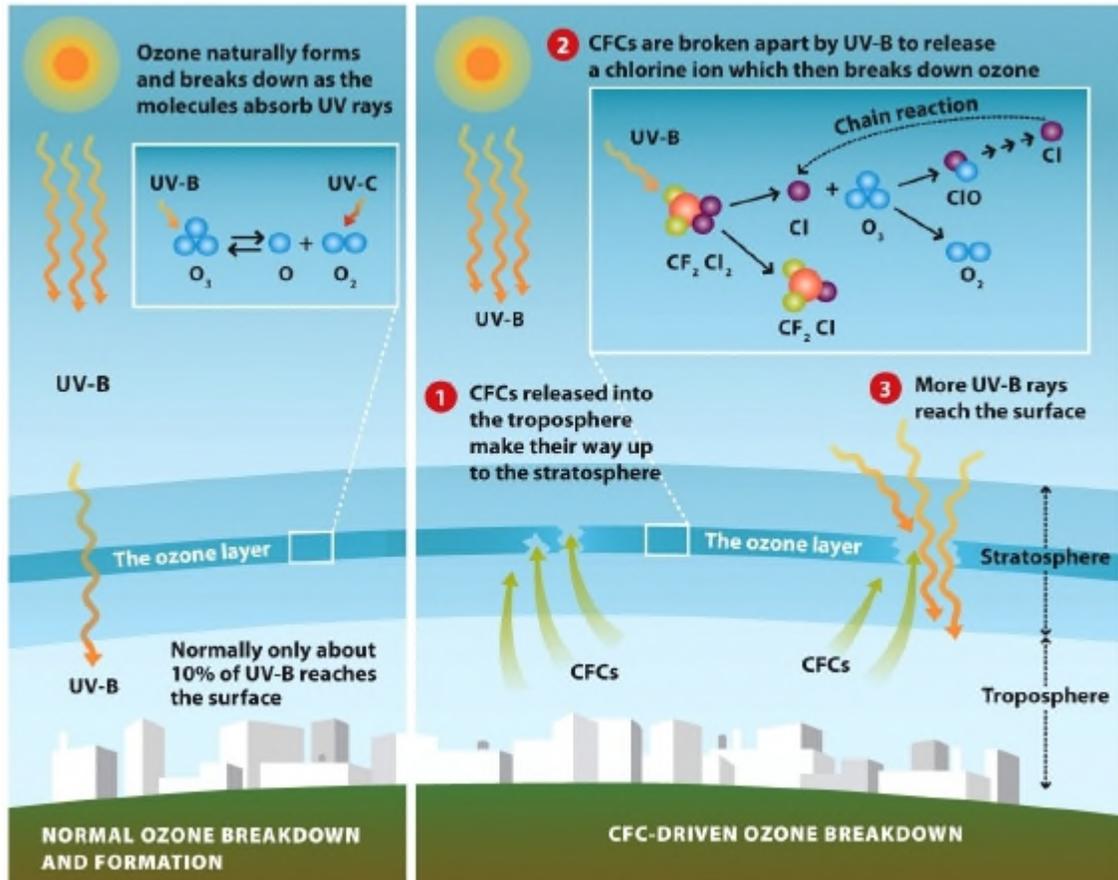
Ans: A control group validates the experiment. The control group should be identical to the test group except for the independent variable. This allows conclusions to be drawn about the outcome by comparing the experimental group with the control group. Any differences are due to the independent variable.

Difficulty level: medium

**Guiding Question 2.3**

**Why is ozone in the stratosphere beneficial to life on Earth and how is it being depleted? What is the evidence that ozone depletion might be harmful to the health of humans or other organisms?**

44. Refer to Infographic 2.4. What happens to the chlorine atom liberated from chlorine monoxide in the second portion of this figure?



Infographic 2.4  
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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.

Ans: D      Difficulty level: easy

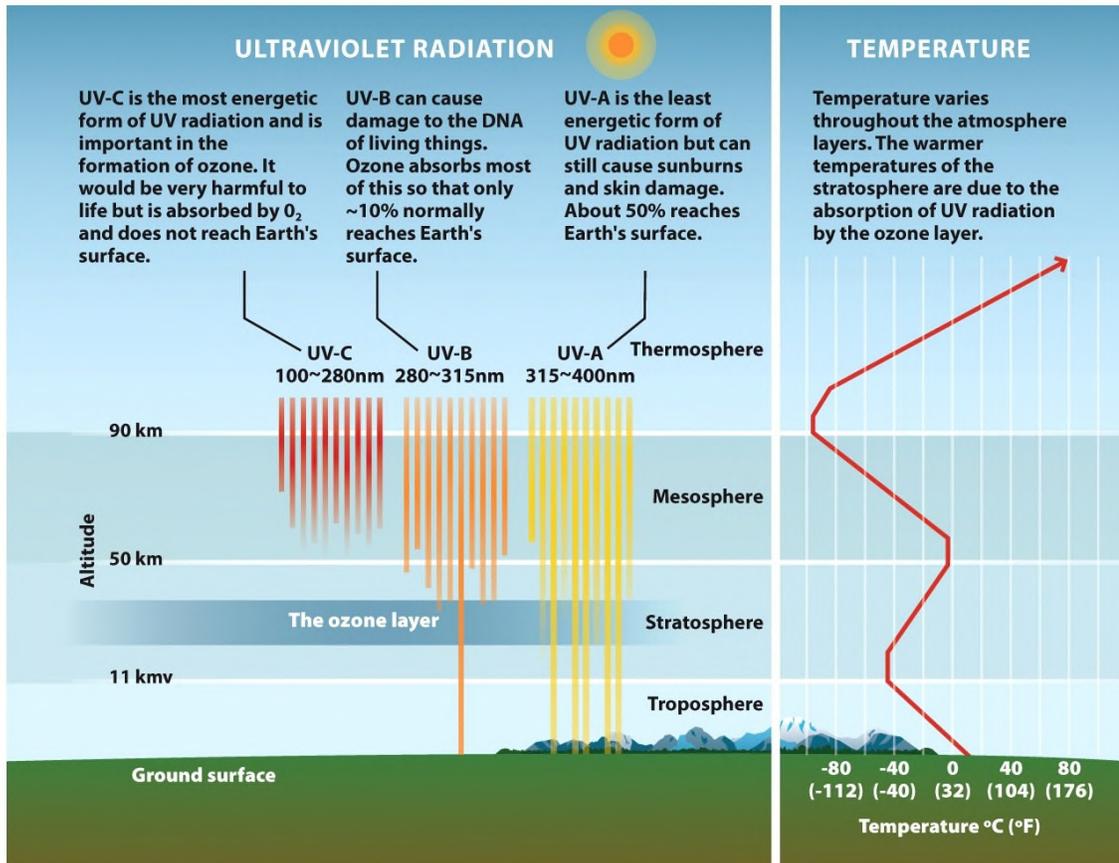
45. The ozone layer is located in the \_\_\_\_\_.

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

Ans: A      Difficulty level: easy

46. What is the chemical formula for ozone?  
A)  $O_2$    B)  $C_2F_2Cl_2$    C)  $SF_6$    D)  $O_3$    E)  $CrO_2Cl_2$   
Ans: D   Difficulty level: easy
47. What's the difference between "good" and "bad" ozone?  
A) "Good" ozone forms grey 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 is a pollutant in the stratosphere.  
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  $O_3$ ; "bad" ozone is abbreviated  $O_2$ .  
Ans: B   Difficulty level: medium
48. 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  
Ans: C   Difficulty level: hard
49. Scientists have concluded that increasing levels of \_\_\_\_\_ were causing the depletion of the ozone layer.  
A) methane   B) smog   C) particulates   D) CFCs   E)  $O_3$   
Ans: D   Difficulty level: easy

50. 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  
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- A) Water vapour 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)  $O_2$  reacts with UV-B and UV-C.

Ans: D Difficulty level: medium

51. Ozone-depleting chemicals are most detrimental at the poles, both in the Arctic and Antarctic. The major reason for this is because

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

Ans: C Difficulty level: hard

52. Where in the atmosphere is ozone found?

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

Ans: D Difficulty level: medium

53. Based on the observations of researchers Newman and Solomon, what is the MOST likely role of NO<sub>x</sub> in ozone depletion?

- A) It plays no role at all.
- B) It enhances ozone loss over Antarctica.
- C) NO<sub>x</sub> reduces UV-C radiation hitting Earth's surface.
- D) NO<sub>x</sub> increases the amount of UV-A coming from the sun.
- E) At modest temperatures, NO<sub>x</sub> likely protects ozone from depletion by CFCs.

Ans: E Difficulty level: hard

54. 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.

Ans: B Difficulty level: easy

55. 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.

Ans: E Difficulty level: medium

56. Which of the following statements is TRUE of CFCs?
- A) CFCs are industrial chemicals that were once used as refrigerants.
  - B) CFCs are 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.

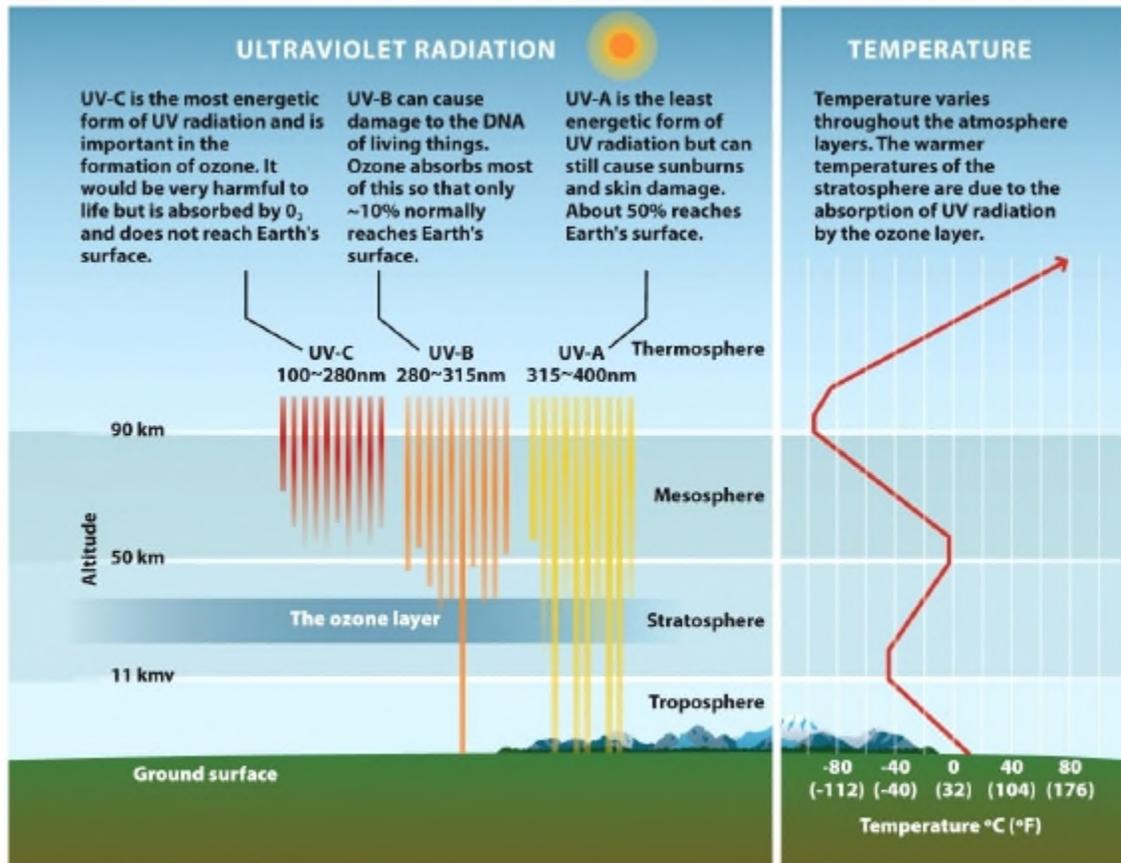
Ans: A      Difficulty level: easy

57. 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 provided support.

Ans: E      Difficulty level: hard

58. Refer to Infographic 2.1. What's the coldest temperature found in Earth's atmosphere? In what layer is it located? How high must we go to find that temperature?



Infographic 2.1  
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Ans: At the boundary between the mesosphere and thermosphere (mesopause) the temperature is approximately  $-100^{\circ}C$ . It is about 90 kilometres above Earth's surface.

Difficulty level: medium

59. 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?

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

Difficulty level: medium

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

Ans: 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.

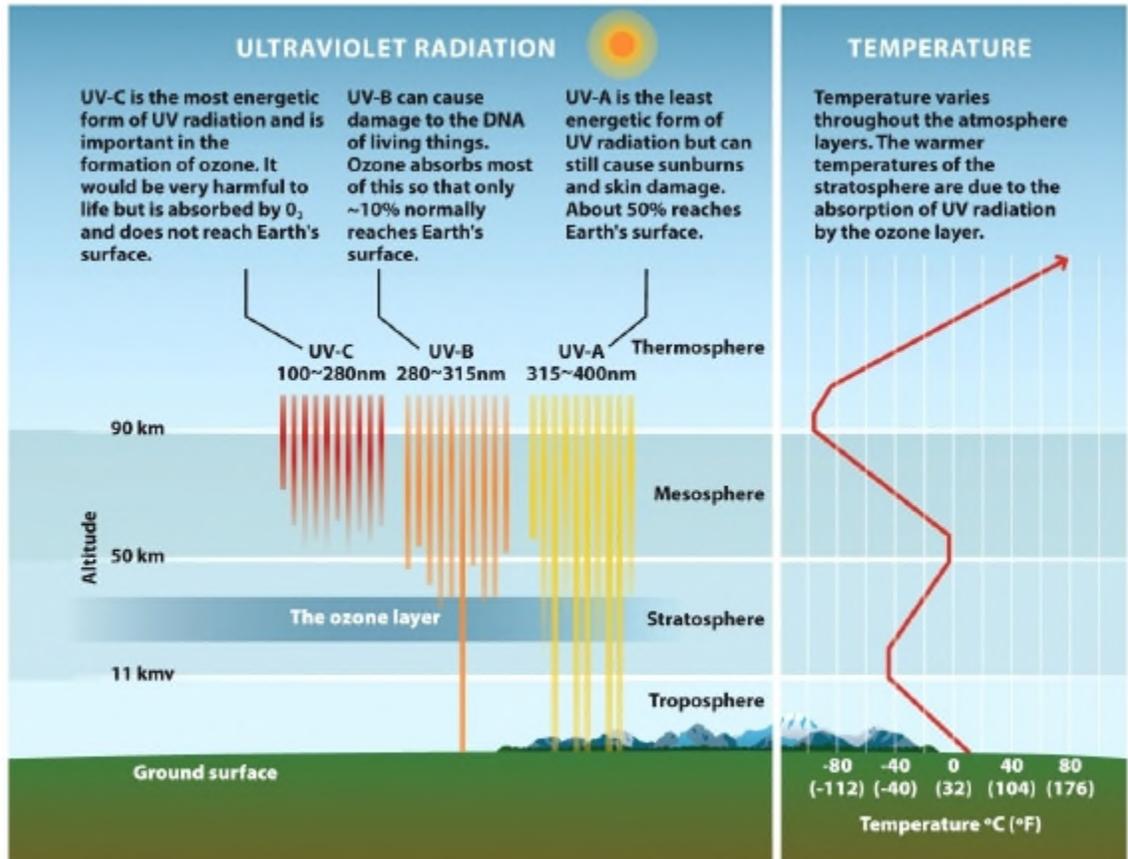
Difficulty level: medium

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

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

Difficulty level: medium

62. Refer to Infographic 2.1. Is there any place in the atmosphere that is as warm, or warmer, than the surface temperature of 25°C?

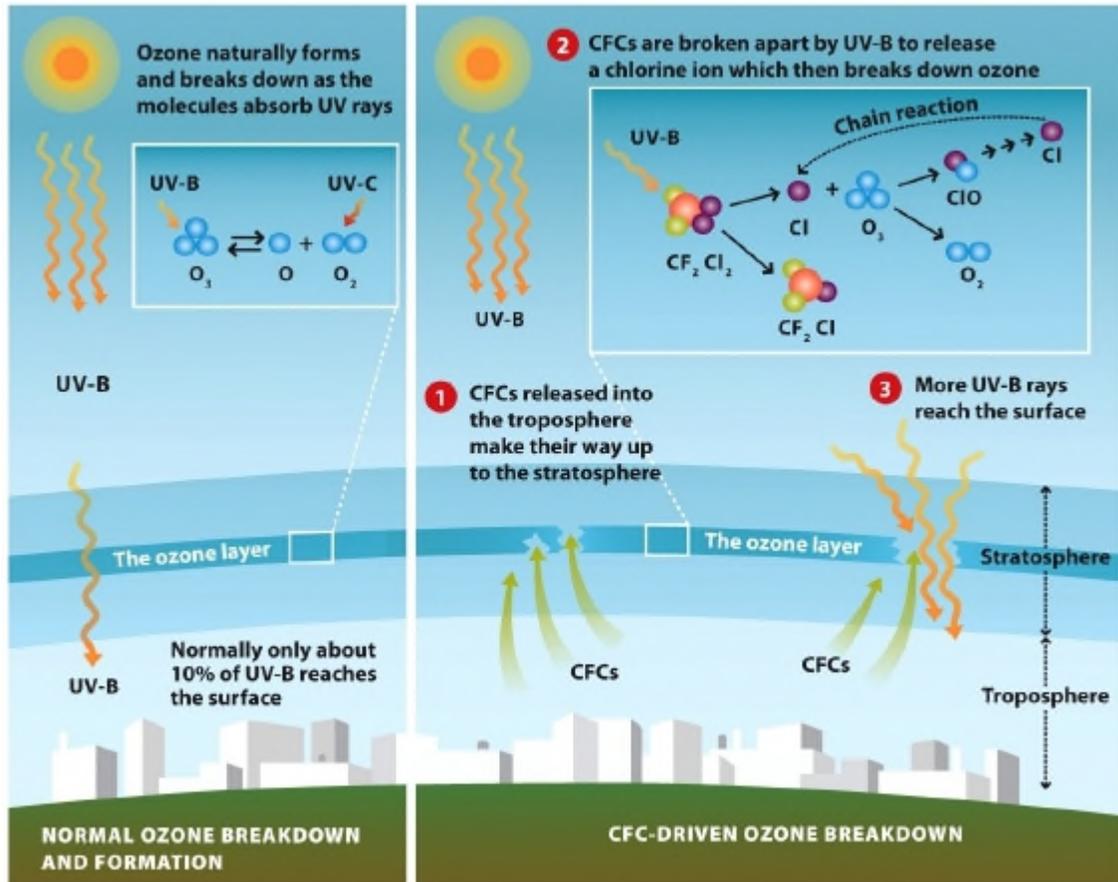


Infographic 2.1  
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Ans: To find a temperature that high one must go into the thermosphere, well past the 90-kilometre boundary on the graph.

Difficulty level: easy

63. Refer to Infographic 2.4. Explain chemically how CFCs in the stratosphere are damaging the ozone layer.



Infographic 2.4  
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Ans: 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).

Difficulty level: medium

### Guiding Question 2-4

How did scientists use the process of science to help us understand what was happening with the ozone layer and what unknowns still exist?

64. 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

Ans: B Difficulty level: easy

65. When data is 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

Ans: B    Difficulty level: medium

66. 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 by a reporter.  
E) A peer-reviewed article will contain scientific jargon that is not easily understood by the general public.

Ans: E    Difficulty level: easy

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

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

Ans: E    Difficulty level: easy

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

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

Ans: B    Difficulty level: easy

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

- A) manipulative study    D) random study  
B) experimental study    E) observational study  
C) theoretical study

Ans: E    Difficulty level: medium

70. 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.

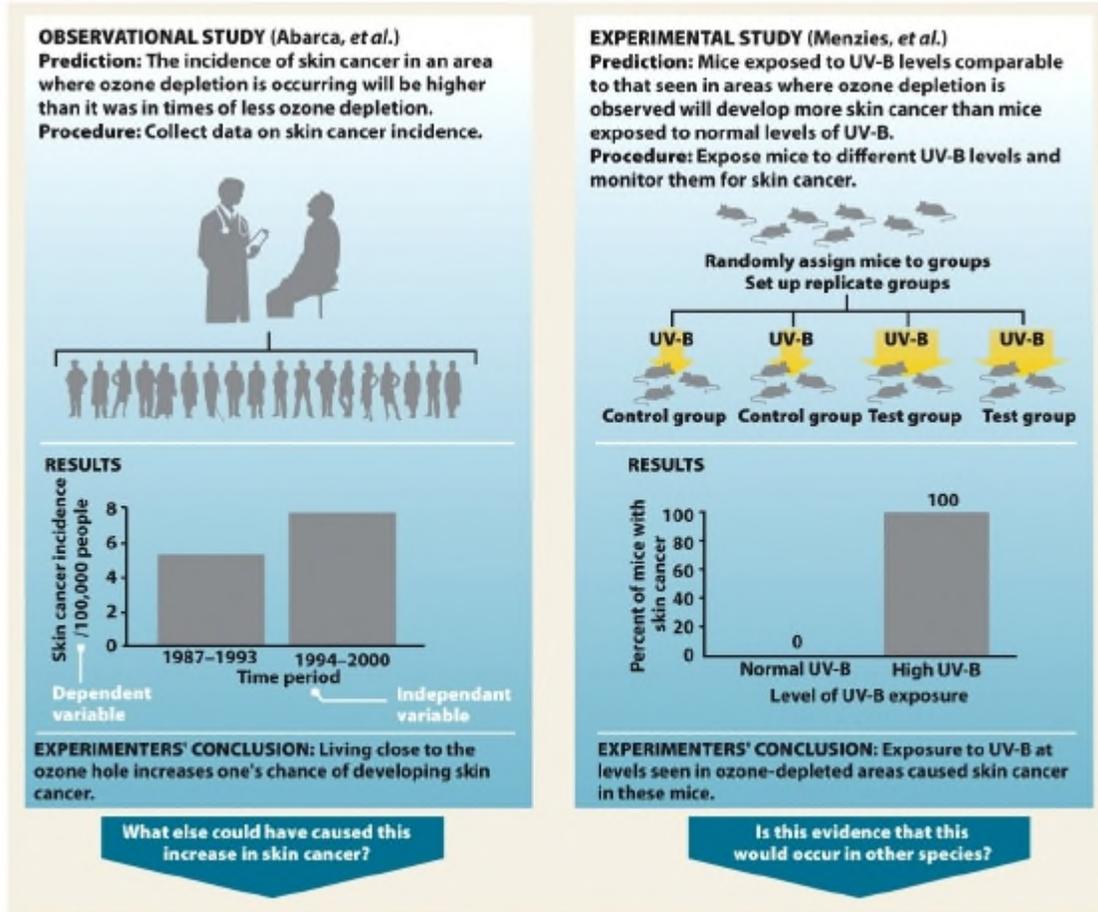
Ans: A      Difficulty level: medium

71. Describe the importance of peer review to the scientific process.

Ans: Prior to publication in a scientific journal, peers in the same area of scientific research analyze the study to determine whether it is of acceptable quality. This ensures only quality scientific reports (without bias, well-controlled studies, etc.) appear in scientific literature.

Difficulty level: medium

72. 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 2.5.

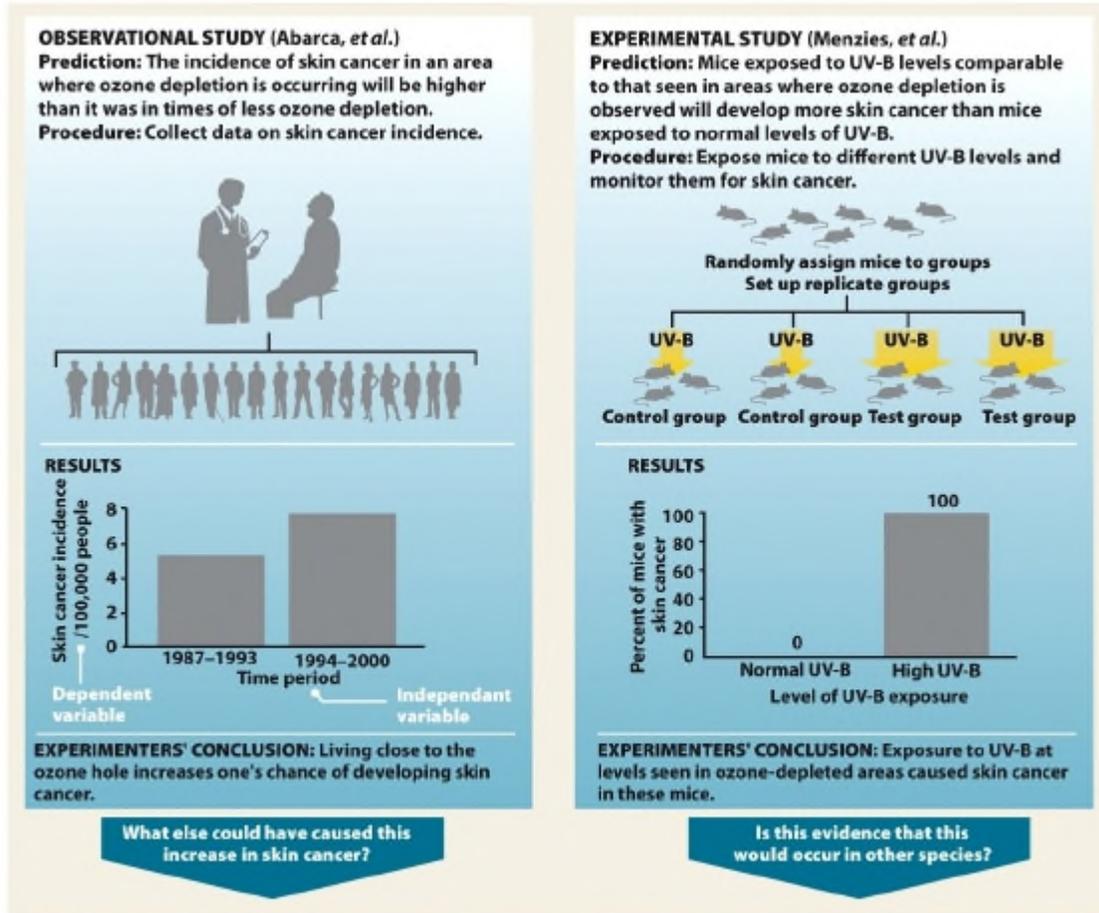


Infographic 2.5 part 2  
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Ans: Start with a large population of humans and divide them into two groups. Over the course of the experiment, the control group is exposed to normal levels of UV-B radiation, while the test group receives UV-B levels similar to that seen in areas with observable ozone depletion. 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 has skin cancer, skin colour is the same, age and sex are controlled for, no one wears sunscreen, 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 similar physiology to humans, such as rats, that can generate data that likely simulates the effect on humans more quickly.

Difficulty level: hard

73. Refer to Infographic 2.5. 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 both groups of mice (control and test groups). Ideally, what should the only difference be between the two groups of mice?



Infographic 2.5 part 2  
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Ans: 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 applied the same way, and skin cancer measured the same way; the mice should also be the same age, same sex (or at least a balance across the groups), fed the same diet, housed in the same conditions, etc. The only difference between the groups should be the independent variable.

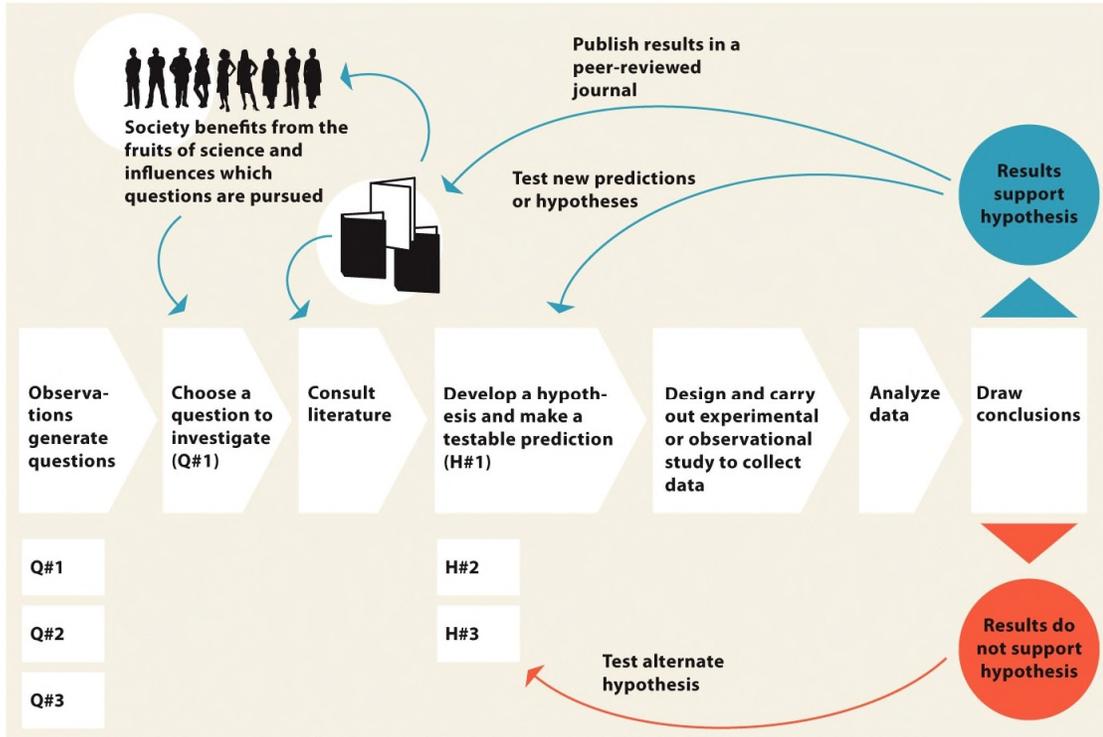
Difficulty level: medium

74. Explain how a theory differs from a hypothesis.

Ans: A theory is a hypothesis that has withstood the test of time. Theories are widely accepted and have been extensively and rigorously tested.

Difficulty level: easy

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

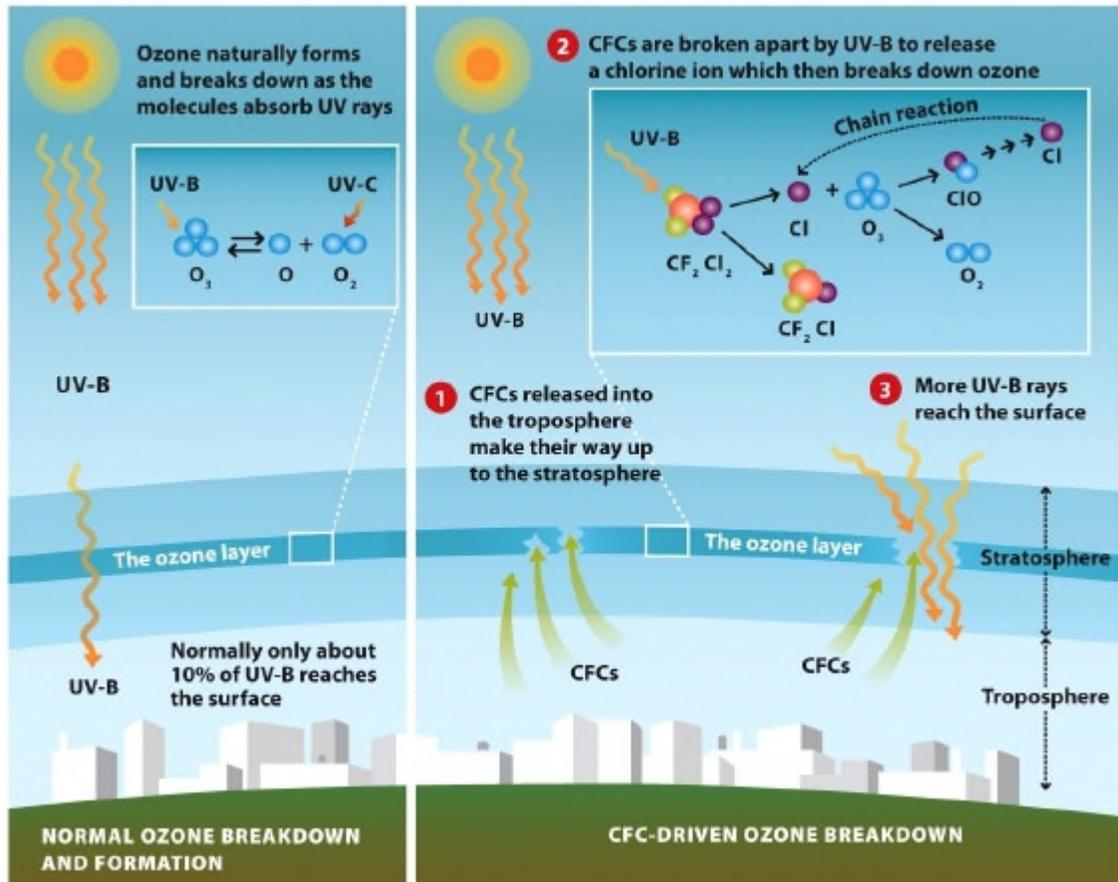


Infographic 2.3  
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Ans: The hypothesis is either rejected (in which case, alternate hypotheses are developed and tested), modified, or accepted (published in a peer-reviewed journal and used to test new predictions or hypotheses).

Difficulty level: medium

76. Refer to Infographic 2.4. Does an increase in the concentration of chlorine monoxide (ClO) in the stratosphere support Solomon's hypothesis that free chlorine molecules (Cl<sub>2</sub>) from CFCs break up into chlorine atoms that destroy ozone?

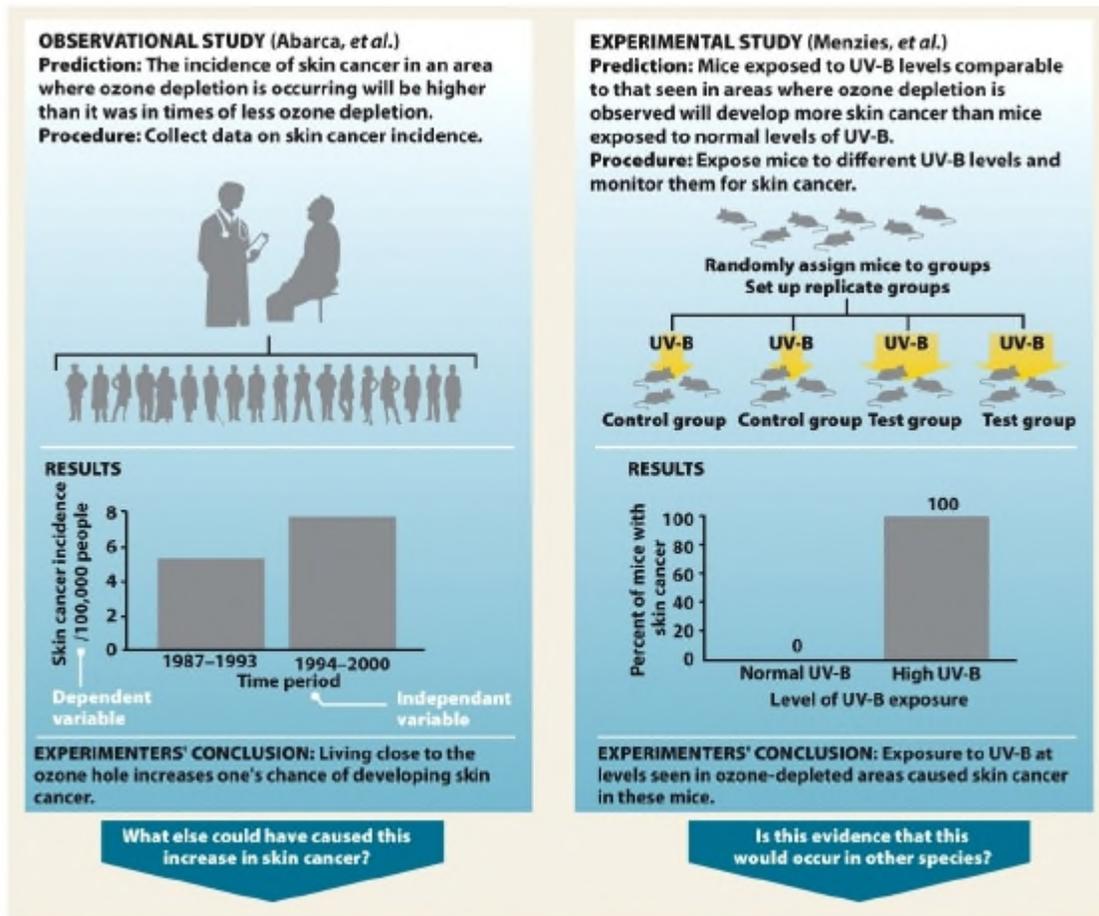


Infographic 2.4  
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Ans: An increase in ClO supports the hypothesis. It forms as an intermediate in the destruction of ozone.

Difficulty level: medium

77. Refer to Infographic 2.5. 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 2.5 part 2  
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Ans: 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.

Difficulty level: medium

78. Explain the difference between the dependent and independent variable in an experiment.

Ans: The independent variable in an experiment is the variable that is manipulated or changed, and the dependent variable is the observed result of the independent variable being manipulated.

Difficulty level: medium

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

Ans: 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.).

Difficulty level: medium

### Guiding Question 2-5

#### How did scientists, policy-makers, and world leaders take the science about ozone depletion and turn it into policy?

80. 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                      D) level of certainty  
B) peer review                                      E) innocent until proven guilty  
C) adaptive management

Ans: C      Difficulty level: easy

81. 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 Montreal Protocol is mandated by the United Nations because ozone depletion is such a serious problem.  
E) None of the above

Ans: C      Difficulty level: easy

82. Which policy(ies) was/were a direct result of applying the precautionary principle? (Select all that apply.)

A) Environmental Contaminants Act              D) Copenhagen Amendment  
B) Montreal Protocol                                E) Beijing Amendment  
C) London Amendment

Ans: A, B      Difficulty level: easy

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

A) Quebec Protocol                                D) Ozone Plan  
B) Montreal Protocol                                E) Global Clean Air Act  
C) CFC Protocol

Ans: B      Difficulty level: easy

84. Which of the following statements about the Montreal 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 Montreal 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 greater than \$20,000, that country is mandated to come into compliance with the Montreal Protocol.

Ans: B      Difficulty level: medium

85. Describe the significance of the Montreal Protocol.

Ans: The Montreal 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.

Difficulty level: medium

86. How can the Montreal 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?

Ans: 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 Montreal Protocol in scope because it is a global environmental crisis and requires agreement across nations.

Difficulty level: hard

87. Apply the precautionary principle to the 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?

Ans: 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 terminally ill cancer patients, this would be difficult because they do not have the luxury of waiting years for access to a drug that could potentially cure them.

Difficulty level: hard

88. Describe the precautionary principle and how it was applied during the formation of the Montreal Protocol.

Ans: The precautionary principle is acting in the face of uncertainty when there is a chance that serious consequences might happen. The Montreal 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.

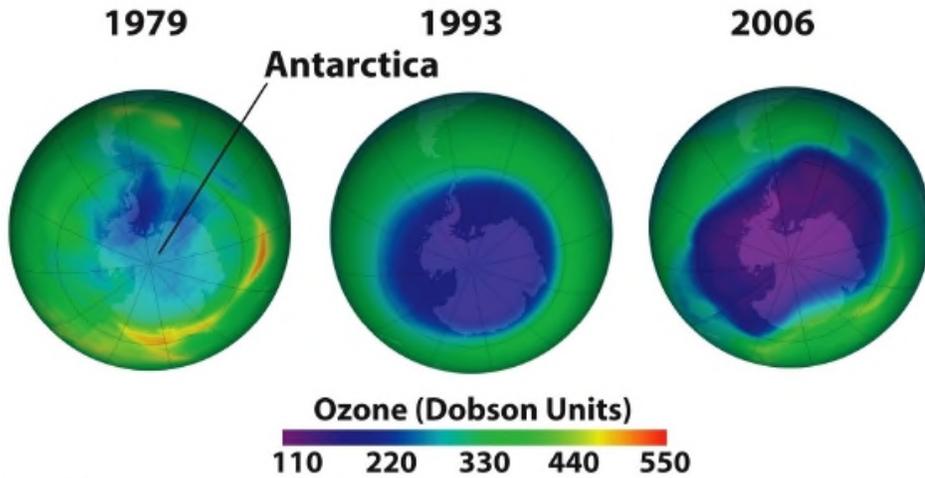
Difficulty level: medium

89. The manufacture and sale of CFCs was very profitable for the DuPont chemical company, and they and other industry scientists actively resisted the ban of them 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 the regulation of their products. What approach to environmental policy was used for the Montreal Protocol? Why is it required that scientists acknowledge any competing interests when they submit a manuscript for publication in a peer-reviewed journal?

Ans: 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 Montreal 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.

Difficulty level: hard

90. Refer to Infographic 2.7. The Montreal 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.

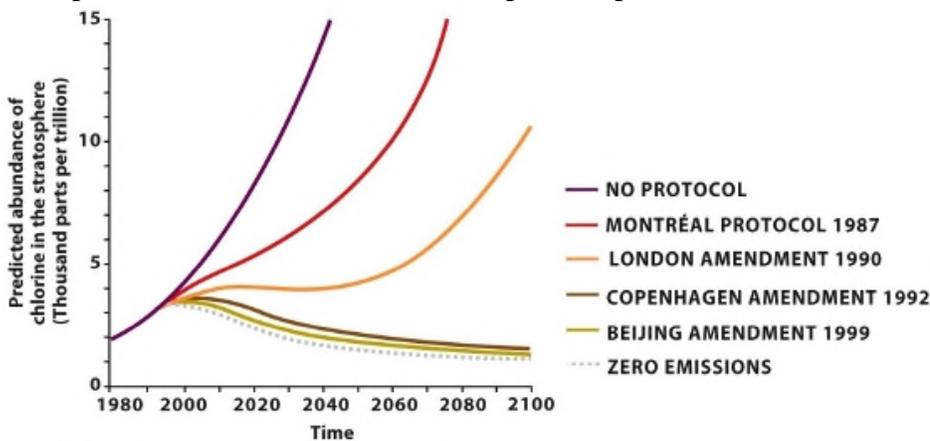


Infographic 2.7b  
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Ans: It takes time for ozone levels to return to normal despite the strides made in CFC reductions. Much of the CFCs released into the troposphere have not yet diffused up into the stratosphere. Also, in wrecking yards around the world, CFCs are likely leaking from old refrigerators or car air conditioners. There is also some limited legal use of CFCs.

Difficulty level: medium

91. Refer to Infographic 2.6. Comparing the Beijing Amendment (1999) to no protocol, by what percent was chlorine in the stratosphere depleted in 2100?

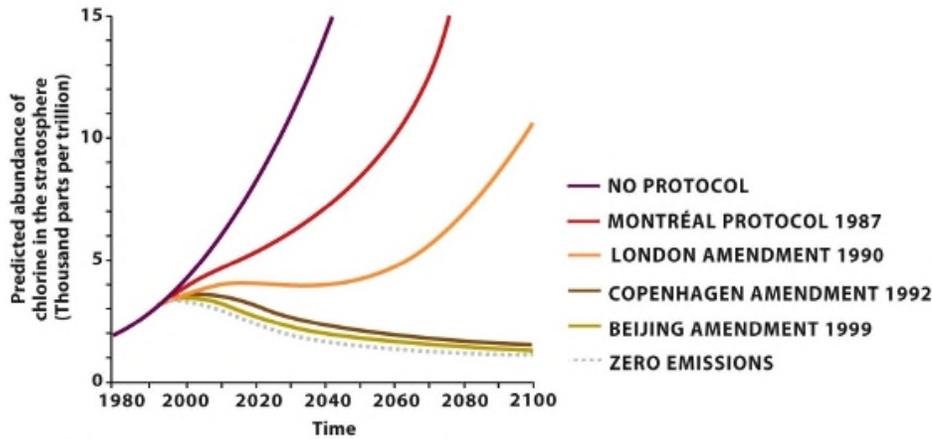


Infographic 2.6  
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Ans: Beijing: 3.5 thousand parts per trillion Cl; compared with no protocol: 6.2.  
% reduction =  $100 * (6.2 - 3.5) / 6.2 =$  about 44% reduction.

Difficulty level: hard

92. Again refer to Infographic 2.6. On the below graph, draw a line representing the predicted abundance of chlorine in the stratosphere for the Environmental Contaminants Act alone. Based on your graph, for the year 2030, would the percent of chlorine in the stratosphere under the Environmental Contaminants Act be higher or lower than the percent under the London Amendment to the Montreal Protocol?



Infographic 2.6  
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Ans: The Environmental Contaminants Acts line would likely fall between the no protocol and Montreal Protocol lines or overlap the Montreal Protocol line, since it occurred before Susan Solomon's studies and were thus based on less of the collected data on ozone depletion. When comparing the Environmental Contaminants Act and the London Amendment to the Montreal Protocol, for the year 2030, there would be a higher percentage of chlorine in the stratosphere under the Environmental Contaminants Act alone.

Difficulty level: medium

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

A. scientific method	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
B. hypothesis	Acting in a way that leaves a safety margin when the data is uncertain or severe consequences are possible
C. testable	Two things occur together—but it doesn't necessarily mean that one caused the other
D. falsifiable	A possible explanation that generates predictions for which empirical evidence can be collected to verify or refute the hypothesis
E. observational study	An idea or a prediction that can be proven wrong by evidence
F. experimental study	Research that gathers data in a real-world setting without intentionally manipulating any variable
G. correlation	An association between two variables that identifies one occurring as a result of or in response to the other
H. cause-and-effect	Procedure scientists use to empirically test a hypothesis
I. precautionary principle	A possible explanation for what we have observed that is based on some previous knowledge
J. independent variable	Plan that allows room for altering strategies as new information becomes available or the situation itself changes
K. adaptive management	The variable in an experiment that is evaluated to see if it changes due to the conditions of the experiment
L. dependent variable	The variable in an experiment that the researcher manipulate or changes to see if it produces an effect

Ans:	A. scientific method	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 (F)
	B. hypothesis	Acting in a way that leaves a safety margin when the data is uncertain or severe consequences are possible (I)
	C. testable	Two things occur together—but it doesn't necessarily mean that one caused the other (G)
	D. falsifiable	A possible explanation that generates predictions for which empirical evidence can be collected to verify or refute the hypothesis (C)
	E. observational study	An idea or a prediction that can be proven wrong by evidence (D)
	F. experimental study	Research that gathers data in a real-world setting without intentionally manipulating any variable (E)

## Chapter 2

G. correlation	An association between two variables that identifies one occurring as a result of or in response to the other (H)
H. cause-and-effect	Procedure scientists use to empirically test a hypothesis (A)
I. precautionary principle	A possible explanation for what we have observed that is based on some previous knowledge (B)
J. independent variable	Plan that allows room for altering strategies as new information becomes available or the situation itself changes (K)
K. adaptive management	The variable in an experiment that is evaluated to see if it changes due to the conditions of the experiment (L)
L. dependent variable	The variable in an experiment that the researcher manipulates or changes to see if it produces an effect (J)