Chapter 7

RADIOBIOLOGICAL PROCESSES

12/3/2021

7.1 INTRODUCTION

The use of radioisotopes as research tools has contributed to the growth in knowledge about biological processes. Radioactive isotopes are used to reveal the secrets of the gene structure of deoxyribonucleic acid (DNA), ribonucleic acid (RNA) and their associated proteins and enzymes. Exploring these secrets is the goal of the new fields of Genomics and Proteomics promises vast advances in medicine, agriculture, chemistry and other human endeavors.

Living organisms including humans have been living in a radiation environment since the dawn of life on Earth. Many forms of radiation exist in nature, other than sunlight, which can cause sunburns and sun strokes. They have become known to them only recently. These forms of radiation are more energetic than sunlight and can do more damage, even though the human senses cannot detect them, and humans need to take precautions against them.

With man being able to imitate nature on a grander scale, artificial forms of radiation have been created in both nonionizing and ionizing forms. The non-ionizing forms include lasers, microwaves, electromagnetic radiation in communications such as cellular phones, and in appliances such as microwave ovens. The ionizing forms include x rays from computer and television screens, from x ray medical diagnostic machines, as well as radioisotopes from nuclear reactors and the fallout from fission and fusion weapons testing. The man made radiation is produced in intensities far exceeding any natural radiation except cosmic rays.

It becomes necessary for humans to learn as much as possible about the effects of radiation on biological matter in view of minimizing its impact, guarding against its deleterious effects when necessary, and finding any possible beneficial applications like nuclear medicine, food preservation and fresh water and energy production.

7.2 LIFE PROCESSES

Cell theory is based on the concept that higher organisms consist of smaller units called cells. An organism is considered as a complete living plant or animal. Some organisms are called unicellular organisms and are composed of a single cell like amoebae. Higher animals are multicellular with aggregations of millions of different specialized cells forming the organs and the different tissues.

All living matter on Earth has a similar molecular composition or structure, and metabolism, which is the total of the biochemical reactions causing the life sustaining functions of the organism, including nutrition, energy production and construction or synthesis of new living material. Metabolism includes the functional manifestations of

life: movement, respiration, growth and reaction to environmental changes or irritability. All living matter has two common properties: metabolism and reproduction.

This similarity implies a common distant origin for living organisms handed down through the reproduction process. Variations resulted from the occasional mutations, which are changes in the nature of the hereditary units caused by internal or external factors like exposure to heat, chemical action or environmental radiation.

7.3 CELL STRUCTURE

Cells are composed of dense mass of cytoplasm including a denser structure called the nucleus. A double membrane full of perforations called the nuclear membrane separates the nucleus from the cytoplasm. The cell is surrounded by the plasma membrane or cell membrane, which constitutes its boundary and protects it from its environment.

The cytoplasm contains a network of membranes called the endoplasmic reticulum generating boundaries of canals and pouches or vesicles. The cytoplasm contains small bodies designated as the ribosomes. Membranous little organs or organelles form the mitochondria, which is structurally independent from the other cytoplasm components. Figure 1 shows a single cell of a primary spermatocyte of a grass hopper magnified 25,000 times.

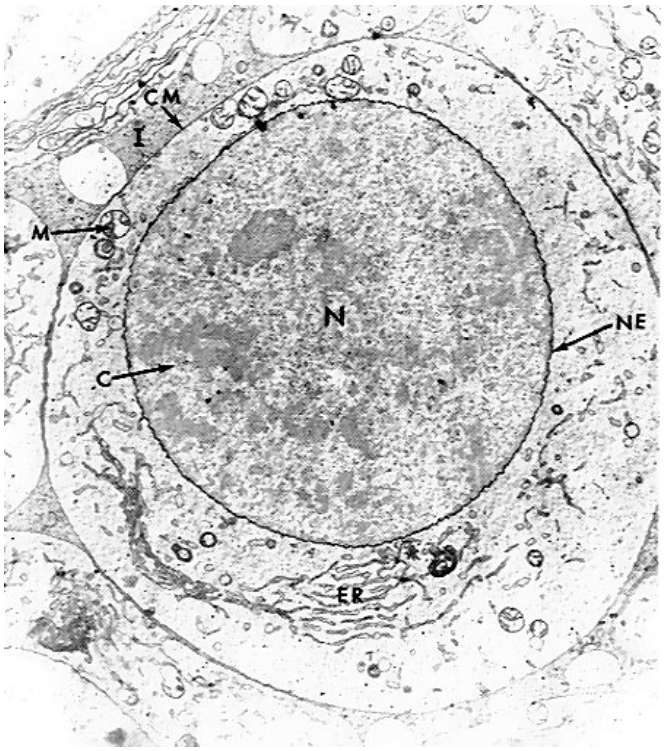

Figure 1. A spermatocyte of a grasshopper magnified 25, 000 times. N is the nucleus, M is a mitochondrion, C is the chromatin, ER is the endoplasmic reticulum, NE is the nuclear envelope or membrane, CM is the cell membrane, and I is the inter cellular space.

The nucleus is normally the largest and most central body in many cells. It contains the heredity controlling system of the cell in the form of the chromosomes. They have a thread like appearance and contain granules of chromatin, which is rich in DNA. These chromosomes can only be distinguished when the cell and the nucleus are in the division state. A spherical body called the nucleolus can be seen when the cell is not dividing, but disappears when it does. Some cells have more than one nucleolus. Cells have different structures. Red blood cells, for instance, do not have a nucleus.

Seventy percent of the cell is in the form of water. It contains other components: the sugars or carbohydrates, the fats or lipids, the proteins, and the nucleic acids, in addition to other organic and inorganic constituents such as vitamins and minerals. Carbohydrates serve as the food supply of the cell and can stored in different forms. They can also serve as structural elements of the cell. Lipids appear in the form of fats, alcohols, steroids, phospholipids and aldehydes. They form membranes and give them their permeability, and they store chemical energy in the form of neutral fats. The proteins appear in many structures and kinds such as enzymes which the catalysts for the metabolic processes in the cell.

7.4 THE NUCLEIC ACIDS: DNA AND RNA

The nucleic acids, DNA and RNA manufacture the proteins in the cell. The DNA in most cells is concentrated in the nucleus. On the other hand, the RNA is distributed in the whole cell. The RNA in the cytoplasm is associated with small particles called microsomes, some of which are called ribosomes since they are rich in RNA.

DNA contains the genetic material itself, whereas RNA translates the genetic message from the DNA into instructions that the cell can use for making proteins.

A fundamental law of biology states that that the DNA content of somatic cells is constant for any given species. Germinal cells such as the female egg and the male sperm cells contain exactly half the amount of DNA of the somatic cells. DNA is thus the hereditary material combining from the two parents to determine the specifications producing the new offspring. Starting from a single fertilized egg, a large amount of DNA is made on the way to adulthood. A mouse cell contains 1 picogram of DNA, where:

$$1 \text{ picogram} = 10^{-12} \text{ gram}.$$

An adult mouse contains 25 milligrams of DNA, which is a 2.5×10^{9}, or 2.5 billion fold increase in the amount of DNA, with each cell a result of the division of another cell.

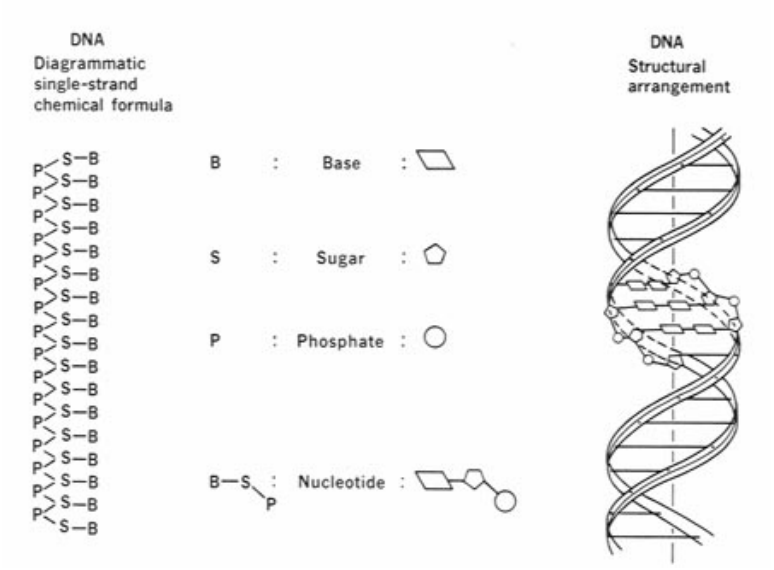

Figure 2. Structure of the deoxyribonucleic acid DNA molecule.

According to the Watson-Crick model, the DNA molecule consists of two strands of smaller molecules twisted around each other in the form of a double helix. Each strand is in turn formed by a sequence of smaller molecules called nucleotides linked linearly to each other. The nucleotides consists of yet three smaller molecules:

1. A sugar, deoxyribose designated as S.
2. Phosphoric Acid, designated as P,
3. Nitrogen base, designated as B.

Each nucleotide is linked to its closest neighbor between the sugar of one and the phosphoric acid of the neighbor. The nitrogen base can attach itself, with hydrogen bonding, to another nitrogen base in the opposite strand of the helix.

The nitrogen bases in higher organisms occur in four types:

1. Adenine,
2. Guanine,
3. Thymine.
4. Cytosine.

Adenine pairs only with thymine in the opposite pair of strands. Guanine pairs only with cytosine in the opposite pair. This makes each strand complementary to the other one. This gives the DNA molecule a structure of a twisted ladder. The sugar and phosphate molecules in the nucleotides form the upright legs of the ladder. The linked nitrogen bases form the rungs of the ladder. The two ends of each rung are dissimilar. Each upright strand is a mirror image of the other, as shown in Fig. 2.

As the organism grows, the DNA is copied or replicated. The two strands separate from each other by separating the rungs of the ladder at the point at which the bases meet, like the untying of a zipper. Each strand then forms a new and similar complementary strand. The end result is two double stranded DNA molecules each identical to the parent molecule and containing the same genetic material. When a cell divides, each new daughter cell gets one of the new double strands. Each new cell now has the same amount of DNA and the same genetic material as the parent cell.

DNA is not the molecule responsible for the difference among cells. Cells differ from each other based on the kinds of proteins they contain. Differences in the composition of RNA, the translator molecule, is the basis for the diversity of organisms on Earth.

There exist three types of RNA molecules:

1. Ribosomal RNA or r-RNA is found in conjunction with proteins and constitutes the structural frame on which the protein synthesis process is built. The r-RNA and the proteins to which it is bound form the ribosomes, which are attached to the endoplasmic reticulum. The proteins are synthesized on the ribosomes.
2. Soluble or transfer RNA, designated as s-RNA, combines with r-RNA to complete the sequence of events that synthesizes the proteins.
3. Messenger or template RNA or m-RNA, establishes the bond between the r-RNA and s-RNA. It is the messenger that carries the genetic message from DNA to the protein synthesis system.

In an analogy to a newspaper staff, DNA is the editor, m-RNA are the copy boys carrying the editorials to the typing staff, the r-RNA and s-RNA molecules, who then take the letters of nucleic acid and type them in a word processor into slots according to the editor's directions. The enzymes, special kinds of proteins, delete typing errors and create new replacements. Each kind of cell in the organism represents a different section sports section for muscle cells, medical section for pancreas cells, for instance. Each kind of cell has a specialized editor. All the cells have the same board of editors, but one editor only specializes for each section.

This implies that only a portion of the total DNA is active in the functions in each specialized cell. This active DNA is making the m-RNA that carries instructions to the protein synthesizing machinery of the particular type of cell. Cells in the same organism thus differ from one another from the perspective of the segments of DNA that is active in making the m-RNA.

With the determination of the composition of the Human Genome, and that of other species like corn, the number of players and their positions in the game are now known. The real game involves the interactions between the genes and the RNA, and how the proteins and enzymes interact in the game of life. Scientists were disappointed to discover that the Human Genome contains a relatively small number of genes of 30,000 by some estimates and of 100,000 by others. Their hands and their minds will be full in the coming years figuring out the complex interactions in enzymes and proteins synthesis. The game has not even started yet.

7.5 CELL DIVISION: MITOSIS

After a cell reaches a certain stage in its life, it splits into two parts through the process of mitosis, which in turn can divide in two again, eventually generating the 50 trillion cells composing the human body. This accounts for the growth in plants and animals, and for the repair of damaged tissue.

The different stages of mitosis are shown in Fig. 3. In the interphase stage, the cell metabolizes new cellular material and synthesizes new chromosomes. In the prophase stage, the chromosomes each become composed of two identical strands called chromatids, shorten by coiling up, and the nucleolus and nuclear membrane disappear. In

the metaphase stage, the chromosomes line up in a plane near the cell's equator. In the anaphase stage, the duplicate chromatids in each chromosome separate and each moves toward the poles of the cell. In the telophase stage, the chromosomes uncoil and return to being invisible. A new nucleus, nucleolus and a nuclear membrane are generated at each end of the cell. Division occurs between the two formed nuclei forming two identical cells, with a full set of chromosomes. Since the genes are in the chromosomes, each cell has the same genetic complement. Figure 4 shows the five chromosomes of the Trillium plant with five chromosomes in the anaphase stage.

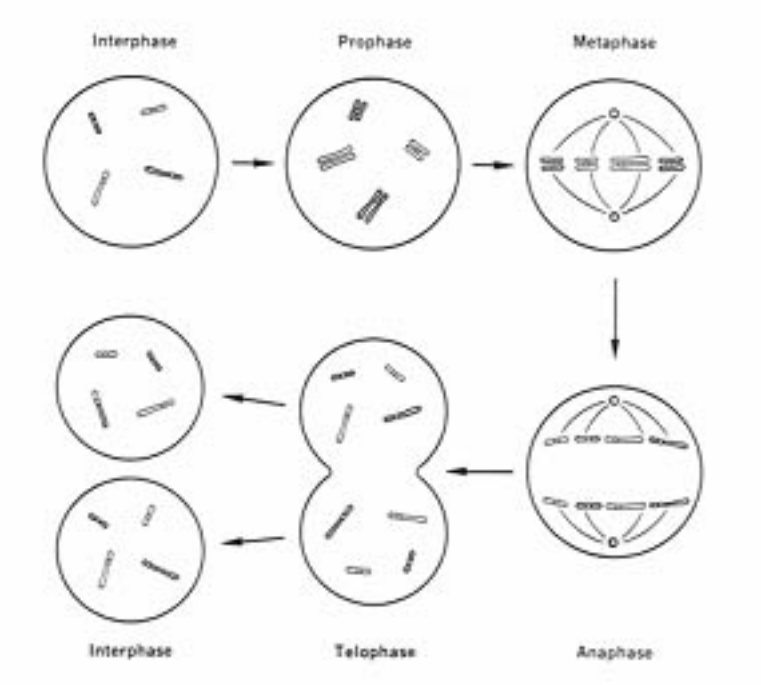

Figure 3. Stages in the mitosis process.

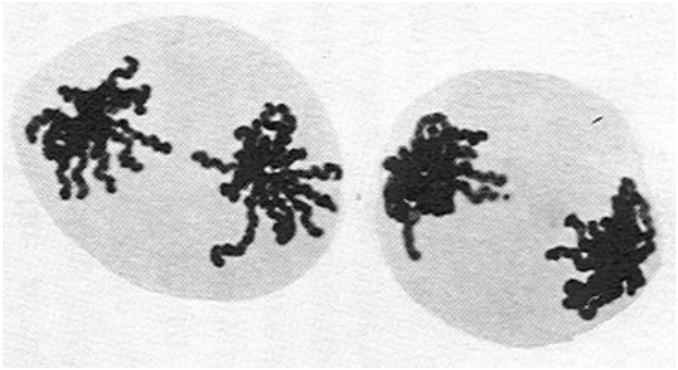

Figure 4. The anaphase stage in the mitosis of the five chromosomes in the Trillium plant.

The mitochondria take part in the reactions by which the energy in the sugars is supplied for the cell's activities.

7.6 CHROMOSOMES

The human cell contains 23 pairs of chromosomes, or 46 chromosomes. They become apparent in the nucleus only when the cell is ready to divide in the process of mitosis. In the replication process the number of chromosomes doubles, and are then shared between the two divided cells.

To see the chromosomes, a cell that is in the process of dividing is chosen. A derivative of colchicine is used to treat the cell to stop the cell division at the metaphase stage. The chromosomes become visible even though still too tangled to be identified, counted, or measured. The cell is then treated with a low concentration salt solution, which leads to the swelling of the chromosomes and disperses them so that they become distinct structures as shown in Fig. 5.

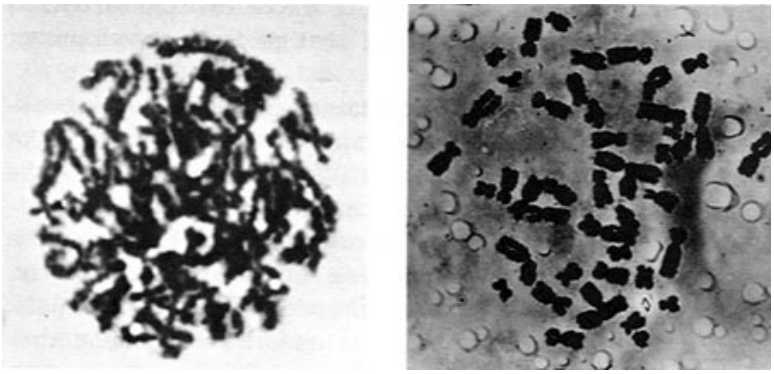

Figure 5. Chromosomes in the metaphase stage at left, dispersed and swollen at right.

The separated chromosomes in the dividing cell are photographed and classified according to their overall length, the position of the centromere where the two strands join, and other features. The photomicrographs of the individual chromosomes are then grouped in an arrangement according to a standard classification to show chromosome complement and abnormalities, called karyotype.

The karyotype in Fig. 6 is of a normal male showing the X and Y sex chromosomes and 22 pairs of other autosomal chromosomes.

The karyotype shown in Fig. 7 is of a human female with two X chromosomes. This karyotype shows the presence of Down's syndrome or Mongolism. During meosis, both chromosomes number 21 of the mother instead of just one, went into the ovum. The father added another third number 21 chromosome.

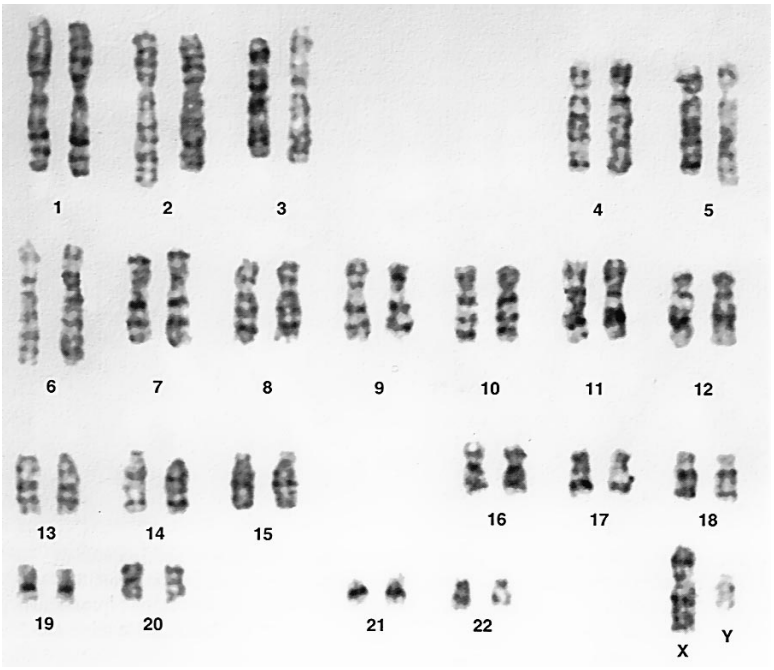

Figure 6. Karyotype of a normal human male with X and Y chromosomes.

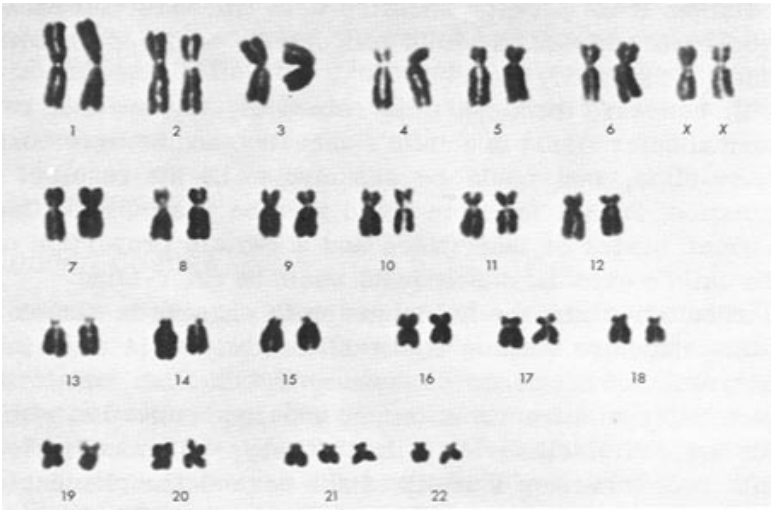

Figure 7. Karyotype of an abnormal human female with Down's syndrome, or Mongolism showing the 3 chromosomes number 21.

7.7 MEIOSIS: EGG AND SPERM CELLS FORMATION

Adult individuals possess gonads in which the sex cells are formed as sperm cells in the testes in males and as eggs in the ovaries in females. Meiosis is the cell division process in which the chromosomes group into pairs and are then apportioned between the daughter cells one of each pair to a cell. Such a division is unaccompanied by replication means that in place of the usual 23 pairs of chromosomes in each cell, each sex cell has only 23 individual chromosomes or half a set of chromosomes.

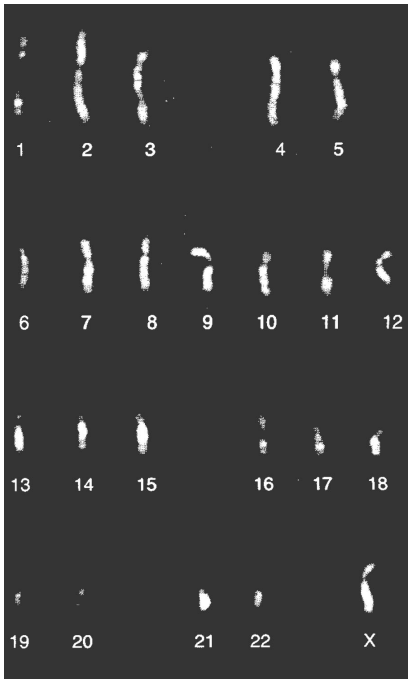

Figure 8. Female egg showing 23 individual chromosomes and a single X chromosome.

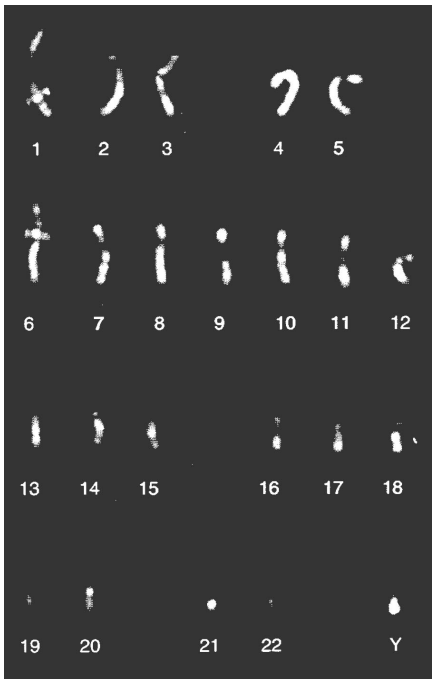

Figure 9. Male spermatozoid showing 23 individual chromosomes and a single Y chromosome.

Figures 8 and 9 show the karyotype of an egg with 23 individual chromosomes and a single X chromosome and the karyotype of a spermatozoid with a single Y chromosome.

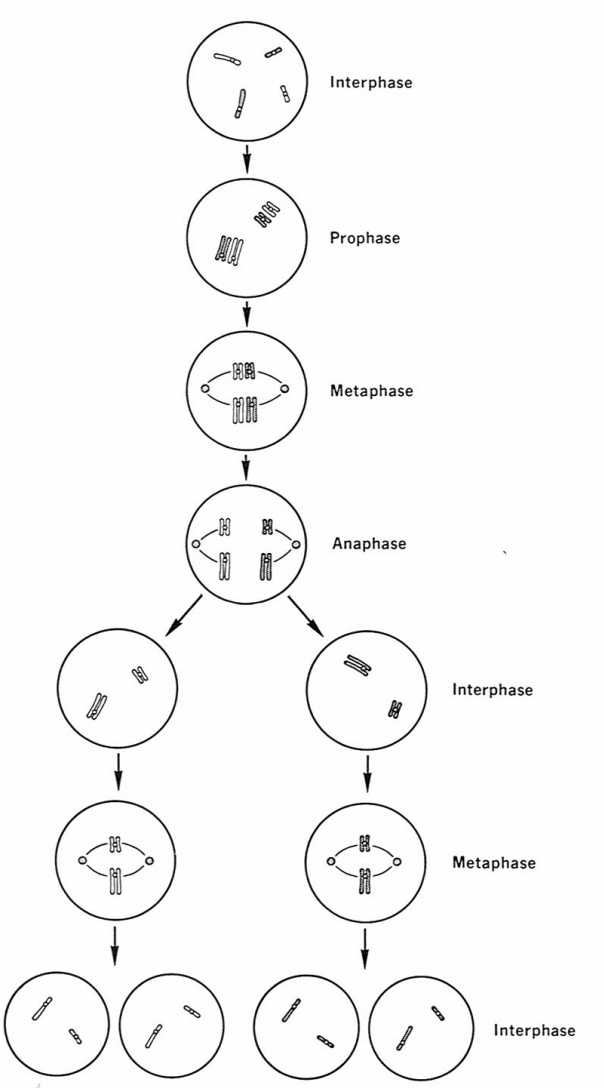

Figure 10. Steps in the meiosis process.

Upon fertilization, a sperm cell enters an egg and merges with an egg cell, restoring the full set of 23 pairs of chromosomes. Each newborn individual is in this sense a random reshuffling of chromosomes. Since the chromosome pairs can separate in either fashion into one cell or the other, the 23 pairs doing this randomly can generate about 10 million different combinations of chromosomes in the sex cells of a single individual.

In addition to this shuffling within a divided cell, the shuffling between the sperm cell and the egg cell could produce offspring with any of 100 trillion possible chromosome combinations. This explains the great deal of diversity between living beings, even among individuals within the same species. There are still other sources of difference in which the a chromosome is capable of exchanging pieces with its pair with a cross over process producing chromosomes with a brand new pattern of gene varieties.

The shifts in chromosome combinations with or without crossovers can produce unique organisms and even novelties in individual characteristics.

7.8 MUTATIONS

It is possible for the chromosomes to undergo more structural or chemical changes so that entirely new characteristics are produced that otherwise might not exist in the process of mutation. These chromosome mutations can arise in different ways. Chromosomes can replicate without the cell itself dividing resulting in cells with two or more times the normal complement of chromosomes or polyploidy. This can be found in plants and some groups of invertebrates. When it occurs in mammals, it leads to death.

In less extreme changes, chromosomes break and fail to reunite, or break and then reunite incorrectly. This situation exists in the case of Down's syndrome, and was discovered in 1959. An afflicted individual as shown in Fig. 7 has 47 chromosomes instead of the usual 46. The 21st pair of chromosomes, in an order of decreasing size, consists of three instead of two chromosomes.

Most mutations are not associated with chromosomes structure, and are due to changes in the chemical structure of the genes that make up the chromosomes, fall under the category of gene mutations. These can occur through the action of some chemical or other environmental influence. If present in a sex cell, it can be passed to its descendents in an indefinite number of generations.

If chromosome or gene mutations happen in ordinary cells they are designated as somatic mutations. These changes may be trivial or serious. It is suggested that tumors can result from somatic mutations in which some cells lose the capacity to regulate their growth properly. Somatic mutations do not involve the sex cells and are not consequently passed to offspring.

Spontaneous mutations occur in nature without human interference and arise from the very random nature of the complex mechanism of gene replication. Mutations can be beneficial if the change helps the organism survive better, live more comfortably and adapt to his environment. Over the ages, creatures have changed primarily through the effects of beneficial mutations to adapt to climatic, food supply and reproductive changes. The variation in gene pool makes adaptation to the changing environmental conditions possible. A species with an invariable set of genes could not change to suit any altered conditions that could wipe it out. Over millions of years, for instance, the human brain has through mutations and beneficial shifts in emphasis within the gene pool increased notably in size. Figure 11 shows an x ray mutation in fruit flies producing extra wings and double thoraxes through gene mutations and chromosome rearrangement. The left picture is of a normal male Drosophila, and the right picture shows a double thorax with four wings fly.

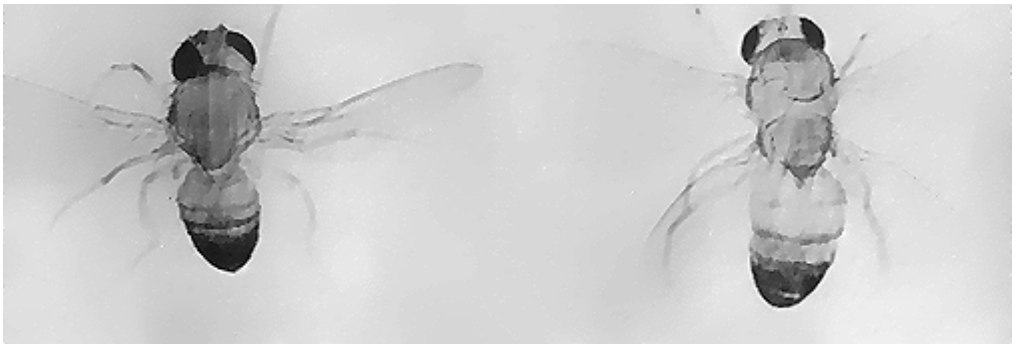

Figure 11. X ray mutation in fruit flies. Left picture is of a normal male Drosophila fly, the right picture shows a double thoraxes with four wings fly.

7.9 IONIZING RADIATION

Our technological civilization exposes humans to two types of genetic effectors:

1. Synthetic chemicals at unprecedented higher concentrations than in nature can interfere with the process of replication by offering alternate pathways with which the cellular composition is not used to. The cells in direct contact with the chemicals are affected such as the skin, the intestinal linings, the lungs, the kidneys and the liver. These can undergo somatic mutations and an increase of the incidence of tumors in those tissues.
2. Energetic radiation at unprecedented intensities and new types. Radiation can consist of waves such as electromagnetic radiation, or of particles like electrons, protons, neutrons, or alpha particles. Electromagnetic radiation more energetic than ultra violet light such as x or gamma rays carry sufficient energy to cause changes in the molecules as well as in the atoms constituting these molecules.

Electromagnetic radiation such as x or gamma rays interacting with atoms can lead to the release of electrons leaving a positively charged ion, hence the designation as ionizing radiation. Particle radiation in the form of cosmic rays, alpha particles, and beta particles, also carry enough energy that they are ionizing in nature. Ionizing radiation is capable of imparting so much energy to molecules as to cause them to vibrate producing not only ions but also high energy uncharged molecular fragments called free radicals.

Ionizing radiation can affect the chromosomes by disrupting the chemical bonds even breaking them into fragments. Figure 12 shows a plant cell with the chromosomes divided into two groups. After irradiation with x rays, broken fragments and bridges between the groups are apparent.

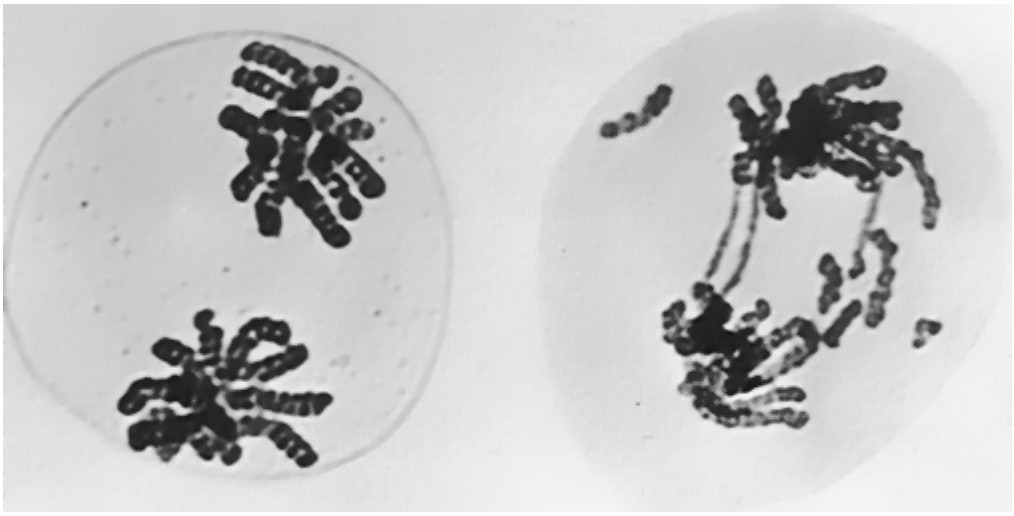

Figure 12. Plant cell chromosomes before and after irradiation with x rays.

The direct effect of ionizing radiation on chromosomes can be serious disrupting enough chemical bonds to the point of breaking it into fragments. Even if not broken, an individual gene along its length may be so much damaged so as to produce a mutation. These direct hits are comparatively rare. Near misses and indirect effects can also be serious in the breaking of the molecule and the creation of free radicals. These free radicals can be energetic enough to bring about chemical reactions in neighboring molecules. If it were to strike a neighboring gene with sufficient energy, it can produce a mutation as surely as the original radiation would have done.

Ionizing radiation of the electromagnetic type tends to be penetrating exposing the interior of the body to its effects, not just its surface. The gonads are thus exposed to the effects of cosmic rays, x rays, or gamma rays. Somatic mutations can be the result, threatening the individuals actually exposed as well as their next generations.

7.10 BACKGROUND RADIATION

Background radiation is low intensity radiation that is a part of our natural environment. Part of it is from constituents in the soil such as the heavy metals of thorium and uranium and their daughter nuclides such as radium and radon. These are continuously transforming through the process of radioactive decay giving up emissions of alpha, beta and gamma radiation. Although not very abundant, they are widely spread and minerals containing them are practically everywhere.

Cosmic rays from outer space also bombard the Earth with streams of highly energetic particles, and high energy particles from the Solar wind continuously fall on the Earth and increase in intensity during solar flares and at the peaks of the 11 years solar cycle.

There are sources of radiation inevitably within the body itself such as $Carbon^{14}$ and $Potassium^{40}$.

7.11 MAN-MADE SOURCES OF RADIATION

In 1895 x rays were discovered by Röntgen in Germany and have become since then a useful source of medical diagnosis and therapy. In 1896 radioactivity was discovered by Henry Becquerel in France. In 1934 it was discovered that radioisotopes can be made and their usage spread in hospitals laboratories and industries. In 1945 atomic devices were developed and tested originally in the atmosphere, underground, and then their testing was banned. The fission fragments and resulting from the atomic testing in 1950s still exist in the stratosphere and are descending to the Earth's surface as radioactive fallout.

Other sources of technological radiation exposure include high flying airplanes, space travel, particle accelerators, and television and computer video screens.

Man-made radiation from all sources is being absorbed at nearly half the rate (67.2) of natural radiation (126). The additional dosage is primarily as a result of the use of x rays in the search for decayed teeth, broken bones, lung lesions, swallowed objects, instruments left inside the body in surgical procedures, and other useful or sometimes useless, but profitable, procedures.

7.12 BIOLOGICAL EFFECTS OF RADIATION

We tend to think of biological effects of radiation in terms of their effect on living cells. For low levels of radiation exposure, the biological effects are so small they may not be detected. The body possesses repair mechanisms against damage induced by radiation as well as by chemical toxins. Consequently, the biological effects of radiation on living cells may result in three possible outcomes:

1. Injured or damaged cells repair themselves, resulting in no residual damage,
2. Cells die, much like millions of body cells do every day, being replaced through normal biological processes,
3. Cells incorrectly repair themselves resulting in a biophysical change.

The associations between radiation exposure and the development of cancer are mostly based on populations exposed to relatively high levels of ionizing radiation such as the Japanese atomic bomb survivors, and recipients of selected diagnostic or therapeutic medical procedures such as the ankylosing spondilitis patients. Cancers associated with high dose exposure greater than 50 cSv or rem include leukemia, breast, bladder, colon, liver, lung, esophagus, ovarian, multiple myeloma, and stomach cancers.

The USA's Department of Health and Human Services literature also suggests a possible association between ionizing radiation exposure and prostate, nasal cavity/sinuses, pharyngeal and laryngeal, and pancreatic cancer.

The period of time between radiation exposure and the detection of cancer is known as the latent period and can be many years. Those cancers that may develop as a result of radiation exposure are indistinguishable from those that occur naturally or as a result of exposure to other chemical carcinogens. Furthermore, the National Cancer Institute literature indicates that other chemical and physical hazards and lifestyle factors such as smoking, alcohol consumption, and diet, significantly contribute to the onset of many of these same diseases.

Although radiation may cause cancers at high doses and high dose rates, currently there are no data to unequivocally establish the occurrence of cancer following exposure to low doses and dose rates below about 10 cSv or rem. Those people living in areas having high levels of background radiation above 1 cSv or rem per year such as Denver, Colorado have shown no adverse biological effects.

The radiation protection community conservatively assumes that any amount of radiation may pose some risk for causing cancer and hereditary effect, and that the risk is higher for higher radiation exposures. The linear, no-threshold (LNT) dose response relationship is used to describe the relationship between radiation dose and the occurrence of cancer. This dose-response model suggests that any increase in dose, no matter how small, results in an incremental increase in risk. The LNT hypothesis is accepted by the NRC as a conservative model for determining radiation dose standards recognizing that the model may over estimate radiation risk.

High radiation doses tend to kill cells, while low doses tend to damage or alter the genetic code in the DNA of the irradiated cells. High doses can kill so many cells that tissues and organs are damaged immediately. This in turn may cause a rapid body response often called Acute Radiation Syndrome. The higher the radiation dose, the sooner the effects of radiation will appear, and the higher the probability of death. This syndrome was observed in many atomic bomb survivors in 1945 and emergency workers responding to the 1986 Chernobyl nuclear power plant accident.

Approximately 134 plant workers and firefighters battling the fire at the Chernobyl power plant received high radiation doses of 80 to 1,600 cSv or rem, and suffered from acute radiation sickness. Of these, 28 died within the first three months from their radiation injuries. Two more patients died during the first days as a result of combined injuries from the fire and radiation.

Because radiation affects different people in different ways, it is not possible to indicate what dose is needed to be fatal. However, it is believed that 50% of a population would die within thirty days after receiving a dose to the whole body, over a period ranging from a few minutes to a few hours, between 350 to 500 cSv or rem. This would vary depending on the health of the individuals before the exposure and the medical care received after the exposure. These doses expose the whole body to radiation in a very short period of time measured in minutes to hours. Similar exposure of only parts of the body will likely lead to more localized effects, such as skin burns.

Conversely, low doses, less than 10 cSv or rem, spread out over long periods of time of years to decades, and do not cause an immediate problem to any body organ. The effects of low doses of radiation, if any, would occur at the level of the cell, and thus changes may not be observed for many years, usually 5-20 years, after exposure.

Genetic effects and the development of cancer are the primary health concerns attributed to radiation exposure. The likelihood of cancer occurring after radiation exposure is about five times greater than a genetic effect such as increased still births, congenital abnormalities, infant mortality, childhood mortality, and decreased birth weight. Genetic effects are the result of a mutation produced in the reproductive cells of an exposed individual that are passed on to their offspring. These effects may appear in the exposed person's direct offspring, or may appear several generations later, depending on whether the altered genes are dominant or recessive.

Although radiation-induced genetic effects have been observed in laboratory animals, given very high doses of radiation, no evidence of genetic effects has been observed among the children born to atomic bomb survivors from Hiroshima and Nagasaki.

Ionizing radiation can cause changes in the chemical balance of cells. Some of those changes can result in cancer. In addition, by damaging the genetic material (DNA) contained in all cells of the body, ionizing radiation can cause harmful genetic mutations that can be passed on to future generations. Exposure to large amounts of radiation, a rare occurrence, can cause sickness in a few hours or days and death within 60 days of exposure. In extreme cases, it can cause death within a few hours of exposure.

7.13 LIVING ORGANISMS RESPONSE TO IONIZING RADIATION

Early on, with the expanded use of radiation, including its fraudulent use as a tonic and cure, some of its medical effects became readily apparent under high doses:

1. Erythema which is the abnormal redness of the skin like in burns,
2. Edema which is the swelling due to the abnormal accumulation of fluids,
3. Epilation which is the abnormal loss of hair.

By 1897, 69 cases of x-ray burns were observed by radiologists. Researchers in the field such as Henry Becquerel and Mme Curie suffered radiation burns. By 1911, 94 cases of x-rays induced tumors were observed. About 100 radiologists died prematurely from radiation induced cancer by 1922 and suffered a higher incidence of leukemia which is a cancer of the blood forming organs in the bone marrow.

The miners in the Cobalt mines of Saxony in Southeastern Germany and in the pitchblende uranium ore mines in Czechoslovakia suffered 30 times the normal incidence of lung cancer from the inhalation of radon gas and its decay products from the uranium and thorium decay chains. In the period from 1915 to 1930, radium and thorium were injected as tonics causing both chemical toxicity as heavy metals and radio toxicity as radioactive substances in the filtering organs of the human body: the kidneys and liver.

As late as the 1928 to 1945 period, people were injected with ThO_2 as a contrasting agent for x rays diagnostics subjecting them to the possibility of liver tumors. This has been replaced recently by barium as a contrasting agent.

Table 1. Time scale of an organism's response to ionizing radiation.

Seconds	*Minutes*	*Hours*	*Days, Weeks, Years*
Radiation Damage	**Cellular Response**	**Cell Function, Fate**	**Medical Consequences**
DNA strand breaks	Gene Activation and Expression Changes: mRNA, Protein	Cell Death	Acute Syndrome
			Organ Failure

Oxidative Damage to DNA, lipids, other biomolecules	Protein modification	Genomic instability	Cancer
			Birth defects
			Gene pool

A notorious case for the misuse of radioactive sources is the radium luminous dial painters at US Radium Corporation in Orange, New Jersey, who licked the tips of their paint brushes to create a thin point, which resulted in 50 out of 2,000 workers dying of cancer.

7.14 CONCLUSION

The fields of Nuclear Chemistry and Molecular Biology are recently having a fresh look at the effects of radiation on living organisms in the light of the knowledge acquired in the sequencing of the genomes of humans and other plant and animals.

An organism's time response to ionizing radiation is a set of complex physical, chemical, and biological events. On the seconds scale ionizing radiation produces damage to DNA and oxidizes the proteins and DNA, lipids, and other biomolecules. On the minutes scale, the cell responds by changing the activation levels and expression of particular genes and the modification of certain molecules. If the radiation doses are high, the result may involve acute organ failure leading to death, or genomic instability that causes cancer, birth defects and mutations that can affect future generations. At low doses, the cells can recover, and at even lower doses an adaptive process may come into play. Radiation exposure should be managed wisely and controlled, and since it is unavoidable, not feared.

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