CHAPTER 8 ENVIRONMENTAL HEALTH AND TOXICOLOGY

Chapter Overview

This chapter contains information on diseases and toxins. How and where diseases and toxins move through the environment are examined. Measuring toxicity and its implications are important environmental concepts. Specifically, LD_{50} or LC_{50} is an essential concept for AP students. The ideas of bioaccumulation and biomagnification, with specific reference to food chains, needs to be emphasized. Risk and risk assessment are also stressed. Students need to be versed in a cost/benefit analysis when considering any environmental problem.

Topics and Key Concepts

Pollution

- Identify which specific body systems are impacted by toxins, and be able to link a toxin to a specific physiological impact to that body system.
- Categorize toxins based on their origin, environmental effects, and human health.
- Infer the difference between bioaccumulation and biomagnification in living organisms.
- Design a controlled experiment to test the toxicity of a specific toxin on a living organism using a LC50 or a LC50 test.
- Explain the use of a cost benefit analysis to risk and risk assessment.

Global Change

- Categorize infectious and non-infectious human disease by vector and transmission mode, and indicate if they are historical or emerging.

Key Terms

acute effects
allergens
antigens
bioaccumulation
biomagnification
body burden
cancer
carcinogens
chronic effects
conservation medicine
disability-adjusted life years
disease
*dose response curves
ecological diseases
emergent diseases
endocrine disruptors
environmental health
fetal alcohol syndrome
health
LD50
morbidity
mortality
mutagens
neurotoxins
persistant organic pollutants (POPs)
risk
risk assessment
sick building syndrome
*synergism
teratogens
*toxins

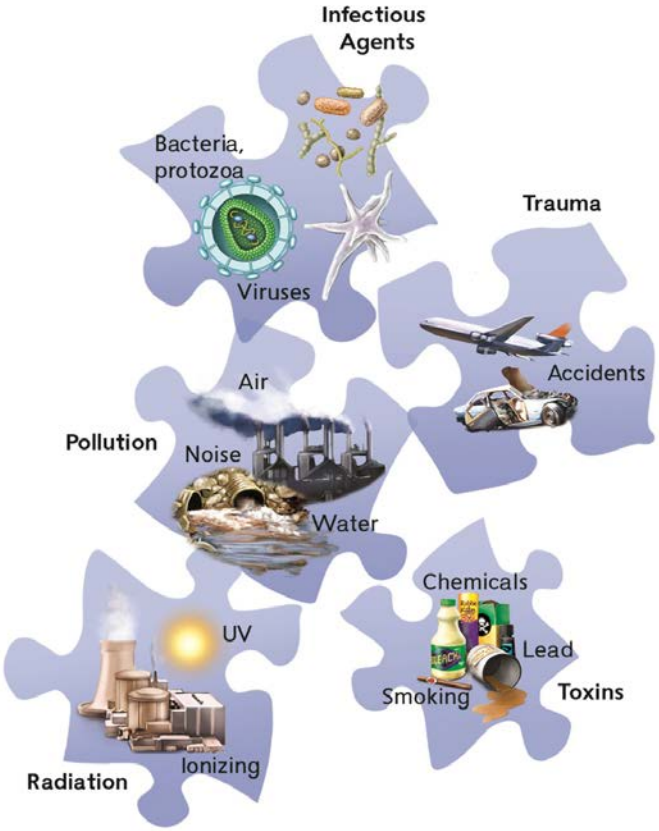
** These key terms are not boldfaced in the chapter text, but are still important for the AP Exam.*

Pacing Guide

Plan to spend 5–7 days on the chapter.

Approach and Tips

Ask students to list the things they do to stay healthy. It is doubtful that their lists will include things such as immunizations and avoidance of toxic substances. Discuss how environmental health plays a role in the general health of the population.



Students should be familiar with common infectious diseases, both historical and emerging (such as SARS, malaria, cholera, and MRSA). Students should know how the infections are transmitted (zoonotic, epizootic, vector-borne, or water-borne). Students need to be versed in several disease including SARS, malaria, cholera, and MRSA. The difference between an acute and chronic disease needs to be stressed. It is essential that the AP student knows the roles of pathogens and vectors regarding the transmission of disease.

Below is a list of some common diseases. Students don't need to memorize all of these, but they are examples which commonly show up on the AP exam. Understanding of these diseases and how they are spread can help students strengthen their answers to free response questions.

Prions	**Viruses**	**Bacteria**	**Protozoa (pared with vector where appropriate)**	**Worms**	**WHO Neglected Tropical Diseases**
BSE	Influenza	Plague (*Yersinia pestis*)	Malaria *(Plasmodium) Anopheles* mosquitoes	*Schistosoma*	Chagas
Scrapie	SARS	Tuberculosis (*Mycobacterium)*	*Cryptosporidium*	*Wuchereria*	Dengue
Varient Crutzfeld-Jakob	West Nile	Cholera (*Vibrio*)	*Entamoeba*	lymphatic filariasis	Chikungunya
Chronic wasting disease	Dengue	*Salmonella*	*Giardia*	*Platyhelminthes* – trematodes (flukes) and cestodes (tapeworms)	African trypanosomiasis
	Ebola	*Shigella*	African trypanosomiasis – tse tse fly		Leishmaniosis
	HIV	*Escherichia coli (esp 0157:H7)*	Chagas Disease – Triatomine bugs		Lymphatic filariasis
	Measles	Methicillin Resistant *Staphylococcus aureus*(MRSA)	*Leishmania* – sand flies		Onchocerciasis – river blindness
	HPV				Guinea worms (Dracunculiasis)
	Hepatitis (A, others)				Leprosy

	Rabies				Schistosomiasis
	Yellow Fever				
	Polio				
	Chikungunya				
	Zika				

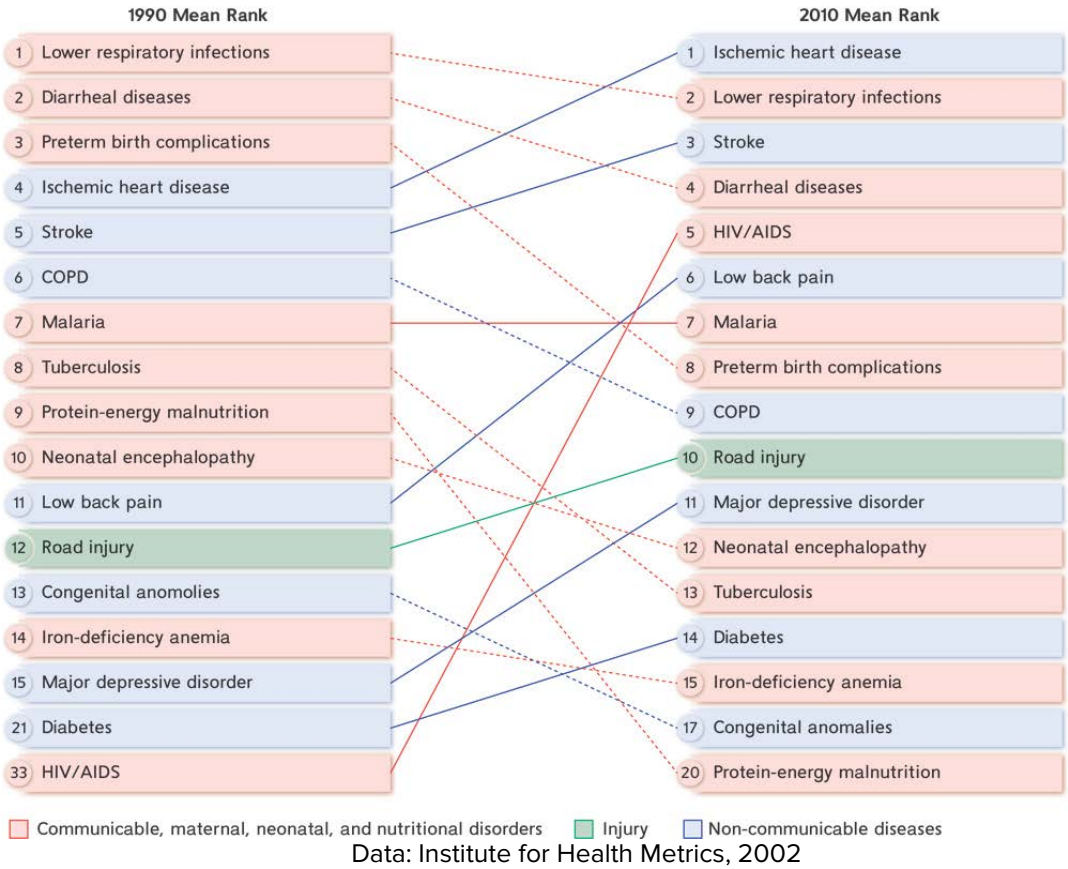
As a discussion of toxins proceeds, explain the differences between the major categories of toxins. Stress the five main types of toxins: endocrine disruptors, neurotoxins, mutagens, teratogens, and carcinogens. Make sure the students know an example of each, where it can be found, and what the effect is on the human body. Endocrine disrupters change the body's regulatory chemistry, which affects our development, our behavior, and our physiology. Neurotoxins disrupt the functions of our nervous system by killing cells and/or disrupting nerve signal transmission. Mutagens and teratogens damage or alter genetic material, causing abnormalities in growth and development. Carcinogens have increased with industrialization. Scientists cite both lifestyle changes and chemicals in the environment as the causes. Emphasize that toxins are found in common household items and affect indoor air quality. Explain sick building syndrome. Students need to know the difference between lethal and sub-lethal human health effects.

Below are some important toxins/pollutants which may show up on the AP exam. You may need to do some research on the various toxins that students should know. Many of the governmental offices that deal with regulation and environmental issues (EPA, USDA, FDA) have information pages on the below toxins.

Aluminum
Arsenic
Asbestos
Benzene
BPA (removed from plastics)
Cadmium
CFCs
CO
CO_2
Copper
Cyanide
Dioxins
Environmental Tobacco Smoke (ETS)
Formaldehyde
Lead
Mercury
Methane
Microplastics
MTBE
NO_2
N_2O
Oil (Petroleum)
Oxygen Demanding Wastes
Ozone
Particulates (PM)
PCBs
Pesticides (3 categories)
Phosphates
Plastics
Radioactive isotopes
Radon
Sediment
SO_2
Thermal Pollution
VOCs

Explain that risk is the possibility of suffering harm or loss and that risk assessment is the scientific process of estimating the threat that specific hazards pose to human health. When asked about environmental problems, students are quite frequently asked to describe costs/benefits of a given scenario. Students need to practice cost/benefit analysis whenever possible, paying particular attention to whether it is economic or environmental costs/benefits. Reference risk assessment programs which establish perceived versus actual risks to determine cost/benefit analysis.

Using the information given in Figure 8.2 of the textbook, ask students to give examples of health risks in their own lives. Then ask them how they could minimize their risk.



Data: Institute for Health Metrics, 2002

Continue the discussion using the information given in Table 8.1 of the textbook. The information comes from the World Health Organization. Discuss the changes in rankings and their relationship to environmental factors such as sanitation, urbanization, exposure to toxins, and the availability of health care. Relate this information to the age structure graphs and demographic transition information from chapter 7.

Review the hydrologic cycle. At some point in the cycle, introduce an industrial pollutant. Have students trace the path of the toxin through the cycle and describe and discuss where the chemical accumulates and why. Expand the discussion to the food chain and how the chemical accumulates and is magnified through the chain. The first documented case of biomagnification was DDT. It was shown to interfere with the reproductive process in raptors. Banning DDT has had a significant impact on the populations of these birds; population numbers increased dramatically since the pesticide was banned in the US. Students should be able to give examples other than DDT.

In her book *Silent Spring*, Rachel Carson wrote extensively about the effects of toxins in the environment. While there may not be time to have your students read the entire book, have them read parts of chapters and summarize what they have learned. There is also a video called American Experience: Rachel Carson's Silent Spring that is available through PBS.

Students should know the concept of synergism and antagonism. Emphasize how the interaction of one substance with another can exacerbate the effects. The importance of whether a substance is fat or water-soluble will be a determinant of the effects of that substance.

All AP students should know how to measure toxicity. Explain that LD_{50}/LC_{50} is one technique used to determine toxicity. LD_{50} (lethal dose) is used if the organism can be given the dose internally; LC_{50} (lethal concentration) is used if the chemical is administered externally to an animal or to a plant.

Students should either conduct an LD_{50} assay on a living organism (such as a plant or *Daphnia*) or complete a paper and pencil simulation to practice generating dose-response curves. If students want to perform an experiment using herbicides and test them on plants, make sure this experiment is performed outdoors. Even low levels of exposure in the classroom can trigger allergic responses and asthma-like symptoms. Regardless of the organism (or simulation) used, students will need to practice graphing data, comparing the dose vs. the % mortality, and using their graph to determine the LD/LC_{50}. Discuss the implications of the results and how this might or might not pertain to humans. Indicate to students that quantitative data is expressed in values or numerical sets and qualitative data is not expressed with numerical values, but as categorical information.

The acceptable levels of various chemicals in our environment and our food are determined through legislation and the establishment of public policies. In the United States, various agencies set the standards and monitor the levels of chemical toxins in the environment. The Environmental Protection Agency (EPA) is one of those agencies.

Table 8.4 (p. 176) from the textbook shows the assessment of risk to our welfare for several problems scientists have been studying over the past few years. Notice that the high-risk problems involve global concerns, whereas the low-risk concerns appear to be more local in scope. This table provides an excellent opportunity to remind students that the concerns are global in scale, that there is no "away," and that actions in one part of the world ultimately affect the entire human population (NIMBY).

Relative Risks to Human Welfare
Relatively High-Risk Problems
Habitat alteration and destruction
Species extinction and loss of biological diversity
Stratospheric ozone depletion
Global climate change
Relatively Medium-Risk Problems
Herbicides/pesticides
Toxics and pollutants in surface waters
Acid deposition
Airborne toxics
Relatively Low-Risk Problems
Oil spills
Groundwater pollution
Radionuclides
Thermal pollution

Source: *Environmental Protection Agency.*

Common Mistakes and Misconceptions

Students need to be sure to know the difference between lethal and sub-lethal effects when referencing effects of toxins. Frequently, an AP student will give a lethal effect when a sub-lethal effect is requested. Along the same line, there needs to be a distinction between chronic and acute effects. When explaining LD_{50}, students need to be clear that it is the lethal dose that kills 50% of the test population. Students simply say organisms or population. An LD_{50} is a laboratory experiment and deals with a test population. Students should also ensure that they know exactly which pollutants elicit which specific human health effects. "Lung problems" isn't enough detail if they are asked about the human health effects of increased ozone; "exacerbates COPD or asthma" would be correct.

Activities

Toxicology Webquest

Provide students with the Toxicology Webquest document found at www.biology.arizona.edu. Students should answer pre-lab questions first, then check their answers and complete the remaining portions of the webquest at the website. Learning guides can be found at the website under Lung Toxicology.

LD_{50} Activity

A common experiment to demonstrate LD_{50} (lethal dose 50) uses *Daphnia* or brine shrimp. Brine shrimp are sold at most pet stores that have aquariums and are easily hatched and grown in a classroom. The brine shrimp are sold in a package that contains everything they need to survive long enough for the experiment to take place. Follow the instructions on the brine shrimp package to hatch and grow the shrimp. It will generally take about a week or two before the brine shrimp are large enough to see and remove with forceps, so make sure to hatch them in plenty of time before you plan to do this experiment.

Using the template for experimental design from chapter 2, have the students plan their investigation. You can order chemicals from a chemical supply company. They then put it into the IVCDV chart. The chart would look something like this:

Independent Variable (IV)	Constant (C)	Dependent Variable (DV)
Examples of items to be tested: Copper sulfate Herbicide	Brine shrimp Temperature Container Water Salinity	Mortality

The students would then set up serial dilutions of 10%, 1%, 0.1%, 0.01%, and the control (the shrimps' aquarium water). Do this by starting with 90 mLs of water and 10 mLs of the item they are testing. This makes the 10% solution. (Make sure they are only testing one item.) Then, take 10 mLs of the 10% solution and add 90 mLs of water. This makes the 1% solution. Continue diluting in the same manner to make the 0.1% and 0.01% solutions.

Next, the students will need 5 containers that will hold the brine shrimp and the different diluted solutions. Small beakers, medium to large test tubes, or empty petri dishes will work. Put 10 mLs of each of the solutions into the container and add 50 mLs of the salt water that the brine shrimp are in. Add 10 brine shrimp to the container using a pipette or forceps.

Have the students perform observations, complete a data analysis, and write conclusions by completing the worksheet located at the end of this teacher's manual chapter.

Questions for Review

1. How do people contract malaria? What was the disease vector? Is this a chronic or an acute condition? Why? Could this illness have been prevented? How?
   People are bitten by a mosquito that has a plasmodium in its salivary glands. The vector is the Anopheles mosquito. Malaria can be either chronic or acute. It can be deadly in a short period of time making it an acute disease. But, it also has the distinction of lasting for a long period of time, which would make it chronic. Malaria can be prevented by using either mosquito nettings on beds or by using insecticides that kill the mosquito. The key is not to get bitten by a mosquito. There are also drugs that can be taken before, during, and after a trip to an area that is prone to malaria.

2. Why does every human have some persistent organic pollutants (POPs) in his/her body? How might these chemicals have gotten there? Where are these chemicals most likely to be stored in the body? Why? How might the chemicals affect our health? Is this a chronic or an acute exposure? POPs are very pervasive in the environment, and in products that people regularly use in their homes.
   One of the most common POP is BPA which is used in the production of plastics and can leach from plastics that are heated in a microwave. POPs are accumulated in food chains and can reach toxic concentrations in long-living top level predators like the swordfish. Substances that do not break down readily are called persistent. Many substances have POPs as part of their production. Food packaging, toys, plastics and herbicides are all materials that contain POPs. They are fat soluble and stored in fatty tissue in the human body. Cancer, reproductive issues, birth defects, and neurological damage are all results of POPs. Exposure in most cases appears to be chronic.

3. How do toxins biomagnify and which animals are most affected?

The top level predators are affected the most. This is because toxins biomagnify by building up in the tissues of prey organisms. Higher level consumers must eat a large quantity of prey, leading to high toxin concentration in their tissue.

4. What is sick building syndrome? What are the symptoms of sick building syndrome?
   Sick building syndrome is caused by poorly vented indoor air contaminated by mold spores, carbon monoxide, nitrogen oxides, formaldehyde, and other toxins released from carpets, insulation, plastics, building materials, and other sources. This can occur in office buildings where employees may complain of headaches, allergies and chronic fatigue.

5. In toxicity testing, what is LD50? What is a threshold level?
   LD50 means lethal dose 50. This refers to the dose of a substance that kills 50% of the test population. The threshold level refers to the dose below which no effect is seen, and above which deleterious effects are seen.

Practice Questions

Multiple Choice:

Directions for questions 1-5: The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

(A) endocrine disruptors
(B) mutagens
(C) teratogens
(D) carcinogens
(E) allergens

1. formaldehyde and PCBs

2. thalidomide and alcohol

3. smoke from cigarettes and sun overexposure

4. causes abnormalities during embryonic growth

5. BPA and dioxin

6. The SARS disease has been reported to have started with
   (A) mosquitos carrying the virus
   (B) Asian chicken markets
   (C) monkeys imported from South America
   (D) crows from the Mid-western United States
   (E) exotic birds imported from Central America

7. All of the following are reason why parasites and diseases are spreading into new area except
   (A) increase in ocean temperatures
   (B) increase in precipitation
   (C) increase in the range of a species
   (D) decrease in tundra temperatures
   (E) increase in tolerance to insecticides

Use the following description for questions 8-10.

In a small pond it has been observed that phytoplankton are eaten by minnows. The minnows are a food source of a small mouth bass. The small mouth bass is one of the favorite foods of an eagle. Nearby, a fruit orchard uses pesticides to eliminate a beetle that eats their fruit. A stream runs through the orchard and empties into the pond.

8. Which of the following organisms will contain the highest amount of pesticide in their body?
   (A) beetles
   (B) minnows
   (C) phytoplankton
   (D) small mouth bass
   (E) eagle

9. Identify the phenomenon responsible for the result in question number 8.
   (A) biomagnification
   (B) LD50
   (C) food chain result
   (D) pesticide build-up
   (E) bioillumination

10. Identify the process that causes the pesticide to accumulate in the pond.
   (A) The carbon cycle carries the pesticide to the pond
   (B) The pesticide travels to the pond by the nitrogen cycle
   (C) Run-off of pesticide into the stream when it rains
   (D) The phytoplankton change the pesticide into nutrients for the minnows
   (E) The water from the pond changes nutrients in the pond to pesticides

Free-Response Question:

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. An experiment was performed to test the toxicity of atrazine using brine shrimp and the following data was collected.

Dose	% Mortality
0.01 mg/L	5
0.10 mg/L	5
0.20 mg/L	10
0.30 mg/L	40
0.40 mg/L	70
0.50 mg/L	90
0.60 mg/L	100
0.70 mg/L	100
0.80 mg/L	100

(a) Graph the data. Use a sigmoid shaped curve to connect the points.

(b) From the graph:

(i) Determine the LD50.
(ii) Explain the meaning of LD50.
(iii) On the graph, label the threshold level of toxicity.
(iv) Define the threshold level of toxic.

(c) Can these results tell you about the possible toxicity of atrazine to humans? Explain your answer.

(d) It was found when atrazine was combined with another toxic substance the results of the LD50 experiment was much greater than the two substances combined. What is this called? Explain how this happens.

Answers to Practice Questions

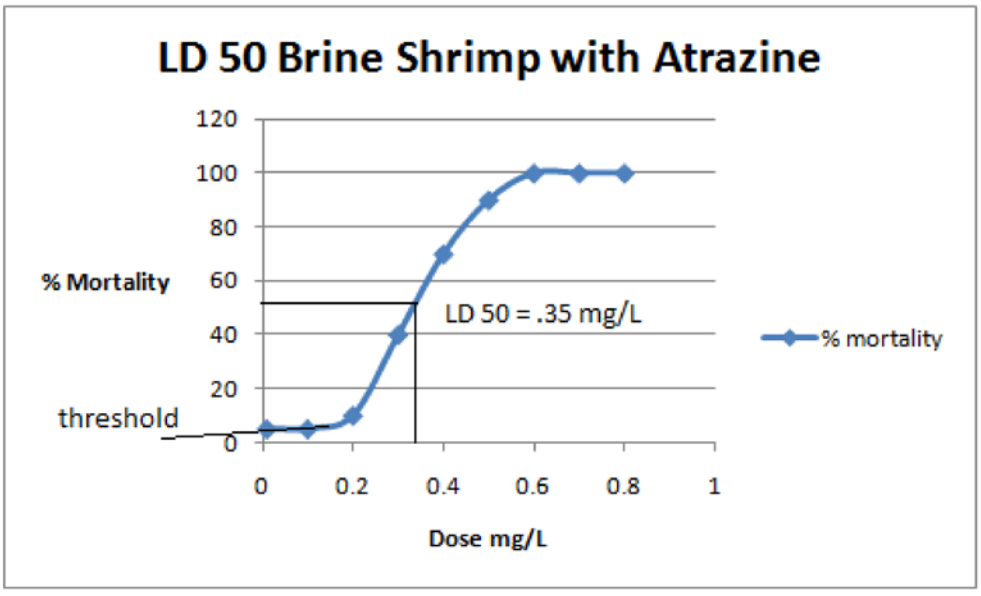
Multiple Choice:

1. A
2. C
3. D
4. C
5. A
6. B
7. D
8. E
9. A
10. C

Free-Response Question:

This question is based on 10 points.

1. (a) 2 points total. 1 point for correctly plotting all points and 1 point for drawing a sigmoid curve through all points.



(b) (i) 1 point for determining the LD50. LD50 = 0.35 mg/L

(ii) 1 point for the correct definition of LD50. It is the dose that kills 50% of the test population.

(iii) 1 point for correctly labeling threshold on the graph.

(iv) 1 point for defining threshold level of toxicity. It is the dose below which no measurable effect is shown.

(c) 2 points total. 1 point for answering either yes or no and 1 point for the explanation. If the answer is yes, then the student needs to explain that the substance is toxic to a living organism so it is very likely that it could be toxic to humans as well. If the answer is no, then some difference between humans and brine shrimp should be noted.

(d) 2 points total. 1 point for the answer synergism and 1 point for the explanation. Synergism is the interaction of the two substances where the effect of the two is worse than the total of the individual effects of each substance.

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (page 154)

(A) The 1976 Toxic Substances Control Act regulates the EPA's ability to investigate a chemical because it is much more difficult to prove that a chemical does no harm than proving that a substance is harmful. Determining that a substance is harmful is difficult because oftentimes that requires a study done on humans that indisputably concludes that the substance definitely causes harmful effects. It also assumes that all chemicals are safe, so oftentimes testing is not done until a lawsuit or some deleterious effects of the chemical are noticed by consumers. Potentially harmful chemicals can be on the market for years before the proper regulatory agencies find out that the chemicals are actually harmful. If a chemical is assumed to be harmful and needs to be proven as safe before use, that means that all chemicals must go through extensive testing in order to be put into the hands of consumers.

(B) Answers will vary.

AP Connections Review Answers (pages 175-176)

Multiple-Choice

1. c. Avian influenza (SARS) is an example of an emergent disease because it is not currently prevalent. All of the other diseases are, unfortunately, common.

2. c. An endocrine disrupter would interfere with hormone function. A neurotoxin could cause difficulty breathing and impair nerve impulse transmission. A mutagen would induce mutation in body cells, and a teratogen would cause birth defects.

3. c. The best reason for extrapolating mouse LD_{50} studies to humans would be that mice likely metabolize a toxin as humans metabolize it. The fact that mice have a different size, physiology, and metabolic rate would make the case for not extrapolating human data and because they might respond differently from a guinea pig, they likely would not respond the same as a human.

4. b. All of the other examples are of biomagnifications of toxins in apex predators.

5. b. Embryonic cells are affected by teratogens such as alcohol.

6. c. Children can be more susceptible to inhaled toxins because they breathe more rapidly than adults allowing mor exposure to occur.

7. a. Hazardous chemicals can be flammable, cause an allergic response, irritate the skin, or burn the skin. Mutagens induce mutation.

8. e. Tuberculosis is a respiratory (air-borne) diseases.

Data Analysis and Free-Response Questions

1A Most of the chemicals in the figure (radioative waste, PCBs, DDT, and even lead) fall between medium and high on the "Dread Level" perception of risk.

1B When assessing risk, we often consider the mystery, newness, or unknown delayed effects of exposure or usage.

1C

i Answers may include the following: Human health impacts of lead include: neurological damage (acts as a neurotoxin), decreased mental ability and IQ level, kidney damage, anemia, issues with fertility, behavioral problems, genital deformities, and cancer.

ii Lead enters the body through inhalation or consumption and then moves into the blood stream. Over time, cells selectively absorb and store lead, eventually reaching dangerous levels.

2A i-iv Answers will vary, but can rely upon the discussion of dose-response curves (p.168) and the brief discussion of PCBs on p. 162.

2B Reasons that animal research would support toxicity in humans are that we have similar methods of breathing and reproduction, consume similar food sources, and have similar responses to toxins. Reasons that animal research may not explain human toxicity are that urelated species can react differently based on differences in body size, physiology, metabolism, and genetics.

LD_{50} Activity Worksheet

*Student:*_____

Independent Variable (IV)	Constant (C)	Dependent Variable (DV)

Procedure:

1. Set up serial dilutions of 10%, 1%, 0.1%, 0.01%, and the control.

2. Put 10 mLs of each of the solutions into 5 separate containers and add 50 mLs of the salt water that the brine shrimp are in. Add 10 brine shrimp to the container using a pipette or forceps.

3. Observe the brine shrimp in class the next day and record the results in the chart.

Concentration	Number of dead brine shrimp
10%	
1%	
0.1%	
0.01%	
Control	

Data Analysis:

1. Determine the percent mortality for each concentration.

2. Graph the concentration vs. % mortality.

3. Using your graph, determine the LD_{50} for your substance.

Conclusions:

1. What is the LD_{50} of your substance on brine shrimp?

2. Ask other students in the class and find out which substance had the worst LD_{50} levels. What does this tell you about that substance, and how will that information change what you eat or how you live?

3. Do you think your results are valid? Why or why not?