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Scope of Study: This report covers a few of the basic effects of radiation which the author feels are appropriate for an introductory unit in high school biology. This includes the effects on body cells individually, genetic effects, and some of the more prevalent pathological effects. Safety measure are also reviewed.

Findings and Conclusions: Any amount of radiation regardless of how small can cause genetic damage to the cells. Pathological damage depends upon the dosage rate and the part of the body effected. Every possible safety precaution should be undertaken to hold radiation exposure to a minimum. The danger to the human body will increase in the future, therefore, all high school students need a basic knowledge of radiation effects.

Advisor's Approval: James H. Zant.

THE EFFECTS OF RADIATION ON THE HUMAN BODY: AN INTRODUCTORY UNIT FOR HIGH SCHOOL BIOLOGY

BY

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PART I

"INTRODUCTION"

The mind of the modern man has accomplished one of its greatest feats in the discovery of ways to manipulate nuclear energy. The great constructive and destructive uses of it are the background of much acientific research at present. Along with this research are articles in many news communication which tend to draw the public's attention to radiation and its effects on mankind.

The increase in radiation conscionsness of the general public is quite a demanding phenomenon. This widespread interest is undoubledly due to extensive newspaper and magazine publicity, often ill informed and unfortunately bedeviled by conflicting political and ethical points of view. The only point of agreement between these points of view is that the population of the world is being subjected to an increasing burden of ionizing radiation and that such radiations are potentially harmful.

The demand for a better understanding of this phenomenon reaches into our secondary schools of today. The better students, who usually read more than their instructors, are eager for enlightment on the effects of radiation. With this eager curiosity, motivation has taken its highest value to learning. It is then the responsibility of the instructor to direct this motivating force into increasing the knowledge of radiation to its maximum for the individual student.

The average secondary school science curriculum at present is overloaded. This gives rise to the question as where in the curriculum should a discussion of radiation effects be introduced. In evaluation of the processes of radiation we see that in operation it is physics. In action it is an ionizing agent which classes it as chemistry. In effect it acts upon living tissue, therefore, placing it in the category of bilolgy.

From the three mentioned categories for radiation, biology is selected as the starting point for teaching its effects. However, the other two categories must of necessity follow with ample explanation for a complete understanding of radiation. Biology is selected by the author on the following basis:

1. Biology is usually taught first in the highschool curriculum.
2. It shows both need and application from the biological viewpoint. The publicity given the effects to the human body is basis for a need of a better understanding of these effects. This understanding can be applied to future life in protection of self and progeny from the ill effects of radiation. Both need and application must be demonstrated before interest can be aroused in any course.
3. A higher percent of our students will be working with radiation and need to know the effects in order to take necessary precautions for personal safety.
4. The inheritance mechanism is by far the most sensitive

to radiation and will afford a background unit for introdution to the unit covered in this paper.

5. The basic vocabulary acquired in this unit will serve as a background for radiation study in future science courses in high school and college.

The biology curriculum of the average high school is just as overloaded as the physic and chemistry curricula. The big problem for the teacher then is how to squeeze radiation into an already loaded program. This, as in most other problems, is one which must be handed by the individual instructor. The one suggestion by the author would be the deletion of a part of that long tedious "operation frog" which is a standard part of many high school biology curriculums. The need for a study of such modern changes in our environment should be the driving force behind the biologist who wishes to keep his course up to date.

It is through personal concern for the biology curriculum and the influence a teacher has upon his students future that has prompted the writing of this paper. The contents of this report cannot possibly be taken as an all inclusive account of radiation and its biological effects, because many of them are unknown today. The purpose of the paper shall be its value as a guide for a unit to be taught in high school biology. The body of the paper shall be a summary of the effects now known and published by well known scientist in the field of radiation biology. This summation will not be all inclusive but will cover material the author feels can be adapted to the high school level.

The contents of this report will include a summary of ionizing radiation, radiation effects upon the cells, genetic effects of radiation, its pathological effects, and a short coverage on possible safety measures to prevent harmful radiation exposure. In the research and writing of this paper the author hopes to increase his personal knowledge of the subject enough to enlighten future students upon its possible effects and the roll it will play in their future. Every indication is that the problem will increase in the future. If it does it must be met intelligently and vigilantly by future scientists so that the development of atomic energy will not be hindered and at the same time afford the greatest possible protection for humanity during this development.

PART II

IONIZING RADIATION AND ITS MEANS OF ACTIVITY

The radiation with which this paper is concerned are the alpha, beta, and gamma radiations along with x-rays, protons, and neutrons. The entire group can be classified together as ionizing radiation. We might also be concerned with ultra-violet light which is not a true ioizing radiation. To clarify the term ionization it is explained by Lea, as follows: "an atom consists of a positively charged nucleus and a surrounding constellation of negative electrons, the whole being electrically neutral. The principal means of energy dissipation by an ionizing radiation in its passage through matter is the ejection of electrons from atoms through which it passes. An atom so ionized is left positively charged, and referred to as an ion."[1]

The biological action of radiation is due to the change which produces these ions. A small part may possibly be due to the separation of electrical charges but most of them can be attributed to chemical changes resulting from the ionization. The latter deduction is derived from the fact that when an electron is removed from an atom it is almost certain to change the molecule of which it is a part chemically. The electron removmoved could be a bonding electron which is shared by two atoms of a molecule. If this were the case, dissociation would occur

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[1]D. E. Lea, Action of Radiation on Living Cells (Cambridge, 1955), p. 1

and with it chemical change. The excessive energy needed to remove an electron could also create chemical change in a molecule.

Ultra-violet light as well as some ionizing radiations dissipate energy by excitation in the tissue. This consists of raising an electron in an atom to a higher energy level, an orbit farther from the nucleus, and producing a change within a molecule. The damage produced by this is less drastic in effect on the human body than from ionization.

Since we see that energy plays a large part in the effect of radiation, it is feasible to understand the use of the roentgen as the unit to measure the quantity of absorbed radiation. It involves a measure of the actual energy absorbed in the tissue. "The rigorous scientific definition of the roentgen involves the number of ions produced in a cubic centimeter of standard air."[2] The dosage of radiation determines the effect from radiation. Schubert and Lapp[3] give the following dose rate and effect information:

Dose Rate in Roentgens	Effects
0 - 25	No observable effect
25 - 50	Blood change (as manifested by count)
50 - 100	10% exhibit symptoms of radiation sickness. Full recovery within few days
100 - 200	25% exhibit symptoms, probably no deaths, possible disability

[2]Jack Schubert and Ralph E. Lapp, Radiation: What It Is and How It Affects You, (New York, 1957), p. 33

[3]Ibid., p. 45

Dose Rate in Roentgens	Effects
200 - 300	50% exhibit symptoms, 25% deaths
300 - 400	90% exhibit symptoms, 25% deaths, injury possible to all 90%
400 - 500	50% lethal
600 or over	Nearly all die within 30 days

From this information we can see that radiation does have some effect on the human body. Further in this report we will discover that even the small doses have drastic effects though they are not observable by the human eye until later in life or even in future generation of our progeny.

PART III

RADIATION AND THE BODY CELLS

The fundamental effects of radiation begin with the cell. It is here that the ultimate demonstration of how radiation acts on living matter must be found. Cells themselves, despite enormous differences in their size, shapes, and functions are constructed according to a certain plan. They are surrounded by a nearly invisible outer membrane known as the plama membrane. Next they contain a gelatinous material known as cytoplasm in which is suspended a very dense particle known as the nucleus. This nucleus is bound by its own membrane and is the heart of the cell's activity.

The nucleus contains threadlike chromosomes which under the microscope appear as a tangled network. Each chromosome in the human body contains a large number of genes arranged in single file along the entire chromosome. Each of these genes has its own unique function in regulating the continuous series of chemical reactions necessary to maintain life. Radiation affects the cell by creating a change in composition or arrangement of these genes.

We think of this cell as the smallest unit of organismal structure, but from the point of view of physics and chemistry it is multitudinous. "It consists of 10^8 to 10^9 molecules of such diverse materials as water, minerals, proteins, carbohydrates, fats, etc., which are in active motion."[1] Cells however are mainly water and it is in this water that a primary effect of radiation takes place.

"When water in the cell is acted upon by radiation, a small fraction is decomposed into extremely reactive fragments called free radicals, which readily interact to form peroxides and other cell poisons. These peroxides, as well as many other decomposition products, can move around for a short while until they alter a receptive molecule. Among the most sensitive substances in the cell are enzymes, which are essentially large protein molecules, one enzyme molecule modified by radiation may transform 100,000 or more molecules needed for perpetuation of the metabolic activities of the cell."[2]

Ionizing radiation has a minor effect on cellular metabolism such as respiration and glycolysis but it has a marked influences on the mitotic processes. It causes a drop in the rate of mitosis, followed by an attempt to recover and the appearance of degenerate cells.

It is in the mitotic process that cell nuclei are primarily involved and ionizing radiation has its greatest influence on the cell nucleus during this time. Irradiation can influence the rate of mitosis in all five stages of mitosis but the cell has a better chance of recovery if it occurs after metaphase.

The chief constituent of the nucleus desoxyribonucleoprotein, may be the most important constituent in cell damage. Ionizing radiation possibly through the intermediary of active radicals produced in the tissue water as previously men-

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[1] Friedrich Ellinger, Medical Radiation Biology, (Springfield, 1957), p. 14

[2] Schubert and Lapp, p. 67

tioned interferes with the synthesis of this nuclear constituent. The extent of this interference depends on the dose and density of the ionization produced in the surrounding tissue. This interference can interrupt cell division to the point of mutation or cell degeneration by interrupting the conversion of ribo-nucleic acid, usually found in the cell plasma, into the desoxy-ribonucleic acid of the nucleus.

Attempts made to explain the effects of ionizing radiation during the mitotic processes of a cell on the basis of interference of the synthetic processes taking place in the cell must also consider other possibilities in addition to the synthesis of desoxyribonucleoprotein. "If under the action of ionizing particles chromosome threads are broken, synthetic processes taking place on the thread surface may also be influenced or interrupted. There is a possibility, also, that enzymatic processes taking place in the cytoplasm are governed by the happenings in the nucleus. In that case a chromosome break may have far-reaching consequences"[3] as previously mentioned from other sources.

Under the microscope the irradiated cells exhibit the phenomena of vacuolation and pycnosis of the nucleus. This pycnosis or denser appearance of the nuclear material is due to chemical changes of the chromatin, the substance making up the cell nucleus.

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[3] George Hevesy, "Ionizing Radiation and Cellular Metabolism", Symposium of Radiobiology: Oberlin College, (New York, 1956) p. 203

After this discussion of the different effects upon the individual cell the different cells of the body should be classified according to their sensitivity to ionizing radiation. Cells which are considered to be highly sensitive to radiation damage are: bone-marrow cells, lymphocytes, cells of gonads, spleen cells, cells of thyroid, and intestinal mucous cells. Cells affected to a moderate extent include those in: growing bones, epithelium of skin, salivary gland, connective tissue, and elastic tissue. The following include organ and tissues of which their cells are considered to be relatively radiation-resistant: kidney, liver, mature bone, and the brain or nervous tissue. This classification is based primarily on the one given by Schubert and Lapp[4] in their very informative book upon radiation. The significant thing to remember is that any cells can be damaged if the dosage is great enough but the damage to some cells is much slower in showing up than in others.

[4]Schubert and Lapp, p. 45

PART IV

"GENETIC EFFECTS OF RADIATION"

In the study of the genetic effects of radiation there must be a background in the basic concepts of heredity. The most prevalent theory of heredity today is the gene theory. Each cell of the body contains a great collection of 30,000 or more genes. These diverse hereditary units are strung together in a single file arrangement to form the tiny threads visible under the microscope called chromosomes. It is by the interaction of the chemical products of these genes that the composition and structure of every living thing are determined.

Before any cell divides each of its genes duplicates itself, thus each chromosome thread becomes two both structurally identical. Then when the cell divides each of the two resulting cells has chromosomes exactly alike or very similar depending upon the activities occuring within the cell during division. Some activities within the cell can bring about rare chemical accidents which change the genes. These accidents are called mutations.

These mutations usually strike one gene at a time and these genes produce new ones having different or abonormal characteristics. Very rarely a mutant gene happens to have an advantageous effect. In fact, Muller[1] states that 99 percent of

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[1] Muller, H. J. "Radiation and Human Mutation," Scientific American, November 1955, p. 58

mutant genes in man produce some harmful effect or disturbance in function. This disturbance can vary from slight malfunction of a cell to the extent that inheritance of mutant gene might mean death if the same defective gene was received from both parents. Such a gene as the latter is refered to as a lethal gene. Normally the danger is not from lethal genes but from genes which produce some detriment, giving rise to a risk of premature death or failure to reproduce.

This risk is involved in genes which give rise to only slight impairment to the person inheriting them. Because of its persistance the slightly detrimental gene can produce a total amount of damage comparable to that produced by the very lethal ones. The sum effect in disability from these genes can be noticeable and is usually felt more as we grow older or in successive generations. The damage from a mutant gene can only disappear when the inheritance line in which they are carried dies out. In case of severe and obvious damage this may happen in the first generation, in other cases it may require hundreds of generations. Thus, for the general population a little radiation, producing mutations, to a lot of people is as harmful as a lot of radiation to a few since the total number of mutant genes can be the same in the two case.

The greatest effect of radiation on the human body is this ability to produce mutant genes which can transfer damage to future generation. There is controversy over the effects which radiation has upon genes, but the three most prevalent are mentioned by Glasstone[2] as: 1. production of toxic

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[2]Glasstone, Samuel, Sourcebook of Atomic Energy, (Princeton, 1957), p. 524

substances, 2. ionization by breakage of chemical bonds, and 3. the causing of two or more breaks in the chromosomes. The basis behind the production of toxic substances is that certain chemicals such as mustard gas cause mutations simular to those resulting from radiation exposure. The genes are believed to be large, complex molecules simular to protein and it is known that any breakage in the chemical bonds due to ionization will destroy or change the nature of large molecules in experimental work. The third mode would leave room for mutation in the recombination of the chromosome parts. It is known that the parts of a broken chromosome tend to rejoin and if a small part containing a gene were lost a mutant condition would be produced. These parts could also be rearranged within the chromosome and produce genetic changes great enough to produce mutation.

The results of a mutant gene is duplicated in subsequent cell divisions. Once a gene mutates it never recovers its original form unless a further restorative mutation occurs. Most geneticists agree that a restorative mutation would be quite rare. A mutation could occur in either a body cell or sex cell. The ones occuring in a body cell would merely be passed along to other body cells and will be discussed under the pathological effects of radiation in chapter V. The ones of greatest concern here are those mutations which arise in sex cells and are therefore hereditary.

"Radiation can affect the reproductive cells in three ways: It can kill the cells outright; it can break or damage the chromosome, and it can cause the genes to mutate".[3] The latter two have already been discussed and the first is of no concern here because the death of the cell automatically eliminates it from influencing heredity. The main concern with the reproductive cells is that there is no minimum amount of radiation which must be exceeded before mutation occurs. "Any amount, however small, that reaches the reproductive cells can cause a correspondingly small number of mutations. The more radiation received the more mutations".[4] The harm done is cumulative, and depends on the total accumulated gonad dose received by people from their own conception to the conception of their last child.

The cumulative harm may be exemplified by a female child since she contains at birth all the ova she will ever use. "It is very improtant to note that exposure of the ovaries to radiation affects eggs which are to be fertilized in the future. Thus radiation damage is preserved by the ova and may result in defective children. Even if the children appear normal, they may carry defects in their heredity make-up (the genes) which will be manifest in later generation".[5] The exposure should be held to an extreme minimum from birth through the reproductive life of a female.

In the male the testes produce spermatozoa. These ma-

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[3]Schubert and Lapp, p. 186

[4]Report to the Public. A Study of the Biological Effects of Atomic Radiation, (Washington, 1956), p. 28

[5]Schubert and Lapp, p. 77

ture from very young cells called spermatogoina which are among the most radiosensitive cells of the human body. A small amount of radiation can kill these cells and render temporary sterility to an individual. Fertility returns to a male after an adequate number of spermatogonia have matured. Radiation can render some of these spermatogonia defective or produce mutant gene in them. This often happens when mature spermatozoa are exposed to radiation or from defects in the first ones to mature after temporary sterility due to radiation. The best precaution for the male is during medical exposure is to protect the gonads with a lead shield.

During a symposium on radiobiology Russell of Oak Ridge listed the following unique feature as the basis for the importance of genetic effects among the hazards of exposure to radiation:

1. "There is usually no healing of the damage. Some type of damage to the genetic material, for example the breaking of a chromosome, may, under certain conditions heal. Others, for example "cell lethal" mutations, are by their nature prevented from passing on to any descendants. However, from the effects that are actually hereditary, in the sense of becoming manifest in the next or subsequent generations, the only chance of healing lies in the remote possibility of reverse mutation.

2. The damage is transmitted to descentants. Arguments to the effects that we should be phlegmatic about the effects of small doses of radiation, because the total damage is probably no worse than that resulting from various other insults to the organism which man tolerates or even enjoys, ignore the fact that among commonly tolerated insults radiation is the only one known to affect descendant generations.

3. The damage is hidden for a long time before it becomes manifested. Hereditary effects obviously require at least one generation to express themselves. For the large class of recessive mutations, many generation would on the average, be required in a large, more or less random breeding population. This class of mutations is particularly insidious in the sense that even when a particular recessive mutation is finally revealed,

it is usually only a very small fraction of the total effect that has become manifest, the rest still being hidden in individuals heterozygous for the mutation.

4. There is no threshold dose. Genetic changes may occur at any dose, no matter how small. In drawing up safety measures against genetic effects of radiation in human populations, serious attention must be given this point. If there is no threshold dose, then a so called "tolerance" dose cannot be one which produces no genetic effect, but only one which does not add a "serious" increase to the effects that already occur as a result of natural radiation and other causes".[6]

Most of these conclusion are based on experimental animals and extrapolated to human biology. Since experiments with human beings are not feasible, studies are being made with animals in the hopes of obtaining some definite information. "The evidence so far indicates that true mutations can be induced in mice by means of radiation, the number of mutations being approximately proportional to the total exposure to radiation".[7] These mutations are essentially independent of the dose rate and appear to be cumulative throught the years.

Along with this experimental work on animals observations being made by the Atomic Bomb Casualty Commission of the National Research Council may impart some light on the direct human effects by observation of persons exposed to radiation from the atomic bombs exploded over Japan in 1945. This work is sponsored by the U.S. Atomic Commission and has reported reliable data on pathological effects and collected some information upon genetic effects.

Because of the great importance of the subjects on ge-

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[6]Russell, W. L., "Mammalian Radiation Genetics", Symposium of Radiobiology; Oberlin College, ed. James J. Nickerson (New York, 1952), p.p. 427-28

[7]Glasstone, p. 524

netic effects to the human body, careful and detailed study must be carried out before the present theories can be accepted without reservations. In view of the experimental results with animals such as mice there is no doubt in the geneticist's mind that radiation can produce mutation. The amount of radiation needed to produce noticeable mutation is an uncertainty at present, but there is great indication of the cumulative dosage through the years which should make each person strive to keep personal exposure to a minimum. Man must protect his genetic heritage as best he can until adequate information is available to substantiate control or protection from radiation.

PART V

PATHOLOGICAL EFFECTS

In study of the pathological effects of radiation the first thing covered will be the initial response of the human body to radiation exposure. This initial response, or radiation sickness, is known as a benign but unpleasant state occuring during the first few hours following irradiation. According to information from Brues and Sacher[1] the automatic nervous system plays the most important role in this syndrone. The most characteristic symptoms of radiation sickness are; (1) a rapid accumulation of uric acid in the blood and tissue, (2) hypotension, and (3) death to some if the dosage is large enough. The most remarkable thing about this syndrone is the length of time elapsed between the physiochemical exposure and the appearance of symptoms. It takes an extremely large dose to kill a human being.

The bulk of the pathological effects are secondary, at least in time. Such secondary effects are not unusual in toxicology, of course, and their period of latency may depend on the length of time the organism can get along without some essential function. The appearance of these effects varies with the individual and the tissue which has been damaged by the radiation. It has long been known that many of the features of an acute radiation syndrome resemble responses to infection.

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[1] Brues, A. M., and George A. Sacher, "Analysis of Mammalian Radiation Injury and Lethality", Symposium of Radiobiology: Oberlin College, ed. James J. Nickerson (New York, 1952) p. 441

This can be accredited to damage incurred by the tissue which form the cells for fighting infectious invasion. Without the production of these cells latent organisms of the body or new organisms which may have gained entrance through the cytological discontinuity set up an infection which can cause death as a secondary effect of irradiation.

Most of the pathological effects of radiation seem to have a cytological basis and just as the genetic effects are based on mutation of the gene within the sex cell the pathological effects are due primarily to mutation occuring in a somatic (body) cell. When a mutation occurs in a body cell other than a sex cell it is merely passed along to other body cells and not to one's descendants. These mutated body cells can acquire or become more receptive to uncontrolled invasion growth which is thought by many to be the cause of leukemia and other cancerous growth.[2] This type of abnormal growth of the somatic cells after irradiation occurs in tissue like skin, liver, or bone marrow producing many harmful changes in the exposed individual.

One of these changes in an exposed individual which is observed soon after irradiation is in the blood. It is known that an ounce of blood contains about one-hundred and fifty billion red blood cells and about two-hundred million white cells. There are several varities of white cells, and those most sensitive to radiation and the lymphocytes, which constitute about twenty five percent of all the white cells. It is reported that a single dose of 50 roentgens of radiation to

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[2]Schubert and Lapp, p. 185

the whole body causes the number of lymphocytes to drop by one-half in about two or three days.[3] It takes the normal system about a week to return to the preradiation level. The primary functions of these blood cells are to protect the body against infection, to aid the body in the repair of tissue, and to promote clotting of the blood. As already mentioned exposure to radiation increases greatly the body's susceptibility to infections. The effect upon clotting of blood is shown in the bleeding tendency which is one symptom of radiation sickness. "This bleeding tendency is related in part to the disappearance of blood platelets (again on a cytological basis) and in part to the appearance in the blood of substances which interfere with coagulation.[4] Small changes in the blood cell may be the forerunners of anemia, leukemia and other serious and fatal blood diseases.

Leukemia is the blood disease which needs study from the radiation effect cause because of the ultimate fatality of it. It is a rare disease in which uncontrolled overproduction of the white blood cells occurs. The cause of this overproduction is unknown and lies in the fact that many organs in the body are responsible for blood-cell production, removal of dead cell, and other functions necessary to regulate the blood composition. The organs include the lymph node, spleen, and bone marrow. The lymph nodes and spleen produce mainly the lymphocytes and both are very sensitive to radiation. Other white cells and the red cells are produced in the bone marrow which is very sen-

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[5]Schubert and Lapp, p. 157

[6]Ibid, p. 158

sitive to radiation and when damaged may fail to produce new cells. Leukemia could possibly be a combination of uncontrolled invasion growth of the lymphocytes in the lymph nodes and spleen while the bone marrow has reduced its production of red cells. Both of these can occur from radiation exposure.

In connection with leukemia being far more prevalent in human beings who have received radiation overexposure Schubert and Lapp give the following report.

"In the group that was 0 to 19 years of age at Hiroshima, 21 cases of leukemia were found by the end of 1954, 9 years after the dropping of the bomb. These were children within 1500 meters of the center of the explosion, which means that they received dosages of three-hundred roentgens or more. Not more than two cases of leukemia would have been expected in an unexposed Japanese population of the same age and numbers."[5]

Leukemia has been observed in children who were exposed to x-rays in infancy during treatments for enlargement of their thymus glands. Parents of children who have already received radiation treatments for enlarged thymus can take comfort in the statistical fact that at most only one child in two hundred so treated has developed leukemia.[6]

From the blood we go to the skin where a noticeable effect of radiation is the production of a reddening (erythema), which results partly from an enlargement of the small blood vessels supplying the skin. The development of an erythema is often used to gauge the amount of radiation delivered during x-ray or radium treatment. This erythema is an inflammatory reaction of the skin which is reversible if the dosage is not too great.

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[5]Schubert and Lapp, p. 157

[6]Ibid, p. 158

The next type of skin change could be classed as a conditional reversible change where the pigmentation of the irradiated skin changes which may last for weeks to months or even years.

"Radiation pigmented skin does not react to further exposure with the same sensitivity as does skin not exposed, hence the classification as a conditional reversible skin effect.[7] Along with this pigmented skin should be classified the temporary loss of hair due to irradiation. The hair follicles and glands of the skin are often affected by radiation. In heavily exposed skin, destruction of the sweat glands can cause the skin to lose completely the ability to sweat. With very high dosage the skin also loses its normal greasy texture because of destruction of the oil-producing glands.

With increased irradiation skin changes reach the point in which they are all irreversible. The glanular changes can reach this extreme. The following types of disorders have been observed with excessive radiation dosage: (1) acute or chronic dermatitis with atrophic or hypertrophic skin changes, (2) formation of teleangiectases, (3) formation of skin ulcers, and (4) on the extreme end skin cancers. All four of these are considered to be irreversible and the most baffling relationship is the very long latency period between exposure and the appearance of symptoms which indicate that the original damage was this great.

Mature bone is considered to be radiation-resistant but much harm can be incurred if radiation occurs in growing bone.

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[7]Ellinger, p. 113

As the age of the person increases there is a definite decrease in sensitivity of bones to radiation. It is generally recognized that the sensitive part of the bone is the epiphysis where most cell activity is taking place.[8] It is here that cytological malformation can occur. From this fact alone every attempt possible should be taken to protect the epiphyseal lines of the bones of growing children during therapeutic procedures. One of the therapeutic practices of today occurs in the diagnostic x-rays used by many dentists. The patient should be sure of his doctor's knowledge before having an excessive number of such x-rays taken. The pathological disease occuring after such practices is jaw necrosis. It is found to occur more frequently in the mandibula than in the maxilla and in instances where carious or diseased teeth were present during radiation therapy along with poor mouth hygiene immediately following exposure. It may occur within a few months to four or more years after irradiation. Tooth extraction immediately following irradiation has repeatedly been recognized as the cause of this osteonecrosis. In many places the extraction of diseased teeth prior to the institution of radiation therapy is mandatory. The jaw is then given at least two weeks in order to allow some reconstruction of the jaw bones before irradiation. This delay is justified on the basis of the seriousness of jaw necrosis and future complication such as the possibility of bone cancer due to accumulation of isotopes stored in the bone.

Another pathological effect which seems to have a cyto-

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[8]Ibid, p. 185

logical basis is sterility which occurs after the cells of the gonads undergo change brought about by radiation. The testes of man are much more susceptible than the ovaries of woman. Whether the cell destruction that occurs here is from a mechanical breakdown of the chromosomes or from fluid poison produced in the body fluids is unknown. The cells most susceptible to irradiation appear to be those which show rapid division for replacement and which do not have a large nucleic acid reserve according to Giles.[9] This is true of many of the cellular basis of the pathological effects covered in this paper.

Last let us remind you that the chronic lifetime effects of irradiation are cancer and a shortening of life based on heredity or some pathological disorder. To increase longevity and reduce suffering let each person keep personal exposure to a minimum.

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[9] Giles, Norman J. Jr., "Recent Evidence on the Mechanism of Chromosome Aberration Production by Ionizing Radiations", Symposium of Radiobiology: Oberlin College, ed. James J. Nickerson, (New York, 1952) p. 268

PART VI

"RADIATION SAFETY"

Radiation damage is a comparatively new hazard to man's well-being and safety measures must start from the beginning by educating the public. The public must be awakened to the perils of radiation hazards before they can be brought under proper control. Naturally the first prerequisite for action and the constructive approach to the problem is knowledge. In this case the awareness of the radiation effect mentioned previously is most important. The intimate detalis are better left to the expert but the public needs to know enough to evaluate the biological hazards and to insist on proper control legislation. Future research is necessary in the mechanism of cell damage by radiation, the nature of cell repair, and to extend present inadequate knowledge of the mechanism of cell growth.

Schubert and Lapp suggest one of the best legislative moves in radiation safety.

> "Control Service should be authorized to license all fluoroscopes of all kinds, of radium devices, and of all radiation producing machines. Such a license should be granted only after the applicant has demonstrated a competence to use the equipment and an adequate knowledge of safe radiation practice. Licensees would be subject to preiodic check-ups to insure that proper radiation controls were in effect. The licensee would be required to keep up-to-date records of every dose delivered to a patient in excess of one roentgen. Data about individual exposure would be collected by the Control Service in a national registry. No doubt such record-keeping would be expensive, but it would serve as an excellent check upon the individual's dosage and would curtail excessive irradiation for benigh conditions. It would, in addition, permit orderly follow up studies of people who are known to have been overexposed. It seems to us that the keeping of radiation histories or diaries for U.S. citizens is an essen-

tial feature of the atomic age. Modern business machines and electronic computers should ease the problem of tedious and costly record-keeping. However, federal record-keeping is apt to be looked upon by organized medicine as akin to socialized medicine, and congress may expect bitter opposition to this control feature of radiation protection".[1]

Adequate personal record keeping would greatly aid in radiation control. Shielding of the patient from unnecessary radiation would aid also. In most cases shielding is not a difficult matter, yet for some reason the practice is not widely adopted in U.S. Shielding especially of the gonads would reduce the effects of radiation upon heredity. The purpose of radiation control is to limit radiation hazards and not to eliminate them entirely, for the diagnostic value of x-rays is of immense value in corrective and preventive medicine. Likewise radioisotopes show comparable diagnostic value, but their unrestricted use on a large scale right now seems premature in the light of our lack of knowledge of the ultimate biological effects and in view of the inadequate controls which govern their use.

All work on control of radiation is not left to the future for radiation experts have recognized the great hazards of radiation exposure to children and have given special recommendations and regulation for control.

"1. In the U.S., employment of persons under 18 yrs of age for work with radioactive materials is prohibited by regulations promulgated by the Secretary of labor.

2. In cases in which minors may be exposed to radia- in the course of their normal activities, protective measures (should) be taken to make sure that no minor actually receives radiation at a weekly rate higher than 1/10 the permissible weekly doses.

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[1] Schubert and Lapp, p. 261

3. The permissible dose for persons over 45 years of age are double those allowed for younger adults with respect to most tissue.

4. The radiation protection group at the Harvard Medical school has for many years applied a policy dictating that in cases where tracer doses of radioactive isotopes are used for experimental purposes (excluding alpha-emitting isotopes which are regarded extremely dangerous), the doses for children under 15 yrs of age must be no more than 1/5 those allowed the adults".[2]

The individual who works with radiation must practice every safety precaution. The obvious way of avoiding radiation is to increase the distance between the worker and the source of radiation. Where the distance is still near enough for appreciable damage suitable absorbers or shields should be used. The type of shield or absorber depends upon the type of radiation. Beta particles can be shielded with plastics, such as lucite or even glass while gamma radiation requires materials with high density and high atomic number such as lead.[3] Rubber gloves are sufficient to absorb alpha particles and most alpha emitters can be manipulated without difficulty, provided rigid precautions are taken to avoid inhalation.

The work with substances emitting alpha particles should be carried out in well ventilated spaces, or a respirator should be worn. Gloves should be used, in any case, to prevent radiation contact with the skin. Special protective clothing is worn during work which is shed when leaving the radioactive area. "Food should not be stored, prepared, or eaten in places where radioactive substances are present, and there should be no smoking because of the danger of ingestion of active materi-

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[2]Ibid, p. 155

[3]Glasstone, p. 513

als from contaminated hands".[4] Ingestion of radioactive substances has greater danger due to the fact that it works from the inside near vital organs. It's radiation need not be penetrating to be very damaging. It is known when a complex organism is exposed to radiation the degree of damage depends on which body cells are affected. The more vital parts are generally some distance from the surface. Radiation coming from outside can only harm cells according to it penetrating power. X-rays and gamma rays are much more penetrating that the particle radiation. If radiation originates inside the body then its effects can harm vital organs sooner. Care should then be taken that hands be well washed and in most plants hands and shoes are monitored before leaving the working area for radio activity.

Another safety factor which is faced by the science laboratories working with isotope tracers is the disposal of radioactive waste. Glasstone list the two general principles which are presently recommended.

"First the particular radioisotope should be mixed with a large amount of a stable isotope (or isotopes) of the same element in the same chemical form. In this way, the amount of active material likely to be taken up, by a plant or other living organism is greatly diminished since the various isotopes of a given element will be absorbed in the proportions present. Second, the waste solutions should be very greatly diluted with water, so as to reduce the activity in a given volume before discharge to the sewer. By keeping below certain limits radiophosphous (p32) and radio iodine (I131) can be disposed of in this manner. Radio active carbon (C14) compounds can be burned, and the gases exhausted into the air, with due precautions to insure very through dilution. All radioactive wastes can be buried in the earth at a minimum depth of 5 feet in suitably restricted areas, provided the material is first mixed with a stable isotope of the same element, in the same chemical form. The activity of the material that may be buried each day is strictly limited".[5]

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[4]Ibid

[5]Ibid, p. 522

Precautions can be followed before medical exposure which greatly reduce the general damage to the system. This consist of giving the patient certain agents before and during exposure which compete for oxygen in the body. These agents tie up the oxygen which would otherwise be use by radiation to oxidize and thus alter the components of the body cells. Two such agents which show good promise for this purpose are cysteine and glutothione.[6]

After an individual has been exposed to radiation especially an excessive amount the following recommended measures should be followed.[7]

1. blood tranfusion if necessary from laboratory test
2. bed rest and sedatives
3. maintanence of body fluids and mineral balance
4. if infection develops, the administration of broad spectrum antibiotics in large doses.
5. give anti-shock drugs
6. give spleen tissue and bone marrow tissue if necessary.

Most scientist feel that the danger from missuse medically is greater than from bomb tests. The safety precautions here becomes of individual concern and it is up to each individual to acquire enough knowledge to determine his own situation.

"You may be somewhat embarrased about examining your doctor on his knowledge of radiation, but it is well to remember

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[6]Atomic Energy Commission, Use of Isotopes in Medical Research, Diagnosis, and Therapy (Washington, 1956), p. 14

[7]Schubert and Lapp, p.p. 85-86

that the risks involved in continuous exposure before the fluoroscopic screen are much greater than from an ordinary x-ray photo. First of all find out which form of irradiation is to be used. Our advice is to follow these few rules.

1. Ask your doctor whether he is going to take x-ray photos, if he says, "no" and uses an x-ray machine, he is using fluoroscopy. In that case it may be well to pause and consider.

2. If you suspect that you are pregnant, tell the doctor that you wish to have the routine x-ray examination postponed.

3. If you know that you are pregnant, do not allow any x-rays unless they are quite localized as to an extremity, or unless there is preferential shielding of the womb or unless the condition is so critical as to warrant the calculated risk.

4. If it is necessary for you or your children to undergo radiotherapy, ask if the condition being treated is malignant. If it is non-malignant, ask the doctor about alternative modes of treatment.

5. Tell the doctor that you are keeping a personal radiation diary for yourself and your family. Ask him to give you in writing a summary of the x-ray or radium treatment, including a specification of the roentgen dosage, the area treated, and an estimate of the dosage to the gonads".[8]

As a safety measure keep that radiation diary and have your own doctor record an dosage that the body might receive. Schubert and Lapp gives an excellent one as an appendage on the flyleaf of their book which is worth giving in this report. A form of their diary is illustrated on the following page.

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[8]Ibid, p. 179

Your Radiation Diary

Name____________________ Sex____________________

Address____________________ Date of Birth____________________

Date	Physician	Locality	Details Of Irradiation specify area irradia-ed, shielding, type of treatment, quality of radiation, and filter factors.	Dosage	Estimated Dose to Gonads	Comments

PART VII

"CONCLUSION"

Ionizing radiation by it dissipation of energy in removal of electrons from the molecules making up the human body can bring about chemical changes which are detrimental to the cells or tissue in which the molecule is found. This can be done by actually ejecting an electron and leaving the molecule ionized or by excitation (changing the energy level of the electron). The former has more drastic effect on the human body than does the latter.

The fundamental effects of radiation begin with the cell. Here where there is a very large percent of water the ionizing radiation can decompose this water and form peroxides which are toxic to the cell. Especially the cell nucleus feels this interference in synthesis of essential material and mitosis or cell division is delayed or completely stopped due to radiation effects. The different cells of the body exhibit different sensitivity to radiation.

Radiation interferes more with the heredity or genetic makeup of an individual than any other part. Here it can cause drastic chemical changes in the basic units, genes, which can bring about a change within future generations. These changes can range from slight malfunction of a cell within the body to death from a lethal gene produced during mutation from radiation. The total effect of a slight malfunction can be greater than a lethal gene if a large enough percent of the entire population is effected in this way by radiation. These mutations can be caused by radiation, by the production of toxic substances, ionization breakage of chemical bonds, or causing two or more breaks in a chromosome. Most of these mutant genes will produce a harmful effect or disturbance in man. A much higher percent of these mutations occur when the gonads are allowed to receive direct radiation. The radiation effect to heredity is accumulative from birth until the last child is born of a parent.

Most of the pathological effects of radiation seem to have a cytological basis due primarily to mutation of the somatic cells. The first pathological change noticed after irradiation is a change in the blood. This change can vary from a temporary upset in proportion of red and white blood cell to a malignant condition such as leukemia. This early change in blood usually greatly reduces the body's defense against infection and can lead to serious infectious diseases. The pathological effect on the skin, also, has a wide range. It can vary from erythema to skin cancer. Effected along with the skin epitheluim is the hair follicles (loss of hair) sweat glands, and oil glands found in the skin. Bone, especially growing bone, can be retarted in growth by radiation. The mature bone on the other hand is quite resistant unless radioactive isotopes are being deposited in them which can lead to bone cancer. In all pathological effects the outstanding feature lies in the shortening of life and production of cancer which result from excess exposure.

Safety from radiation will only come from knowledge of its effects and by control legislation based on sound scientific principles. Personal safety will come from adequate personal records and sensible medical use. We know that medically radiation has done more good than harm but let us strive for a wide ratio between the two. The person working directly with radio isotopes should practice every safety precaution and take advantage of all shielding devices and protective clothing known. The disposal of waste has already been placed under control legislation which will suffice if followed to the letter. Work is also progressing on the use of agents to reduce the effects of radiation during therapeutic treatments. The compounds such as cysteine and glutothione show great promise in this field.

This brief summation of the effects of radiation should serve well as an introductory unit in high school biology. It is an attempt to show to the student a need for this type of knowledge and to help them realize how they will be involved with radiation in the future. It covers primarily the hazards of ionizing radiation and included will be the acquiring of a basic vocabulary of the related biological terms listed in the accompaning glossary.

Present day research indicates a large variety of peace time applications which will play a part in nearly every student's future. These application include:

1. Production of power
2. Improved medical therapy

3. Isotopic tracer study of disease
4. Leukemia therapy
5. Insect killing
6. Sterilizing foods infested with parasites
7. Bacterial sterilization
8. Agricultural application
    a. New strains of plants from radiation mutations
    b. Measurement of fats on beef animals
    c. Sterilization of screw worm fly (males)
9. Radiography of welds
10. Cracking of gasoline
11. Changing characteristics of plastics
12. Detecting leaks in gas and oil mains
13. Thickness gauge.

From a survey of this list of applications it is evident that a large percent is closely related to biology and should be of interest to future biologist. The ultimate value of radiation to the human race will depend to a great extent on how well scientist meet and cope with these effects upon the human body which regulate the dividing line between constructive and destructive value of all ionizing radiation produced. It is the responsibility of biology instructors to caution the students about the possible hazards along with the scientific future which radiation has in biological research.

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GLOSSARY

1. Anemia - A condition in which the blood cells are either deficient in number or abnormal in other ways such as hemoglobin content.

2. Atom - the smallest part of an element that enters into the composition of molecules.

3. Carious - have decayed area on the teeth or bones.

4. Cell - smallest unit of organismal structure.

5. Chromatin - a deeply staining protoplasmic material occuring in the mucleus of cells.

6. Chromosome - important rod-shape constituent of all cells containing the genes or heredity determining units.

7. Coagulation - the act or state of becoming viscous, jellylide, or solid.

8. Cytological - dealing with or related to the structure, functions and organic processes of the cells.

9. Cytoplasm - the protoplasm of the cell exclusive of the nucleus.

10. Desoxyribonucleoprotein - the primary constituent of the cell nucleus.

11. Enzyme - organic catalyses, protein in nature, with specific powers of reaction formed by living cells but independent of latter in action.

12. Epiphysis - the growing portion of the bone.

13. Erythema - morbid redness of skin due to congestion of the capillaries.

14. Excitation - raising of an electron in an atom to a higher energy level.

15. Free radical - extremely reactive fragments of molecules released by radiation within an organism.

16. Gene - the smallest unit of heredity found on the chromosone and concerned with hereditary characters.

17. Glycolyses - hydrolytic decomposition of sugar.

18. Gonads - essential sexual glands, ovaries or testes.

19. Infectious - capable of being easily spread or any disease caused by entrance, growth, and multiplication of microorganisms.

20. Ingestion - taking within the body as food for digestion.

21. Inhalation - act of breathing or taking in of air.

22. Ionizing radiation - any type of radiation which can remove an electron from a molecule during dissipation of energy.

23. Isotopes - two or more species of the same element.

24. Latency period - the time elapse between exposure and first manifestation of radiation damage.

25. Lethal gene - any gene which is fatal in its hereditary effects.

26. Leukemia - rare disease in which uncontrolled overproduction of the white blood cells occurs.

27. Longevity - length of life.

28. Lymphocytes - one of the white blood corpuscles derived from the lymph nodes and use to protect the body from infection.

29. Metabolism - the process by which cells or tissues transform food materials into their won vital substances.

30. Mitosis - indirect cell division involving differentiation of chromosomes.

31. Mutation - any sudden change in heredity from parent to offspring.

32. Necrosis - death of cell tissue or bone.

33. Pathological - pertaining to the causes of disease.

34. Phlegmatic - containing a viscous, watery mucous.

35. Physiochemical - pertaining to the chemistry of the body processes.

36. Pycnosis - a thickening or condensation of the cell nucleus.

37. Respiration - the chemical processes by which the organism absorbs oxygen and gives off waste products.

38. Roentgen - unit used to measure the quantity of absorbed radiation based on amount of ionization produced under specific conditions.

39. Spermatozoa - immature male sexual cells.

40. Sterility - lack of fertility.

41. Syndrome - a set of symptons which occur together and characteristic of a certain ailment.

42. Teleangrectases - dilatation of blood or lymph capillary vessels.

43. Therapeutic - pertaining to act of healing such as remedies for diseases.

44. Thymus - a gland of lympoid character concerned with growth and blood formation.

45. Vacuolation - the development of small cavities or spaces in the cells which contain air or fluid.

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