**NATIONAL UNIVERSITY OF LIFE AND ENVIRONMENTAL SCIENCES OF UKRAINE**

Radiobiology and Radioecology Department

**"CONFIRMED"**
Acting Dean of Faculty of Plant Protection,
Biotechnology and Ecology
_____ J.V. Kolomiets
"___" _____ 2020

**CONSIDERED AND APPROVED**
at the meeting of Radiobiology and Radioecology Department
Protocol №_12_ from "_17_" _June___2020 p.
Head of the Department
_____ A.V. Klepko

# CURRICULUM WORKING PROGRAM

## "RADIOBIOLOGY AND RADIOECOLOGY"

| | |
|---|---|
| **Specialty:** | 101 - Ecology |
| **Educational program:** | «Ecology» |
| **Faculty:** | Plant protection, biotechnology and ecology |
| **Developers:** | Volodymyr Illienko , PhD in Biology, senior lecturer of Radiobiology and Radioecology Department |
| | Alla Klepko , PhD in Biology, Head of the Radiobiology and Radioecology Department |

**Kyiv – 2020**

## 1. PURPOSE AND OBJECTIVE OF THE DISCIPLINE

*Radiobiology, or radiation biology, is a science about effects of ionizing radiations on living organisms and their groups.*

During the last decades in a radiobiology next to such traditional directions as a medical radiobiology, animal radiobiology, plant radiobiology, agricultural radiobiology, radiation ecology, et al some new directions was expressly selected. They are molecular radiobiology, radiation biochemistry, radiation cytology, radiation genetics. That means that the objects of study of radiobiology are not only living organisms and their groups, but also molecules, cells and cell populations, separate processes of metabolism. And *new determination of radiobiology* appears. Now it is *the science about effects of ionizing radiations on the living systems of all of levels of organization*. This formulation is not alternative to the first are they both correct.

A basic task of radiobiology is a study of mechanism of effects of ionizing radiations on a living organism with the purpose of search of possibilities of management organisms reactions on this factor, mainly, diminishing of harmful effects. Main tasks of agricultural radiobiology as a direction which is accented in agrarian educational establishments, are: study of sensitiveness of agricultural plants and animals to the ionizing radiations, development of facilities of their protecting from a radiation defeat, search of ways of the use of ionizing radiations for an agricultural production, research of ways of migration and biological effects of the radionuclides incorporated plants and animals. However, the last task is basic for the separate section of radiobiology - radioecology.

Radioecology, or radiation ecology, is the section of radiobiology, which arose up on the joint of it with ecology. *Radioecology studies concentrations and migration of radionuclides in the environment and ionizing radiation influence on living organisms and their groups*.

Basic tasks of radioecology are: discovery of territories, contaminated by radionuclides, and determination of their concentrations; a study of migration of radionuclides in the objects of environment and ways, which they get in plants,

organism of animals and man; a study of biological effects of incorporated ionizing radioactive elements radiations on living organisms; elaboration of bases of the rational use of territories contaminated by radionuclides o, in particular case agricultural lands. taking into account the specific of contamination and ground-climatic terms of regions; research of other anthropogenic factors influence which are introduced into agrosystem (ameliorator, mineral and organic fertilizers, physiological active matters, heavy metals, acid rains et al), on passing of radionuclides to the products of agricultural production, food stuffs et al; development of the scientifically grounded system of separate branches conduction which provide the permanent diminishing of level of radiocontammant of this products.

A primary aim of these tasks is diminishing of radionuclides receipt to the organism of man by a food chain soil-plants-animals- plant-grower and anomal production-man by interrupting or abatement of ecological connections on any area of this chain and decline of dose of internal radiation.

Program of course «Radiobiology and radioecology» foresees the deep study of sections of common radiobiology, including plant, animal, man, radiobiology especially related to antirad action protecting of products of agriculture from a radiocontammant, to radiation safety in separate industries of production. Part, related to the study of radioecology is given in more generalized kind, taking into account that in subsequent students will study a separate course «Agricultural radioecology».

Primary purpose of study of discipline “Radiobiology and radioecology» is a capture thorough knowledge about influence of ionizing radiations on living organisms, mastering of the applied aspects of specialty, related to radiation safety, and also practical application of knowledge, for the solving of research and applied tasks.

## 2. AFTER FINISHING OF COURSE STUDENTS HAVE TO

As a result of radiobiology study student are:

to know: sources of ionizing radiations in the environment, mechanisms of radiations influence on living organisms, radiosensitivity of basic types of plants and

animals, principles of defense of living organisms, from radiations, ways of ionizing radiations use in different spheres production, including agrarian production, theoretical bases of radionuclides application in scientific researches.

To be able: to estimate a radiation situation by the dosimetric devices of the different systems, to develop the system of radioprotective measures of radionuclides radiation defeat and contamination warning of agrocenosis, to apply radionuclides in scientific researches.

A student are to master:

1) general information about physical nature, ionization of matter under influence of physical factors, nature of corpuscular and electromagnetic radiations which are studied in the courses of «Physics» and „Biophysics";

2) chemical elements and their basic isotopes, including radioactive, types of their co-operation one with other, compounds which appear here, that studied are in courses «General chemistry» and other chemical disciplines;

3) bases of ecology, especially sections about migration of anthropogenic origin pollutants in the objects of environment and agriculture, which are studied in courses «General ecology», «Agroecology» and other ecological disciplines;

4) systems of tillage, methods of growing and storage of agricultural cultures, basis of stock-raising, geneticists, which are studied in courses «Agriculture», „Plant-growing", „Soil Science", „Agricultural Chemistry"; «Bases of stock-raising», «Genetics».

## 3. DISCIPLINE CONTENT AND TYPES OF EDUCATIONAL WORK

| Types of educational activity | Total hours |
|---|---|
| The total laboriousness of the discipline | 240 |
| Lectures | 30 |
| Laboratory works | 30 |
| Independent student work | 30 |
| Term paper | 90 |
| Educational practice | 60 |
| Type of final control | Exam |

## 4. CONTENTS OF DISCIPLINE MODULES AND TYPES TO WORK

| № | Topic | The topic content, recommended literature | Types of educational activity, hours. | | |
|---|---|---|---|---|---|
| | | | lectures | laboratory work | independent work |
| **Module 1. Introduction. Physical basics of radiobiology and radioecology** | | | | | |
| 1.1. | Introduction to radiobiology. History | Definition of radiobiology (radiation biology) and radioecology (radiation ecology). Radioecology as a component of radiobiology. Radiobiology objects of studying. Organizational structure of radiobiology. A place of radiobiology among the allied science. Directions of radiobiology development. Tasks of radiobiology and radioecology. History of radiobiology and radioecology development. A role of achievements of nuclear physics is at the end of a $19^{th}$ century in an origin and development of radiobiology. Stages of radiobiology and radioecology development. Development of radiobiology and radioecology in Ukraine. Modern problems of radiobiology and radioecology: specific of influence on the living organisms of small doses of ionizing radiations, features of influence on the | 4 | 4 | 7 |

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| | | living organisms of chronic irradiation, prophylaxis and therapy of sharp and chronic radiation defeats, radiation dysimmunity, remote consequences of irradiation, general influence on the organism of ionizing radiations and other factors, migration of natural and artificial radionuclides in the objects of environment, features of influence on the organism of the incorporated radionuclides, in plants, organisms of animals and man, blocking of receipt of radionuclides, in plants, organism of animals and man, leading out of radionuclide from an organism. Theoretical and practical value of radiobiology. Necessity of wide propaganda of radiobiological knowledge. | | | |
| | | *Literature: 1, 8-12* | | | |
| 1.2 | Physical basics of radiobiology | Phenomenon of radioactivity. Law of radioactive decay. Nature atoms and molecules of matter ionization. Definition of concept of ionizing radiations. Types of ionizing radiations: electromagnetic and corpuscular radiation. Types of electromagnetic ionizing radiations: x-ray photography, gamma- and slowing-down radiation. Physical descriptions of basic types of radiations: alpha -, beta-, proton and neutron radiations. Exposure, absorbed and equivalent doses of ionizing radiations. Power of dose. Types of irradiation depending on power of dose, factor of time and multipleness of irradiation: sharp and prolonged (chronic), non-permanent and frequent (fractionating). Units of radioactivity and doses of ionizing radiations. Connection between radioactivity of matter and dose ionizing a radiation. | 2 | 4 | 7 |
| | | *Literature: 1, 2, 4, 8-11, 23* | | | |
| 1.3 | Sources of radioactive substances and ionizing radiation | Natural and artificial sources of ionizing radiations. Natural ionizing radiation. Space radiation and radiation of natural radioactive elements. Sun and galactic radiation. Radiation of radioactive elements from families of uranium, actinouranium and to thorium. Payment of radiation of radon. Radiation of non-family natural radionuclides. Payment of radiation | 2 | 2 | - |

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| | | radioactive calcium. Radiation of cosmogenic radioactive elements. Radioactive hydrogen and carbon. Natural radiation background. Estimations of doses of irradiation of living organisms, predefined a natural ionizing radiation. The possible value of natural radiation in the processes of vital functions of organisms. Ionizing a radiation from artificial radionuclides. Sources of artificial radionuclides in environment. Radiation from radionuclides which appear as a result of tests of nuclear-powered weapon. «Global» nuclear fall-outs. Radiation of radionuclides which enter environment from the enterprises of nuclear energy. Radiation from sources which are used in medicine and everyday life. | | | |
| | | *Literature: 1, 3, 4, 7, 8, 10-13* | | | |
| | | **Module 2. Biological effects of ionizing radiation** | | | |
| 2.1 | Biological effects of ionizing radiation on plants and animals | Concept of radiobiology effect. Classification of radiobiology effects. Somatic and genetic radiobiology effects. Essence of radiation stimulation. Radiation stimulation of plants and animals. Basic types of morphological changes of organs of plants under ionizing radiations influence. Animal morphological changes. Essence of teratogenic influence of ionizing radiations. Concept of radiation chimera. Carcinogenic influence of radiations. Mechanisms of morphological origin changes at the influence of ionizing radiations. Radiation illness of plants. Kinds and degrees of mammal's radiation illness. Influence of ionizing radiations is on the acceleration of senescence and life-span. Death of organisms is at the high doses of irradiation. «Death under a ray». Specific of plants radiation death. «Gamma-germs». Features of ionizing radiation influence on the forest planting. Reactions of trees on an irradiation.<br>Unspecificity of types of mutations which arise up at the influence of ionizing radiations. Thresholdless and threshold conceptions of ionizing radiation influence. Thresholdless character of carcinogenic and genetic influence of ionizing radiations. Close and remote effects of ionizing radiations . Stochastic character of remote | 2 | 2 | - |

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| | | consequences of radiation defeat. Features of influenceof small doses of ionizing are radiations on living organisms: stimulative, antiimmune, carcinogenic, genetic effects. Biological effects of radiotelemetrings. *Literature: 1, 3, 9-12, 24* | | | |
| 2.2 | Radiosensitivity of plants, animals and other organisms | Concept of radiosensibility and radiofirmness of organisms. Effective doses: lethal, half-lethal and critical. Principles and methodology of construction of dose-effect curves. An analysis of dose-effect curves and determination of effective doses of ionizing radiations on them. Comparative radiosensibility of types of different taxonomical origin. Radiosensibility of plants. Radiosensibility of agricultural plants. Comparative radiosensibility of vegetans plants and seed. Radiosensibility of plants on the separate stages of ontogenesis. Radiosensibility of animals. Radiosensibility of agricultural animals. Radiosensibility of other organisms: birds, fishes, amphibians, reptiles, invertebrate animals, simplest, bacteria, viruses, mushrooms. Radiosensibility of animals is on the separate stages of ontogenesis. Radiosensibility of biocenosis, phytogenesis, agrocenosis. Reasons of wide variability of organisms' radiosensibility: structural and functional factors. Comparative radiosensibilityof cells is on the different phases of development. Bergon'e and Tribondo Law (rule). Genesial and interphase necrocytosis. Critical fabrics and organs of plants and animals. *Literature: 1, 7-12, 19* | 2 | 2 | - |
| 2.3 | Radiation protection and radiosensitization | The phenomena of antagonism and synergism are at the general influence on the living organisms of ionizing radiations and other factors. Concept of modification of radiation defeat of organism. Antirad biological defense and sensibilization of radiation defeat. Physical antirad and radiosensibilization factors: composition of atmosphere, temperature, humidity, light et al. Oxygen effect. Quantitative description of oxygen effect is an oxygen amplification factor ($K_{OA}$). Chemical radioprotective | 2 | 2 | - |

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| | | matters and radiosensitizers. Determination of radioprotectors, radioblocators and radiodcopyrants concepts. The basic requirements to a description of radioprotective matters. Factor of changing dose (FCD) and its definition Quantitative descriptions of antirad influence. Basic classes of radioprotectors. Natural and artificial radioprotectors. Native radioprotectors of cells. Antioxidants as radioprotectors. Radioprotectors of the prolonged action. Mechanisms of action of radioprotectors: induction of the hypoxive state, «interception» of the free radicals states, formation of mixed disulfides, hypothesis of «biochemical shock». Chemical radiosensibilization matters. Mechanisms of influence of radiosensibilizators. | | | |
| | | *Literature: 1-3, 7, 10, 13, 17* | | | |
| 2.4 | Post-radiation recovery of plants and animals | Concept of postradiation renewal. Basic ways of postradiation renewal: reparation, repopulation, regeneration and compensatory renewal. Reparation of DNA and other molecules and structures of cell. Subletal and potentially lethal damages of DNA and their reparation. Photoreactivation. Dark reparation. Postreplicative reparation. SOS- reparation. Collection of supramolecular aggregation. Reparation of the membrane system of cell. R in chromosomes. Heterogeneity of cells of critical fabrics and organs of plants and animals. Radiosensibility of cells in the different phases of cellular cycle. State of cellular rest. A role of radioresistant cells and out of cycle cells in forming of backlogs of repopulational renewal. Fabrics and organs in a spacehold. Centers of regeneration. A role of the apical dominating of plants in their regeneration renewal. Postradiation renewal in the forests. A temporal acceleration of fission critical fabricsand organs as primary reaction is on a radiation damage. Dedifferentiation of cells as a separate way of their postradiation renewal. Possibilities of management of postradiation renewal processes. | 2 | 4 | 9 |
| | | *Literature: 1, 7, 9-12* | | | |
| | | **Module 3. Agriculture in terms of radioactive contamination** | | | |

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| 3.1 | Migration of radionuclides in the environment and objects of agriculture | General ways of migration of radionuclides in the objects of environment and agriculture. Trophic, or food, chain. Sources of receipt of radionuclides in atmosphere. Ways of receipt of radionuclides in soil. A role of physical and chemical and agricultural chemistry properties of radionuclides in their migration in soil. Vertical and horizontal migration. Influence of weather-climatic terms on migration of radionuclides in soil. Ways of receipt of radionuclides are in plants: out of roots (air) and root. Quantitative indexes of radionuclides piling up by plants: coefficient of accumulation (*KA*), transition coefficient (*KT*). A specific of out of roots receipt of radionuclides from hard aerosols. There is entering of soluble radionuclides plants from air. Wind and rain getting up of radionuclides from the surface of soil as a source of the secondary contamination of plants. Influence of biological features of plants and weather terms is on the out of roots entering of radionuclides into the plants. Influence of properties of soil on the root entering of radionuclides into the plants: mechanical composition, mineral particle, organic matters, acidity, carbonate , to moisture, distributing of radionuclides, on the type of soil. Specific of entering agricultural plants of separate radionuclides. Features of radionuclides migration in forest geobiocenosiss. Ways of receipt of radionuclides are in the organism of animals: peroral (through a gastrointestinal tract), inhalation (through the organs of breathing) and perkutal (through a skin and wound surface). Quantitative indexes of piling up of radionuclides in the organism of animals: a coefficient of accumulation (*KA*), coefficient of suction (*KS*, period, half-leadingout of radionuclides (*Th/l*). Metabolism of radionuclides is in the organism of agricultural animals. A specific of piling up of radionuclides is in the organism of animals at the protracted receipt. Basic ways of leadingout of radionuclides from organism of animals. Determination of concept of incorporated | 4 | 2 | - |

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| | | radionuclides. Features of action of incorporated radionuclides on an organism. Features of biological action of hot particles. Methods of prognostication of radionuclides receipt in agricultural plants. Principles of prognostication of receipt of radionuclides in the organism of agricultural animals. Ways near setting of receipt norms and piling up of radionuclides in agricultural plants and organism of agricultural animals. | | | |
| | | *Literature: 1-4, 8-12, 15, 17* | | | |
| 3.2 | Measures to reduce the accumulation of radionuclides into crop and livestock products | Basic principles of receptions application on transition of radionuclides diminishing from soil in agricultural plants. Generally accepted and special receptions of soil tilling, which reduce entering of radionuclides plants: cultivating and ploughing, deep ploughing, is by a trencher plough, removal of epiphase of soil, filing up of muddy layer by clean soil. Agricultural chemistry facilities of diminishing of receipt of radionuclides to plants: liming and gypsuming, application of megascopic norms of phosphoric and potassium fertilizers, use of oligoelementss, organic fertilizers. Selection of agricultural cultures, as a measure on diminishing of maintenance of radionuclides in plants. A management of irrigation regime is an effective measure of decline of receipt of radionuclides in agricultural cultures. Application of the special chemical matters and connections is for diminishing of piling up of radionuclides in plants. Phytodezactivation of soils. Land- of radionuclides contamined meadows and pastures as a mean of diminishing of maintenance of radionuclides in sterns. Aerophare control of forages and products of stock-raising. Influence of changing of the regim of feeding and will make rations, to maintenance in the ration of alkali-earth elements and other factors on the transition of radionuclides from forages to milk, meat, eggs and other products of stock-raising. tothe rations of mineral additions and preparations which prevent the transition of radionuclides from forages to the organism of animals and acceleration of their leadingout. Radioblocators and | 4 | 4 | - |

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| | | radiodecorporants. Organizational measures. Cleaning of products of plant-grower from radionuclides washing off external contamination, receipt of oil, exception of carbonhydratess, receipt of alcohol, receipt of forage and food albumen, cleaning of grain, exception of pharmacological, bioactive and other connection, culinary treatment. Cleaning of products of stock-raising is from radionuclides: processing of milk, washing of milk products, cleaning of milk, by ion-exchanging connections and electrodialysis, culinary treatment of meat, fat and other products. Coefficient of cleaning of products. | | | |
| | | *Literature: 1, 5, 8, 10-12, 18* | | | |
| 3.3 | Application of ionizing radiation in agricultural production and other fields of human activity and method of isotope indicators in biology and ecology | Determination of concept of radiation biological technology. Radiation technique which is used in radiation biological technologies. Ways of the use of ionizing radiations are in agriculture. The use in a plant-grower: a preseed irradiation of seed and presowing irradiation of vegetative reproductive and seedlings organs is in stimulant doses for a growth, development and increase of the productivity of plants acceleration; an irradiation of seed and plants for the receipt of new varieties; radiation biotechnology of fabrics incompatibility overcoming and stimulation of growth at the vegetative inoculations of plants; radiation the biotechnology of fight against the insects-wreckers of agricultural plants; radiation technology of medical plants quality improvement; radiation technologies of lengthening of shelf-lives products of plant-grower and fruit-growing, prevention of germination of tubers, root crops and bulbs; radiation pasteurization and canning. The use is in a stock-raising: an irradiation of chicken eggs and young animals in stimulant doses with the purpose of growth acceleration and development of animals; radicidation of products of stock-raising and sterilization of insects-higglers of illnesses of animals and man; radiation disinfestation of stock-raising products; radiation disinfestation of stock-raising complexes flow waters; radiation canning of forages and improvement of their | 6 | 4 | 7 |

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| | quality; radiation sterilization of tool and materials is in veterinary medicine; radiation pasteurization and canning of products of stock-raising. The use of ionizing radiations is in medicine, food retail and pharmaceutical industry. Definition of concept of isotopic indicators, or isotope-tracers. Essence of method of isotopic indicators. Radioactive and stable isotopes. Isotopes which are used in biological researches. Methods of receipt of the marked connections. | | | |
| | *Literature: 1, 2, 6, 10-12* | | | |
| | **Total:** | **30** | **30** | **30** |

## 5. STUDENT RATINGS

5.1 Criteria for calculating the maximum number of points in conditions of rating by hours:

***Lectures*** - for each hour of listened and recapitulated lecture – 0.5 points.

***Laboratory works*** - for every hour of completed and assigned task of practical classes - 1 point.

***Independent work*** - for every hour of self-prepared and assigned task - 0.5 points.

Rating (maximum) of the student by modules considering hours as a criterion

| **Module** | **$R_{e.w.}$** | **Credits** | **Lectures** | **Laboratory works** | **Independent work** | **Total** |
|---|---|---|---|---|---|---|
| 1 | $M_1$ | 1.0 | 8 · 0.5 = 4 | 10 · 1 = 10 | 14 · 0.5 = 7 | 21 |
| 2 | $M_2$ | 1.0 | 8 · 0.5 = 4 | 10 · 1 = 10 | 9 · 0.5 = 4.5 | 18.5 |
| 3 | $M_3$ | 1.0 | 14 · 0.5 = 7 | 10 · 1 = 10 | 7 · 0.5 = 3.5 | 20.5 |
| | Total | 3.0 | 15 | 30 | 15 | **60** |

Rating of educational work $\mathbf{R_{e.w.}}$ = 70 %, and rating of exam $\mathbf{R_{exam}}$ = 30 % from the total number of points (according to the Regulations).

In case of 100% mastering of discipline the student can get $\mathbf{R_{e.w.}}$ - 42 points, and $\mathbf{R_{exam}}$ - 18 points.

5.2 Rating of attestation for discipline

| **National score** | **ECTS** | **Definition ECTS** | **$R_{dis.}$, points** | **$R_{dis.}$, actual points for discipline** |
|---|---|---|---|---|
| Excellent | A | ***Excellent*** - perfectly performance, with only a small number of errors. | (0.9 – 1.0) · $R_{dis.}$ | 54 – 60 |
| Good | B | ***Very good*** - above average level with several mistakes | (0.82 – 0.89) · $R_{dis.}$ | 49 – 53 |

| | | | | |
|---|---|---|---|---|
| | C | ***Good*** - generally correct with some mistakes | $(0.75 – 0.82) \cdot R_{dis.}$ | 45 – 48 |
| Satisfactory | D | ***Satisfactory*** - not bad, but with a significant number of shortcomings | $(0.66 – 0.74) \cdot R_{dis.}$ | 40 – 44 |
| | E | ***Enough*** - execution satisfies the minimum criteria | $(0.60 – 0.65) \cdot R_{dis.}$ | 36 – 39 |
| Unsatisfactory | FX | ***Unsatisfactory*** - you need to work before getting a score (positive rating) | $(0.35 – 0.59) \cdot R_{dis.}$ | 21 – 35 |
| | F | ***Unsatisfactory*** - serious further work is needed | $(0.01 – 0.34) \cdot R_{dis.}$ | 1 – 20 |

5.3 Discipline rating

$$R_{dis.} = R_{e.w.} + R_{exam} + R_{add.w.} – R_{penal}$$

Assume that the student scored only 45 points, which is 75% of 3.0 credits or $\mathbf{R_{dis.}}$ of student is 2.25 credit.

## 6. EXAMPLE OF CONTROL TASKS

<table>
<tr><td colspan="4">National University of Life and Environmental Sciences of Ukraine</td></tr>
<tr><td>Bachelor 3rd year study Specialty 101 «Ecology»</td><td>Radiobiology and Radioecology Department 2019/2020 study year</td><td>Test № 1 from the course Radiobiology and Radioecology</td><td>Approved<br>Head of department<br><br>Gudkov I.M.</td></tr>
<tr><td colspan="4">Questions</td></tr>
<tr><td colspan="4">1. Factors affecting the migration of radionuclides in the atmosphere.</td></tr>
<tr><td colspan="4">2. Definition of oxygen effect concept.</td></tr>
<tr><td colspan="4">Tests</td></tr>
<tr><td>1.</td><td colspan="3">Water has _____ action<br>a) Radiosensitizing; b) Radioprotective; c) Both; d) There is no correct answer</td></tr>
<tr><td>2.</td><td colspan="3">What element has an antagonist with Cs?<br>a) Sr; b) Ca; c) K; d) Pb</td></tr>
<tr><td>3.</td><td colspan="3">What phase of cell cycle is the most radiosensitive?<br>a) S; b) $G_1$; c) M; d) $G_2$</td></tr>
<tr><td>4.</td><td colspan="3">Arrange the correct links on types of radionuclides distribution in animals (few radionuclide can respond to one type)<br><table><tr><td>1</td><td>bone</td></tr><tr><td>2</td><td>diffuse</td></tr><tr><td>3</td><td>reticuloendothelial</td></tr></table><table><tr><td>a</td><td>Transuranic elements</td></tr><tr><td>b</td><td>Cs</td></tr><tr><td>c</td><td>Sr</td></tr><tr><td>d</td><td>Rb</td></tr><tr><td>e</td><td>Pu</td></tr></table></td></tr>
<tr><td>5.</td><td colspan="3">Critical tissue in plants are:<br>a) phloem; b) xylem; c) meristem; d) parenchyma</td></tr>
<tr><td>6.</td><td colspan="3">Which of the natural potassium isotopes is radioactive?<br>a) $^{39}$K; b) $^{40}$K; c) $^{41}$K; d) $^{42}$K</td></tr>
<tr><td>7.</td><td colspan="3">Among vertebrate animals, the highest radioresistance have:<br>a) fishes; b) birds; c) mammals; d) reptile</td></tr>
<tr><td>8.</td><td colspan="3">A critical organ to $^{14}$C is:<br>a) eye lens; b) bone tissue; c) spleen; d) fatty tissue</td></tr>
<tr><td>9.</td><td colspan="3">To construct the survival curve is carried out:<br>a) experiments in vacuum conditions; b) experiments on the neutralization of ionizing radiation; c) experiments with irradiation in different doses; d) experiments on irradiation in stimulating doses</td></tr>
<tr><td>10.</td><td colspan="3">What statements are correct for α-particles:<br>a) Have ‘2-‘ charge; b) Consists of 2 protons and 2 neutrons; c) Is a nuclei of helium d) Is the most harmful for organism</td></tr>
</table>

## 7. RECOMMENDED LITERATURE


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