**NATIONAL ACADEMY OF SCIENCES**
**OF THE REPUBLIC OF ARMENIA**

# R E P O R T
# ON MAJOR RESEARCH OUTCOMES
# FOR 2021

**Yerevan – 2022**

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***Scientific Organizational Department on the basis of materials submitted by the NAS RA***
***Divisions of Sciences,***
***Research Organizations and Sub-Divisions***

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## INTRODUCTION

In 2021, in the difficult conditions of the post-war period and the COVID-19 pandemic, the National Academy of Sciences of the Republic of Armenia continued its scientific and scientific-organizational activities, fundamental and applied research was conducted in scientific organizations of the NAS system in various fields of science.

In 2016, the elections of the governing bodies of NAS were held. Academician A.Saghyan was elected the president, corresponding member H.Matevosyan - the vice-president and corresponding member A.Ishkhanyan - the academician-secretary of NAS. Academicians L.Aghalovyan (Division of Mathematical and Technical Sciences), R.Kostanyan (Division of Physics and Astrophysics), L.Tavadyan (Division of Chemistry and Earth Science), Yu.Souvaryan (Division of Armenology and Social Sciences) and corresponding member R.Aroutyunian ( Division of Natural Sciences) were approved as the academician-secretaries of the NAS scientific divisions and elected the members of the Presidium. Academicians G.Gevorkyan, G.Ghazinyan, R.Martirosyan, A.Melkonyan, G.Poghosyan, corresponding members A.Hakhoumyan and V.Melikyan were also elected the members of the Presidium.

The structure of the Presidium of NAS was optimized, as a result of which new subdivisions were created: departments of Development Programs and Monitoring, Special Programs and Investments, Programs on the Training of Scientific Personnel; the departments of Support for International Grants and Popularization of Science and Public Relations were reorganized; positions of deputy presidents of NAS as well as of the representative of the NAS Presidium in Artsakh were opened.

In 2021, NAS continued active cooperation with international scientific institutions and academies of sciences. During the visit to Armenia of the delegation of RAS, headed by A.Sergeev, the President of RAS, a Roadmap was signed for the implementation of the provisions of the Agreement on scientific and technical cooperation between RAS and NAS RA, in which the mentioned 54 joint proposals include various fields of science. The delegations of the Academy took part in the work of the international scientific-practical conference "30 years of the Commonwealth of Independent States: results, prospects", the session of the International Association of Academies of Sciences (IAAS), the III Forum of the Scientists of the CIS Member States. The meetings have contributed to the development of scientific and technical cooperation between the scientific institutions of the countries, stimulated the implementation of joint research projects.

As in previous years, the Academy actively participated in the work on introducing amendments and additions to some paragraphs of RA draft law "On Higher Education and Science" concerning the Academy.

In 2021, at the scientific organizations of the NAS system, attestation of scientific personnel was carried out, as a result of which, in accordance with the Decree of the RA N 747-L of May 13, 2021, the salary of scientific employees was increased.

In the reporting year, the scientists of the NAS system were directly involved in the work of various parts of the military-industrial complex of the Republic.

In 2021, the NAS institutes organized 37 international and 42 local conferences. The scientific institutions of NAS carried out research work on 5 target, 44 basic, 186 contractual economic programs and 313 works funded by the RA MESCS Science committee. Based on the results, 160 monographs and collections (including 20 abroad), 21 manuals, 1550 articles in peer-reviewed journals (including 615 abroad), 481 articles in collections of materials of scientific conferences (including 210 abroad), 349 theses (including 187 abroad) were published.

Since 2021, the elaboration of the Development Strategy of NAS RA for 2022-2026 has been launched and is currently at the final stage, aimed at increasing the efficiency of scientific research conducted in academic organizations, strengthening the science - education – production connection, stimulating excellence, promoting the integration of academic organizations into the

international research space and thus ensuring the sustainable development of the academic system.

A program of structural reforms of NAS is also being developed, which provides for the concentration of the Academy's resources on fundamental and / or based on the needs of the economy of the Republic or aimed at increasing national security research that meets modern standards of science; the formation of large research centers / organizations implementing modern programs with clear ideas about development and expected results.

In order to increase the efficiency of the reproduction of scientific personnel, it is planned to transform the International Scientific and Educational Center of NAS into a research university, the primary task of which will be to train personnel, conditioned by the demand of scientific organizations of the Republic.

***President of NAS RA, academician A.Saghyan***

## DIVISION OF MATHEMATICAL AND TECHNICAL SCIENCES

***Academician-Secretary – academician L.Aghalovyan***
***Scientific Secretary – L.Martirosyan***

The Division of Mathematical and Technical Sciences includes the Institutes of Mathematics, Mechanics, for Informatics and Automation Problems, as well as the Department of Hydromechanics and Vibrotechnics.

The Division includes 12 academicians, 7 corresponding members, 24 foreign members, 5 honorary doctors.

During the reporting year 3 general meetings of the Division were held.

At the annual general meeting held on April 22 the report of L.Aghalovyan, the Academician-Secretary of the Division, "On the main scientific and scientific-and-organizational results of the Division for 2020" was discussed and approved (the meeting was held online).

At the general meeting held on June 29 according to the results of a closed secret ballot academician L.Aghalovyan was elected a candidate for the post of the Academician-Secretary of the Division.

At the general meeting held on July 7 the new staff of the Bureau and the Scientific Secretary of the Division were elected. Academicians G.Baghdasaryan, A.Tarverdyan, corresponding members L.Aslanyan, B.Nahapetian, as well as the directors of the Division Institutes G.Karagulyan, V.Avetisyan, H.Ascatryan, G.Avetisyan were elected the members of the Bureau of the Division. L.Martirosyan was elected the Scientific Secretary of the Division.

17 meetings of the Bureau were held. The following issues were discussed and approved: the working plan of the Division for 2021; the number of postgraduate vacancies and their distribution among the Institutes for the 2021-2022 academic year; the results of admission to the postgraduate school, research advisers and scientific topics of the postgraduate students; the decision project of the general meeting for the reporting year; applications for the programs of basic financing of scientific and scientific-and-technical activities: "Preservation and development of infrastructure" and "Preservation of scientific objects of national value" as well as for scientific and scientific-and-technical state target programs for 2022; the reports of the Institutes of the Division for 2021, including on the programs of basic funding; applications of the Institutes of the Division for submission of funding at the expense of the program "Re-equipping the organizations of the NAS RA with equipment" as well as applications for scientific trips, the results of the attestation of the scientific staff held in the Institutes, the main results of the activity of the scientific organizations of the Division, as well as other scientific-organizational issues.

The following scientific journals are published on the Division specialities: "Proceedings of NAS RA. Mathematics" (6 issues), "Proceedings of NAS RA. Mechanics" (4 issues), "Proceedings of NAS RA and NPUA (series of technical sciences)" (4 issues), "Mathematical Problems of Computer Science" (2 issues), as well as the electronic "Armenian mathematical journal".

148 scientific articles: 99 in the peer-reviewed journals (50 abroad) and 49 in the conference proceedings (10 abroad), 21 theses (15 abroad) were published in 2021 by the researchers of the Institutes of the Division.

The Institutes of the Division have organized 6 international and local scientific conferences, 6 projects on international grants have been implemented (the Institute for Informatics and Automation Problems).

2 Candidate's dissertations were defended by the researchers of the Institutes. 3 Candidate's dissertations were defended at the Scientific Councils of the Institutes of the Division (the Institute of Mechanics).

In December of the reporting year annual report meetings of the Institutes were held (in the Institute for Informatics and Automation Problems the meeting was held online), the reports of the Institutes for 2021 were discussed and approved.

## Institute of Mathematics

### *Major achievements*

Good-lambda inequalities, known in harmonic analysis, characterize certain relationship between two operators. Such inequalities first appeared in the 70s in the works of American mathematicians in the studies of the properties of martingales. Currently, a variety of good-lambda inequalities, widely used both in harmonic analysis and probability theory, is known. In G.Karagulyan's work "On good-lambda inequalities for couples of measurable functions" two classes of good-lambda inequalities, which contain several known inequalities, are introduced. By the results new properties of some operators of harmonic analysis have been determined. In particular, a new exponential valuation for Carlson type operators has been obtained (Sup.: DSc(phys.-math.) G.Karagulyan).

## Institute of Mechanics

### *Major achievements*

For a linearly deformed Korenev base the influence function of which is expressed by the Macdonald function with a zero index depending on the distance between two points in the considered contact problems it has been shown that concentrated forces act on the boundary line of the contact zone. Necessary and sufficient conditions for the boundedness of contact stresses have been obtained (Sup.: corr. memb. S.Mkhitaryan).

### *Outcomes of applied developments*

The total energy loss, arising from the pulsating axial tension or the simple torsion of thin-walled fiberglass laminated pipes with initially broken symmetry of the direction of reinforcement relative to the axis, has been divided into two components: energy loss due to the main deformations (recorded in the loading direction) and energy loss arising owing to the appearance of accompanying main deformations (shear at the first mentioned case of loading and axial at the second one). Recommendations are formulated aimed at the optimal design of thin-walled pipes made of laminated composites subjected to pulsating axial tension or simple torsion during their operation (Sup.: DSc(tech.) K.Karapetyan, cand.(tech.) S.Valesyan).

## Institute for Informatics and Automation Problems

### *Major achievements*

For a tournament to be strongly $d$-panconnected, the following theorem has been proved, which improves a number of related results.

**Theorem.** Let $T$ be an $m$-irregular tournament of order $p$ such that $p + m \geq 11$. If $m \leq \frac{1}{3}(p-5)$ (respectively, $m \leq \frac{1}{5}(p-3)$), then $T$ is 4-strongly panconnected (respectively, 3-strongly panconnected or $T$ belongs to a set of tournaments, which is well described) (Sup.: cand.(phys.-math.) S.Darbinyan).

E - capacity - equivocation region and E - secrecy - capacity new notions of wiretap channel have been introduced and investigated. The outer and inner bounds of the corresponding regions have been constructed. Special classes of the basic wiretap channel have been considered and the corresponding bounds have been constructed (Sup.: DSc(phys.-math.) M.Haroutunyan).

### *Outcomes of applied developments*

A data analysis service and a method have been developed to analyze the astronomical data of Margaryan's survey which allows to detect and classify several million spectra.

Dask parallel Python and Kubernetes platforms have been developed within the cloud infrastructure. Dask allows users to build their software in coordination with other community projects like NumPy, Pandas, and scikit-learn, while Kubernetes manages containerized workloads and services.

A performance-efficient service has been developed to find an optimal tradeoff between I/O and CPU using data compression in Big Data frameworks. The service consists of Prediction and Recommendation modules to predict an application's execution time with given metrics and provide optimal configurations considering the simulation time.

Services on monitoring and forecasting of air temperature, delineating the coastline of water bodies, and monitoring of air pollutants have been developed within the Armenian Data Cube, developed under the Armenian-Swiss initiative. The services have been evaluated using the extraction of surface air temperature in the Ararat valley, the delineation of Lake Sevan coastline and the monitoring of the level of air $NO_2$ pollutant (Sup.: cand.(tech.) H.Astsatryan).

Software solution for uploading data in RDF format, storing it in a distributed file system or converting it to Property Graph is being developed. The application of known algorithms is studied on this data (Sup.: cand.(tech.) T.Shahinyan).

Methods for distributing the workload of distributed video conferencing systems have been investigated. MEET.ASNET.AM videoconferencing platform has been updated as a result of research application. The work was presented at the CSIT-2021 conference.

A new solution for freeradius IMAP connectors for password control of the eduroam system has been tested. Telegram Bot systems have been investigated. Pilot network server alert systems for existing network services have been developed (Sup.: cand.(tech.) A.Petrosyan).

Together with GEANT European partners, research and testing of the WiFiMon solution for the monitoring of the performance of the eduroam system have been carried out (Sup.: cand.(tech.) R.Tadevosyan).

Work on improving the security of DNS, E-mail and web servers of ASNET-AM network has been continued. Further upgrades of ASNET-AM unified webmail system, ASNET-AM email management system and ASNET-AM DNS system have been done (Sup.: cand.(tech.) G.Petrosyan).

Prototype of automatic rigging software for 3D human body skeleton has been investigated. A software prototype has been developed for applying a rigged skeleton to a human 3D model scanned in a special pose (A-Pose) which allows later to add mobility (to animate it). Various artificial intelligence (AI) methods have been used such as collecting data-set, training, AI model acquisition, optimization. Machine learning library PyTorch has been used in the Blender environment.

A software module has been developed that allows to load an animated skeletal 3D model into an already compiled project created with the Unreal Engine system when the project is already running. Before module development, in order to change a model inside a project, it was necessary to change the original code of the project, re-compile and then rerun it (Sup.: cand.(tech.) S.Abrahamyan).

3D model generation based on various 3D scanning technologies has been investigated. Several 3D scanning technologies are used for different purposes. Laser scanning provides high accuracy of the resulting 3D model, which, for example in the case of buildings, can be used in architectural calculations. With photo scanning, unlike laser scanning, it is possible to keep the colors of the scanned object, but lose the high accuracy of the model. Aerial scanning (mainly with the use of UAV - unmanned aerial vehicles) can scan large areas and use the result, for example, for geodetic calculations, but lose the accuracy for even larger sections. Within the framework of this point, approaches have been developed and applied allowing to perform an effective scan of buildings of different types by combining all the above-mentioned technologies, providing both high accuracy and color spectrum (Sup.: cand.(tech.) S.Balyan).

A comprehensive statistical analysis of the behavior of teachers and students has been carried out on the basis of data accumulated over 5 years on the MOODLE distance learning platform of the Scientific-Educational Center of the NAS RA (Sup.: cand.(phys.-math.) P.Hakobyan).

An educational ecosystem built with Wikipedia and other wiki projects has been introduced. It gives teachers the opportunity to continue their creative education and, in case of students, deepen their interdisciplinary knowledge in future professional fields (Sup.: cand.(phys.-math.) S.Mkrtchyan).

The following has been carried out:

creation of an image recognition model using the TensorFlow deep neural network creation system, creation of a text classification model using initial models from the TensorFlow Hub model database and data from various open sources;

experimental creation of a simple system for recognizing the faces of arbitrary people on a local computer using the basic facial recognition model FaceNet developed by Google;

solving simple question-and-answer problems using BERT neural networks for natural language recognition (Sup.: cand.(tech.) M.Gyurdjyan).

## Department of Hydromechanics and Vibrotechnics

### *Major achievements*

Within the framework of the topic "Control of wave and oscillatory processes in pipeline systems" research has been carried out to study and control wave and vibration processes in reactive radial-axial hydraulic turbines of medium power and pressure in order to reduce wave resistance in spiral chambers, impeller chambers and guiding devices. Technique and means have been developed, which significantly reduce the energy consumption for the passage of the fluid flow through the hydraulic turbine. Studies have been carried out on a laboratory model of a hydroelectric unit with a radial-axial turbine. During the modeling of complex physical phenomena, occurring in a hydraulic turbine, modeling methods based on the theory of similarity have been applied. All three conditions (geometric, kinematic and dynamic), arising from the theory of similarities of mechanical processes in fluid flows, have been met. Investigations of the influence of the developed technique and means for reducing the wave resistance on the experimental stands have been carried out by measuring the power characteristics of the hydraulic unit in the entire range of changes in flow rates and pressure. Determination of its energy characteristics has been achieved without installing the developed devices – stabilizers of pressure pulsations and fluid flow on the supply pressure pipeline of a hydraulic turbine and without installing a stabilizer on the pressure pipeline. The developed multifunctional stabilizers installed on the pressure pipeline of the hydraulic turbines effectively function both in transient and steady-state modes of operation of the hydraulic unit: they extinguish the pulsations of pressure and fluid flow by 85-90%. The power of the hydraulic turbine increases by 5-7%. Consequently, the throughput of the path and efficiency of the hydraulic unit increase by the same amount. This is the result of a decrease in the magnitude of the wave drag in the spiral chambers, impeller chambers and guiding devices of the hydraulic turbine (Sup.: cand.(tech.) G.Avetisyan).

### *Outcomes of applied developments*

Measurement of costs and quantities of water is the base hydraulic technical characteristics of water flow, which is necessary for the design of various hydraulic structures. In case of hydroelectric stations – to calculate their capacity; in case of irrigation systems – to obtain the real area of irrigated land; in case of operational services – for the management and distribution of water resources to agricultural water users; in case of drinking and industrial water supply – to calculate the amount of water for settlements and production needs without compromising the environment. A method and a structure have been developed for measuring the levels of water flow rates and expenditure of water in canals and rivers, as well as in water supply for water accounting. The goal of the research is to increase the level of water in canals, accuracy of measuring the flow rate of water. The water-measuring structure contains a soothing well with a water-measuring device located on the bank of the water utility. The well is in communication with the canal via a supply pipeline with a pressure fluctuation stabilizer. The real height of the water flow consists of the sum of the height $h$ of the displacement of the float of the water measuring device and the value of the velocity head - $V^2/2g$, determined from the Bernoulli equation. Water flow is equal to the product of the total height of the water and the average speed of water flow along the canal. The proposed method and structure for measuring the flow rate and amount of water in the canals allows to measure the water flow in canals with an accuracy of about 1%. Implementation of the results of this applied research to measure the amount of water withdrawn from Lake Sevan saves 12 - 17 mil. cub. meters of fresh water per year. A technical and economic proposal on improving the accuracy of measuring the amount of water withdrawn from Lake Sevan was submitted to the RA government (Sup.: A.Simonyan).

## DIVISION OF PHYSICS AND ASTROPHYSICS

***Academician-Secretary – academician R.Kostanyan***
***Scientific Secretary – N.Davidyan***

The Division includes the Byurakan Observatory after V.Ambartsumian, the Institute for Physical Research, the Institute of Applied Problems of Physics, the Institute of Radiophysics and Electronics and the IO ICRANet Center.

The Division includes 6 academicians, 10 corresponding members and 27 foreign members.

During the reporting year 3 general meetings and 14 sessions of the Bureau were held.

At the annual general meeting held on April 22 the report on "The main results of scientific and organizational activity of the Division for 2020" by the Academician-Secretary academician R.Kostanyan was discussed and approved.

At the general meeting on June 29 academician R.Kostanyan was elected a candidate for the post of the Academician-Secretary of the Division. The new staff of the Bureau was reelected and approved.

During the sessions the Bureau discussed and approved the applications for the programs of basic financing of scientific and scientific-and-technical activity: "Preservation and development of infrastructure" and "Preservation of scientific objects of national value", postgraduate and travel applications. Expert opinions on the letters received from governmental various agencies were given.

Applications on purchase of equipment submitted from the Byurakan Observatory after V.Ambartsumian, the Institute for Physical Research and the Institute of Radiophysics and Electronics were considered and satisfied. Authorized representatives of the Division Institutes were elected. On June 27, the program for attestation of employees of the Institutes called "General regulations on attestation of scientific staff in the organizations of NAS RA" was launched, the results were published in the reports and discussed at the meetings of the Bureau.

During the reporting year a number of local and international scientific events were held, international cooperation in the scientific organizations of the Division has expanded, new agreements have been signed, cooperation between scientific and educational institutions has been continued. The draft proposal of the Republic of Armenia on "Higher Education and Science" and the main standards, pros and cons related to the development of science were discussed. The 2022 basic funding applications, 2022-2027 programs and strategy of the Institutes of the Division were discussed. The proposals of the Institutes on participation in the basic research programs of the CIS countries were discussed and approved. In the current situation the organizations of the Division have submitted additional proposals in the field of defense, high-tech and health-care to the relevant departments.

In December of the reporting year, annual reporting meetings were held in the scientific organizations of the Division, the reports on scientific and organizational activity in 2021 were discussed and approved.

8 employees of the Institutes of the Division got their PhDs.

The organizations of the Division have received 3 licenses. 2 study guides, 4 monographs (2 abroad), 221 scientific articles: 189 in the peer-reviewed journals (98 abroad) and 32 in the conference proceedings (8 abroad), 107 theses (27 abroad) were published.

The following scientific journals are published on the Division specialities: "Proceedings of NAS RA. Physics" (imp.f. 0.578, 4 issues), "Astrophysics" (imp.f. 0.655, 4 issues) and the electronic "Armenian Journal of Physics" (4 issues).

### Byurakan Astrophysical Observatory after V.Ambartsumyan

***Major achievements***

Using the SDSS spectroscopy, fine optical spectral classification of activity types for 710 AGN (active galactic nuclei) candidates has been carried out. The fine classification shows that many QSOs (quasi-stellar object) show the same features as Seyferts, i. e. subtypes between S1 and S2. Subtypes for the QSOs: QSO1.0, QSO1.2, QSO1.5, QSO1.8 have been introduced. Thus, independent of the luminosity (which serves as a separator between QSOs and Seyferts), AGN show the same features.

Many objects are classified as objects with composite spectra that have the characteristics of Seyferts and Liners, Seyferts and HII regions, or Liners and HII regions. In some cases, all three characteristics appear together resulting as Sy/LINER/HII subtype. The QSOs subtypes together with Seyfert ones allow to follow AGN properties along larger redshift range expanding our knowledge on the evolution of AGN to the more distant Universe represented by QSOs (Sup.: cand.(phys.-math.) A.Mikaelian).

It has been shown that the HH 83 Herbig-Haro system is bipolar-symmetric in nature. In the shock front of the HH 83 outflow, two kinematic components have been revealed. The linear velocities of their proper motions indicate that they are a shock front and a Mach disk. A spectral study of the young star V565 Mon has revealed its unusual chemical composition and other properties, which testifies to the uniqueness of this object (Sup.: DSc(phys.-math.) T.Magakian).

A comparative analysis of the properties of the interstellar medium (IM) and young stellar objects (YSO) has shown that in the extended region of star formation, which includes the IRAS 05156+3643, 05162+3639, 05168+3634, 05177+3636, and 05184+3635 sources, the subregions with the largest density and mass of IM also contain the largest percentage of YSOs with I evolutionary class. The wide distribution of the evolutionary age of YSOs in all subregions (from 105 to 107 years) indicates that star formation in the observed region occurs sequentially. In those subregions, where the initial mass of the parent molecular cloud is greater, this process is most likely more active and prolonged (Sup.: cand.(phys.-math.) E.Nikoghosyan).

Based on the data obtained with the 6 m telescope for extended HII complexes with large masses it has been shown that stellar processes in them can play the role of a trigger, causing morphological changes. For example, the arm of the Galaxy could have been formed in this way, the beginning of which coincides with the position of the star formation region in which violent activity is observed (Sup.: cand.(phys.-math.) S.Hakopian).

### *Outcomes of applied developments*

At the joint Armenian-Russian station 650000 measurements have been performed altogether and 700 orbits of artificial satellites have been restored during 260 observational nights (Sup.: cand.(phys.-math.) H.Harutyunian).

## Institute for Physical Research

### *Major achievements*

For the first time, the absorption and fluorescence spectra of a Cs vapor nanocell with a thickness $L \sim 400$ nm have been recorded at room temperature. Due to the noticeable sub-Doppler narrowing of the spectral lines D1 and D2 (by a factor of 6), it has become possible to measure the spectral broadening caused by a strong laser field (Sup.: DSc(phys.-math.) D.Sarkisyan).

Based on the Bessel beam technique and LiNbO3:Fe crystal, photovoltaic tweezers have been developed and implemented for capturing and controlled movement of micro- and nano-objects which are promising as lab-on-a-chip devices (Sup.: DSc(phys.-math.) R.Drampyan).

Ferromagnetic nanoparticles (Fe-Fe3C) and (Fe-Fe3O4) with a “core-shell” structure in a carbon matrix have been synthesized by solid-phase pyrolysis of iron phthalocyanine (FePc, Pc=C32N8H16) and ferrocene (FeC10H10); comprehensive studies of their structural and magnetic characteristics have been carried out. The behavior of heating nanoparticles in an aqueous solution under the influence of an alternating magnetic field with an intensity of 200 Oe and a frequency of 350kHz has been studied (Sup.: cand.(phys.-math.) A.Manukyan).

Detectors for the registration of gravitational waves have been proposed based on superconducting Cooper pairs in a strong magnetic field, in which the mechanical motion created by the waves is converted into a magnetic flux. The low threshold of measurement noise has been substantiated, the parameters necessary to ensure high sensitivity have been analyzed (Sup.: V.Nikoghosyan).

### *Outcomes of applied developments*

A photo-receiver device has been developed and submitted for patenting, which, thanks to the applied feedback circuit, makes it possible to register weak pulsed optical radiation - regardless of the level of background illumination (Sup.: corr. member A.Papoyan).

Detection of warm objects by thermal sensors using specially designed amplifiers, conical horns, has been investigated. Digitization and software processing of the signals received by the created device make it possible to determine quickly the location of an object at a distance of 8 m within a 90˚ angle of view (Sup.: DSc(phys.-math.) A.Martirosyan).

A radar system for determining the location of objects, operating in the microwave region of electromagnetic radiation and based on a complex of antenna elements with horizontal and vertical arrangement, has been investigated and developed (Sup.: acad. R.Kostanyan).

It has been shown that the incorporation of Lu3+ ions into Y3Al5O12:Ce3+,Li+ crystals makes it possible to improve the optical quality of the crystals by changing the anti-site substitutions. It has been shown that Y3Al5O12:Ce3+,Tb3+ crystals are indicators of the presence of anti-site defects and make it possible to quantify their concentration. Li+ ions occupy interstitial positions and do not interact with Ce3+ ions, but increase the transparency of crystals in the radiation region (Sup.: DSc(phys.-math.) A.Petrosyan).

Nitrogen-doped carbon microspheres composed of nanographene clusters have been synthesized by solid-phase pyrolysis of metal-free phthalocyanine (H2Pc, Pc=C32N8H16). The structural, morphological, resistive and capacitive characteristics of the obtained samples, as well as their applicability as an electrode material for supercapacitors, have been investigated. The measured specific capacity of the microspheres is 2-4 F/g (Sup.: cand.(phys.-math.) A.Manukyan).

To determine the physical, psychological state and the degree of fatigue of a person, a medical diagnostic device, a "stabilograph", has been created based on 8 SFCO sensors. Analysis of the frequency and temporal behavior of signals received from 4 position sensors and 4 vibration sensors makes it possible to assess the state of the neuropsychological and musculoskeletal systems of a person (Sup.: DSc(phys.-math.) S.Gevorgyan).

## Institute of Applied Problems of Physics

### *Major achievements*

On the basis of obtained experimental data the possibility of operation of an electron beam in electron synchrotrons in a regime of a low-energy stretcher has been theoretically validated (Sup.: corr. member A.Mkrtchyan).

It has been researched and shown that by simultaneously exciting longitudinal and transverse acoustic oscillations in X-cut single crystals of quartz it is possible to control the spatial-temporal characteristics of the reflected X-rays (intensity, direction of propagation, focal length, angular and energy width) (Sup.: cand.(phys.-math.) V.Kocharyan).

### *Outcomes of applied developments*

A new method to develop a new type of acoustoplasma accelerator of the charged particles has been offered. A new type unti-heil acoustic system with controlled characteristics has been developed (Sup.: corr. member A.Mkrtchyan).

A laboratory sample of a simple breathing apparatus for lung ventilation has been developed. Its main feature is the excitation of harmonic and nonharmonic oscillations with different frequencies in the inhaled (exhaled) air. It has been shown that these fluctuations can contribute to removing of phlegm and other foreign bodies from lungs (Sup.: cand.(phys.-math.) H.Khachatryan).

A new method for creating sources of monochromatic radiation based on the phenomena of origination of radiation from forbidden transitions of the environment in an acousttoplasma state of the media has been offered (Sup.: cand.(phys.-math.) A.Abrahamyan).

Scientific and technical research on modernization of developed and created in the institute vacuum deposition systems has been conducted. A device for prevention of viral infections has been

developed and created, its performance characteristics have been defined (Sup.: cand.(phys.-math.) R.Chilingaryan).

Porous luminiferous media with small energy efficiencies have been synthesized (Sup.: cand.(phys.-math.) V.Nalbandyan).

An area disinfection system has been developed and created (Sup.: cand.(phys.-math.) M.Sargsyan).

Using natural resources of RA on the basis of fine dispersive bentonite a new substance has been synthesized which can be used in agriculture as a highly effective low cost fertilizer (Sup.: G.Asatryan).

## Institute of Radiophysics and Electronics

### *Major achievements*

The diffraction of X-band $J_1$ Bessel beam antenna radiation on metallic disks and different size spheres located on straight line between transmitting and receiving antennas has been investigated. Efficient $J_1$ Bessel beam planar antennas developed on the base of radial waveguide have been investigated. In the absence of any obstacle the Bessel-type structure of the beam remains unchanged for more than 3 meters propagation. The obstacles, overlapping the beam till the first maximum of $J_1$ function, do not cause any significant loss. In case of more extensive obstacles the losses are sufficiently less compared with Gaussian beam. The remarkable feature of the developed Bessel beams is the reconstruction of field structure after passing the obstacle (Sup.: corr. member A.Hakhoumian).

A new method for estimation of radar cross section (RCS) has been proposed which does not need the application of an expensive echoless camera. Such method is based on the moving target indication (MTI), which allows to exclude reflections from external standing objects. Measurements in Ku band have been taken and RCS of trihedral reflector has been evaluated (Sup.: cand.(phys.-math.) T.Zakaryan, N.Pogosyan).

Graphene quantum dot with Maxwell "fish eye" potential energy profile has been studied. A quasiclassical approximation has been used given that potential energy is a slowly varying function of coordinates. Near the zero energy the spectrum of electron macroscopically degenerates. All the electron trajectories are closed circles that are classified by angular momentum and an additional integral of motion. Upon the complete filling of the lower Dirac zone, a universal value for Hall conductivity has been found (Sup.: DSc(phys.-math.) Zh.Gevorgyan).

Quasi-two-dimensional MoS2 crystals have been fabricated by pulsed laser deposition consisting of one or more atomic monolayers. Ohmic contacts have been fabricated and the photoelectric properties of these two-dimensional crystals have been studied. It has been shown that the optoelectric properties of such ultrathin crystals, in particular the bandgap width, strongly depend on the number of atomic monolayers (Sup.: corr. member S.Petrosyan).

Characteristics of a semiconductor nanowire (NW) pH sensor have been theoretically studied. The dependences of the sensor characteristics, in particular the sensitivity, on the geometrical and physical parameters of the NW have been obtained. An optimal set of parameters has been proposed for the sensor design (Sup.: cand.(phys.-math.) A.Yesayan).

### *Outcomes of applied developments*

A new method of estimation of radar cross section (RCS), which does not need the application of an expensive echoless camera, has been proposed. Such method is based on the moving target indication (MTI), which allows to exclude reflections from external standing objects. Measurements in Ku band have been taken and RCS of trihedral reflector has been evaluated (Sup.: cand.(phys.-math.) T.Zakaryan, N.Pogosyan).

As a result of the improvement of technological modes and more precise control of the atomic ratio of components, double-doped ceramic samples have been synthesized, the low frequency dielectric permeability of which exceeds $1.5 \cdot 10^5$. Work is underway to reduce the dielectric losses in such material in order to create capacitors with colossal high capacity (Sup.: corr. member S.Petrosyan).

Based on the p-InSb/n-CdTe anisotropy heterostructure , four-coordinate photosensitive photo detectors have been fabricated, their properties have been studied, and the linear range of coordinate- and photo- sensitivities of the infrared rays has been found (Sup.: L.Matevosyan).

Aqueous solution with iron nanoparticles obtained by laser ablation has been studied using a microwave strip sensor. The response of the sensor has been used to determine the minimum concentration of iron nanoparticles that can be measured at the resonant frequency. The registered excess part of the microwave response of the sensor system can be explained by additional structural changes in water clusters as a result of ablation of metal nanoparticles (Sup.: cand.(phys.-math.) R.Khachatryan).

An electrical circuit of miostimulator has been developed and a laboratory specimen has been made for physiotherapy. Muscle stimulation and contraction functions have been tested at one therapeutic point. Updating of the device and application of the processing program will allow it to work from 5 up to 10 therapeutic points at the same time (Sup.: acad. A.Ghulyan).

## IO ICRAnet Center

### *Major achievements*

Based on the remarkable behavior of the 4FGL J1544.3-0649 source, a new type of transient blazar has been introduced. 4FGL J1544.3-0649, a mid-intensity radio source, has never been detected at high energies, but after 2017/2018, for several months, it was one of the brightest extreme blazars in the X-ray and gamma-ray sky (Sup.: cand.(phys.-math.) N.Sahakyan).

## DIVISION OF NATURAL SCIENCES

***Academician-Secretary – corresponding member R.Aroutiounian***
***Scientific Secretary – cand.(biol.) S.Atshemyan***

The Division includes the Scientific and Production Centre (SPC) "Armbiotechnology", the Scientific Centre of Zoology and Hydroecology, the Institute of Botany after A. Takhtajian, the Centre for Ecological-Noosphere Studies, the Institute of Biochemistry after H.Buniatyan, the Institute of Hydroponics after G.Davtyan, the Institute of Molecular Biology, the Institute of Physiology after L.Orbeli.

The Division includes 7 academicians, 9 corresponding members, 27 foreign members as well as 12 honorary doctors.

2 general meetings, 16 Bureau meetings of the Division, 8 reporting meetings of the scientific Institutes were held during the reporting year.

At the annual general meeting of the Division held on April 22 the report of the Academician-Secretary R.Aroutiounian on the scientific and scientific-organizational activities of the Division during five years was heard. The main fundamental and applied results of the Institutes, the possibility of involving foreign members of the NAS RA in the development of international scientific relations were discussed.

At the general meeting held on June 29 corr.member R.Aroutiounian was elected a candidate for the post of the Academician-Secretary of the Division, the new stuff of the Bureau was elected.

At the 16 meetings of the Bureau the following was discussed and approved: the 2021 working plan of the Division; the reports of the institutions of the Division on 2020 base funding, applications for the programs of basic financing of scientific and scientific-and-technical activity: "Preservation and development of infrastructure" and "Preservation of scientific objects of national value" as well as for scientific and scientific and technical state target programs for 2022; applications for places in postgraduate and doctoral studies for the 2021-2022 academic year; applications of the Institutes for new appliances.

During the reporting period, the Division organized an international round table dedicated to the problems of genetics in the 21st century, where reports were presented by geneticists from the Republic of Armenia and the Russian Federation. Division was a co-organizer of the International conference, dedicated to the 120th anniversary of N.Timofeeff-Ressovsky.

As a result of discussions at the meetings of the tender commission of the NAS RA the Institutes of the Division were provided with financing for the purchase of necessary equipment.

13 local and international events were organized by the Institutes of the Division including seminars, conferences, scientific expeditions, a total of 711 participants, 268 of which were from abroad.

290 articles: 253 in the peer-reviewed journals (152 abroad) and 37 in the conference proceedings (18 abroad), 26 theses, 6 monographs, 2 educational tutorials were published by the Institutes of the Division, 2 patents were obtained.

8 Candidates' and 1 Doctorates' dissertations were defended by the researchers of the Institutes at 5 specialized councils of the Division.

### Institute of Botany

#### *Major achievements*

Within the framework of the project "Conservation of wild pears (*Pyrus* L.) of Armenia in the Yerevan Botanical Garden", supported by BGCI / ArbNet, a new pear variety *Pyrus hyrcana* var. *yeghegisi* Akopian, found in the gorge of the Yeghegis river, Vayots Dzor region of RA, has been described. This species is reported for the first time for the Darelegis floristic region of Armenia (Sup.: DSc(biol.) J.Akopian).

In cooperation with experts from the Berlin Botanical Garden and Botanical Museum (BGBM), phylogenetic studies of the *Dianthus (Caryophyllaceae*) genus have been conducted. A complete taxonomic and nomenclature list of the species belonging to the genus has been compiled according to the global distribution of the taxon (Sup.: cand.(biol.) A.Nersesyan).

Within the framework of paleobotanical research it has been shown that 232 taxa of fossil plants found in sediments belong to 190 species, 111 genera from 55 plant families. Of these, 37 equivalents of modern taxa do not grow in Armenia today, and about 160 taxa are listed for the fossil flora of Armenia for the first time. The modern flora of the Vorotan River basin, as well as the region as a whole, is quite similar to the flora of the early Pleistocene. In the Early Pleistocene, the vertical zoning of vegetation was clearly expressed, but, in contrast to modern, the boundaries of broadleaf forest vegetation were higher, and the forests occupied a larger area than today. Comparison of modern and early Pleistocene climatic conditions has shown that the current climatic parameters of the middle stream of the Vorotan River basin correspond to the coldest and "relatively humid" climate parameter of the Early Pleistocene, identified from the fossil vegetation of the Sisian diatomite sequence (Sup.: cand.(biol.) I.Gabrielyan).

## Centre for Ecological-Noosphere Studies

### *Major achievements*

For the purpose of evaluating spatial and temporal peculiarities, levels and intensity of modern anthropogenesis, interdisciplinary studies aiming to detect geochemical background contents and natural associations of elements have been continued. On the example of an anthropogenic biogeochemical province - city of Yerevan - background geochemical associations of chemical elements (Fe, Ti, Mn, Co, V, Ba, Cr, Sr, Rb, Zr, Cu, Pb, Zn) in volcanic soils have been studied. Applying up-to-date statistical methods two natural geochemical associations of the studied elements: I.Fe-Co-Ti-V-Mn-Zr-Cr-Ba and II. Cu-Pb-Zn-Rb-Sr have been verified. Through a concurrent application of spectral separation methods based on multifractal analysis and a Fourier transform the background areas and manmade anomalies of naturally occurring radionuclides U-238, Th-232, K-40 have been contoured out. Analogous interdisciplinary background studies have a profound applied significance in formation of a scientifically robust monitoring system (Sup.: cand.(biol.) G.Tepanosyan, cand.(biol.) O.Belyaeva).

### *Outcomes of applied developments*

Expert maps of naturally occurring and manmade radionuclides distribution in the lands of agricultural designation in Armavir Marz RA have been developed. The maps are required for risk assessment which serves as a basis for assuring food security and sustainable agriculture. The maps can contribute to the reduction of costs for state monitoring programs and are necessary for the private sector as well (Sup.: cand.(biol.) O.Belyaeva).

In the frames of studies aimed at assessing risks of chemical hazards in food (heavy metals, antibiotic substances, and growth promoters), residual hormones in fish and antibiotics in milk, produced in Armenia, have been found. Despite the fact that diet-caused health risks are in the allowable range, it does become a serious obstacle for exporting (Sup.: DSc(food sci.) D.Pipoyan).

With the purpose of creation of a RS system of ecological monitoring of Armenia’s landscapes, work has been continued on creation of a multidimensional information system (a datacube) (http://datacube.sci.am) for satellite imagery collection and processing in partnership with the Institute of Informatics and Automation Problems NAS RA and University of Geneva in Switzerland. The system’s dataset includes Landsat and Sentinel imagery and is upgraded periodically. An attempt has been made to develop satellite imagery-based model algorithms of water body delimitation and surface temperatures (Sup.: cand.(geogr.) Sh.Asmaryan).

## Scientific Centre of Zoology and Hydroecology

### *Major achievements*

For Lake Sevan the role of cyanobacterial akinetes in the ecosystem has been studied for the first time. These cyanobacteria overwintering in bottom sediments may renew growth and return to water column under suitable conditions. The investigations conducted have shown that the number of akinetes in the bottom sediments of Big Sevan is noticeably higher compared to Small Sevan.

Laboratory experiments have clarified that the development of akinetes is suppressed in the absence of light as well as in the conditions of low nutrient concentrations. In the presence of light, up to 21000 cyanobacterial (*Dolichospermum and Aphanizomenon*) cells can grow from akinetes existed in 1 g bottom sediment (Sup.: cand.(biol.) G.Gevorgyan).

A model device for removing cyanobacteria from the water of Lake Sevan has been designed.

The quality of the waters of the Aghstev River and its tributaries has been assessed based on the hydrobiological methods for water quality assessment. It has been revealed that the river is mainly polluted in the area of Dilijan National Park, but due to dilution on account of relatively clean waters of the tributaries and self-purification processes, it flows into the Kura River with relatively good water quality (Sup.: DSc(biol.) B.Gabrielyan).

The species composition of vertebrates of the National Park "Sevan", the reserve "Artanish" and "Getik" State Sanctuary of the Tavush region has been determined, both widespread and rare 233 species have been recorded. Significant changes in the species composition and abundance of these groups of animals, especially birds, have been noted (Sup.: cand.(biol.) M.Ghasabyan).

About 700 species of insects have been registered, including 2 species new for science, 7 species new for the fauna of Armenia, and 17 species new for the Tavush region (Sup.: cand.(biol.) M.Kalashyan).

Based on the results of DNA sequencing, phylogenetic trees of Armenian representatives of the beetle genus Dorcadion have been constructed for the first time, the karyotypes of the 6 species of the same genus have been studied for the first time (Sup.: cand.(biol.) G.Karagyan).

For the fauna of Armenia 4 new species of plant pests from the Tydeidae family have been noted (Sup.: DSc(biol.) K.Dilbaryan).

***Outcomes of applied developments***

Narrow-clawed crayfish reserves in Lake Sevan are completely deteriorated. The mentioned hydrobiont is under the threat of extinction. The reserves are continually decreasing while the poaching has not been stopped yet. The results of studies in frames of the contract with the Ministry of Environment of the RA have shown that the share of infected crayfish is 10-11% in the lake and the overall biomass has decreased by 27 tons compared with the previous year (Sup.: cand.(biol.) E.Ghukasyan).

Ichthyological studies carried out in Lake Sevan have shown that recently the whitefish stock has grown by 9.6% compared with the 2020. It is mainly due to staffing with fertile generation of whitefish in the lake. Prior to the whitefish active period of spawning in November of 2021 the stock was about 641.8 tons (SD±20,09). Allowed catch size for the whitefish in Lake Sevan in 2022 will be determined only after consultations with the Ministry of Environment of RA on the topic of reconstruction of the system of fishery (Sup.: DSc(biol.) B.Gabrielyan).

The infection of livestock with trematodes (*Fasciola hepatica, F. gigantica, Dicrocoelium lanceatum, Paramphistomum cervi*), intestinal strongyloides (*Trichocephalus ovis, Chabertia sp., Haemonchus sp, Paramphistomum sp.),* respiratory nematodes *(Protostrongilus sp.),* cestodes *(Monezia expansa, Echinococcus granulosus),* protozoa *(Eimeria arloingi, E. intricata, Piroplasma bigeminum)* have been detected. *Babesia canis, Leishmania tropica, Hydatigera taeniaeformis, Toxocara canis, Uncinaria stenocephala, Ancylostoma caninum* have been diagnosed among studied dogs; *Fasciola hepatica, Eimeria stiedae, E.magna, E.perforans* – among rabbits, *Ascaridia galli* and *E.tenella, E. acervulina* – among chicken, *Hydatigera taeniaeformis, Toxocara cati, Toxascaris leonina, Trichuris vulpis, Cystoisospora felis* and *C. rivolta, Giardia intestinalis, Toxoplasma gondii* protozoan parasites – among cats. Different animal species examination for the ixodid ticks infestation has revealed the presence of following ticks species: *Ixodes ricinus, Dermacentor marginatus, Rhipicephalus bursa, Rhipicephalus annulatus, Hyalomma marginatum, Ripicephalus turanicus, Haemaphisalis punctata, Rhipisephalus sanguineus, Hyaloma anatolicum*. The spesies diversity of helminths identified in fish as well as infection extencity and intencity have been determined. Ecto- and endoparasitic nematodes of fruit crops, conifer trees and vineyards have been recorded. Among them harmful species from *Xiphinema, Macroposthonia, Helicotylenchus* genera are predominate (Sup.: acad. S.Movsesyan).

Investigations on identification of new approaches to biological control of agricultural pests have been continued. Four new pest tick species have been discovered for the fauna of Armenia. Extracts from different plant species have been developed and tested. The repellent activity and relative efficacy of prepared extracts for the control of different groups of agricultural pests have been identified (Sup.: DSc(biol.) K.Dilbaryan).

## Institute of Biochemistry after H.Buniatyan

### *Major achievements*

To reveal the mechanisms of the biological activity of the proline-rich peptide PRP1, the energy of interaction of PRP1 with human methogen-activated protein kinase p38, with its phosphorylated form, as well as with forms of the enzyme carrying inactivating and activating mutations with application of AutoDock Vina software package has been studied. A variant of human mutagen-activated protein kinase p38 with inactivating mutation Y323F (pdb 3OEF) and variants with activating mutations Y323T, Y323Q, and Y323R (pdb 3OD6, pdb 3ODY, pdb 3ODZ, respectively) have been used in the study. The observed strong interactions of mitogen-activated protein kinase p38 receptors with the studied proline-rich peptide indicate the possible high biological activity of PRP 1 in inflammatory processes involving these receptors (Sup.: DSc(biol.) S.Chailyan).

Assessment and regulation of enzymatic activities of dipeptidyl peptidase IV (DPPIV), adenosine deaminase (ADA) and glutaminase is important from the perspective of diagnosing, treatment/prevention of some diseases. Protein citrulination, characteristic to autoimmune diseases, has been registered in the blood plasma of patients with type 1 diabetes, where the activities of ADA2 and DPPIV increase in parallel with glucose. Analysis of ADA1 and ADA2 activity is important from the perspective of predicting the glycaemic status of young patients with type 1 diabetes. The decrease in the electrophoretic mobility of citrullinated ADA1 reflects the changes in enzyme folding. The ADA1 accumulation in the synovial fluid of patients with autoimmune rheumatoid arthritis is a consequence of 5-fold weakening of citrullinated ADA1 binding with DPPIV. The complex is essential in the activity of the immune system (Sup.: cand.(biol.) A.Antonyan).

The impact of phosphoribosyl pyrophosphate synthetase 1 effectors in the process of stimulation of post-stroke regeneration processes has been studied. The role of PKC-theta in blood clotting process has been evaluated as well (Sup.: cand.(biol.) K.Danielyan).

New composites have been created from photosensitizer cationic porphyrins and such important blood proteins as transferrin and ceruloplasmin, and their effectiveness have been studied in the culture of cancer cells *in vitro*. These two proteins can actively participate in the transfer of porphyrins to the tumor. The complexes of these proteins with cationic porphyrins can be recommended for use in photodynamic therapy of tumors (Sup.: cand.(biol.) A.Gyulkhandanyan).

### *Outcomes of applied developments*

It has been shown that folate (FA) receptors are 100–300 times higher in cancer cells than in healthy cells. In the [FA + Zn-TOEt4PyP] composite the folic acid binds non-covalently with metalloporphyrin in a ratio of 1.2 / 1, while in the [FA + Zn-TBut4PyP] composite this ratio can reach 20/1. The accessibility of formation of such composites creates an opportunity for their use in targeted PDT of tumors. Porphyrins can also be used to fight bacteria, fungi, yeasts and viruses.

Experiments carried out jointly with the National Center for Disease Control and Prevention of the Ministry of Health of the RA have shown that one of 18 tested cationic porphyrins for dark conditions shows activity against the SARS-CoV-2 coronavirus. Studies of cationic porphyrins under light (photodynamic) conditions have been continued with the aim of their possible use in the treatment of patients with COVID-19 (Sup.: cand. (biol.) A.Gyulkhandanyan).

Of 15 piperazine derivatives synthesized in IFOC, the ADA1 activity is most effectively suppressed by a benzhydryl group containing compound. The values of suppression of intracellular and extracellular activity forms differ by two grades, which allows to use this compound selectively at various pathologies to suppress the activity of the intracellular form (Sup.: cand.(biol.) A.Antonyan).

For the purposes of application in different functions, carbon dots with existence of various functional groups, with high quantum yield and a wide fluorescence range have been synthesized.

The synthesized iron nanoparticles have magnetic properties and peroxidase activity, which allows to use them in biosensors and in different formats of enzyme-linked immunosorbent assay.

Studies related to food safety have been performed, during which enzyme histaminase has been isolated from various plant sources. It is used to determine histamine quantity in food.

Ampicillin-loaded apoferritin has been used in studies of targeted drug delivery to bacterial cells, with lectin used as the molecule recognizing the system. The obtained results provide basis for *in vivo* experiments (Sup.: cand.(biol.) V.Gasparyan).

## Scientific and Production Centre "Armbiotechnology"

### *Major achievements*

A biologically active food additive "Narargin" has been developed and officially registered. The preparation contains live lyophilized lactic acid bacteria *Lactobacillus acidophilus* MDC 9602 (Er. 317/402 "NARINE") and *L. ramnosus* MDC 9631 - producer of the amino acid arginine. The complex preparation "Narargin" simultaneously stimulates the efficiency of the gastrointestinal tract and pancreas operation in healthy people and people with diabetes of the 2nd type. The preparation promotes the secretion of insulin and glucagon, lowers blood sugar levels (Sup.: cand.(biol.) F.Tkhruni).

In order to increase the biosynthetic activity of the recombinant strain producer *E. coli* HK (pargJ-T) (carries the argJ gene of the thermophilic bacterium *Thermotoga neapolitana*), mutants resistant to various pyrimidine analogs and non-catabolizing arginine mutants have been obtained. It has been shown that mutants resistant to 5-fluorouracil ($5Fu^r$), synthesizing up to 22 g/L L-arginine, exhibite the highest biosynthetic activity (Sup.: cand.(biol.) A.Hovsepyan).

It has been shown that synthetic compounds (2R, 3S)-hydroxyleucine and N-formyl-methionyl-(2R, 3S)-hydroxyleucine at a concentration of 1 mM suppress the proteolytic activity of strains of the *Pseudomonas* genus (Sup.: cand.(biol.) N.Hovhannisyan).

The minimum concentration of m-fluorophenylalanine (analogue of L-tryptophan), which suppresses the growth of the wild-type strain of *Brevibacterium flavum* ATCC 14067, has been determined. The *Br. flavum* 14067 mutants resistant to m-fluorophenylalanine have been obtained by chemical mutagenesis and genetic selection (Sup.: cand.(biol.) G.Avetisova).

Organoleptic, physicochemical properties and chemical composition of natural oils obtained by extraction from grape seeds of the Khindogni and Areni varieties have been studied. The optimal yields of the target product have been determined (Sup.: cand.(chem.) S.Dadayan).

Using the stepwise method of activated esters of peptide synthesis, new amino acids and dipeptides protected by the 9-fluorenylmethoxycarbonyl group have been synthesized (Sup.: cand.(chem.) Z.Mardiyan).

An improved method for obtaining sodium nucleinate, widely used in medicine and animal husbandry to increase the body's immunity, has been developed and patented (Sup.: cand.(chem.) A.Tsaturyan).

Comparative characteristics of iron-oxidizing bacteria for leaching valuable metals from secondary raw materials - substandard PC printed circuit boards - have been carried out (Sup.: DSc(biol.) N.Vardanyan).

It has been shown that the association of nodule bacteria of peanuts and soybeans increases the yield of peanuts by 33.9-34.5% (Sup.: cand.(vet.) V.Goginyan).

The 1st volume of the Catalog of cultures of microorganisms "Aerobic spore-forming bacteria" has been prepared for publication. The Microbial Depository Center was admitted to the European Organization for Collections of Cultures (ECCO, http://www.eccosite.org) with full membership (Sup.: cand.(biol.) V.Bagiyan).

### *Outcomes of applied developments*

Production and sale on the European market of a number of optically active non-proteinogenic amino acids of great medical, pharmaceutical and diagnostic importance have been continued (Sup.: acad. A.Saghyan).

Manufacturing of the fermented milk product “Narine” using the culture of lactic acid bacterium *L. acidophilus* MDC 9602 has been continued. The production of fruit and drinkable “Narine” has been continued with the addition of natural syrups from apricot, peach, black mulberry and cherry. The production of the lyophilized drug "Narine" has been continued. The production of fermented milk product “Narine” in enteric-soluble hard gelatin capsules has been set up. The products are sold in the leading pharmacy chains and supermarkets of Yerevan (Sup.: R.Hayrapetyan).

Production of complex biofertilizers “Ecobiofeed” and “Ecobiofeed +” for the needs of agriculture has been continued. During the reporting period, about 1,5 tons of biological preparations, sold in various farms of the Republic, have been produced (Sup.: cand.(biol.) G.Avetisova).

Production of drugs demanded on the Armenian drug market (hydrogen peroxide 3% and 30%, boric acid, magnesium sulfate, potassium permanganate, ammonium aqueous solution, castor oil, glycerin, 5% iodine solution) has been continued. On a contractual basis these products are sold in the wholesale network “Natali-Pharm”, “Vaga-Pharm”, “Farm-House”, “Uni-Pharm”, “Sanus”, “Armpharmacy”, “Alta” and others (Sup.: cand.(chem.) G.Hovsepyan).

Production of natural vegetable oils of sea buckthorn, flax, milk thistle, almond, white and black sesame, apricot, peach, black cumin, pumpkin seeds and prune seeds has been continued using the method of cold pressing. Serial production of new pomegranate seed oil has been set up. All these oils are of valuable nutritional, therapeutic prophylactic and cosmetological value (Sup.: DSc(chem.) S.Dadayan).

Conditions of surface cultivation of the culture of the fungus *Rhizomucor miehei*, a producer of a microbial substitute for rennet have been studied and its process has been optimized (Sup.: cand.(biol.) A.Karagulyan).

## Institute of Molecular Biology

### *Major achievements*

For the first time in Armenia, complete genome sequencing and molecular genetic monitoring of new variants of coronavirus circulating in Armenia in 2020-2021 have been carried out with nanopore sequencing. According to the study, the Alpha variant of SARS-CoV-2 appeared in Armenia in March 2021, and then was replaced by a more dangerous Delta variant in June. The latter is the dominant strain in our country today. Sequencing studies have confirmed the presence of mutations in the Delta strain that cause high virulence and reduce vaccine efficacy. These monthly studies made it possible to determine the dynamics of the variability of the coronavirus in Armenia, as well as to assess the effect of mutations on the accuracy of PCR tests. The data obtained are regularly submitted to the RA Ministry of Health (Sup.: DSc(biol.) A.Arakelyan).

In chronic lymphocytic leukemia (CLL) a strong association between the percentage of intermediate monocytes and the time to primary and secondary treatment has been observed. According to the results the threshold of intermediate monocytes of 5.4% is a prognostic criterion for determining the timing of treatment initiation in patients with CLL (Sup.: cand(biol.) G.Manukyan).

Jointly with the Institute for Grape Breeding, Germany, an inventory, molecular identification and documentation of endangered autochthonous grape varieties and wild grapes of Vayots Dzor region of Armenia have been carried out. The results have been used to enlarge and update records in AVT and VIVC databases (www.vitis.am, www.vivc.de) (Sup.: cand.(biol.) K.Margaryan).

### *Outcomes of applied developments*

"ARAMAX" and "Armenikum" preparations have been studied using *in vitro* in cell culture and *in vivo* in a model of Syrian hamsters. The results indicate that the "ARAMAX" has a therapeutic effect against the SARS Cov-2 coronavirus (delta strain), significantly alleviating the pathogenesis of viral infection in Syrian hamsters, however without significant viral titers. Disease course improvement has been manifested as the absence of fever and weight loss, which are characteristic of coronavirus infection in Syrian hamsters. During therapy with the studied preparation there is a rapid dynamics of a decrease in interstitial inflammation of the lungs of hamsters as well (determined by computed tomography of the lungs and pathological analysis). The drug almost completely removes

the pathological effect of the virus in the lungs of hamsters by the end of the 7th day of the disease, while in the control group the symptoms of lung damage persist for up to 2-4 weeks. The "Armenikum" preparation has shown not only a therapeutic effect, but also a strong antiviral effect. A significant decrease in viral titers up to the disappearance of the virus from the body of hamsters by 3-5 days post-infection has been revealed. The therapeutic effect of the drug "Armenikum" is similar to that of the drug "ARAMAX" (Sup.: DSc(biol.) Z.Karalyan).

For the first time in Armenia, an organic vineyard of local grape varieties with an area of 1.5 hectares has been established in the village of Artabuink, Vayots Dzor, at an altitude of 2050m above sea level. The ampelographic characterization, molecular identification of autochthonous grape varieties, genotyping of the *VvMybA1* and *VvMybA2* genes as well as whole genome sequencing of the studied varieties have been carried out (Sup.: cand.(biol.) K.Margaryan).

Highly effective bacteriophages have been isolated against clinical strains of intestinal infections circulating in Armenia, which can serve as an alternative therapy against antibiotic-resistant pathogens (Sup.: cand.(biol.) A.Sedrakyan).

## Institute of Hydroponics Problems after G.Davtyan

### *Major achievements*

Using microgranular mycorrhiza "Aegis" (*Glomus intraradices and Glomus mosseae*) in the rhizosphere of plants with 92% decrease in the phosphorus content in the nutrient solution compared to the control increases the height and annual growth of plants by 1.6 and 1.7 times, accordingly. No significant difference has been recorded in the accumulation of photosynthetic pigments in the leaves of the inoculated and control seedlings. The microscopic method confirms the presence of mycorrhizal fungi colonization in the roots of inoculated seedlings in hydroponics.

*Ocimum tenuiflorum* L. and *Withania somnifera* L. have been introduced into hydroponic culture for the first time. In hydroponic culture medicinal raw material of *Ocimum tenuiflorum* L. has exceeded soil culture with the fresh weight by 2.4 times. In hydroponic plants 1.2 times higher content of sum flavonoids and vitamin C, 1.3 times higher content of phenolic acids and 1.1 times higher content of β-carotenoids have been observed compared to the soil plants. However, the latter excels with 30% higher content of extractives.

The callusogenic and morphogenic potential of various explants (meristem, leaf, stem) *Ziziphus jujuba* Mill. has been studied in the *in vitro* culture for the first time. In the nutrient medium of Murashige Skoog, the combination of concentrations of phytohormones IAA (3.0-3.5mg/l) and BAP (2.0-2.5 mg/l) in callus tissues of meristemic origin stimulates organogenesis, with the formation in average of 2 adventitious shoots.

It has been shown that the decorative tree *Styphnolobium japonicum* L., introduced into Armenia, has exceled as a natural accumulator of the radionuclides. The leaves of the tree have exceeded the leaves of the native trees - mediterranian cypress (*Cupressus sempervirens* L.), eastern red cedar (*Juniperus virginiana* L.), oak (*Quércus* L.) in terms of total β-radioactivity, 1.1, 1.5, 2.1 times, respectively (Sup.: corr. memb. S.Mayrapetyan).

### *Outcomes of applied developments*

For the first time in Armenia valuable tea plant Clitoria ternatea L., valuable medicinal plants sacred basil and ashwagandha have been introduced and cultivated. They are successfully adapted to soilless conditions and can be of great practical importance (Sup.: corr. memb. S.Mayrapetyan).

The seeds of ornamental white Judea tree - Cercis siliquastrum "Alba", have been introduced into Armenia. They have been tested in hydroponic culture. The received seedlings can be of significant importance in the field of landscaping (Sup.: cand.(biol.) M. Babakhanyan).

An open day has been organized, during which the features of the hydroponic cultivation of Moringa oleifera have been presented, as well as various products from leaf powder: teas, confectionery, cheese (Sup.: cand.(biol.) A.Tadevosyan).

LGEP -21/05 tender for the supply of trees and shrubs for the needs of ONCO "Landscape gardening and environmental protection" (Virginia juniper, Oriental plane, Biota, etc.) has been won

in the amount of 4 million 640 thousand drams (Sup.: cand.(biol.) A.Tadevosyan, cand.(biol.) Kh.Mayrapetyan).

Saplings of about 600 different tree-shrubs produced as a result of scientific experiments (thuja, sycamore, juniper, oak, sophora, judea tree, silk tree) have been sold for 641500 drams (Sup.: cand.(biol.) Kh.Mayrapetyan).

Practical radioprotective suggestions have been developed. Their use in hydroponics and agrocenoses will ensure receiving of the radioecologically safer plant raw material and will have ecological and sanitary-hygienyc significance (Sup.: cand.(biol.) L.Ghalachyan).

## Institute of Physiology after L.Orbeli

### *Major achievements*

Ovine antivenom against the snake *Macrovipera lebetina obtuse* venom has been developed, and several types of testing by various experimental *in vivo* and *in vitro* approaches have been performed to evaluate the effectiveness of the serum. The cross-reactivity and paraspecificity of this experimental antivenom against the second most important viper of Armenia – *Montivipera raddei* have been investigated. Series of experiments to study the effectiveness of the experimental polyvalent antivenom INOSERP Europe (Inosan, France) against venom of Transcaucasian gjurza and Armenian viper have been done. Research on the membranotropic action of the viper venom's different fractions on the erythrocyte ghost membranes has been continued (Sup.: DSc(biol.) N.Ayvazyan).

Polymorbidity (cardiovascular disease, antioxidant depletion, neuropathies, and dementias) is a key characteristic of type 2 diabetes mellitus (T2DM), requiring multifunctional therapy. Data have been obtained supporting the hypothetical concept of synergistic effects of antidiabetic phytocollection "Diabephyt", which may have a significant effect in the prevention of acetylcholine-mediated diabetic dementia and endothelin-mediated diabetic angiopathy along with antihyperglycemic activity. Type 2 diabetes mellitus remains one of the most common and expensive chronic diseases, and from a pharmacological perspective, ethnobotanical therapeutic agents can serve as a cost-effective therapy for polymorbid complications (Sup.: DSc(biol.) V.Chavushyan-Papyan).

### *Outcomes of applied developments*

Within the theme “Investigation of analgesic and anti-inflammatory effects of a combination preparation based on cobra venom and oregano essential oil” in scientific cooperation with the Department of Pharmacognosy of the Yerevan Medical University after M.Heratsi the antinociceptive, anti-inflammatory and cytotoxic effects of oregano (Origanum vulgare) have been investigated using the following methods: formalin test, "hot plate" method and MTT test. To deepen the research in this area and obtain the optimal composition of a new analgesic drug, a multifunctional distiller for the production of essential oils has been purchased (Sup.: cand.(biol.) A.Voskanyan).

Within the theme “Development of technologies for the production of albumin and normal immunoglobulin preparations from human blood plasma and obtaining a pilot samples” corresponding protocols have been developed, filters have been purchased (Sup.: cand.(biol.) G.Kirakosyan).

Within the theme “Analysis of the combined effect of modified nanoparticles and 5-fluorouracil on the growth and development of Crocker's sarcoma and rabdomiosarcoma” nanoparticles have been received from Belarusian colleagues. An animal model of Crocker sarcoma has been obtained for further experiments on mice (Sup.: cand.(biol.) G.Kirakosyan).

In cooperation with PSI Ltd, polygraphic studies of physiological reactions in response to modulation of a person's emotional state have been carried out using SFCO sensors. For the first time in the labaratory virtual reality technologies have been used to initiate the emotional reactions of the subject. As a result of a comprehensive study of the biorhythmological features of the functional state of the brain with an assessment of a simple visual-motor reaction (SVMR) time, differences in the spectral components of the SVMR intervalogram have been revealed, depending on the effectiveness of the SVMR test performance in the studied age groups (Sup.: cand.(biol.) A.Khachunts).

## DIVISION OF CHEMISTRY AND EARTH SCIENCE

***Academician-Secretary – academician L.Tavadyan***
***Scientific Secretary – cand.(tech.) L.Gasparyan***

The Division includes the Scientific Technological Center of Organic and Pharmaceutical Chemistry, the Institute of Chemical Physics after A.Nalbandyan, the Institute of General and Inorganic Chemistry after A.Manvelyan, the Institute of Geological Sciences, the Institute of Geophysics and Engineering Seismology after A.Nazarov.

The Division includes 5 academicians, 5 corresponding members and 19 foreign members.

4 general and 3 extended meetings, 8 meetings of the Bureau were held during the reporting year.

At the annual general meeting of the Division held on April 23 the reports of the Academician-Secretary, acad. L.Tavadyan, directors of the Institutes of the Division on their scientific and technical activity in 2020 were discussed. Due to pandemic the meeting was held on line.

At the general meeting held on June 29 academician L.Tavadyan was elected a candidate for the post of the Academician-Secretary of the Division, the new stuff of the Bureau was elected

At the general and extended meetings of the Division the annual report of the editorial board of the journal "Proceedings of NAS RA. Earth Sciences" was discussed and approved, the candidacy of the corresponding member G.Danagulyan for the vacancy of the editor-in-chief of the "Chemical journal of Armenia" was heard and discussed. The following scientific reports were discussed and approved: " Current state and development of scientific research in the field of seismology and engineering seismology in the NAS RA" (Kh.Meliksetyan, DSc(geol.) and J.Karapetyan, cand.(geol.), directors of the Istitutes of Geological Sciences and Geophysics and Engineering Seismology after A.Nazarov), "Current state and development of the search for new drugs in the Scientific Technological Center of Organic and Pharmaceutical Chemistry of the NAS RA" (DSc(chem.) A.Harutyunyan, the director of the STCOPhCh of the NAS RA), "An integrated approach to the production of copper and the processing of sulfur in RA offered by the Institute of General and Inorganic Chemistry (K.Grigoryan, cand. (tech.), the director of IGICh of the NAS RA).

At the meetings of the Bureau the following issues were discussed and approved: applications for the programs of basic financing of scientific and scientific-and-technical activity: "Preservation and development of infrastructure" and "Preservation of scientific objects of national value" as well as for state target programs; working plan for 2021, distribution of free postgraduate and doctoral places for 2021/2022, as well as of full-time and part-time postgraduate free places of the NAS RA for 2022/2023; applications for purchase of the equipment in the scope of the programs on "Improvement of saturation and modernization of the Institutes of the NAS RA" and "Maintenance, rearmament of scientific equipment, purchase of substances for scientific research, fulfillment of unforeseen urgent expenses of the Institutes of the NAS RA" for 2021; the new stuff of the academic council of the Institute of Geophysics and Engineering Seismology after A.Nazarov. The issue on publication of Arsh.Avagyan's (the leading researcher of the Laboratory of Geological Information of IGS) monography on "Study of the spread and development of hazardous exogenous processes and phenomena and of their impact on transport communications of highlands countries (in terms of the South Caucasus and Central Asia)" was heard and approved.

Candidacies of A.Harutyunyan, N.Knyazyan, Kh.Meliksetyan and J.Karapetyan (directors of the Institutes of the Division) as the authorized representatives were heard and approved. V.Ananikov's (an academician of the RAS, a member of the European Academy) scientific report on "The universal theory of catalysis from A.A.Balandina up to nowadays" was organized with the direct participation of the Division.

The reports on the scientific and technical activity of the Institutes on the program "Preservation and development of infrastructure" of the Basic funding and state target programs for 2021, the new stuff of editorial board of the "Chemical journal of Armenia", the new structure of the Institute of Chemical Physics after A. Nalbandyan were discussed and approved.

149 scientific articles: 139 in the peer-reviewed journals (90 abroad) and 10 in the conference proceedings (10 abroad), 62 theses (55 abroad), 10 monographs (4 abroad) were published by the Institutes of the Division, 1 patent was obtained.

Nine Candidates' and one Doctor's dissertations were defended in 2020.

The Division actively took part in the discussion of the scientific results of the Institutes during the annual meetings of these organizations.

## Scientific Technological Center of Organic and Pharmaceutical Chemistry

### *Major achievements*

By the interaction of 2-phenyl-4-(propoxyphenyl)-6-(*p*-tolyl)pyrimidine with (*E*)-N-benzylidene- and 2-chlorobenzylideneanilines (*E*)-4-(4-(4-arylstyryl)phenyl)-2-phenyl-6-(4-propoxyphenyl) pyrimidines have been synthesized. 1-(5-methoxy-2-((4-methyl-2-phenyl-5,6-benzo-[4′,5′]imidazo[2′,1′:6,1]pyrido- [2,3-d]pyrimidin-6-yl)benzyluracil- and 5-fluorouracil have been

synthesized as well, the latter as a pro-drug transport form of the active anticancer drug 5-fluorouracil. By three-component one-pot condensation of N-substituted isatin with compounds with an active methylene group and aromatic and heteroaromatic ketones new N-substituted indolin-2-ones spiro-fused at the position 3 of the ring have been synthesized (Sup.: DSc(chem.) A.Haroutyunyan).

***Outcomes of applied developments***

The hydrolysis reactions, self-catalyzed by an amino group, the polycondensation of 3-aminopropyltriethoxysilane (APTES) and copolycondensation with tetraethoxysilane (TEOS) have been studied in aqueous media with the formation of silica xerogels. It has been found that as a result of APTES polycondensation and copolycondensation with TEOS at a ratio of APTES: TEOS = 4: 1, xerogels with a branched polymer chain structure soluble in water and ethanol are formed, and at a ratio of APTES: TEOS = 1: 1 insoluble (three-dimensional) structure is formed. The process is exothermic. Along with the sorption properties characteristic of silica xerogels, xerogels obtained as a result of sol-gel synthesis contain a reactive primary amino group convenient for further functionalization and synthesis of potential biologically active compounds immobilized (chemisorbed) on the silica substrate (Sup.: DSc(chem.) S.Grigoryan).

## Institute of Chemical Physics after A.Nalbandyan

***Major achievements***

By partial oxidation of nanosized carbides of transition metals (molybdenum, tungsten) nanooxides of these metals have been obtained, which show high catalytic activity in the oxidation of organosulfur compounds. Such catalysts are promising in the desulfurization of diesel fuel under mild conditions (Sup.: cand.(chem.) R.Mnatsakanyan).

For the first time single-phase MAX-phases (compounds combining the advantages of both ceramics and metallic materials) $Ti_2AlC$; $Ti_3AlC_2$ and $Ti_2AlN$ have been synthesized by the hydride cycle (HC) method using carbohydrides ($TiC_{0.5}H_{0.22\div0.73}$, $TiC_{0.67}H_{0.31\text{-}0.39}$, $TiC_{0.45}H_{1.07\div1.17}$) and hydridonitrides ($TiN_{0.15\text{-}0.19}H_{1.5}$) of titanium as the initial reagents obtained by the self-propagating high-temperature synthesis (SHS) method. It has been shown that the formation of MAX-phases in HC proceeds by the solid-phase mechanism (Sup.: DSc(tech.) S.Dolukhanyan).

***Outcomes of applied developments***

A database on the content of pesticides in the water and bottom sediments of Lake Sevan and its tributaries has been created. Three-dimensional maps of the concentration distribution of pesticides in Lake Sevan by years have been compiled.

In the framework of the project "EU Water Initiative Plus for the Eastern Partnership (EUWI+4 EaP) and International Office for Water" (2019-2021) a management plan for the water basin of the Hrazdan River has been compiled based on the methodology and approaches of the EU Water Framework Directive and submitted for approval by the Ministry of Environment and the Government of RA (Sup.: cand.(chem.) S.Minasyan**)**.

## Institute of General and Inorganic Chemistry after M.Manvelyan

***Major achievements***

Fertilizers obtainment technology from phosphorus-containing biogenic diatomaceous rocks of Armenia has been developed and vegetative tests have been carried out at the State Agrarian University of Armenia (SAUA). Fertilizers have been also obtained from RA serpentinites containing magnesium and amorphous silica. The results of the preliminary vegetative tests are positive and promising for industrial production and use of this fertilizer (Sup.: cand.(tech.) K.Grigoryan)

The possibility of changing the properties of glasses and glass crystals based on the $MeF_2$-MgO - $Al_2O_3TiO_2$ - $SiO_2$ system modified by the diffusion of silver molecules on surfaces has been investigated. It has been found that as a result of diffusion treatment an increase in absorption in the UV region of the spectrum is observed. The UV irradiation of a glass sample obtained by the diffusion treatment gives rise to a broad band in the luminescence spectrum, which attests to the formation of

$Ag_n$ molecular clusters ($n \leq 5$). The spectra of clusters show overlapping absorption bands located in a broad spectral range from 250 to 410 nm and the corresponding luminescence bands in the 380–610 nm range. Thus, the use of silver diffusion-modified MgO–Al2O3– TiO2–SiO2 glasses as photoactive elements provides a broad spectral range of sensitivity of UV radiation sensor (Sup.: DSc(tech.) N.Knyazyan).

***Outcomes of applied developments***

Fertilizers obtainment technology from phosphorus-containing biogenic diatomaceous rocks of Armenia has been developed and vegetative tests have been carried out at the State Agrarian University of Armenia (SAUA). Fertilizers have been also obtained from RA serpentinites containing magnesium and amorphous silica. The results of the preliminary vegetative tests are positive and promising for industrial production and use of this fertilizer (Sup.: cand.(tech.) K.Grigoryan)

Transparent, low-melting, stable crystallization of glass with high transmittance in the infrared region and a wide range of refractive index and relative dispersion values, used in modern optics, optoelectronics, and optical instrumentation, have been synthesized.

A transparent glass-ceramic with $BaAl_2Si_2O_8$ crystalline phase, activated by Eu2 +, has been developed, the properties of which have been investigated by X-ray diffraction and photoluminescence spectroscopy. Thermal treatment of glass in air atmosphere leads to the formation of numerous crystal phases, the main of them are celsian and hexacelsian. Eu ions are present in both valence states ($Eu^{2+}$ and $Eu^{3+}$) in the structure of glass. The crystallization process is accompanied by the decrease of $Eu^{3+}$ ions concentration caused by the formation of $Eu^{2+}$ ones which exist in the structure of glass in the form of nanocrystals thereby significantly increasing the intensity of blue emission of prepared glass ceramics. The transparent $Eu^{2+}$-doped $BaAl_2Si_2O_8$ glass ceramics synthesized can be used as white LEDs (Sup.: DSc(tech.) N.Knyazyan).

## Institute of Geological Sciences

***Major achievements***

The results of Pliocene and Quaternary volcanic samples of Syunik and Vardenis plateaus, including $^{40}Ar/^{39}Ar$ isotope dating of the eighteen Holocene volcanic rocks have been summarized and published. For the first time, the age of the transition of the mostly polygenetic volcanism to monogenetic in the mentioned plateaus has been obtained. For the Syunik Plateau, the mentioned transition is estimated at 1 Ma, and within the Vardenis Plateau boundaries it occurred earlier, since the volcanism aged 1.4 Ma is already monogene. The transition of polygene volcanism to monogene is conditioned by the combination of various factors, including the increase of tectonic extension in the region as a result of activity of Pambak-Sevan-Syunik fault yielded formation of local structures favorable for the development of monogenetic volcanic plateaus, as well as the relative decrease in the volumes of magma generation (Sup.: DSc(geol.) Kh.Meliksetian).

As a result of the application of modern research methods, high contents of noble and rare metals of particular interest have been found in the occurrences of coals, oil shales, and bituminous limestones in a number of regions of Armenia (Sup.: cand.(tech.) A.Hovhannisyan).

From the sediments of Arpi (Ertich) and Jrovank sections, 6 *rhinchonellides* and 1 *orthida brachiopods* of the lower Famennian age have been found. 4 of the *rhinchonellides* and the only *orthida* (*Crinisarina pseudoglobularis n. sp*) have been found in Armenia for the first time. Greira transcaucasica (Erlanger, 1993) is among the new founds which is the oldest known species with a porous shell. For the first time *ectoparasites* have been found on the shell of *brachiopods*. Palaeobiogeographical peculiarities of *brachiopods* found in Armenia and the biodiversity recovery rates of *brachiopods* after the Frannian-Famennian crisis have been discussed, the presence of Tornatospirifer *armenicus* (Abrahamyan, 1974) species has been proved. It has been confirmed that Caucasia species found by the researchers in the famen sediments of Nakhijevan Gyumushlu sections is not new but is the same *armenicus* (Sup.: cand.(geol.) A.Grigoryan).

In the Paleozoic sediments of Armenia Middle and Late Devonian *trilobites* represented by an obvious proteoid pygidium and several facopides have been found. Their palaeo-ecological assessment

and analysis of their archaeo-biogeographical dispersion has been carried out (Sup.: cand.(geol.) A.Grigoryan).

***Outcomes of applied developments***

Research on the active landslides potential hazardous to the transport communications in the northern part of Armenia, namely in Odzun, Ayrum, and Tumanyan areas, carried out in the recent years has been summarized and published. Based on the engineering-geological and geophysical research results, interpretaion has been made in the landslide bodies of the mentioned territories; 3D modeling of the landslide bodies has been applied; the landslide sliding surfaces have been determined; the current state of the slide activeness has been assessed and anti-slide measures have been stated (Sup.: cand.(geol.) M.Gevorgyan).

Research on the problem of obtaining synthetic soil seismograms and accelerograms has been continued. Via the proposed method, based on the synthetic accelerograms, earthquake response spectra for normative I-IV class ground construction sites with seismic properties have been acquired. The implemented research has shown that the response spectra acquired via synthetic accelerograms are identical – both in their qualitative and structural character – to the spectrum of earthquake responses based on real earthquakes, which testifies to the need for practical application of the proposed synthetic accelerograms.

The normative document "ՀՀՇՆ 20.04-2020 seismic codes designed to protect property" elaborated in collaboration with the National University of Architecture and Construction of Armenia, based on the new seismic hazard assessment map of the territory of the RA designed by international consortium (USA, Italy, Armenia consortium), has been put into practice since January 1, 2021, by the decree of the RA Urban Development Committee (Sup.: acad. E.Khachiyan).

The website of IGS e-library http://10.77.0.181:5000 has been transferred from the local network to the web environment, which provides remote access to the library of IGS: http://library.geology.am/ (Sup.: cand.(geol.) A.Avagyan).

## Institute of Geophysics and Engineering Seismology after A.Nazarov

***Major achievements***

Studies have been carried out in the territory of Aragats volcanic massif, particularly in the eastern slopes. As a result of the studies, a correlation between modern and ancient relief soft area has been determined. As a result of mapping of the terrain of regional water-rejecting rocks, the distribution of ground water has been determined. Effective territories for the detection of ancient river beds and groundwater of local basin have been suggested (Sup.: DSc(geol.) R.Minasyan).

Detailed analysis of spatial-temporal-energy distribution of Shorzha, Yerevan and Javakhk earthquakes of 2021 has been carried out. The kinematic and dynamic parameters of the fault formation of earthquake center have been quantified, the spectral characteristics of the epicentre radiation have been determined. Based on solutions of the epicentre mechanisms, tensor analysis of seismic moment and the data of the Lode-Noda coefficient characterizing the stress state, realistic geodynamic models adequately reflecting geological-tectonic conditions of the above mentioned earthquake centers have been developed, more precise image of the seismogenesis of the epicentre area has been received (Sup.: cand.(phys.-math.) E.Gyodakyan).

A new generation of oscillation seismic sensors have been developed and tested to record vertical variations of soil caused by earthquakes (Sup.: A.Gasparyan).

***Outcomes of applied developments***

As a result of the studies carried out, a correlation has been determined between modern and paleo reliefs. A seismic sensor operating in a special frequency (0.75 Hz) has been designed and tested to study the technical state of buildings (Sup.: A.Gasparyan).

A seismic protection system has been developed and tested for the operation of reservoir dams (Sup.: cand.(geol.) J.Karapetyan).

Portable electronic-reconnaissance, functionally flexible multi-electrode device has been developed and tested (Sup.: M.Miranyan).

A "smart" system of uninterrupted operation of geophysical stations has been developed and tested (Sup.: S.Shahparonyan).

## DIVISION OF ARMENOLOGY AND SOCIAL SCIENCES

***Academician - Secretary - academician Yu.Suvaryan***
***Scientific secretary - A.Melkumyan***

The Division includes the Institute of History, the Institute of Economics after M.Kotanyan, the Institute of Philosophy, Sociology and Law, the Institute of Language after H.Acharyan, the Institute of Literature after M.Abeghyan, the Institute of Oriental Studies, the Institute of Archaeology and Ethnography, the Institute of Arts, Shirak Center for Armenian Studies, "Armenian Encyclopedia. Publishing House". All Armenian foundation for financing Armenian Studies acts in the frames of the Division.

The Division includes 7 academicians and 17 corresponding members.

In 2021 2 general meetings of the Division were held. .

At the annual general meeting held on April 22 the report of academician Yu.Suvaryan on "The main results of scientific and scientific-organizational activities of the Division during 2020" was heard and approved.

At the general meeting on June 29 academician Yu.Suvaryan was elected a candidate for the post of the Academician-Secretary of the Division, the new staff of the Division Bureau was elected.

During the reporting year 12 Bureau sessions were held.

The following issues were discussed and approved: the working plan for 2021; applications for the programs of basic financing of scientific and scientific-and-technical activities: "Preservation and development of infrastructure" and "Preservation of scientific objects of national value" as well as for scientific and scientific-and-technical state target programs for 2022; reports on realization of the mentioned programs in 2021; the results of admission to the postgraduate school in 2021; the issues on possible directions of the Division reforms; on the attestation of the scientific staff of the Division Institutes; on the results of the work on internationalization of scientific journals, as well as the schedules of the reporting meetings of the scientific organizations of the Division.

The Division has initiated and organized 3 international conferences: "The Great Armenian Illuminators Mkrtich Khrimyan and Ghevond Alishan (on occasion of their 200th anniversary)", "On the Crossroads of Armenian Genocide, Armenian demands for restitution and the Artsakh Issue: Retrospective Assessments and Perspectives", a conference dedicated to the 30th anniversary of the proclamation of the Republic of Artsakh and the Third Republic of Armenia.

At the meeting of the Bureau on December 22 the reports on scientific and scientific-organizational activities of the Bureau and the scientific organizations during 2021 were discussed and approved.

In 2021 three issues of "Historical-Philological Journal", "Herald of Armenology" and "Journal of Social Sciences", two issues of "Armenian Economic Journal", as well as two issues of English electronic journal "Fundamental Armenology" were published. The Institute of Language after H.Acharyan published two issues of the "Language and Linguistics" journal, the Institute of Literature after M.Abeghyan - two issues of the "Journal of Literature Studies".

137 books (9 abroad), 1 encyclopedia, 16 textbooks and manuals, 1187 scientific articles: 845 in the peer-reviewed journals (216 abroad) and 342 in the conference proceedings (153 abroad), 61 theses (37 abroad) were issued by the staff of the Division scientific organizations.

## Institute of History

### *Major achievements*

Within the framework of the theme "Armenia and Armenians in the modern period. The Armenian question and the Armenian Genocide" (Sup.: DSc(hist.) K.Khachatryan) a collective work on the problem of Armenian territories forcibly annexed to Kemalist Turkey and Soviet Azerbaijan in 1920-1930 was published in English. The work provides an opportunity for a foreign reader to get an idea of the process of drawing the borders of the Republic of Armenia and the Republic of Artsakh. The fact of Azerbaijani aggression against the Republic of Armenia and Artsakh until 2020 is substantiated, as a result of which a number of territories that are part of the latter were transferred to Soviet Azerbaijan and Turkey in the noted years. This is of actual importance both from a historiographical and political point of view.

A.Hakobyan's book "Moscow and Kars Treaties in the Fate of the Armenian People" outlines the history of the signing of two closely related Moscow and Kars Treaties in 1921, which left a deep mark on the historical and political fate of Armenia and the Armenian people. The diplomatic preparations for the conferences of the same name, their progress and the texts of the signed agreements with annexes are presented. Historical, critical and comparative analysis of the articles of the agreements has been carried out. Special attention is paid to the Armenian-Turkish territorial-border problems. The author has made an attempt to consider the legality of these treaties, their compliance with international treaty law, etc. An attempt is also made to compare the circumstances of the conclusion of these two agreements that infringe on Armenian interests, as well as to compare them with modern realities.

## Institute of Archaeology and Ethnography

### *Major achievements*

During the reporting year a number of studies have been completed in the field of anthropology of "war and violence". The theses presented in those works provide opportunities for evaluation and re-evaluation of current perceptions within the region and the Armenian reality. Details on taking of

Khojaly settlement of Artsakh by the Armenian military forces on February 26, 1992 and the fate of its civil population in the following days have been analyzed for the first time by a combination of archival, field-work, as well as Armenian, Azerbaijani, Russian and English-language printed sources. The study clearly reveals the plan of involving the civil population of Khojaly in the armed conflict by the militant groups of the People's Front of Azerbaijan as a result of criminal deception. As a result of these events a significant part of the civil population suffered heavy casualties after leaving the settlement. The Azeri-Turkish falsification of the occupation of Khojaly settlement and the "genocidal acts against the population", widely disseminated during 28 years through false scientific, diplomatic, cultural and other propaganda means, have been revealed in this investigation. The study was published in Armenian, English and Russian (Sup.: cand.(hist.) H.Kharatyan).

A study on the analysis of the current situation of the Syrian Armenians has been conducted, co-authored by Marcello Mollika, a professor at the University of Messina. The work discusses the situation of the Armenian population of three Syrian cities in the conditions of the war unleashed in Syria. The destructive role of the Turkish factor has been thoroughly revealed not only concerning the Armenian population living in the memory of the Genocide: moreover, it has been shown to be a threat to the whole of Europe and the world. The study was published in English (Sup.: cand.(hist.) A.Hakobyan).

Significant results have been recorded in the field of comparative analysis of the Armenian Genocide and the Holocaust. The thematic subject of the work presents specific steps taken to preserve the memory of Holocaust (mentioning the theme of the struggle in the name of Remembrance Day, compiling a database on victims, availability of audio-video recordings of stories of survivors, and using them in the educational system), as well as reveals them to be the main challenges in preserving the memory of the Armenian Genocide in the 21st century. It has been clearly substantiated that the rejection of the fact of the Armenian Genocide leads to danger of its recurrence, one of the manifestations of which was the 44-Day War, as well as the rise of anti-Armenianism in Azerbaijan for decades. One of the reflections of it was the opening of the "Museum of Military Glory" in Baku. It is argued that when talking about xenophobia, not only anti-Semitism should be emphasized: one of the reasons for the opening of the above-mentioned "museum" was the fact that the international community (which prefers talking about xenophobic manifestations mostly by example of antisemitism) did not react on warnings about the real danger of genocide during the 44-Day War, as well as the requests of the Armenians for professional assistance (Sup.: DSc(hist.) H.Marutyan).

***Outcomes of applied developments***

In response to the destruction and occupation of the culture of Artsakh in connection with the occupation of the majority of the Artsakh Republic as a result of the 44-Day War, the implementers of the sub-program "Study of Historical and Cultural Heritage of Artsakh" have created an academic platform with Armenian and international partners (https://monumentwatch.org/). The website represents the cultural heritage of Artsakh, as well as traces its current condition. The site is trilingual: in Armenian, English and Russian. The website consists of four main sections and ten subsections. The "Monitoring and Alerts" section consists of two subsections: "Alert" and "Artsakh Monument Watch". The "Alert" section presents the cases of destruction of cultural heritage of Artsakh, Azerbaijani vandalism during and after the Artsakh war. 40 such cases have already been presented on the website (Sup.: DSc(hist.) H.Petrosyan).

The implementers of the sub-program "Applied Ethnography" have developed the module of the training course "Application of research-based methods in history teaching" for the training of history teachers to attestation in RA secondary schools. On September 2, 2012, it was guaranteed by the Ministry of Education, Science, Culture and Sport of the RA as a training course for history teachers to attestation for the next 3 years. In October-November 2021, more than 40 teachers from Yerevan, Shirak and Tavush regions of the RA were trained by this program. They participated in the work of the Concept Development Group of the Civil Education Center of the National Assembly of the RA (including the development of the needs assessment methodology), in the field work, in the preparation and presentation of the concept (Sup.: cand.(hist.) H.Kharatyan).

The website iae-archive.am has been successfully created by the efforts of the Archive staff, in which the "home saint" manuscripts are presented and which will later include also the results of other programs implemented by the Archive team. The following materials were digitized: "Ethnography of Karin" (V.and G.Sanasaryans) and "History and Ethnography of Shapin-Garahisar" (A.Odabashyan) (Sup.: cand.(hist.) L.Simonyan).

Based on the results of the excavations of the tomb of Shahumyan, a temporary exhibition has been organized at the Museum of Folk Arts after H. Sharambeyan, which will run until February 2022 (Sup.: DSc(hist.) R.Badalyan).

Finds from 16 sites of different periods have been restored and prepared for research and museification: among them 446 clay vessels, more than 15.000 sherds, ca. 150 valuable items made of metal, glass, stone and bone (Sup.: L.Manukyan).

## Institute of Oriental Studies

### *Major achievements*

Within the framework of the program "Eastern sources of the ancient, medieval and new period about Armenia and the Armenians. Armenia and the problems of political, social, cultural and ethnic history of Turkey, Iran, Caucasia and Arab countries of Mashriq. International relations in Near East, Eastern Asia, South Caucasus and the Republic of Armenia" (Sup.: cand.(hist.) R.Ghazaryan) the history of the provinces of Artsakh and Utik and Caucasian Albania from the early period up to the developed Middle Ages has been discussed. The history of written culture of Armenia before Mashtots has been discussed, as well as documents with Arabic script have been studied. Special attention was paid to the written and lithographic sources of the issues discussed, most of which were published with scientific-critical original texts. A number of other issues of urgent importance have been studied as well, namely the tendencies of development of geopolitical thought in Turkey, Turkey's military and political behavior in the First and 44-day Artsakh war, and the policy of the Islamic world towards Azerbaijan.

### *Outcomes of applied developments*

The researchers of the Institute have regularly presented to the relevant bodies scientific and scientific-analytical materials contributing to the development and implementation of a number of main directions of the RA foreign policy (particularly in the Middle East and the region), as well as concerning the RA national security. The employees of the Institute have been involved in the discourse around the RA foreign policy, presenting the results of their scientific studies during the expert interviews given to leading Armenian and foreign mass media.

One of the important achievements of applied significance is the publication of school textbooks and higher education textbooks by the employees of the Institute, particularly the textbooks prepared and printed for Yezidi schools.

## Institute of Language after R. Acharyan

### *Major achievements*

Significant results have been achieved in the field of Armenian lexicography. The following books were published: "A Dictionary of Bayazet Dialect" (V.Katvalyan), "New Words in the Western Armenian, Book A" (S.Tioyan, A.Fishenkjian, H.Marashlian), "New Words" (A.Galstyan, G.Hovsepyan, N.Sargsyan). The new dictionaries include both dialect words and phrase units (7000 entities), and words used in the Eastern Armenian and Western Armenian fiction, scientific literature and press, which are not registered in the explanatory dictionaries and the dictionaries of neologisms.

Within the framework of the theme "Issues on Historical Development of the Armenian Language" (Sup.: cand.(phil.) G.Mkhitaryan), verbs and verbal forms with Grabarian (Old Armenian), Middle Armenian, purely dialectal or borrowed roots in the verbal system of Karabakh (Artsakh) dialect have been examined, about thirty dialectal verbs with h.-e. roots and non-evidenced in Old Armenian have been studied as well. The dialectal words and word variants evidenced in the "History of Armenia" by Pavstos Buzand have been taken out and interpreted, the words and word-forms that

deviate from the Grabarian rules have been separated, and their relation to the dialects of the time has been mentioned. The influence of Latin in the translated literature has been observed, formations with Latin roots have been examined. The research findings are summarized in the collection of "Issues on the History of the Armenian Language", in articles and reports.

Within the framework of the topic "Problems of the Study and Regulation of Modern Eastern and Western Armenian Languages" (Sup.: corr. memb. A.Sargsyan) studies have been conducted in the field of Armenian sectoral terminology, the principles of Armenian translation of foreign terms have been identified and interpreted. The principles of regulation of the Western Armenian language have been developed, for the first time in Armenology the general picture of the latest stage of statistical linguistics has been presented in detail.

Within the framework of the topic "Study of Armenian Dialects" (Sup.: DSc(phil.) V.Katvalyan) the dialectal features have been grouped according to territorial coverage, means of expression of plural forms in dialectal Armenian have been observed, the mid-dialect of northern Goghtn and the speech of Chmshkatsag have been studied and described. The results of the research are presented in a monograph, in scientific articles and reports.

***Outcomes of applied developments***

Dictionaries of dialectal words and neologisms, manuals on the regulation and teaching of literary language have been published. An Armenian electronic proofreading system has been launched, which operates on a separate bilingual website armspell.am(https://armspell.am/hy), it checks spelling and grammatical errors by comparing them with words in the database.

An electronic database of Armenian word formation has been created on a separate bilingual website formlang.am(https://formlang.am/hy). The database has a wide range of advanced search options.

The book "Directory of the NAS RA Institute of Language 2020" has been published, which presents summaries of the works published in 2020 by the staff of the Institute in three languages and allows the reader to get necessary information about the work of the Institute.

## Institute of Literature after M.Abeghyan

***Major achievements***

Research has been carried out within the framework of the theme "History and Theory of Armenian Literature" (Sup.: DSc(phil.) V.Devrikyan) aimed at illustrating the characteristic features of the Russian and world literature classics in the Armenian literature and criticism. National, political and literary perceptions of the time which made an impact on the literary evaluation of each Armenian literary critic and author have been revealed,. By implementing the synchronic method, the Armenian literary perceptions have been viewed in parallel with characterizations of other authors of the world literature.

Within the framework of the ongoing joint cooperation with the Mekhitarist Congregation, the second and the third volumes of Father Ghevond Alishan's "Namakani" (Correspondence) have been completed and published. The general principles of publishing the correspondence of the Mekhitarist Congregation members in Venice have been carried out.

The letters of the Mekhitarist authors have been considered as the sources of their works, and the expressions of their literary-theoretical perceptions. Special principles of annotations and an appropriate scientific system (apparatus) have been implemented for the analysis of correspondence. Based on those principles the publication of Arsen Bagratuni, Manuel Jakhjakhyan and the other Mekhitarist fathers' correspondence has been initiated in separate volumes.

## Institute of Philosophy, Sociology and Law

***Major achievements***

Within the framework of the theme "Philosophical, socio-political and legal issues of the Armenian society (history and modernity)" (Sup.: cand.(law) L.Kazanchian) research in four scientific areas: philosophy, sociology, law and political science has been conducted.

Large-scale interdisciplinary research devoted to the analysis of current problems existing in the Republic of Armenia and in the region, such as multilevel migration processes, repatriation, identification of the Armenian civilized identity, problems of the institute of the modern Armenian family, constitutional and judicial reforms, analysis of the socio-political consequences of the Armenian-Azerbaijani war, as well as identification of public opinion about the government and snap parliamentary elections, has been conducted.

In the context of linguistic philosophy, theoretical and practical studies have been conducted aimed at monitoring political and social processes as a type of communication, which includes the definition of theoretical and practical aspects of multidimensional complexes used in these processes and their interpretive reproduction.

Effective research and scientific work devoted to the identification and detailed analysis of the legal status of the individual has been carried out. In particular, as a result of perennial scientific research and development, the scientific community has been presented with a large-scale treatise "The legal status of the individual. Constitutional and legal research", which analyzes in detail the features of the main elements of the legal status of individual-rights, freedoms, legitimate interests, duties, legal personality, citizenship, as well as the characteristic features of the implementation and legal guarantees of their protection.

### *Outcomes of applied developments*

In cooperation with law offices in the RA, The Chamber of Advocates of the RA and the School of Advocates of the RA, applied research on constitutional and legal reforms, the transition to a parliamentary form of government has been continued, and the results have been presented to government agencies and interested organizations. Moreover, the lawyers have provided free legal consultations to victims of the Armenian-Azerbaijani war. Within the framework of domestic and international cooperation, a number of domestic structures have been provided with legal advice and opinions on controversial, conflicting legal issues (Sup.: cand.(law) L.Kazanchian).

## Institute of Economics after M. Kotanyan

### *Major achievements*

Within the scope of the research project "Composition and structure of tax revenues of the RA statebudget and tendencies of their change in post-revolutionary Armenia" (Sup.: corr. memb. V.Haroutyunyan), changes taking place in the tax system in post-revolutionary Armenia, tendencies of changes in tax revenues of the RA state budget, impact of changes in the tax code of the Republic of Armenia on the public debt of the Republic of Armenia, trends in the change in the state debt of the Republic of Armenia in the post-revolutionary period along with changes in tax revenues have been analyzed, changes in direct and indirect taxes and their dynamics before and after the revolution have been shown. By the method of economic assessment, buoyancy coefficients have been obtained for 4 of the main types of taxes in the structure of tax revenues (VAT, income tax, income tax, excise taxes), as well as short-term tax revenues. Based on the analysis of legislative changes, as well as the tax stability coefficients calculated by the authors, an assessment of the role of changes in tax legislation in increasing tax revenues has been made.

Within the scope of the research project "The growth of international competitiveness as a guarantee for the development of the Armenian economy" (Sup.: cand.(econ.) L.Sargsyan) it has been revealed that the main factors contributing to the growth of the international competitiveness index are GDP growth, FDI inflows and exports. Other factors affecting a country's competitiveness are improvements in science and innovation, as well as the human development index. The analysis shows that the relationship between the change in the position of economic growth in the Republic of Armenia and the competitiveness index is weak. As a result of econometric analysis, it has become clear that during the year the inflow of foreign direct investment to Armenia increases international competitiveness by 0.14 percentage points, and the growth of exports causes the increase of

international competitiveness by 0.56 percentage points. The influence of other factors on the competitiveness of the Republic of Armenia cannot be assessed econometrically.

### *Outcomes of applied developments*

Within the scope of the research project "Composition and structure of tax revenues of the RA state budget and tendencies of their change in post-revolutionary Armenia" (Sup.: corr.memb. V.Harutyunyan) appropriate conclusions have been drawn for each type of tax. Based on a review of the literature, it has been found out, following the example of Armenia, the threshold of which can be considered as the threshold for the ratio of public debt to GDP, exceeding of which may negatively affect real GDP, the dynamics of 4 types of taxes, taken into account in the structure of tax revenues, and the factors affecting their increase, as well as other serious risks associated with debt, especially after the debt crisis, have been shown. Within the framework of the topic, the features of the policy adopted by the Internal Revenue Service of the United States (IRS) over the past decade have been studied. Based on the results of the aforementioned studies, carried out using the best taxation methodology, an attempt has been made to assess the relationship between tax rates and the balance of labor supply/demand in the Republic of Armenia. The international experience of introducing financial technologies (EU, Kenya), the possibility of its localization in the financial sector of Armenia have been studied. The process of granting tax incentives by the State Revenue Committee of the Republic of Armenia has been analyzed; the system of granting tax incentives for the US Internal Revenue Service (IRS), in particular, the timing and effectiveness of tax credits, has been chosen as a benchmark for comparison. Based on the analysis, an attempt has been made to compare the effectiveness of the system of tax incentives and direct subsidies.

Within the scope of the research project "The growth of international competitiveness as a guarantee for the development of the Armenian economy" (Sup.: cand.(econ.) L.Sargsyan) a toolkit for the implementation of measures promoting the growth of international competitiveness has been elaborated in detail. Accordingly, in order to increase labor productivity, it has been proposed to introduce a system for forecasting labor market demand, as well as to link the educational programs with labor market demand. In order to increase competitiveness in the commodity markets, it is necessary to use the whole toolkit of export promotion: support for the participation of Armenian organizations in international exhibitions, promotion of Armenian goods in foreign markets through RA trade representatives etc. In order to ensure the growth of investments, 3 packages of proposals have been developed: general proposals for legislative reforms, proposals for the activities of regional development organizations, proposals aimed at improving the activities of exporting organizations.

Within the scope of the research project "Problems of crisis management of the economy in the Republic of Armenia" (Sup.: cand.(econ.) H.Markosyan) the following has been proposed:

- to develop an effective anti-crisis management system on the development of sectoral anti-crisis management strategies based on the principles of early crisis diagnosis, urgency, adequacy, targeting, complicity, and temporality. They should assess the risks threatening the sector, possible consequences, monitoring mechanisms and a set of measures that should be applied in case of a particular risk, including a list of measures related to the legal, financial and real sectors and social regulation;
- to develop an anti-crisis monitoring system based on a combination of the choice of measurable indicators, determination of permissible deviations, the implementation of strategies in accordance with the recorded deviations and a system for monitoring results. They must have legal force, listening to a guarantee of the implementation of urgent and adequate anti-crisis measures, protecting the economy from serious shocks in conditions of political and external instability;
- to propose principles for the development of sectoral anti-crisis strategies based on the study of macroeconomic indicators of the Republic of Armenia in the areas of labor migration, public administration system, energy system, agriculture, financial system, health care system, tourism, food supply system and the real estate sector, aimed at reducing and overcoming risks emergence of crisis situations.

Within the framework of the research "The role of the digital economy in the agri-food system of the RA" ((Sup.: cand.(econ.) M.Manucharyan) it has been proposed:

• to raise awareness of farmers about digital agriculture, as well as to increase the level of electronic literacy of the population (training of staff and transformation of education). For this, it is necessary to organize trainings, prepare information booklets on digital agriculture, television and radio programs. This function should be performed by the Department of Agricultural Advice, Innovation and Monitoring of the Ministry of Economy RA;

• to develop programs of state support aimed at the development and dissemination of digital agriculture;

• to select competitively an IT company that will develop telephone applications helping farmers to receive agro-climatic information, to track the stages of growth and development of crops, to receive financial services, etc.

Based on the study of the Estonian experience, it has been proposed to introduce in the Republic of Armenia the X-road state network, which provides fast and secure exchange of data between different bodies, companies, services, people based on the introduction of digital identification program and residence electronic system, which is an effective mechanism for the digital development of the country.

Within the scope of the research project "Possibilities and structures of diversification of the economy on the basis of high technology in the Republic of Armenia" (Sup.:cand.(econ.) S.Dallakyan) it has been proposed to develop a strategy for diversification of the innovative economy of RA, which will include the main narrow specialized fields by which the economy of the Republic of Armenia can have an advanced development perspectives, in particular, development of apps that require program and technical resolutions, biotech and digital healthcare, engineering seismology development, digital insurance.

## Institute of Art

### *Major achievements*

Within the framework of the basic project "Complex Study of Armenian Art" (Sup.: corr. memb. A.Aghasyan) the Armenian-Russian artistic relations have been comprehensively studied and for the first time offered to the Russian-speaking audience in the form of a brief essay, along with creative portraits of the Armenian artist Dmitry Nalbandyan, sculptors Nikolay Nikoghosyan, Fridrikh Soghoyan and Henrikh Frangulyan, who lived and created in Moscow, as well as of the founder of contemporary Armenian architecture Alexander Tamanyan, who was educated in Russia. The outstanding art historian Lidia Durnovo's contribution has been analyzed, with particular mention of such milestones in her academic career as opening to world culture the value of medieval Armenian frescoes and making copies of many of them; authoring the first researches on the history of monumental painting and sculpture of medieval Armenia; laying the foundation for studying Armenian cloth prints and ornaments; training a team of young artists-copyists. Common characteristics for the iconography of the "Assumption of the Virgin Mary" in the art of Armenia and Russia have been examined. It has been found that the epigraph to the article "Ivan Konstantinovich Aivazovsky" by the musicologist, musical and public figure Barsegh Ghorghanyan served as a basis for the poetic text of the requiem "In Memory of I.K.Aivazovsky" (op. 86 N 22, Des-dur, 1902) for voice and piano by the Russian composer, music critic, member of the "Moguchaya kuchka [The Mighty Handful]" Cesar Cui. In cooperation with the Moscow-based Pavel Tretyakov Charitable Foundation, the results of the studies were published in the third, exclusive issue of the "Russkoe iskusstvo [Russian Art]" journal – "RUSSIA-ARMENIA. Dialogue of Cultures in the Language of Art". It has been an unprecedented phenomenon in the field of Armenian academic art studies, and an important step toward internationalization of the results of Armenian art studies.

The study and evaluation of the life, creative legacy, performing, musical and public activity of the prominent Armenian composer Alexander Spendiaryan (1871-1928) have been continued. The results of the studies were presented at the international scholarly session "Alexander Spendiaryan – 150", organized by the Institute. This event, unprecedented by the scope of presented topics and the geography of participants, became an important phase in international Spendiaryan Studies.

## Shirak Centre for Armenian Studies

***Major achievements***

Within the theme "Archaeological and historical-ethnographic studies of Shirak-3" (Sup.: cand.(hist.) A.Hayrapetyan) the following has been done:

a. as a result of Jradzor's castle-settlement excavations, some parallel facts have been revealed in the settlements in Shirak IX-VIII BC. Saj and mills were found on the paved floor of № 5 dwelling in Jradzor. In the same place a pit was found filled with things dating back to the VIII BC. The same picture is in the shelter next to the gate of Azatan and Shirakavan fortresses.

The existence of such similarities in the various monuments allows us to conclude that both castles and settlements were attacked in VIII BC. In case of Azatan, it is expressed by fire, for Jradzor fortress settlement and Shirakavan fortress Urartian broken and bent weapons with arrowheads were discovered. The comparison of these facts with the data of the two Urartian protocols in Shirak allows us to observe the directions of the Urartian troops from the north-east to the south-west, and then through the Akhuryan river basin to the Ararat plain.

b. during the excavations of the kurgana Lernakert № 1, burials were opened dating back to the passing period from middle bronze to late bronze (the 2nd half of the XVI BC- the 1st half of XV BC) where objects belonging to middle bronze age red fortress and late-bronze age are evident. Excavations of shallow tombs of the Bronze Age are of great importance.

The district is a fixed cromlech with rocky outcrops to the east, a tomb on the east side, dating to the later Bronze and Iron Ages, it is not typical of modern-day Shirak monuments. In the staging process two-layered mass burials have been documented with different combustion constraints. Anthropological, archaeological and radiometric studies of mass burials provide a representation of the chronologies, sequences and cultures of the Aragats.

c. following the example of Alexandropol, the activities of local self-government bodies during the years of the First Republic of Armenia have been studied. The formation of local self-government bodies was the most important means of exercising public administration and public power in the newly independent republic. The examination of their activities is important for the completion of the history of the state system of the First Republic of Armenia, and the experience gained is useful from the point of view of the formation of the current system of territorial administration and local self-government bodies of the Republic of Armenia.

## Armenian Encyclopedia. Publishing house

Work has been carried out on the compilation of the vocabulary of the new "Armenian Universal Encyclopedia" (7-8 volumes). Its thematic sections have been compiled. After academic discussions they can be combined in a consolidated vocabulary and become the main guide for the general publication.

Work has been completed to supplement the vocabulary and prepare articles for the encyclopedia "HayAshkhar", which will be completed in 2022. Afterwards the book (2 volumes) will be prepared for publication in electronic form.

## National Bureau of Expertise SNPO

***Major achievements***

The Organization published the 5th and 6th issues of the scientific periodical "Armenian Journal of Forensic Expertise and Criminalistics", as well as, together with the specialists of the "Zdorowy Les" LLC (RF), a manual "Assignment of forensic expertise in the detection and investigation of crimes related to illegal logging. Guidelines".

Work has been carried out to retrofit the organization's instrumentation base, namely, the Organization has obtained and combined its gas chromatograph /Agilent 7820A GC-NPD/ with an

automated evaporation system /Agilent 7697 A Headspace Sampler, 12 vials/ and a flame ionization detector (FID), which makes it possible to carry out forensic chemical expert studies using new modern methods to determine the presence of alcohols and other volatile substances in biological media to obtain necessary quantitative values.

More than 10,000 expert researches have been carried out with obtaining evidence-based results. Two methodological guidelines have been developed. Work has been continued to replenish databases in the relevant research areas.

The Organization took part in the development of a number of normative documents and other legal acts related to the forensic activities of the region, including draft decision of the Government of the Republic of Armenia No. 1864-L dated November 11, 2021, explanations were developed to justify its adoption as well. The leading experts of the Organization actively took part in the programs organized by the European Union Agency on the development of international cooperation in combating crime and ensuring public security and law enforcement (CEPOL program).

***Outcomes of applied developments***

In 2021, 9262 forensic expertise were carried out, it is also planned to conduct 745expertise. Thus, for the entire reporting year, the total number of forensic expertise performed will be 10,007.

Within the framework of the current Code of Criminal Procedure of the Republic of Armenia, expert examinations were carried out in 27 expert types and approximately in 129 expert subtypes and technological areas, 185 expert examinations were also conducted within the framework of civil legal proceedings, 26 - within the framework of administrative legal proceedings and 352 - on the basis of contracts concluded with individuals and legal entities within the framework of civil law relations.

## STATE TARGET PROGRAMS

### Creating a cloud computing environment for solving scientific and applied problems

*Coordinator V.Sahakyan, cand.(phys.-math.), Deputy director of the Institute for Informatics and Automation Problems*

The program is aimed at addressing the problems of natural sciences (hydrometeorology, ecology, seismology, biology, and medical genetics) and the development of a cloud infrastructure using the possibilities of national research e-infrastructure.

Leading specialists took part in the program from the Institutes for Informatics and Automation Problems, the Institute of Geological Sciences, the Institute of Geophysics and Engineering Seismology after A.Nazarov, the Institute of Physiology after L.Orbeli, the Institute of Molecular Biology, the International Scientific and Educational Centre and the Ministry of Environment of RA.

During the reporting year research has been carried out for the development of cloud infrastructures and services to ensure the solution of scientific problems. In particular, some activities have been carried out to establish a data storage and cloud computing service, which has expanded the capabilities of the cloud computing environment created and developed in recent years, equipping it with new computing (multiprocessor servers and servers with general purpose GPUs) and data storage capacity. The problems of searching, receiving, processing and storing the necessary satellite images have been solved using the Armenian Data Cube platform and machine learning technologies, the following services have been developed: air temperature monitoring, forecasting, shoreline segregation of water objects, monitoring of air pollutant concentrations, etc.

Research activities have been continued in the field of meteorology and ecology for implementation of climate change and vulnerability assessment models in Armenia, for obtaining high-resolution weather forecasts using the Weather Research and Forecasting (WRF) digital weather forecast model, and for development of a spatial model for the distribution of solar radiation and wind potential distribution, creation and development of atmospheric emission reservoirs (for implementation of the mechanism of territorial normalization, for development of modern models for the assessment and forecast of atmospheric emissions, for testing, implementation and development of air pollution forecasting software).

In the field of seismology activities have been continued in the following areas: storage of archive data of wave images received from YSI seismic stations, creation of a cloud storage for storage, ensuring its uninterrupted work, data entry, archiving, installation of necessary software packages in the cloud environment, ensuring the availability of databases in the cloud environment, as well as the availability of appropriate tools for data retrieval and the development of an early warning geographic information system for the possible prevention of natural and man-made disasters.

In the field of biology work has been carried out to model a system of lipid bilayer/transmembrane receptors, complex systems characteristic of a fairly wide range of natural processes have been studied by comparing the existing results of computer modeling with experimental data.

In the field of medical genetics the following two problems have been solved: "The link between somatic and inherited mutations in gene expression and biological processes in cancer" and "Study of changes in the expression of the complete genome during normal and pathological development of the brain."

The results achieved during the implementation of the State Targeted Program have been published in 32 articles.

### Development of Geochemical Maps to Ensure Sustainable Agricultural Development and Food Safety

*Coordinator L.Sahakyan, cand. (geogr.), director of the Center for Ecological-Noosphere Studies*

Kotayki Marz soil survey of a regional scale has been conducted; 86 samples have been collected and analyzed to determine Cr, V, Ti, As, Zn, Cu, Co, Fe, Mn, Ba, Pb, Mo contents and indices of α- and β-activity. A relevant database has been created and the studied indices have been mapped. It has been ultimately proved that the peculiarties of spatial distribution of studied indices are mainly due to geological foundation and are represented by two individual geochemical associations: 1) Fe, Co, Ti, As, Cu, and Cr (basalts, andesites, dacites, etc.) and 2) Pb, Zn, Mn, and Ba (granites, granodiorites, gabbro, etc.). Exceedances of MAC, set up by the RA, have been determined in case of Cr, As, Cu, Mn, Pb, whereas no monoelemental noncarcinogenic health risks and life-time carcinogenic risks have been identified. In children, monoelemenal noncarcinogenic risk has been identified in case of As and on a single location. In almost entire area of Kotayki Marz, noncarcinogenic health risk to children has been identified mainly due to Fe, Co, Mn, Pb, As.

**Assessment of the mechanisms of eutrophication of Lake Sevan and development of methods to combat "algal blooms"**

*Coordinator B.Gabrielyan, DSc(biol.), director of the Scientific Center of Zoology and Hydroecology*

Studies on the phytoplankton blooms in Lake Sevan aimed at monitoring of the blooming process and developing of methods of combatting it have been continued. The intensity of bloomings has been estimated. Water composition during bloomings and after cleaning by functionalized zeolites has been investigated. Biotestings for revealing the genotioxic and clastogenic potential of water in the blooming period and after cleaning have been conducted (using *Tradescantia* clone 02). A model device for water cleaning has been projected and constructed.

The study of the changes in the phytoplankton community has shown that blooming had a local character and was not spread all over the lake. In June, blooming was noted near the village Lichk, with the cyanobacteria *Dolichospermum/Anabaena flos-aquae* the number of which reached 25132000 cell/l and biomass - 100 g/l. In the water samples near Lichk heretocycsts of the Anabaena (up to 500000 cell/l) were also found, After cleaning by funcionalized zeolites heterocycsts and algae of the *Anabaena flos-aquae* in the lake's water samples were not found.

The water samples during blooming period were characterized by a high level of point mutations (genotoxic exposure three times higher than control), non surviving stamen hair (teratogenic effect three times greater than control), and micronuclei in tetrads and percentage of tetrads with microneuclei (clastogenic effects, exceeding the control by 2.5 times). Hydrochemical analysis of water samples has shown that the samples near the village Lichk were more acidic (pH 5.9), contained high concentration of ions *K, Mg, Cl, Na, $SO_4$, $HCO_3$* and organic substances which likely contributed to the genotoxic effect mentioned above. In the water samples treated by zeolites all studied markers were lower.

**Geopark as a stimulus for sustainable economic development and environmental protection in Gegharkuniq, Vayots Dzor and Syunik marzes**

*Coordinator A.Avagyan, cand.(geol.), Institute of Geological Sciences*

Scientific prerequisites for the establishment of the first Geopark in Armenia have been developed. The existing international and local experience for the selection criteria (Geosite) has been analyzed.

Before the selection of geosites a detailed review of publications and preliminary fieldwork have been carried out in all suggested areas. Initially, the existing lists of natural and geological monuments have been analyzed (e.g. Qocharyan 1979, Grigoryan et al., 1987, Melik-Adamyan 1998, Melik-Adamyan et al., 2019, Avanesyan 2017, Nature of Armenia 2006, (https://ace.aua.am/hy/gis-and-remotesensing/maps/natural-monuments/)). Several works of Armenian and foreign geologists have become the basis for the final selection of the geosites. The geosites provide evidences referring to different geological disciplines, such as tectonics or active tectonics (e.g. Philip et al., 2001; Karakhanyan et al., 2017a, b; Trifonov et al., 1994, 2017; Avagyan et al., 2010, 2017, 2018; Ritz et al.

2016), volcanism (e.g. Karakhanian et al., 2002, 2013; Jrbashyan 2013; Neill et al. 2015; Navasardyan 2006; Meliksetian 2018), geodynamics and stratigraphy (e.g. Galoyan et al., 2009; Sosson et al., 2010; Sahakyan et al., 2017a), sedimentology and paleontology (e.g. Danelian et al., 2012; Sahakyan et al., 2017b,c; Friesenbichler et al., 2018; Joachimski et al., 2019; Serobyan et al., 2021), and hydrogeochemistry (e.g. Shahinyan et al., 2019) and others.

Numerous examples of international and local literature have been studied for geosite classification, and for the first Armenian Geopark a form consisting of 10 passport requirements has been developed, as well as a partial and general assessment table of geosites.

Areas proposed for inclusion in the Geopark are situated mainly in the Gegharkunik and Vayots Dzor regions of the RA. There are three main reasons for this: multiple funding cuts; covering the most compact space; the emergence of border areas due to hostilities. However, in the course of work, small parts from the Ararat and Kotayk regions were incorporated as well to include a few more objects of regional and international significance.

Analyzing the rich geological heritage, as well as the international experience of Geoparks it has been proposed to create a Geopark of geological hazards rather than Geopark of general geological monuments. The Armenian Geopark will be distinguished by the fact that it will include examples related to different areas of geological hazards and their evidences such as geodynamics, active tectonics, volcanism, seismology, stratigraphy, hydrogeology, etc. within a limited area. It will give the Geopark a peculiarity, especially when as a result we will have several geosites of regional and international significance.

The proposed first Geopark of the Republic of Armenia will cover an area of about 4,573 km2, which corresponds to 15.3% of the territory of the Republic of Armenia. It covers 62 community areas, which can get extra income from geotourism. The relief is mountainous and includes the absolute altitudes of 1000-3595 m (average altitude is about 2297 m. There are 11 climatic sub-zones, from continental (hot summer and cold winter) to alpine tundra. The Park will encompass geological formations with ages up to 360 Ma.

Combined with historical, archeological, cultural components, the perspective development of geotourism will be an additional impetus for private enterprise and sustainable economic development. Several active faults and surface ruptures, volcanoes and lava flows, are clear evidence of geological disasters. Tectonically-induced landslides and destroyed historical monuments show the evidences of the “living” planet, which can cause serious destruction at any time, if we are not aware of them. Dissemination of knowledge about geological hazards, educational activity is an important factor in terms of population protection and risk reduction.

The 1988 Spitak earthquake is a catastrophic testament to the underestimation of geological hazards.

The scientific results were published in one book-atlas, one article (another one is presented in the journal "Geoheritage"), in the materials of three conferences.

## The main directions of the comparative study of the Armenians in their own and other national environment: challenges and prospects of the research

*Coordinator R.Karapetyan, cand. (hist.), Institute of Archaeology and Ethnography*

Based on the data collected by the department of Diaspora studies staff within the framework of the project, the team monograph “Armenian Ethnicity in the Diaspora” has been published.

An international online seminar-discussion on “Problems of identifying and documenting the potential of the Armenian Diaspora, ways to invest it in Armenia” has been held with the participation of a number of Diaspora researchers, scientists from Poland, Germany, France, Lebanon, Ukraine and Russia.