NMDP Basic Radiation Training

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CME Information

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Program Information:

This is a self-administered program that will be mailed out to you. After reading the material, please complete the enclosed course evaluation and exam, than fax the completed form to the NMDP Emergency Preparedness Administrator at (612) 884-8280. The administrator will grade the exam, and then send to the Medical College of Wisconsin to issue the CME certificate. The Medical College of Wisconsin will mail your exam results along with your CME certificate within three weeks of receiving your exam.

This program will take approximately 2 to 3 hours to complete. The Medical College of Wisconsin has designated this educational activity for a maximum of *1.0 AMA PRA Category 1 credit™.*

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Principal Faculty and Planning Committee Disclosure:

Dennis Confer, M.D.	**None**
Nelson Chao, M.D.	**None**
Daniel Weisdorf, M.D.	**Research Support (*Trials*):** AnorMED, Merck, Amgen, Genzyme, SuperGen, Ligand **Honoraria (*Advisory Board*):** Genzyme, Pharmeon, Schering-Plough
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Cullen Case,	**None**
Renee Ryan	**None**

Accreditation & Certification:

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CME Program ID #07120

Introduction

The concept of radiation exposure outside the therapeutic setting can be a scary one. Many of our perceptions of accidental radiation exposure stem from media and Hollywood hype about the potentially deadly effects of a large scale event. The fact is, however, that the controlled, calculated use of radiation saves far more lives on an annual basis than accidental exposure has ever harmed.

Even though we rely on the benefits of radiation, there is still a very real need to understand and prepare for instances of potentially lethal exposure. Understanding the capabilities of radiation as well as its limitations can deter much of the anxiety associated with a radioactive incident.

This course will focus on ionizing radiation; its characteristics, biological effects, protective measures as well as tie it together so that students understand how this all relates to them.

Training Objectives: Would begin each with a verb (e.g., describe, understand, name)

1. Describe the three main types of radiation
2. Understand the difference between radioactive material and radiation
3. Explain the basic measurement of radiation
4. Name the four primary sources of radiation
5. Understand the basics of biological effects of radiation
6. Be able to describe symptoms of Acute Radiation Sickness (ARS)
7. Explain the difference between internal and external contamination and internal and external exposure
8. Explain the concept of shielding

Course Content:

Introduction
Section 1: Radiation basics
Section 2: Biological effects of radiation
Section 3: Exposure vs. contamination and shielding
Section 4: What does all this mean for the hematopoietic stem cell (HSC) transplant community?
Summary
Reference material
Exam
**Interspersed concept and historical examples

How to read this course

- Each section will have a short introduction
- Graphics are used as often as possible to assist in conveying the point
- Interspersed throughout the sections are historical examples (in boxes) to connect the information presented to an actual incident.
- Once you are finished with reading the sections, complete the enclosed multiple choice exam and follow the instructions provided to submit it for review.

This course was not designed to make the student an expert, rather to introduce some of the key concepts associated with a radiological emergency.

Acknowledgement: Significant portions of this course were taken from FEMA Radiological Emergency Management course (IS-3).

Section Overview

Section 1: Radiation basics

There are many sources of radiation that humans are constantly exposed to; some natural and some man-made. The three primary sources of natural background radiation are: cosmic radiation, terrestrial sources and radioactivity in the body. Man-made sources, such as diagnostic radiology, therapeutic radiology and other sources, account for a smaller portion of the exposure to humans on a daily basis. Despite the prevalence of natural radiation sources (82% of all radiation the average person is exposed to), the amount of exposure due to it is generally very limited and result in negligible effects on the human body.

There are three main types of ionizing radiation emitted from radioactive atoms: alpha, beta and gamma. Alpha particles are the heaviest and most highly charged of the ionizing radiations. Beta particles are smaller and travel much faster than alpha particles and gamma rays are similar to medical x-rays.

Section 2: Biological effects of radiation

Radiation is the most studied environmental hazard in the world. The biological effects of radiation exposure are dependent on the type of exposure (acute or chronic), the level of exposure, and certain biological factors. Protective measures can be used to reduce an individual's radiation exposure. The use of time, distance, and shielding principles are critical to reducing exposure to radiation.

Section 3: Exposure versus contamination and shielding

You can be exposed to radiation without becoming contaminated. When you are exposed to radiation, the radiation does its damage, expends all its energy, and is gone. If you carry radioactive contamination on your clothes or body, the material continues to emit radiation as long as it is radioactive. There are three important factors in protecting individuals from radiation: time, distance and shielding. The less time an individual remains in a radiation field, the less exposure he or she receives. The further an individual remains from the source, the less exposure they receive. The more material placed between an individual and a radiation source, the less exposure the individual will receive.

Section 4: What does this mean for the hematopoietic stem cell transplant community?

Expectations of casualties vary greatly from expert to expert. Like with all disasters, there is a worst case scenario, a best case and many variations in-between. The transplant community should expect public panic, mass confusion and an overflow of patients once they are triaged from the incident location to the appropriate facility for treatment. Additionally, the quantity of injured patients will far exceed the eventual number of patients that receive transplants.

Section 1: Radiation Basics

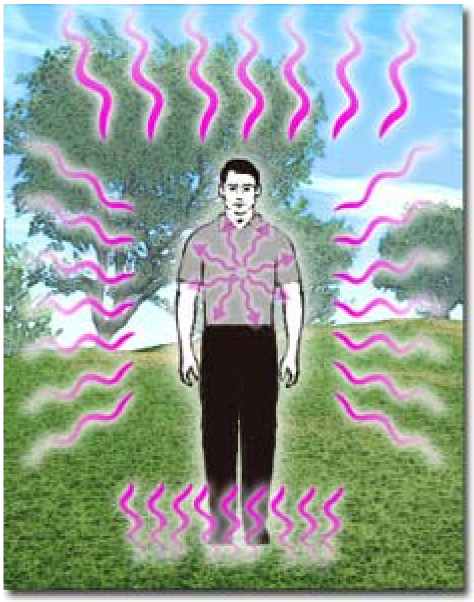
In this section you will learn about:
- Sources of radiation
- Ionizing radiation
- Measurement of radiation

Sources of radiation:

Most people are unaware that they are exposed to very low levels of radiation every day from their environment. There are many sources of radiation, some natural and some man-made that are constantly affecting humans. The following sources will be briefly described here:

Types of natural background radiation include:
- Cosmic radiation
- Terrestrial sources
- Radioactivity in the body

Types of man-made sources of radiation include:
- Diagnostic radiology
- Therapeutic radiology
- Other sources



Natural Radiation Surrounds Humans

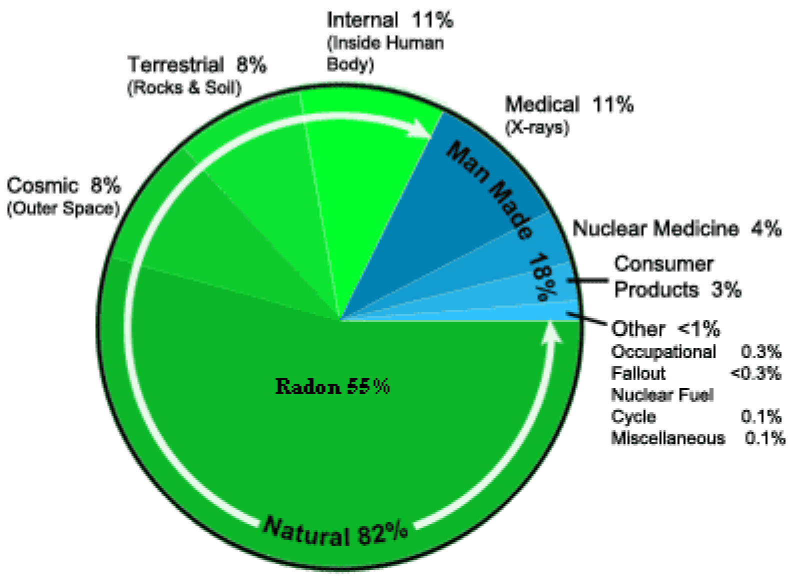
It is important to understand what sources of radiation can affect a person as well as to what extent these sources are important.

Natural and Man-made Radiation Sources

The three primary sources of natural background radiation are:
- **Cosmic radiation**: primarily radiation from our sun, the earth's atmosphere shields the planet from the majority of this radiation.
- **Terrestrial sources**: the earth has naturally occurring materials that are radioactive; small amounts of these materials can be found in the soil. As these materials breakdown, they become radon gas that can seep into buildings in some regions, usually at low levels.
- **Radioactivity in the body**: the body naturally contains very minute quantities of radioactive substances.

Man-made sources of radiation account for a smaller portion of the exposure to humans on a daily basis:

- **Diagnostic radiology**: exposure from medical procedures to determine a patient's medical condition (e.g. x-rays, or bone scans).
- **Therapeutic radiology**: uses radioactive material to treat a patient's condition (e.g. cancer therapy).
- **Other sources**: include fallout from military experiments, occupational exposure, and other miscellaneous sources.



Sources of Radiation Exposure in the U.S. Population

Despite the number of natural radiation sources, the amounts of exposure are generally very limited resulting in negligible effects on the human body.

Ionizing radiation:

Radioactivity

Although radiation has always been present in our environment, it was not discovered until the late 1800s. To understand ionizing radiation (also called nuclear radiation), you need to know how radioactive atoms emit radiation and some of the terms used to express amounts of radiation present.

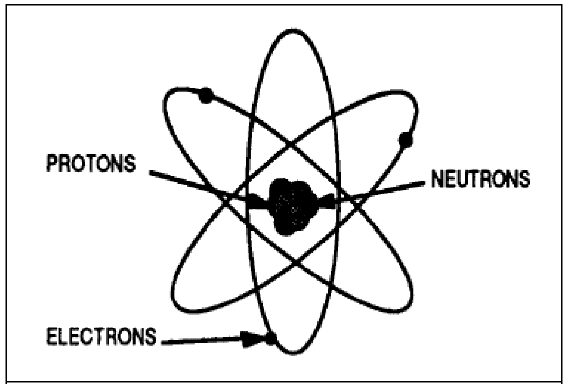
> **Chicago, IL, USA:** In 1896 a man had a broken ankle x-rayed by a doctor, after which he developed skin injuries eventually requiring amputation of the foot. He later sued the doctor and was awarded $10,000. (http://www.johnstonsarchive.net/nuclear/radevents/1896USA1.html)

Elements and Atoms

Elements are simple fundamental substances, commonly referred to as nature's building blocks. Although there are at least 106 known elements, 98% of the planet is made up of only six elements: iron, oxygen, magnesium, silicon, sulfur and nickel. The first 92 are naturally occurring elements; the remainder are man-made and radioactive.

Nature's Building Blocks

An atom is the smallest particle of an element that has all of the physical and chemical properties of that element necessary to identify it as a particular element. Atoms are composed of smaller particles including protons, neutrons, and electrons. **Protons** and **neutrons** are heavy particles that are found in the center, or **nucleus**, of the atom. The basic difference between a proton and neutron is their associated electrical charge. Protons have a positive charge and neutrons have no charge. **Electrons** are even smaller, negatively charged particles.



Atom

Electrons orbit the nucleus producing what is often described as a “shell” around the atom. The extent of the orbits of the electrons determines the size of an atom. If an atom could be enlarged such that the nucleus would be the size of a baseball, the outer electrons would be tiny specks nearly a mile away.

Radioactivity and Ionizing Radiation

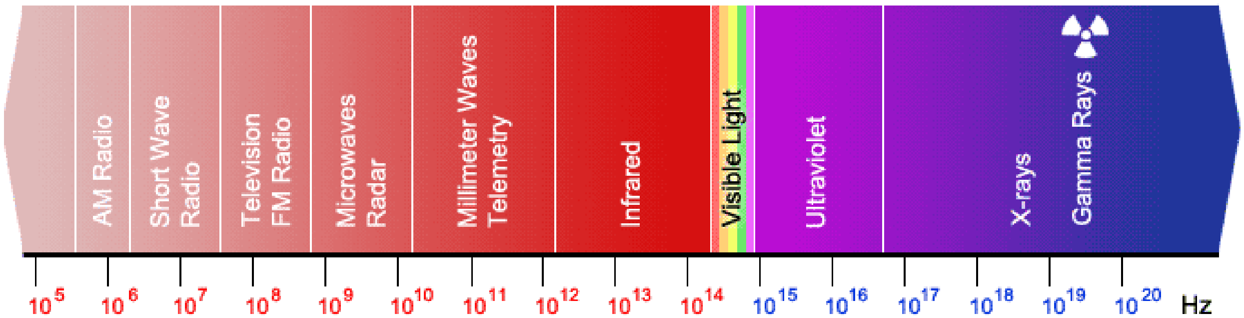
Everything in nature would prefer to be in a relaxed, or stable state. Unstable atoms undergo nuclear processes that cause them to become more stable. One such process involves emitting excess energy from the nucleus. This process is called radioactivity or **radioactive decay**. The energy released from unstable (radioactive) atoms is called **ionizing radiation**. The terms "radiation" and "radioactive" are often confused. By keeping the following relationship in mind, these two terms can be distinguished: RADIOACTIVE ATOMS EMIT RADIATION.

There are three main types of ionizing radiation emitted from radioactive atoms:

- Alpha.
- Beta.
- Gamma.

Alpha and beta radiation consist of actual particles that are electrically charged and are commonly referred to as alpha particles and beta particles. Gamma radiation, however, belongs to a class known as electromagnetic radiation. Electromagnetic radiation consists of energy transmitted in the form of waves. Other types of electromagnetic radiation include television and radio waves, microwaves, and visible light. The only differences between gamma rays and these more familiar forms of electromagnetic radiation are that gamma rays are generally higher in energy and that gamma rays originate in the nuclei of atoms.

Types of Electromagnetic Radiation



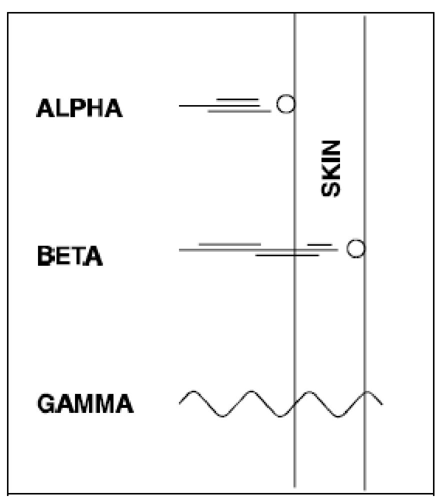
Alpha particles are the heaviest and most highly charged of the ionizing radiations. Without additional energy input, these characteristics make alpha particles less penetrating than beta particles and gamma rays. Their energy is used up before they get very far. Alpha particles cannot travel more than four to seven inches (10 to 18 cm) in air and are completely stopped by an ordinary sheet of paper. Their energy is spent interacting with the charged protons and electrons they meet near any surface they strike.

Even the most energetic alpha particle from radioactive decay can be stopped by the outermost layer of dead skin that covers the body. Therefore, exposure to most alpha particles originating outside the body is not a serious hazard. On the other hand, if alpha-emitting radioactive materials are taken inside the body, they can be the most damaging source of radiation exposure. The short range of the alpha particle causes the damaging effects of the radiation to be concentrated in a very localized area.

Beta particles are smaller and travel much faster than alpha particles. They are physically similar to electrons, but they are not in orbit around an atom. Since beta particles travel faster and have less charge than alpha particles, they penetrate further into any material or tissue. Typical beta particles can travel several millimeters through tissue, but they generally do not penetrate far enough to reach the vital inner organs. Beta particles may be a major hazard when emitted by internally-deposited radioactive material or when interacting with the lens of the eye.

Exposure to beta particles from outside the body is normally thought of as a slight hazard. However, if the skin is exposed to large amounts of beta radiation for long periods of time, skin burns similar to heat burns may result. If removed from the skin shortly after exposure, beta-emitting materials will not cause serious burns and will not pose a severe external hazard.

Like alpha particles, beta particles are considered to be an internal hazard if taken into the body by eating food, drinking water, or breathing air containing radioactive material. Beta emitting contamination can also enter the body through unprotected open wounds.

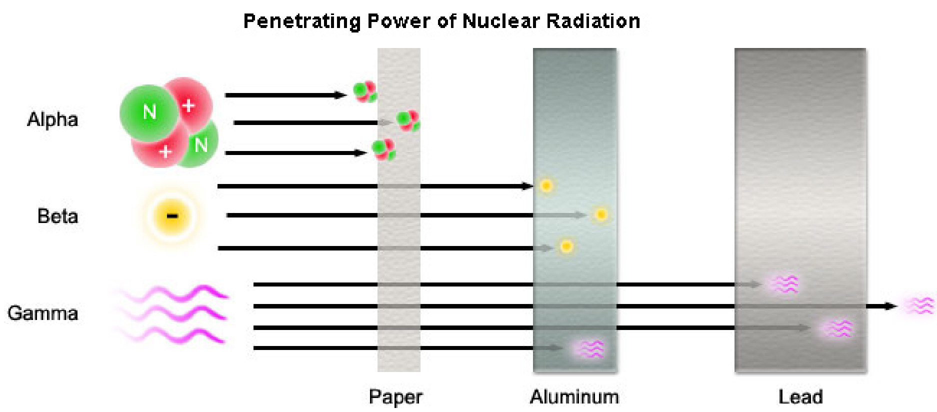


Radiation Penetration Into Skin

Gamma rays are similar to medical x-rays. Gamma rays are a type of electromagnetic radiation, with energy transmitted through space in the form of waves. Different types of electromagnetic radiation have unique physical characteristics, which are measured in wavelength and frequency. Short wavelength and high frequency are characteristic of gamma and x-rays.

Gamma rays are the most hazardous type of radiation from sources outside the body because they can travel much greater distances through air and all types of material. Gamma rays can travel up to a mile (1.6 km) in open air and may present a significant hazard even at fairly large distances. Since gamma rays penetrate more deeply through the body than alpha or beta particles, all tissues and organs can be damaged by sources outside of the body.

In many cases, some type of dense material is needed to reduce the hazard presented by gamma rays. Any material between the radiation source and the receptor (*i.e.,* the person or object receiving the radiation) is called **shielding**, because it absorbs some of the gamma ray energy before it can penetrate. For example, 2-1/2 inches (6 cm) of dense concrete will absorb approximately 50 percent of typical gamma rays. Five inches (13 cm) of water is just as effective.



All three types of ionizing radiation can be a hazard if they are emitted by radioactive material inside the body. Such material can get into your body by eating food with radioactive material in or on it, breathing air with radioactive material in it, or drinking water with radioactive material in it. If you keep radioactive material outside your body, you can use your knowledge of some of the radiation characteristics described in this unit to minimize the amount of radiation that penetrates your body.

In addition to the three types of ionizing radiation, there is also neutron radiation, which will not be discussed in detail. Neutron radiation consists of neutrons in motion. In open air, neutrons can travel up to 3,000 feet (900 m). Neutrons lose their energy mostly by colliding with protons in the nucleus of hydrogen atoms.

Measurement of radiation:

The measurement of radiation can be very confusing, partially because there are so many different units and because, in addition to the intensity of exposure, the time (*i.e.,* duration) of the exposure is critical. This section will discuss the different units of measure of radiation exposure and dose.

This section will focus on measurement of the dose of radiation, as this is what ultimately needs to be known for medical treatment. Some of the terms that will not be explored are used to measure the decay of radioactive material; such as Curie and the Becquerel, which can be used to define the potency of radioactive material.

Radiation Measurements

	Exposure	Absorbed Dose	Dose Equivalent	Radioactivity
Common Units	roentgen (R)	rad	rem	curie (Ci)
SI Units	coulomb/kilogram (C/kg)	gray (Gy)	sievert (Sv)	becquerel (Bq)

**SI – International System of Units

Exposure versus dose:
Radiation Measurement Terms

Since ionizing radiation affects people, we must be able to measure its presence. We also need to relate the amount of radiation received by the body to its physiological effects. Two terms used to relate the amount of radiation received by the body are **exposure** and **dose.** When you are exposed to radiation, your body absorbs a measurable dose of radiation.

Roentgen

Roentgen is the unit used to express the amount of gamma radiation exposure an individual receives. In writing exposures, roentgen is usually abbreviated with a capital "R," which follows immediately after the amount of gamma radiation received. An exposure of 50 roentgens would then be written "50 R." The **roentgen** is independent of the time over which the exposure occurs. For instance, if a man is exposed to 5 R of gamma rays on one occasion, and 6 R on another, the sum of the two, 11 roentgens, is his cumulative gamma radiation exposure. One thousandth of a roentgen is abbreviated "mR".

Rad (radiation absorbed dose)

Different materials that receive the same exposure may not absorb the same amount of energy. The rad was developed to relate the different types of radiation (i.e., alpha, beta, gamma and neutron) to the energy they impart in materials. It is the basic unit of the absorbed dose of radiation. The dose of one rad indicates the absorption of 100 ergs (an erg is a small but measurable amount of energy) per gram of absorbing material. One roentgen of gamma radiation exposure results in about one rad of absorbed dose. To indicate the dose an individual receives in the unit rad, the word "rad" follows immediately after the magnitude, for example, "50 rads." One thousandth of a rad is abbreviated "mrad."

Rem (roentgen equivalent man)

Some types of ionizing radiation produce greater biological effects than others for the same amount of energy imparted. The rem is a unit that relates the dose of any radiation to the biological effect of that dose.

Therefore, to relate the absorbed dose of specific types of radiation, a "quality factor" must be multiplied by the dose in rad. To indicate the dose an individual receives in the unit rem, the word "rem" follows immediately after the magnitude, for example, "50 rem." For gamma rays and beta particles, 1 rad of exposure results in 1 rem of dose. For alpha particles, 1 rad of exposure results in approximately 20 rem of dose. For neutrons, 1 rad of exposure results in approximately 10 rem of dose. One thousandth of a rem is abbreviated as "mrem."

Another quantity measured is the rate at which an individual is exposed to radiation. This is often measured on a per-hour basis, and is called the **exposure rate**. Exposure rates are expressed in terms of roentgen or milliroentgen per hour. An exposure rate of sixty roentgen per hour would be written "60 R/hr."

The International System of Units (SI), which may be used in place of the rem and the rad, are the sievert (Sv) and the gray (Gy). These units are related as follows:

- 1 Sv = 100 rem
- 1 Gy = 100 rad

SI units must be used on labels for identifying radioactive materials during transport. Many radiation meters utilize R/hr for measuring dose rate. To convert R/hr to Sv/hr divide by 100. (*e.g.* 60 R/hr divided by100 = 0.6 Sv/hr.)

Section 2: Biological effects of radiation

In this section you will learn about:
- Acute versus Chronic exposure
- Biological factors
- Acute Radiation Sickness

It is important to remember that the biological effects discussed here are the result of exposure to very large amounts of ionizing radiation over a very short period of time. Although emergencies such as a nuclear power plant release, radioactive cargo accident or industrial radiological accident may result in significant levels of radiation exposure, it is the magnitude and overall extent of the event that determines whether the Radiation Injury Transplant Network (RITN) will be involved. For example, exposure levels resulting from an improvised nuclear device (IND), a military nuclear weapon, or the strategic use of open radiation sources would result in numerous victims across a large geographical area, requiring rapid treatment from the RITN. Smaller scale events that affect a limited number of victims in a contained area would most likely not involve the RITN.

Radiation is the most studied environmental hazard in the world. The biological effects of radiation exposure are dependent on the type of exposure (acute or chronic), the level of exposure, and certain biological factors. The acute biological symptoms due to radiation exposure are primarily non-specific and may be difficult to identify as resulting from radiation exposure. The long-term effects of high doses of radiation include an increased risk of cancer, cataracts, and possibly a shortened life expectancy. Long-term measurable effects of low-level radiation exposure have not been observed but are generally assumed to exist due to the known cancer causing effect of much higher, acute doses.

Protective measures can be used to reduce an individual's radiation exposure. The principles of time, distance, and shielding are especially important for reducing exposure to radiation.

Biological Effects of Radiation

Exposure to radiation received within a short period of time is called **acute exposure**.

Generally, a large acute exposure can result in observable effects, such as radiation sickness or death, shortly after exposure. The severity of these immediate effects depends on the amount of radiation dose. Large acute exposures can also result in long-term effects such as cancer that show up after a number of years. The probability of these long-term effects also depends on the amount of radiation dose.

Exposure to radiation on a continuous or repetitive basis is called **chronic exposure**. An example of chronic exposure is natural background radiation, which exposes individuals to relatively small amounts of radiation over a long period of time.

Small chronic exposures, such as exposure to background radiation, have no immediate observable effects, but may result in the same types of delayed effects that are associated with acute exposures. To understand the types of biological effects resulting from exposure to ionizing radiation, it is important to understand how radiation interacts with the body. Remember, radiation is a form of energy in motion. When alpha, beta and gamma radiation enter the body, some or all of their energy is lost in collisions with the body's atoms. The major characteristic of these atomic interactions is the stripping away of electrons from atoms in the body. This removal of electrons is called **ionization.** For this reason, alpha, beta, and gamma radiation is often called **ionizing radiation**.

The biological effects of radiation are caused by these ionizations, which can damage DNA and other structures inside the body's cells. Cells have elaborate mechanisms for repairing many types of cell damage. However, the damage may be so great that the cell is incapable of performing repair, resulting in cell death. Alternatively, damage to DNA may be repaired incorrectly, resulting in mutations that could ultimately result in cancer.

Acute Effects

The body's inherent ability to repair radiation damage has evolved because we live in an environment with natural sources of radiation. These defenses are quickly overwhelmed by high doses of radiation from **acute exposures**. For example, if a large group of people received an acute exposure of 450 Rad, half of them would probably die within a month without medical care. However, if the same dose of radiation was stretched out of a longer period of time (*e.g.* 0.1 Rad every day for 4500 days), no radiation sickness would be observed, although long term effects like cancer or an overall decrease in long-term survival might occur. This kind of **chronic exposure,** received over an extended period of time, is tolerated by the body with much less biological effect than **acute exposure**.

Biological Factors

Each person differs in their biological response to a given dose of radiation. These differences can mean that, except at extremely high acute doses, two people exposed to the same amount of ionizing radiation may experience different symptoms. Several factors which may influence the effect of radiation on any given person, including his or her age, sex, diet, body temperature, and overall medical health.

Acute Radiation Sickness

Acute radiation sickness occurs when an individual is exposed to a large amount of radiation within a relatively short period. The effects of acute radiation at doses greater than approximately 1 Sv (100 rem) are collectively known as **acute radiation sickness** (also known as acute radiation syndrome). Acute radiation sickness includes:

- Changes in blood cells – the number of certain types of cells in the blood (e.g., lymphocytes) may drop soon after exposure
- Vascular changes (blood vessels) – damage to blood vessels may lead to swelling in areas of the body exposed to radiation or internal damage and bleeding
- Skin irritation - a tingling sensation of the skin and some reddening may persist for a couple of days after exposure. This response is typical of sunburn and may peel. Unlike sunburn, the irritation will return after some time has passed and persist for about 3 weeks. More severe skin burns and blistering occurs after higher exposures.
- Gastrointestinal system effects – damage can cause sores or bleeding within the mouth, throat or intestine. Damage to the gastrointestinal system can also allow bacteria in the intestine to enter the blood or cause other infections.
- Non-specific, "flu"-like symptoms (diarrhea, nausea, vomiting, high fever)
- Hair loss (epilation) – this can occur at any part of the body exposed to radiation

The severity and course of acute radiation sickness depends on how much total dose is received, how much of the body is exposed and the sensitivity of the exposed individual to radiation, which varies significantly between people. Depending on the dose of acute radiation, radiation sickness symptoms may appear shortly after exposure, then disappear for a few days only to reappear in a much more serious form in a week or so. This "latent" period is related to the amount of the exposure. When the symptoms recur, they are sometimes accompanied by swelling in the passages of the nose, mouth, and throat. The symptoms of radiation sickness and their timing after exposure are outlined in the table below.

Clinical Symptoms of Acute Radiation Sickness in Relation to Postexposure Time and Dose

Time after Exposure	Sublethal Dose (100-250 rem)	Lethal Dose (250-450 rem)	Supralethal Dose (>650 rem)
First Week	Nausea and occasional vomiting within hours	Nausea, vomiting, extreme paleness within a few minutes or hours	Nausea, vomiting, extreme paleness within a few minutes
			Shock, unconsciousness, diarrhea, abdominal pains and cramps, fever, severe skin irritation, burns or blisters, insomnia, restlessness
Second Week		Weight loss, general malaise, fatigue, stomatitis	Death certain (without medical attention) within a few hours to a few days
		Fever, anorexia, abdominal pains, severe skin irritation	
Third Week	General malaise, anorexia, mild skin irritation, diarrhea, fatigue, drowsiness	Hair loss, internal bleeding	
	Hair loss		
Fourth Week and Later	Recovery probable	Menstrual irregularities in females	
	Changes in blood cells detectable in laboratory	50% chance of death from changes in blood cells if not treated	

ARS has four stages, symptoms such as anorexia, nausea, vomiting, fever, diarrhea, fluid shifts and electrolyte imbalance become prominent within 48 hours of radiation injury during the **Prodomal phase**. Within days to weeks of initial injury, temporary improvement begins as the individual enters the **Latent phase**. The Latent phase is followed by **Manifest illness** which may last weeks to months, with intense immunocompromise and symptoms specific to 4 major organ systems (hematopoietic system, gastrointestinal system, cutaneous system and neurovascular system). The final phase is **Recovery or Death**. After a lethal dose of radiation, victims may develop a temporal compression of these phases into a period of hours resulting in early death.

Severity Levels

The severity and the time of onset of early radiation sickness after exposure can be used to predict the delayed effects. Nausea, vomiting, diarrhea and anorexia are common non-specific symptoms of early radiation sickness.

Delayed effects after sublethal dose (<250 rem)

After exposure to relatively low doses of radiation, the delayed symptoms may also be non-specific and include:

- Malaise (a vague feeling of illness and depression)
- Fatigue
- Drowsiness
- Weight loss
- Fever
- Abdominal pain
- Insomnia (sleeplessness)
- Restlessness
- Blisters

Delayed effects after a potentially lethal dose (250-650 rem)

After exposure to higher doses of radiation, a significant reduction in the production of blood cells may occur. After exposure to this level of radiation, the individual initially suffers from nausea and vomiting and may appear to recover in about three days. However, his or her white blood cells, which are essential for fighting infections, are greatly reduced in number. After two to three weeks, symptoms including chills, fatigue, and ulceration of the mouth will appear. Susceptibility to secondary infection is greatly increased during this period and may cause death, even with medical care.

Delayed effects after a supralethal dose (>650 rem)

After exposure to extremely high doses of radiation, damage to the stomach lining and/ or intestine may occur, causing decreased absorption, ulceration, and dehydration. Severe infection, fluid loss, blood loss or collapse of the circulatory system may result in death within 7 days after exposure.

Acute doses of over 1000 rem cause irreparable damage to the brain and spinal cord. Symptoms resulting from this damage may include agitation, lack of coordination, breathing difficulty, and occasional periods of disorientation. At these doses, death occurs within hours to days.

The key symptoms of acute radiation syndrome (ARS) are:

- **Nausea**
- **Vomiting**
- **Anorexia**
- **Reduced number of white blood cells (lymphocytes, granulocytes)**
- **Reduced number of platelets**
- **Erythema of the skin**
- **Itching or altered sensation in the skin**
- **Swelling and Edema**
- **Diarrhea**
- **Fatigue**

Severity of Radiation Injury

Dose Range (Gy)	Prodrome	Manifest - Illness	Prognosis (without therapy)
0.5-1.0	Mild	Slight decrease in blood cell counts	Almost certain survival
1.0-2.0	Mild to Moderate	Early signs of BM damage	Highly probable survival (>90% of victims)
2.0-3.5	Moderate	Moderate-severe BM damage	Probable survival
3.5-5.5	Severe	Severe BM damage; mild GI damage	Death within 3.5-6 weeks (50% of victims)
5.5-7.5	Severe	Pancytopenia and moderate GI damage	Death probable within 2-3 weeks
7.5-10.0	Severe	Marked GI and BM damage; hypotension	Death probable within 1-2.5 weeks
10.0-20.0	Severe	Severe GI damage, pneumonitis, altered mental status	Death certain within 5-12 days
20.0-30.0	Severe	CV collapse; fever; shock	Death certain within 2-5 days

Abbreviations: Bone marrow (BM); Cerebrovascular (CV); Gastrointestinal (GI).
Modified from RI Walker and RJ Cerveny, eds.(reference 21).
Provided by Dr. Waselenko

Treatments

Individuals exposed to radiation may suffer from a full range of injuries, from changes in the number of blood cells to skin burns to serious radiation sickness. Whatever the injury, a medical doctor should treat the individual. By examining the person's blood under the microscope, a medical doctor can diagnose radiation exposure before other effects appear or after an exposure not great enough to cause more severe symptoms. As for all medical conditions, the treatment depends upon the nature and severity of the injury. Burns, for example, may be treated just like any other burn.

Long-term Effects

The probability of experiencing long-term effects increases as the level of exposure increases. Three of the most notable long-term effects of radiation exposure are cancer, cataracts and shortening of lifespan. Each of these are discussed below. One of the most serious long-term effects of exposure to ionizing radiation is the increased risk of cancer. Although widely thought of as a cause of cancer, acute radiation exposure only marginally increases cancer risk. For example, of 82,000 Japanese atomic bomb survivors who received an average of approximately 28 rads (0.28 Gy), only 0.2 percent experienced a radiation-induced cancer.

The fibers that comprise the lens of the eye are specialized to transmit light. Damage to these fibers, and particularly to the developing immature cells that give rise to them, can result in dark spots in the lens called **cataracts** that interfere with vision. Acute exposure of 200 rads (2 Gy) or more can induce the formation of vision-impairing cataracts. Exposure to 1,000 rads (10 Gy) over a period of months can also cause cataracts.

Experiments with animals indicate that exposure to radiation can result in a shortened lifespan. Irradiated animals in these investigations appear to die of the same diseases as non-irradiated animals, but they do so at an earlier age. Data from the populations of Hiroshima and Nagasaki indicate that, if **life-shortening** from radiation occurs in humans, it is very slight (*i.e.,* less than 1 year per 100 R).

Table 1-4 shows typical latent periods between exposure and effect:

Table 1-4
Long-Term Effects of Radiation

Effect	Mean Latent Period (years)	Evidence
Leukemia	2-4	Atomic bomb casualties Medical x-ray treatment
Bone cancer	15	Radium luminous dial painters
Thyroid cancer	15-30	Atomic bomb casualties Medical treatment
Lung cancer	10-20	Mine workers
Life-shortening	Not applicable	Experiments with mice
Cataract formation	1-5	Atomic bomb casualties

Section 3: Exposure vs. Contamination

In this section you will learn about:

- Radiation exposure
- Radioactive contamination
- Exposure control techniques

This section will demonstrate the important distinction between radiation exposure and radioactive contamination. This section also describes how one can use the three protective factors of time, distance, and shielding to minimize dose. It is important to understand that radioactive material emits radiation. Therefore, once the radioactive material is safely removed from the area, the radiation hazard is eliminated.

Contamination vs. Radiation

Radioactive material deposited in undesired locations is called radioactive contamination. The difference between contamination and radiation is important to understand. You can be exposed to radiation without becoming contaminated. When you are exposed to radiation, the radiation does its damage, expends all its energy, and is gone. If you carry contamination on your clothes or body, the material continues to emit radiation as long as it is radioactive.

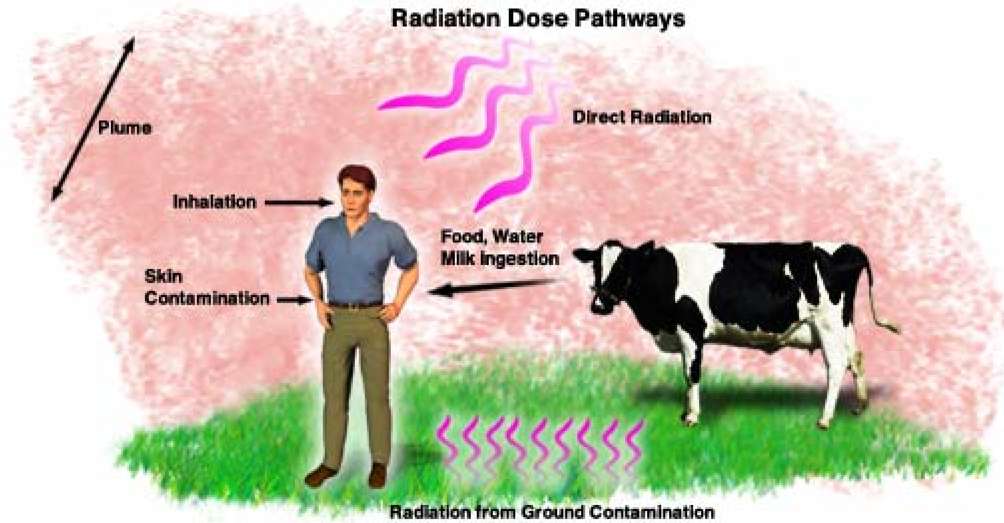
Radioactive contamination on a surface does not make the surface itself radioactive. The particles themselves are radioactive, not the surface they come in contact with. The surface can usually be cleaned of any contamination. <u>REMEMBER</u>: radioactive material emits radiation, once the surface is cleaned o the radioactive material there is no longer a threat.

Radiation is related to contamination in the same way that odor is related to manure and fertilizer. The following analogy illustrates this point. If you stand next to a freshly fertilized field, you can smell the fertilizer (manure). When you walk away from the field, you leave the odor behind. If you had stepped into the field, you would carry some of the fertilizer (manure) away with you on your shoes, and may be able to smell the odor of fertilizer until you clean your shoes. In the same way, if you stand next to contamination, you will be exposed to radiation. As long as you don't get the contamination on your body or clothes, you can walk away and leave the source of radiation behind. If you get contamination on your body, you will continue to be exposed to radiation until you wash the contamination off of your body. The radioactive material continues to emit radiation, but you are no longer carrying it with you.

Contamination Exposure

Radioactive fission products can also present a hazard through direct contact with the exposed individuals. Contact with a plume can result in contamination of a person's clothing or skin. Airborne radioactive materials may also present an internal exposure hazard if inhaled by individuals exposed to the passing radioactive plume. Inhaled material, in addition to directly providing a dose, contains certain elements that concentrate in particular organs (e.g., lungs, bones, or thyroid) and thus become a special threat to those organs.

Radioactive material from a radioactive plume may be swallowed, inhaled or contaminate the skin. It is unlikely that enough fallout particles could be inhaled into the lungs to cause significant harm. However, if it is very dusty, a folded cloth over the nose and mouth may act as a filter. This can prevent some ingestion or inhalation of the fallout particles. For example, radioactive particles deposited on the ground may be eaten by grazing cattle whose meat or milk is consumed by man (see figure below).



Exposure Control Techniques

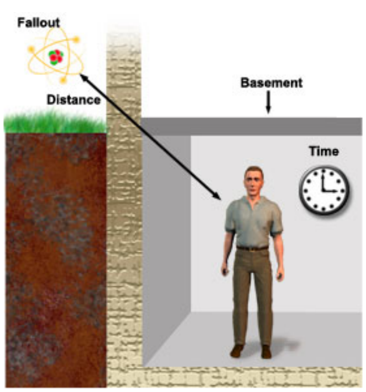
There are three important factors in protecting individuals from radiation: **time**, **distance**, and **shielding**.

Time factor: the less time an individual remains in a radiation field, the less exposure that individual will receive. If you remain in a 100 mR/hr field of radiation for 1 hour, you will be exposed to 100 mR. If you remain in the same 100 mR/hr field for 3 hours, you will be exposed to 300 mR (3 x 100).

Distance factor: the further an individual remains from a radiation source, the less exposure that individual will receive. The intensity of a radiation field decreases as the distance from the source increases. If the exposure rate at one foot away from the source is 1,000 mR/hr, the exposure rate at two feet away will be 250 mR/hr. The 250 mR/hr is one-quarter of the exposure rate at one foot

Shielding factor: the more material placed between an individual and a radiation source, the less exposure that individual will receive. The intensity of a radiation beam is reduced by absorption and scattering with the material. For gamma radiation, dense material such as lead is most effective as a shield. Beta radiation can be shielded by relatively thin amounts of wood or plastic. Alpha is shielded by virtually any material.

All of the above mentioned protective factors may be accomplished by an adequate shelter. The proper shelter provides distance away from the radiation located outside, acts as shielding and can also help prevent inhalation of radioactive material.



Taiwan: In 2003, a Chinese nuclear scientist was given a suspended death sentence for planting radioactive materials in the office of a business rival, sickening the man and 74 other people. These two men's rivalry began in 1997. The case of iridium-192 pellets used as the source of radiation was used for inspection of welded joints.
(WMD Awareness Level Training Student Manual AWR-160 Case Study P. 70)

Section 4: What does all this mean for the hematopoietic stem cell transplant community?

In this section you will learn about:

- Possible casualty levels
- Dangers resulting from a dirty bomb
- Possible timeline from radiation exposure to transplant

Expectations for the number of casualties resulting from a radiation event vary greatly from expert to expert. Like all disasters, there best- and worst-case scenarios, with many variations in-between. The U.S. government has expended considerable effort to provide planning criteria for emergency response personnel. These planning criteria are based on the detonation of an improvised nuclear device (IND) by a terrorist organization. General estimates for the number of patients with acute radiation syndrome after a 1 kiliton or 10 kiliton IND are estimated in the table below. In most worst-case scenarios, the number of victims will far exceed the hematopoietic stem cell transplant communities' resources. Importantly, the number of injured patients will far exceed the eventual number that receive transplants. In addition, the transplant community should expect public panic and mass confusion, as was witnessed after much smaller-scale events like the mailing of anthrax spores in 2001.

	# ARS Patients	
Exposure Level (Gy)	**1 KT IND**	**10 KT IND**
8.3 – 15 (Lethal)	18,000	45,000
5.3 - 8.3	19,500	79,500
3 - 5.3	33,000	108,900
1.5 - 3	66,000	70,000

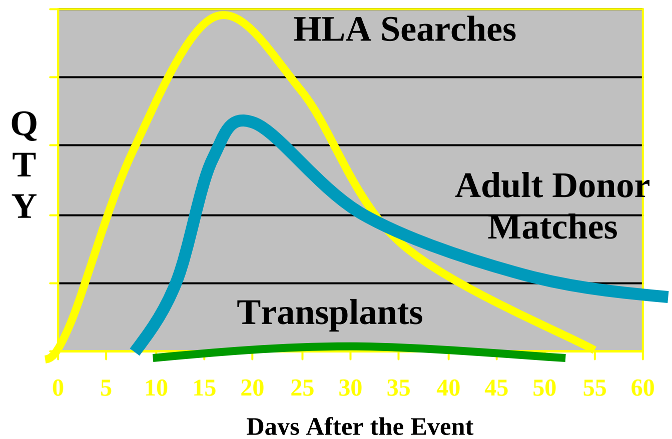
Table provided by Dr. Jamie Waselenko. Abbreviations: KT, kiloton; IND, improvised nuclear device; ARS, acute radiation syndrome. (Hiroshima = 15 KT yield)

Dirty bombs are conventional bombs attached to a source of radioactivity (e.g., Cobalt-60). The bomb explosion spreads the radioactivity around the affected area, resulting in widespread contamination. Dirty bombs, in comparison to an IND, will result in very few casualties, although most experts agree that the greatest danger from a dirty bomb is public panic. Thus, the economic impact of a dirty bomb is significant, far reaching and long lasting when compared to INDs or military nuclear weapons.

Goiania, Brazil: In 1987 scavengers recovered an x-ray machine source from an abandoned cancer treatment clinic. While attempting to recover metal to sell as scrap they opened the sealed device and removed some of the radioactive cesium powder. This blue glowing material was handled without protection and eventually given to children to play with. Many people rubbed this glowing "pretty blue" material on their bodies resulting in ingestion when they later ate without properly cleaning their hands. Of the 20 people that were injured by the radioactive material, five died. Over 113,000 people fearing contamination rushed the medical community for examination, of these only 129 were classified as contaminated. Also, surrounding communities and countries ostracized the region and Brazil by refusing to receive any goods for fear of contamination.

The exact effect on the hematopoietic stem cell transplant community is difficult to determine prior to an incident. The patient load will be based on the number of people who have received high doses of radiation and the subset of that group who are identified as potential transplant candidates. The following chart is an example of the possible flow of patients as it could impact the hematopoietic stem cell transplant community (chart created by Dr. Dennis Confer).

Timelines for Activity - Transplants



"Uncertainty remains about the number of victims who would develop ARS and clinically meaningful pancytopenia consequent to a nuclear detonation. Nonetheless, transplantation physicians, hematologists, and oncologists are challenged to prepare for a role in the management of patients with ARS in the event of a regional, national, or international emergency. We can hope that radiation accidents or attacks to do not occur, but we must improve our preparedness because they might." Weisdorf D, et al. Acute Radiation Injury: Contingency Planning for Triage Supportive Care, and Transplantation. Biology of Blood and Marrow Transplantation 12:672-682 (2006).

Patients most likely will not be available for admission to RITN centers until a number of days after an event, unless the hospital is in the vicinity of the radiological event. The delay would be the result of decontamination, triage, initial treatment and diagnosis and finally identifying a destination for each victim. The primary focus for all victims will be decontamination prior to evacuation to prevent the spread of and further injury from contaminated materials. Once decontaminated, the victims needing medical attention will be triaged and treated by state and federal first responders. Only after this initial treatment phase will patients be forwarded on to RITN centers for more specific care. There is the possibility that patients will present directly to a RITN center, if the event occurs locally or if the receiving hospital is connected to its state Radiological Emergency Preparedness plan, but in most cases there will be a lag of multiple days prior to patients arriving.

Planning for urgent stem cell transplantation for those with intermediate to high-dose radiation may be required. Expediting the recruitment and evaluation of donors to meet the shortened time to transplant will also be key in decreasing the death rate. Patients will effectively have already had their total body irradiation or at least a partial body irradiation and will not have time to wait. Donors may need to be temporarily housed close to the donor center to expedite the work-up and stem cell collection. Inevitably, altered standards of care will be implemented by the Department of Health and Human Services during this time to help shorten the timeframe.

ARS has four stages, symptoms such as anorexia, nausea, vomiting, fever, diarrhea, fluid shifts and electrolyte imbalance become prominent within 48 hours of radiation injury during the **Prodomal phase**. Within days to weeks of initial injury, temporary improvement begins as the individual enters the **Latent phase**. The Latent phase is followed by **Manifest illness** which may last weeks to months, with intense immunocompromise and symptoms specific to 4 major organ systems (hematopoietic system, gastrointestinal system, cutaneous system and neurovascular system). The final phase is **Recovery or Death**. After a lethal dose of radiation, victims may develop a temporal compression of these phases into a period of hours resulting in early death.

Contingency planning is important as the potential risk of accidental and intentional radiation exposure grows. Radioactive natural resources are processed into potentially deadly radioactive material at many sites around the world. Nations constantly clamor for nuclear capabilities for energy and to add to their military power and an uncounted quantity of radiation sources are lost or stolen around the world every day. All of these activities increase the ultimate possibility of a radiological incident that must be prepared for. Knowing the ultimate outcomes of a radioactive incident is not entirely possible. We can only prepare for these disasters as best we can; as Benjamin Franklin wisely stated "By failing to prepare you are preparing to fail."

Summary

Through this course we have presented just the basics of ionizing radiation. From this course we hope that you have learned a basic understanding of ionizing radiation and its components. We have specifically covered:

1. **Three main types of radiation:** The three types of ionizing radiation are alpha, beta and gamma. Alpha and beta radiation consist of actual particles that are electrically charged and are commonly referred to as alpha particles and beta particles. Gamma radiation, however, belongs to a class known as electromagnetic radiation.

2. **Understand the difference between radioactive material and radiation:** Radioactive material emits radiation. Once the material is removed the radiation is no longer a threat.

3. **Basic measurement of radiation:** The measurement of radiation can be very confusing, partially because there are so many different units and because, in addition to the intensity of exposure, the time of the exposure is critical. Two terms used to relate the amount of radiation received by the body are **exposure** and **dose.** When you are exposed to radiation, your body absorbs a dose of radiation. Roentgen is the unit used to express the amount of ionizing radiation exposure an individual receives.

4. **Name the four primary sources of radiation:** Natural and Man-made Radiation Sources, Ionizing radiation, Elements and Atoms, Radioactivity and Ionizing Radiation

5. **Basic overview of the biological effects of radiation:** Generally, a large acute exposure can result in observable effects, such as radiation sickness or death, shortly after exposure. The severity of these immediate effects depends on the amount of radiation dose. Large acute exposures can also result in effects such as cancer that show up after a number of years. Although the effects of exposure to large groups can be predicted, each individual's body differs. These differences can mean that, except at extremely high acute doses, two people exposed to the same amount of ionizing radiation may experience different symptoms. Biological factors which may influence the effect of radiation on an individual include age, sex, diet, body temperature, and health.

6. **Be able to describe symptoms of Acute Radiation Sickness (ARS):** Acute Radiation Sickness has a variety of symptoms ranging from mundane to unique depending on the level of exposure. Initial symptoms include nausea, vomiting and diarrhea these can grow into blistering, edema, reduced blood counts, as well as central nervous system complications.

7. **Explain the difference between internal and external contamination and internal and external exposure:** When you are exposed to radiation, the radiation does its damage, expends all its energy, and is gone. If you carry contamination on your clothes or body, the material continues to emit radiation as long as it is radioactive. Internal contamination is ingested, external contamination can be removed.

8. **Explain the concept of shielding:** The **shielding factor** means that the more material placed between an individual and a radiation source, the less exposure that individual will receive. The intensity of a radiation beam is reduced by absorption and scattering processes with the material. For gamma radiation, dense material such as lead is most effective as a shield. Beta radiation can be shielded by relatively thin amounts of wood or plastic. Alpha is shielded by virtually any material.

Reference materials

Reference Materials:

Radiological Emergency Management Independent Study Course (IS-3), Federal Emergency Management Agency

Some images obtained from FEMA (IS-3) web based training

Dr. Waselenko presentation on Acute Radiation Sickness

Department of Homeland Security - Weapons of Mass Destruction Awareness Level Training

Biology of Blood and Marrow Transplantation Vol. 12, pages 672-682

National Planning Scenarios April 2005:
http://media.washingtonpost.com/wp-srv/nation/nationalsecurity/earlywarning/NationalPlanningScenariosApril2005.pdf

Exam Instructions:

1. To receive credit for completion of training each examinee must submit their answers for grading online as well as complete a survey online:
    - Test link: https://nmdp.ilinc.com/register/xcbkhj
    - Survey link: https://nmdp.ilinc.com/register/zwptxj
    - *Complete the survey (6 questions) to ensure your RITN center receives credit toward its' annual training requirement.*
    - *Physicians seeking CME credit must submit the survey.*
2. Before completing this exam ensure you have read this entire course document.
3. This exam is open book.
4. Be sure to carefully read all possible answers prior to selecting your choice.
5. Results will be reviewed and shared with examinee immediately upon submission of online exam

1. **The rem is a unit used to measure:**
    a. Radiation exposure
    b. Radiation dose in terms of the amount of energy absorbed
    c. Radiation dose in terms of the amount of the biological effect caused by the amount of energy absorbed
    d. Radioactivity

2. **Because of its low penetrating ability, the type of radiation which is usually only a hazard when inhaled or ingested is:**
    a. Alpha radiation
    b. Beta radiation
    c. Gamma radiation
    d. Neutron radiation

3. **Cosmic radiation and radiation from terrestrial sources are examples of:**
    a. Natural background radiation
    b. Natural man-made radiation
    c. Industrial sources of radiation
    d. Radioactive sources used in the medical field

4. **An example of a man-made source of radiation is:**
    a. Terrestrial sources
    b. Cosmic radiation
    c. Diagnostic radiation
    d. Potassium-40 in the human body

5. **The three factors which are important in protecting individuals from radiation are:**
    a. Time, shielding, and dose rate
    b. Dose rate, time, and gender
    c. Time, shielding, and distance
    d. Distance, time, and dose rate

6. **Radiation received by the body over a short period is:**
    a. Chronic exposure
    b. Sublethal exposure
    c. Acute exposure
    d. Supralethal exposure

7. **Chronic exposures are:**
    a. Amounts of radiation received over a short period of time
    b. Amounts of radiation received over a very long period of time
    c. Acute exposures which affect only critical organs of the body
    d. Acute exposures which affect all parts of the body

8. **Radioactive decay is defined as:**
   a. The decrease in the amount of any radioactive material due to the spontaneous emission of ionizing radiation from the nucleus
   b. The decomposition of radioactive atoms due to lengthy exposure to direct sunlight
   c. The gradual decrease in the number of radioactive atoms in radioactive material due to spontaneous fission
   d. The decline in the strength of a radioactive source due to the combined effects of time, distance, and shielding

9. **Radioactive fallout (a.k.a contamination) makes the surface it comes into contact with radioactive. (True or False?)**
   a. True
   b. False

10. **Just over half of a person's exposure to external natural radiation comes from?**
   a. Radon
   b. Cosmic radiation
   c. Rocks
   d. Food

11. **The three main types of ionizing radiation are:**
   a. Microwave, x-ray, gamma
   b. Alpha, gamma, neutron
   c. Beta, gamma, neutron
   d. Alpha, beta, gamma

12. **The amount of radiation absorbed into the body is:**
   a. Charge
   b. Exposure rate
   c. Dose
   d. Contamination

13. **A unit used to express radiation exposure is the:**
   a. Roentgen
   b. Dose
   c. Ray
   d. Curie

14. **The rate at which an individual is exposed to radiation is:**
   a. Watts per hour
   b. Roentgens
   c. Exposure rate
   d. Dose

15. **The most common physical symptoms of early radiation sickness are:**
   a. Nausea, changes in blood cell formation, vomiting
   b. Diarrhea, nausea, vomiting, headache, fatigue
   c. Vomiting, changes in blood cell formation, burns
   d. High fever, changes in blood cell formation, nausea

16. One of the delayed effects of high-level radiation exposure is:

a. Increased risk of cancer
b. Nausea
c. Vomiting
d. Restlessness

17. Radioactivity is the process where unstable atoms disintegrate or decay to stable atoms. The energy released in this process is called:

a. The blast effect
b. The shock wave
c. A mushroom cloud
d. Ionizing radiation

18. The type of radiation that is a major hazard due to its relatively high penetrating power is radiation.

a. Alpha
b. Microwave
c. Gamma
d. Neutron

19. When radioactive particles land on a surface, the original surface:

a. Becomes permanently radioactive
b. Becomes radioactive for a limited period of time
c. Is considered contaminated, but does not become radioactive
d. Is unaffected and is safe to walk about

20. Radiation levels naturally decrease due to radioactive:

a. Decay
b. Decontamination
c. Equilibrium
d. Absorption

21. Almost all of the world population's dose from radioactivity comes from ______________ sources?

a. Radon
b. Natural
c. Nuclear medicine
d. Artificial

22. The source of most of the dose from natural sources of radiation is from what?

a. Radon
b. Lead
c. The sun
d. Consumer products

23. **The most common medical procedure leading to an individual's collective dose of radiation is what?**

a. Radiotherapy
b. Filling a cavity
c. Blood pressure check
d. X-ray

24. **Greatest danger from a dirty bomb is public panic?**

a. True
b. False

25. **Radiation Injury Treatment Network centers will most likely have to decontaminate patients prior to admitting them for treatment?**

a. True
b. False

26. **Symptoms of ARS include:**

a. Nausea
b. Diarrhea
c. Fatigue
d. All of the above

27. **High-levels of ionizing radiation exposure can result in a long-term effect of:**

a. Nausea
b. Restlessness
c. High fever
d. Increased risk of cancer

28. **Terminal ARS symptoms may include:**

a. Over excitability and lack of coordination
b. Breathing difficulty
c. Occasional periods of disorientation
d. All of the above

29. **50 rad is the equivalent of:**

a. 5 Gray
b. 0.5 Gray
c. 0.05 Gray
d. 500 Gray