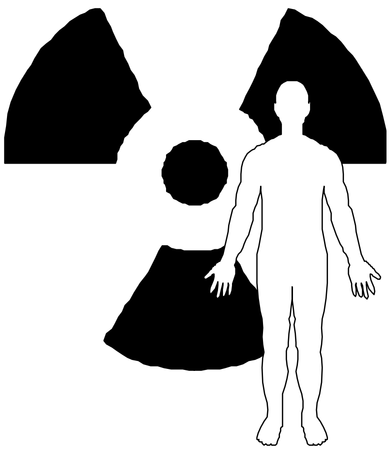
UNIT THREE

BIOLOGICAL EFFECTS AND INTERNAL HAZARDS OF RADIATION EXPOSURE



Unit Two reviewed the mechanism by which ionizing radiation may cause biological damage. That mechanism can be summarized by saying that ions created by radiation, as well as new compounds formed by the pairing up of the ions, disrupt cell organization and function. For radiological emergency responders, the potential biological effects of radiation exposure are important considerations.

You have studied biological effects and internal hazards of radiation in other courses. This unit will incorporate a review of some important basic concepts and introduce a few new terms and details that will better prepare you for radiological emergency response operations.

GATE FRAME QUESTION

You have responded to an accident involving a truck containing radionuclides destined for a research facility. The Incident Commander tells you that a package found on the ground indicates that it contains 0.2 Ci of iodine-131 (I-131). I-131 is a beta emitter, with a radioactive half-life of 8 days.

What potential biological effects are associated with radiation exposure to this type of material, and what factors determine the extent of potential biological damage by this material? (Use another sheet if needed.)

ANSWER

Your answer should include the adjacent information.

The radiation health effects from beta-emitting radionuclides such as I-131 may be early (acute) or late (chronic). Early affects, which occur within two or three months after exposure, include skin damage (such as "beta burns"), loss of appetite, nausea, fatigue, and diarrhea. Late effects, which can occur years after exposure, include cancer, cataracts, and genetic effects.

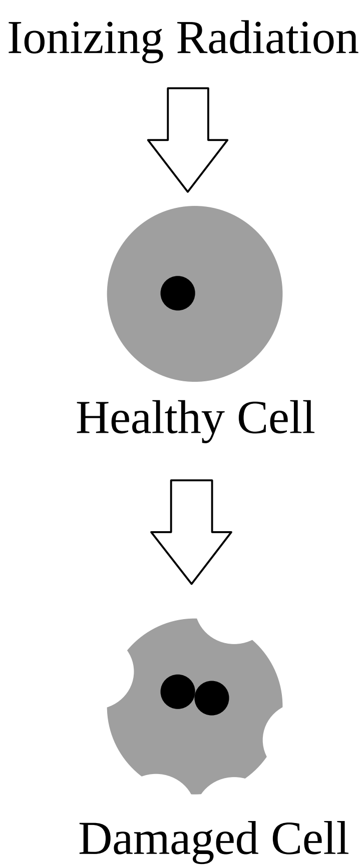
While I-131 is highly radioactive, the amount contained in the intact package would not elicit early effects unless it was ingested. If the package of I-131 were broken, exposure to 0.2 Ci could lead to late effects on health.

The factors that determine the level of biological damage include the following:

- Amount of exposure (measured in rads or rems);
- Duration of exposure (or how long it takes to receive the dose);
- Type of radiation (in this case, beta);
- Exposed person's age, sex, general health, rate of metabolism, size, and weight (collectively referred to as the biological variability factors); and
- Portion of the body exposed (the volume and type of tissue irradiated will influence the response).

If your answer included all or most of the above points, you should be ready for the Summary Questions at the end of this unit. *Turn to page 3-40.*

If your answer did not include these points, it would be advisable for you to complete the programmed instruction for this unit. *Turn to page 3-3.*



RADIATION DAMAGE

Radiation damage affects the vital structure of cells. The effects on these cell structures lead to a wide variety of changes within the cell, which can result in death of the cell or the entire organ, and changes in the genetic makeup of an individual that can lead to delayed effects. These effects cannot be distinguished from damage caused by various chemicals and viruses.

There are two general mechanisms of radiation damage in biological systems: direct action and indirect action mechanisms.

The *direct action mechanism* occurs because of direct insult to a molecule by the ionizing radiation and the consequent breakup of the molecule. In this way, radiation can damage cells by changing the structure of various organic molecules such as enzymes, DNA, and RNA. For example, the molecular structure of enzyme X, which is essential to the formation of energy used by the cell, is changed by radiation. Consequently, energy for the cell can no longer be produced and cell metabolism is disrupted. This disruption causes the cell to die.

The *indirect action mechanism* occurs when water in the body is irradiated. The water molecule is split. The resulting *free radicals* can then damage the cell. A free radical is an atom or molecule that has a single unpaired electron in one orbit (as compared to most electron orbits, which have pairs of electrons). The splitting of water occurs when radiation strikes a water molecule.

The following general formulas outline the processes involved in the breaking down of water. H^o symbolizes the hydrogen radical. OH^o symbolizes the hydroxyl radical.

Radiation

$\downarrow$

$H_2O \rightarrow H^o + OH^o$	Free Radicals
$H^o + H^o \rightarrow H_2$	Hydrogen Gas
$H^o + OH^o \rightarrow H_2O$	Water
$OH^o + OH^o \rightarrow H_2O_2$	Hydrogen Peroxide (poison)
$H^o + O_2 \rightarrow HO_2^o$	Peroxyl Radical

Free radicals, hydrogen peroxide, and the peroxyl radical are extremely harmful to a living cell. The formation of the highly poisonous hydrogen peroxide from recombined free radicals is referred to as the "Poison Water Theory."

To test whether you can distinguish between the direct and indirect mechanisms of radiation damage, answer the following question.

QUESTION

Circle the correct answer.

When radiation damages cells by changing the structure of various organic molecules such as enzymes, DNA, and RNA, which mechanism occurs?

a. direct action mechanism.

b. indirect action mechanism.

Turn the page to check your answer.

ANSWERS

a. Correct. Recall that the direct action mechanism occurs because of direct insult to a molecule by ionizing radiation. This may cause harmful effects within the cell because the radiation changes the structure of the molecule, which in turn changes its function.

Proceed to the next section.

b. Wrong answer. As its name implies, the indirect action mechanism affects cells indirectly by eliciting a series of events (or processes) that lead to the formation of highly reactive molecules and ions that are poisonous to the cell.

Try another question.

QUESTION

Circle the correct answer.

In the "Poison Water Theory," the extremely harmful hydrogen peroxide is formed from the free radicals generated after water is hit by radiation. These free radicals, along with hydrogen peroxide and peroxyl radicals, damage cells via the

a. direct action mechanism.

b. indirect action mechanism.

Turn the page to check your answer.

ANSWERS

a. No, in the given example, radiation harms cells indirectly by breaking up water molecules into extremely harmful molecules and atoms. In contrast, the direct action mechanism occurs because of a *direct* insult to a molecule by the ionizing radiation.

Return to page 3-3 and review this section.

b. Exactly. You were able to recognize the culprits of radiation damage (free radicals, hydrogen peroxide, and peroxyl radicals), as well as the mechanism by which this damage occurs. In the indirect action mechanism, the radiation itself does not damage the cells; it instead causes the formation of highly reactive molecules and ions that are very harmful to the cell.

Move on to the next section.

RADIATION EFFECTS

Radiation effects are generally classified as *early* (or *acute*) and *late* (or *chronic*). The terms early and late refer to the length of the latent period after the exposure. The *latent period* is the time interval between dose and detection of symptoms.

Type of Effect	**Manifested**
Early (Acute)	2-3 Months
Late (Chronic)	Up to years after exposure

Early (acute) radiation health effects are those clinically observable effects on health that are manifested within two or three months after exposure. Their severity depends on the amount of radiation dose that is received. Examples of acute radiation effects include skin damage, loss of appetite, nausea, fatigue, and diarrhea. Late effects can occur years after exposure; examples are cancer, leukemia, cataracts, and genetic effects.

Radiation damage can be repaired if the dose received is not too high and if the dose is received over a long period of time. The time period after the appearance of symptoms and during which repair occurs is called the *recovery period*.

To check your understanding of these concepts, answer the following question.

QUESTION

Circle the correct answer.

In the 1950s, people accidentally contaminated by radioactive fallout from nuclear weapons testing developed beta burns and hair loss. The victims recovered from these effects within approximately six months.

These radiation effects would be classified as

a. early (acute) effects.

b. late (chronic) effects.

Turn the page to check your answer.

ANSWERS

a. Right! You seem to grasp the difference between early and late radiation effects. “Beta burns” occur within hours to days after exposure, and this constitutes an acute radiation effect. However, if years after exposure this individual develops cataracts, it is a *possibility* that the beta exposure is the cause, in which case the effect would be considered a late effect.

Move on to the next section.

b. No, “beta burns” occur within hours to days after exposure. Late, or chronic, effects do not appear until years after radiation exposure. For example, late effects such as cancer and leukemia develop many years after the individual’s exposure to radiation.

Try another question.

QUESTION

Circle the correct answer.

The latent period for acute effects is _________ than that for chronic effects.

a. shorter.

b. longer.

Turn the page to check your answer.

ANSWERS

a. Very good. You remembered that the terms "early" and "late" refer to the length of the latent period after radiation exposure. Since early (acute) effects occur within two or three months after exposure, the latent period also would be within that time period. On the other hand, late (chronic) effects occur years after exposure, therefore the latent period may be many years.

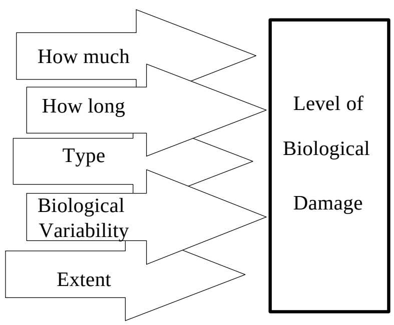
Proceed to the next section.

b. Incorrect. There are actually three concepts presented in this question, and it requires knowledge about all of them to get the answer right. First, the latent period is defined as the period of time when no symptoms or effects are manifested after radiation exposure. Second, you need to know that the terms used to define radiation effects—"early" and "late"—refer to the length of the latent period after radiation exposure. Finally, you should know that early (acute) effects occur within a few months after exposure, so the latent period would be of similar duration. Late (chronic) effects occur years after exposure, so the latent period would also be long.

Return to page 3-7 and review this section.

FACTORS AFFECTING RADIATION DAMAGE

The following factors determine the level of biological damage.



- *Amount of exposure* (or size of the dose received).
- *Duration of exposure* (or how long it takes to receive the dose). This significantly affects the biological result since the body can repair most of the damage (even throughout the duration of exposure).
- *Type of radiation*. Is it gamma, beta, or alpha?
- *Biological variability factors*. These include the exposed person's age, gender, general health, rate of metabolism, size, and weight.
- *Portion of the body exposed*. The extent (volume) of tissue irradiated will influence the response. Most risk estimates, unless otherwise specified, are based on *whole body* exposures or doses. Different tissues have varying sensitivities to radiation.

The following question is intended to test your understanding of these concepts.

QUESTION

Circle the correct answer.

Of the five factors that influence radiation damage, the one that takes into account the varying sensitivities of different organs or tissues to radiation is

a. the general health of the individual.

b. the portion of the body receiving the dose.

Turn the page to check your answer.

ANSWERS

a. No, the general health of the individual is a biological variability factor and does not determine how much or which tissue is damaged by radiation. The portion of the body exposed, however, does influence the level of biological damage. Some tissues or organs are more sensitive to radiation than others.

Try another question.

b. Correct answer! Since different organs or tissues respond to radiation differently, the portion of the body exposed to radiation greatly influences the extent of radiation-induced biological damage.

Move on to the next section.

QUESTION

Circle the correct answer.

If you were conducting an assessment of the potential for radiation-induced biological effects of a radiation accident, which of the following could be determined with radiation detection instruments?

a. biological variability factors.

b. type of radiation.

Turn the page to check your answer.

ANSWERS

a. No, biological variability factors include the exposed individual's age, sex, general health, rate of metabolism, size, and weight. These factors are not measurable using radiation detection instruments. The type of radiation, on the other hand, can be measured using appropriate radiation detection methods.

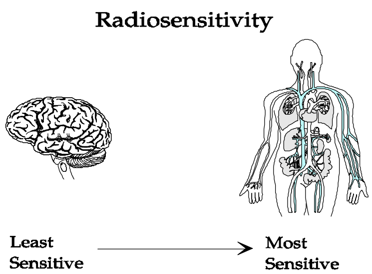
You should return to page 3-10 and reread that section.

b. That is correct. Special radiation detection methods can determine whether gamma, beta, or alpha radiation is present. This type of information, along with the other factors discussed in this section, is useful in determining the extent of biological damage due to radiation.

Proceed to the next section.

RADIOSENSITIVITY

The sensitivity of various cell types can differ markedly, and many organs in the human body have different cell types. In the mature adult, some organs consist of cells that are designed to perform a special function, but essentially no cell division takes place.



- For example, the brain which contains a vast number of special functioning cells, is less radiosensitive than other organs. However, if the brain or any other part of the central nervous system is damaged during adult life, no repair can take place because there are no dividing cells.

Many other tissues, even in the mature adult, contain dividing cells because they have to be replaced continually throughout life.

- For example, the skin, the lining of the stomach and intestines, and the blood system are subject to so much wear and tear that they must be replaced continually by cell division.

Between these extremes lie the vast majority of the tissues of the body, in which cells seldom divide under normal circumstances, but are able to do so if and when the need arises in order to repair damage.

- For example, in the liver there is essentially no cell division under ordinary circumstances. However, if part of the liver is removed by surgery, the remaining cells are triggered into rapid division to make up the loss.

In 1906, Bergonié and Tribondeau examined the cells that were sensitive to radiation. The Bergonié and Tribondeau Law states that cells are radiosensitive if they have a high division rate, have a long dividing future, and are of an unspecialized type.

The *most* radiosensitive cells in humans are mature lymphocytes (white blood cells), erythroblasts (premature red blood cells), and spermatogonia cells (premature sperm cells).

The *least* radiosensitive cells are muscle cells, bone cells, and nerve cells. Both muscle and nerve cells are highly specialized (that is, designed to perform a special function), and when mature are incapable of cell division.

Let's pause now and apply this concept. Answer the following question.

QUESTION

Circle the correct answer.

Given the same amount, duration, and type of radiation exposure, every tissue in the body will be affected to the same degree.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. The sensitivity of various cell types can differ markedly, and many organs in the human body have different cell types. So, each cell type and each organ within the body will respond differently to radiation, depending upon whether it is has a high cell division rate, a long dividing future, and is of an unspecialized type (Bergonié and Tribondeau Law).

Try another question.

b. You are correct, this statement is false because sensitivity to radiation of various cell types can differ drastically. In fact, there are some organs in the body that consist of different cell types with differing degrees of radiosensitivity. The biological response to radiation even by one organ can be very complex.

Move on to the next section.

QUESTION

Circle the correct answer.

Muscle cells, which are highly specialized and incapable of cell division, are ________ sensitive to radiation than are lymphocytes (white blood cells), which are unspecialized and capable of cell division.

a. more.

b. less.

Turn the page to check your answer.

ANSWERS

a. No, recall that the Bergonié and Tribondeau Law states that cells that are of an unspecialized type and capable of cell division are more sensitive to radiation (are more radiosensitive) than are cells that perform a special function and are incapable of cell division. Muscle cells are highly specialized and do not divide (reproduce), whereas lymphocytes are replaced continually by cell division and are unspecialized.

Return to page 3-13 and review this section.

b. Correct answer. You clearly understand that cells that perform a special function and are incapable of cell division are less sensitive to radiation (less radiosensitive) than are cells that are of an unspecialized type and capable of cell division.

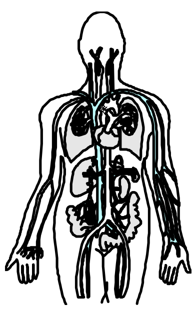
Proceed to the next section.

ACUTE RADIATION SYNDROME

The *acute radiation syndrome* is a set of symptoms that result from short-term radiation overexposures. Symptoms become more severe as radiation doses to the body increase. This syndrome has several forms but all manifest themselves within the first 30 days following exposure and are related to the magnitude of the absorbed dose.

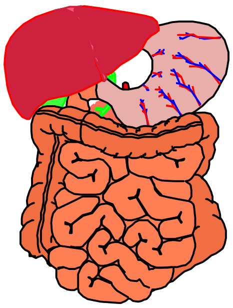
The acute radiation syndrome is divided into three classes: the *hemopoietic syndrome*, the *gastrointestinal syndrome*, and the *central nervous system syndrome*. Some symptoms are common to all three classes; these include nausea and vomiting, malaise (a feeling of lack of health) and fatigue, increased body temperature, and blood chemistry changes. As mentioned earlier, manifestation of illness is a function of dose. No noticeable physical effects result from doses of less than 100 rem. However, some changes in the blood are observable through laboratory testing at about 25 rem.

HEMOPOIETIC SYNDROME



At 100-1,000 rem, the *hemopoietic syndrome* occurs. Symptoms are most usually seen after exposures of 200 rem or more. The degree of severity depends on the dose. Physiological symptoms are destruction or depression of bone marrow, which produces the red blood cells that carry oxygen to every cell in the body and carry away the waste material of the cells. The bone marrow also produces platelets, which contain the blood-clotting factors. Physical symptoms of this syndrome include nausea and vomiting within hours, malaise and fatigue, epilation (hair loss) between the second and third week after exposure, and death, which may occur within one to two months.

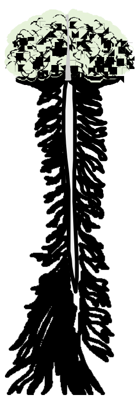
GASTROINTESTINAL SYNDROME



At 1,000 - 2,000 rem, the *gastrointestinal syndrome* occurs. Initial symptoms are they same as the hemopioetic syndrome. Usually severe nausea, vomiting and diarrhea occur within hours. Death usually occurs within one to two weeks.

Physical symptoms are destruction of the lining of the intestines and internal bleeding.

CENTRAL NERVOUS SYSTEM SYNDROME



Above 2,000 rem, *central nervous system syndrome* occurs. Damage to the nervous system occurs in addition to symptoms of the hemopoietic and gastrointestinal syndromes. Unconsciousness occurs within minutes. Death occurs within hours to days.

As a radiological emergency responder, it is important that you understand the different phases of the acute radiation syndrome. Answer the following question to test your knowledge.

QUESTION

Circle the correct answer.

Physiological symptoms of the acute radiation syndrome become

a. more severe as radiation doses to the body increase.

b. less severe as radiation doses to the body increase.

Turn the page to check your answer.

ANSWERS

a. Yes, you understand that the manifestation of illness in the acute radiation syndrome is a function of dose. This syndrome can be described by three separate syndromes: hemopoietic, gastrointestinal, and central nervous system; each occurring at different and increasing levels of radiation exposure.

Proceed to the next section.

b. No, as radiation doses to the body increase, physiological symptoms become *more* severe. Manifestation of illness is a function of dose; as the radiation dose (or the rem) increases, the radiation-induced health effects and symptoms become more life-threatening. Recall that the acute radiation syndrome is divided into three classes: the hemopoietic syndrome, the gastrointestinal syndrome, and the central nervous system syndrome.

Try another question.

QUESTION

At 1 to 99 rem of radiation exposure, which syndrome occurs first?

Circle the correct answer.

a. The hemopoietic syndrome.

b. No noticeable effects result

Turn the page to check your answer.

ANSWERS

a. Incorrect. The hemopoietic syndrome occurs at higher rem levels (100-1,000 rem).

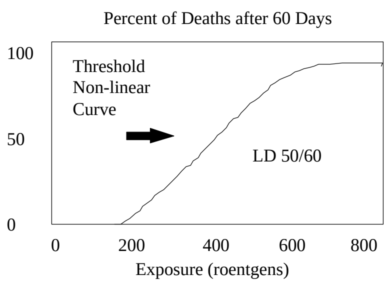
You should return to page 3-17 and reread that section.

b. Correct. At these radiation doses, no physical effect is detected. The majority of field radiological incident responses will involve doses that fall into this lower range. The EPA recommended dose limit for emergency workers is 25 rem.

Proceed to the next section.

$LD_{50/60}$

The whole body dose is the dose resulting from uniform exposure of the entire body to either internal or external sources of radiation. The whole body absorbed dose required to cause death is characterized generally by a median lethal dose (LD_{50}). LD_{50} refers to a dose required to kill 50 percent of the persons irradiated, and it assumes no medical intervention.



It is usually necessary to establish a *rate* with regard to the mortality, which typically is referred to as the $LD_{50/60}$. These are doses that might be expected to result in death in half of the individuals within 60 days.

For humans, the $LD_{50/60}$ from radiation is about 300 rad. This does not account for people who die after 60 days. (Source: EPA 400-R-92-001, May 1992)

Let's pause now and review this concept. Read the following statement and determine whether it is true or false.

QUESTION

The median dose for lethality (LD_{50}) is the radiation dose required to kill a person in 50 days.

Circle the correct answer.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. The number "50" refers to the percent mortality, or the percentage of people who die from the LD_{50} dose. Recall that the term LD_{50} refers to the dose required to kill *50 percent* of the persons irradiated, assuming no medical intervention. Another example would be the LD_{25}, which would be the radiation dose that would kill 25 percent of the individuals irradiated, assuming no medical intervention.

Try another question.

b. Correct answer. LD_{50} refers to a dose required to kill 50 percent of the persons irradiated, and it assumes no medical intervention. The number "50" in the median lethal dose refers to the percent mortality, or the percentage of people who die from the LD_{50} dose.

Move to the next section.

QUESTION

The $LD_{50/60}$ is the radiation dose that would cause

Circle the correct answer.

a. 60 percent mortality in 50 days.

b. 50 percent mortality in 60 days.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. In the term $LD_{50/60}$, the number "50" refers to the percentage of irradiated persons who die from the dose. The number "60" is the length of time (in days) it would take for those deaths to occur.

Return to page 3-21 and review this section.

b. Correct! You understand the meaning of the two numbers describing the median lethal dose.

Move on to the next section.

LONG-TERM EFFECTS OF RADIATION EXPOSURE

The effects of radiation on human beings may be expressed in different ways, depending upon the size of the dose. They may be categorized as somatic effects, stochastic effects, nonstochastic effects, carcinogenic effects, lifespan-shortening effects, embryologic effects, and genetic effects.

SOMATIC EFFECTS

Somatic effects occur in the body of the individual who has been exposed to ionizing radiation. They cannot be passed to future generations. The term “somatic” pertains to the body. Somatic effects may be either stochastic or nonstochastic.

STOCHASTIC EFFECTS

Stochastic effects occur by chance and among unexposed as well as exposed individuals. These effects are not unequivocally related to exposure. The typical stochastic effect is cancer induction.

NONSTOCHASTIC EFFECTS

Nonstochastic effects are those associated with cellular and functional abnormalities in certain tissues (such as radiation-induced skin ulcer). In contrast to stochastic effects, the magnitude of the nonstochastic effect increases with the size of the dose. There is a clear causal effect between exposure and effect. However, a certain minimum dose must be exceeded before the particular effect is observed.

CARCINOGENIC EFFECTS

Carcinogenic effects, or cancers, are produced when a cell goes berserk, ceasing to obey the controls of the body so that it divides again and again with no regard for the well being of the body as a whole, and forms a single large mass or series of masses. The initial event that causes the cell to behave in this way is probably a change in its genetic apparatus. Mutations in a cell affect only the individual concerned, and cannot be passed on to future generations.

LIFESPAN-SHORTENING EFFECTS

Radiation-related mortality increases from diseases other than cancer. A study between 1928 and 1950 of radiologists versus other medical professionals showed a definite pattern of shorter lifespans in the radiologists. In addition, animal experiments show evidence of premature aging after radiation exposure. It has been estimated that the total expected life span of the individual is shortened by one day for each rem whole body dose received.

EMBRYOLOGICAL EFFECTS

Every effort should be made to avoid exposure of the developing embryo or fetus to radiation. *Embryological effects* are somatic effects on the fetus. They may be especially severe due to the fast-growing nature of the fetus.

Some information on human embryological effect is available from a study of the pregnant Japanese women who were exposed to the enormous doses of radiation when the atomic bombs were dropped on Hiroshima and Nagasaki. As a result of the radiation many of these women had miscarriages. The women who did not miscarry delivered fetuses that showed stunting in size, microencephaly (small head size), and increased incidence of mental retardation.

There also are embryologic risks involved with the very small doses from diagnostic x-rays. However, information from the studies of large doses tells us little about the risks involved with diagnostic x-rays or other even smaller amounts. The only completely satisfactory solution is to make sure than no irradiation of a pregnant woman's abdomen or pelvis occurs

GENETIC EFFECTS

Genetic effects are those that can be passed to future generations. Genetic mutations do occur naturally, but radiation exposure may increase the *number* of mutations observed. The only large group of humans available for study are again the Japanese exposed at Nagasaki and Hiroshima. However, the number of people exposed was small by genetic standards and several generations must elapse before recessive mutations can be expressed. Experiments intended to produce information or genetic effects have been conducted on animals. In the absence of solid data from humans, the best that can be done is to assume that animal results apply to man. Examples of mutations include anemia, asthma, diabetes, and mongolism. It has been estimated that exposing each member of a population to 1 rem dose will result in 20 to 90 additional genetic disorders per million live births, and 250 to 800 additional genetic disorders across all subsequent generations.

Answer the following questions to review the information presented in this section

QUESTION

Circle the correct answer

Which of the following long-term radiation health effects affect only the individual concerned and cannot be passed on to future generations?

a. carcinogenic effects.

b. genetic effects.

Turn the page to check your answer.

ANSWERS

a. Yes, carcinogenic effects, or cancer, occur only in the exposed individual and are not hereditary. Radiation-induced genetic effects, on the other hand, can be passed on to subsequent generations.

Move on to the next section.

b. No, genetic effects are exactly as the term implies—genetic. These effects, which include diabetes, mongolism, and anemia, can be passed on to future generations. Radiation-induced carcinogenic effects cannot be passed on to subsequent generations.

Review another aspect of long-term radiation exposure by answering another question.

QUESTION

An adult receives a high radiation exposure and suffers from temporary hair loss and develops cancer 20 years later. This person suffers from

Circle the correct answer.

a. somatic radiation health effects.

b. embryologic radiation health effects.

Turn the page to check your answer.

ANSWERS

a. Yes, you understand the meaning of somatic effects. Somatic effects occur in the body of the individual who has been exposed to ionizing radiation. These effects cannot be passed to future generations. Temporary hair loss certainly fits into these descriptions. Cancer also is a somatic effect that is stochastic in nature.

Proceed to the next section.

b. No. First of all, the situation described is about an adult, and not an embryo or fetus. Embryologic effects are manifested in the developing embryo or fetus that has been exposed to radiation. Radiation-induced embryologic effects include stunting in size, microencephaly, and mental retardation.

You should go back to page 3-24 and reread that section.

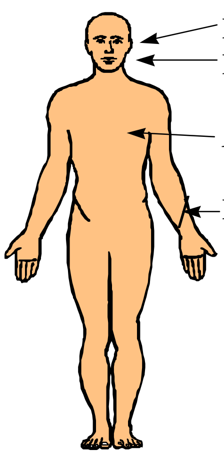
DEPOSITION OF RADIOACTIVE MATERIAL INTO THE BODY

There are four major pathways of deposition of radioactive material into the body.

If an individual is immersed in a radioactive release (such as smoke from a truck fire involving radioactive material), then there is a chance that person will *inhale* some of that radioactive material.

If individuals working, or in contact, with a radioactive substance contaminates their hands and then proceeds to eat without decontaminating, it is likely that they will *ingest* some radioactive material.

There are some radionuclides that can be *absorbed* directly into the body through the skin. For example, tritium (hydrogen-3), as a water vapor, is used frequently in research and can be absorbed by the skin.



The last mode of entry into the body is through breaks in the skin, as might be the case in an accident involving injuries and radioactive material, or intentional *injection* of radioactive material for medical purposes.

Inhalation and ingestion (both of which are also called "in-take") are the most common pathways of radioactive material into the body. Inhalation of radioactive material can be omitted as a common pathway into the body by donning respiratory equipment. You should, however, be trained and personally fitted for your choice of self-contained breathing apparatus (SCBA).

Ingestion can be omitted as a common pathway by use of decontamination and the prohibition of eating or drinking in radiation areas.

QUESTION

Circle the correct answer.

A truck carrying "yellow cake" (uranium-238) in 55-gallon drums has jackknifed on a rural highway. Several of the drums have been crushed and broken open, and the wind is blowing powder over a wide area. Which pathway of deposition of the radioactive powder into the body is most likely to occur?

a. absorption.

b. inhalation.

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. The radioactive powder cannot be absorbed through the skin. Of the four deposition pathways, inhalation and ingestion are the most probable ways that the uranium-238 will enter the exposed individual's body.

Try another question.

b. Correct answer. Individuals exposed to the "yellow cake" powder will most likely inhale, or even ingest, the material. It is unlikely that this radioactive powder will be absorbed through the skin.

Move on to the next section

QUESTION

Circle the correct answer.

Of the four deposition pathways, which two are the most common routes that radioactive material enters the body?

a. absorption and injection.

b. inhalation and ingestion.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. Not many radionuclides can be absorbed directly into the body through the skin. Entry of radioactive substances through breaks in the skin, via wounds or injection, is also not the most common deposition pathway. Inhalation and ingestion (also collectively called “intake”) are the most common pathways of deposition of radioactive material into the body.

Return to page 3-29 and review this section.

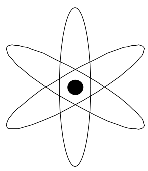
b. Correct! Most incidents involving exposure to radioactive materials (such as via radioactive plumes or spillage) lead to contamination and/or exposure of individuals via inhalation and ingestion. While absorption and injection (or entry through wounds) of radioactive material do occur, they are not as common as the other two pathways.

Proceed to the next section.

DISTRIBUTION OF RADIOACTIVE MATERIAL IN THE BODY

The distribution of radioactive material in the exposed individual depends on the nuclear, physical, and chemical properties of the material.

NUCLEAR PROPERTIES

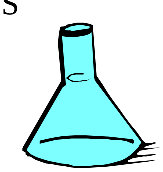


Nuclear properties of radioactive atoms depend on the condition of the nucleus, which can be described by factors such as radioactive half-life, atomic mass (total number of protons and neutrons), and atomic number (number of protons). Radioactive and nonradioactive material are treated the same after internal deposition because the body cannot discern the differences in their nuclear properties.

PHYSICAL PROPERTIES

Physical properties of radioisotopes, including factors such as size and solubility, will determine how the radioactive material will be distributed in the body. For example, how easily does the radionuclide dissolve in the blood? The physical state of the radioactive material also determines the way the material is distributed in the body. For example, is the material a particle or a gas, or a combination of both?

CHEMICAL PROPERTIES



Chemical, or biological, properties of radioactive material determine where in the body the material will most likely concentrate after deposition. The chemical structure of the radionuclide, for instance, determines if it will react specifically with certain molecules within the body. For example, radioactive iodine will concentrate in the thyroid, radioactive lead will build up in the kidney, radioactive strontium will deposit mainly in the bones, and radioactive cesium can spread throughout the whole body.

As a radiological emergency responder, it is important that you understand the factors affecting the distribution of radioactive material in the body.

Test your knowledge by answering the question on the next page.

QUESTION

The body does not differentiate between which properties?

Circle the correct answer.

a. nuclear.

b. physical.

Turn the page to check your answer.

ANSWERS

a. Correct answer. The body cannot distinguish nuclear properties of molecules, and therefore cannot tell whether a substance is radioactive or not.

Move on to the next section.

b. Incorrect answer. Physical properties of radionuclides, such as size and solubility, determine how the material interacts with the body. In other words, radionuclides may be distributed differently throughout the body and may interact with different cells of the body. Nuclear properties, however, do not determine the fate of the nuclide in the body, so both radioactive and non-radioactive substances are treated the same.

Try another question.

QUESTION

Circle the correct answer.

Radioactive iodine will concentrate in the thyroid because of its _________ properties.

a. chemical.

b. nuclear.

Turn the page to check your answer.

ANSWERS

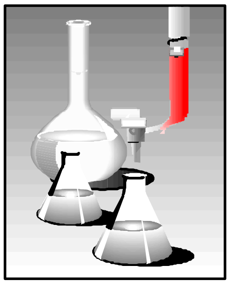
a. Correct answer. Chemical, or biological, properties of radioactive material determine where in the body the material will most likely concentrate after deposition. The chemical structure of the iodine allows it to react specifically with certain molecules of the thyroid. Similarly, radioactive lead will tend to build up in the kidney, but not in the thyroid, because the lead molecule has a greater affinity for certain molecules in the kidney than in the thyroid.

Proceed to the next section.

b. Incorrect answer. Nuclear properties determine whether the nuclide is radioactive or not; the body cannot "recognize" nuclear properties of an atom. So, the fact that radioactive iodine tends to concentrate in the thyroid has nothing to do with the nuclear properties of iodine. Both radioactive and nonradioactive iodine will tend to reside in the thyroid.

Return to page 3-33 and review this section.

DETECTION, MEASUREMENT, AND EVALUATION OF RADIOACTIVE MATERIAL INSIDE THE BODY



After an individual has been exposed to internal contamination it is important to detect, measure, and evaluate the amount of radioactive material that has actually been deposited into the body. Both biological assays and whole body counting are available to perform these tasks.

Biological assays (or bioassays) determine the kind, quantity or concentration, and location of radioactive material in the human body. "Indirect" bioassays may be performed using urine samples (urinalysis), fecal samples, and blood samples. The radioactivity is measured in these samples using special radiation detection instruments, and the results are used to predict the amount of radioactive material deposited in the entire body.

Whole body counting, which is considered a "direct" bioassay, is also used to detect, identify, measure, and locate gamma-emitting radioactive material in the body. A whole-body counting device is used to identify and measure radionuclides in the body of humans (and animals for research purposes). It uses heavy shielding (to keep out background radiation), ultrasensitive gamma radiation detectors, and electronic equipment that will read, evaluate, and store the data generated during a whole body count.

Try the next question to test your knowledge of these concepts.

QUESTION

Circle the correct answer.

Urinalysis is considered a(n) ________ bioassay.

a. direct.

b. indirect.

Turn the page to check your answer.

ANSWERS

a. Incorrect answer. Urinalysis entails measuring the radioactivity in a sample of urine and extrapolating the results to get the whole body exposure. This type of bioassay is considered indirect. A direct bioassay is whole body counting, which does not require sampling of urine, fecal matter, or blood and subsequent extrapolation of the results.

Try another problem.

b. Correct answer. Since urinalysis involves taking a sample of urine, measuring the radioactivity in that sample, and extrapolating the results to determine the whole body exposure, this bioassay would be considered as indirect. Whole body counting, on the other hand, does not require sampling and extrapolation of the results, and is therefore considered as a direct bioassay.

Move on to the Summary Questions.

QUESTION

Circle the correct answer.

Whole body counting measures only the concentration of gamma-emitting radioactive material located in the bone marrow.

a. true.

b. false.

Turn the page to check your answer.

ANSWERS

a. Wrong answer. As its name implies, whole body counting is used to detect, identify, measure, and locate gamma-emitting radioactive material in the entire body. Now, it may be that the radioactive material has concentrated in the bones (such as with strontium), but whole body counting has the capability of measuring radioactivity emanating from all parts of the body.

Return to page 3-37 and review this section.

b. Correct! You understand that whole body counting can detect, identify, measure, and locate gamma-emitting radioactive material in the entire body, and not just in the bones.

Proceed to the Summary Questions.

SUMMARY QUESTIONS

QUESTION

Circle the correct answer.

1. Somatic radiation effects may be either stochastic or nonstochastic. In contrast to nonstochastic effects, stochastic effects

   a. occur by chance and among unexposed as well as exposed individuals.

   b. become more severe as the level of the radiation dose increases.

Turn the page to check your answer.

ANSWERS

a. Very good. You answered this correctly. Stochastic effects occur by chance, occur among unexposed and exposed persons, and are not unequivocally related to exposure. Cancer is a typical stochastic effect.

Move on to the next Summary Question.

b. No, you have the terms stochastic and nonstochastic mixed up.

Stochastic effects occur by chance and among un-exposed as well as exposed individuals. These effects are not related to exposure. In contrast to stochastic effects, the magnitude of the nonstochastic effect increases with the increasing levels of radiation dose. Moreover, there is a causal relationship between exposure and effect.

You should go back to page 3-24 and reread that section.

QUESTION

Circle the correct answer.

2. A serious truck accident has caused a large shipment of Low Specific Activity (LSA) class material to be engulfed in flames. A “radioactive” plume has formed and is beginning to disperse toward a housing development. Which pathway of deposition into the exposed individuals would *most likely* occur?

    a. absorption.

    b. inhalation.

Turn the page to check your answer.

ANSWERS

a. No, it is likely that the radioactive material in this plume would be particulate in nature and unlikely to be absorbed into the body through the skin.

Go back and review page 3-29 before moving on to Unit Four.

b. That is correct. Airborne radioactive material may be inhaled into the body by people in the open when the plume passes.

Continue with Unit Four.