University of Zagreb Faculty of Science

Strategic Programme of Scientific Research 2018 - 2023

University of Zagreb Faculty of Science

University of Zagreb Faculty of Science

The Faculty of Science of the University of Zagreb has from its foundation been **one of the leading research institutions** in Croatia. Such a prominent position entails major responsibilities and high demands. As STEM (Science, Technology, Engineering & Mathematics) focused research and teaching is one of the leading global trends, the Croatian success in keeping up with such trend largely depends on the capacity of the Faculty of Science in Zagreb to focus its research on globally relevant topics. Such focus inevitably extends to the teaching component of the Faculty as well. This presumption naturally leads to the strategic goals of the Faculty of Science in research. What should be noted is that most world regions clearly display systematic efforts to raise the universities and research centres to a higher level. This means the Faculty of Science is expected to exert additional efforts just to retain its current positions while improvement would require a highly coordinated policy on the level of the entire Faculty.

Purpose of Establishing and Operation of the Research Institution

The Faculty of Science was founded 1946, building upon a tradition of teaching and research activities dating back to 1876 at the Science Department of the Faculty of Philosophy. The purpose of its foundation was predominantly the higher education of students in the fields of mathematics, physics, chemistry, biology, geology, geography and geophysics. From its foundation until today, the Faculty of Science has had a crucial role and significance for the society in general and the development of the Republic of Croatia, through the education and formation of secondary school teachers, researchers at the Croatian universities and institutes, as well as employees in various private and public-sector companies and entrepreneurs.

An important premise for such strategy is that the **university education is inevitably based on scientific research**. Only such form of higher education can cope with the challenges of fast changes in daily life, predominantly resulting from the technological development. Only higher education based on the research may prepare highly educated people ready to accept and develop new knowledge and innovation and be active factors of the economic development, but also to respond to the sustainability challenges of the humanity and the environment. The Faculty of Science has from its foundation until today been a pivotal research institution in the Republic of Croatia.

The scientific research at the Faculty of Science is conducted through several essential forms of activities, which are all intertwined and interrelated. First of them is **experimental and theoretical research** about many open scientific issues, the results of which are visible in the scientific publications. The Faculty of Science researchers continuously publish the results of their research in the leading global scientific journals including *Nature, Science, PNAS, Nature Communications, Science Advances, Royal Society Open Science, Journal of Differential Equations, ACM Transactions of Mathematical Software, Mathematische Annalen, Journal of Mathematical Analysis and Applications , SIAM Journal on Matrix Analysis and Applications, Communications in Partial Differential Equations, International Mathematics Research Notices, Discrete and Continuous Dynamical Systems – Series A, Stochastic Processes and their Applications, Geometry & Topology, Annals of Probability, Probability Theory and Related Fields, Annals of Applied Probability, Journal of the American Mathematical Society, Duke Mathematical Journal, Journal of the European Mathematical Society, Applied and Computational Harmonic Analysis, Physical Review Letters, Physical Review A-E, Nature Physics, Cell, Angewandte Chemie International Edition, Chemistry – A European Journal, Physical Chemistry-Chemical Physics, Inorganic Chemistry, Journal of Organic Chemistry, Analytical Chemistry, The EMBO*

University of Zagreb Faculty of Science

Journal, PlosONE, Nature Biotechnology, Genome Research, DNA Research, Progress in Retinal and Eye Research, Chemosphere, Freshwater Biology, Hydrobiologia, Nature Climate Change, Atmospheric Chemistry and Physics, Journal of Geophysical Research, Seismological Research Letters, Paleo3, Mineralogical Magazine, Palaios, Lithos, Facies, The Cryosphere, Geomorphology, Palaeogeography, Palaeoclimatology, Palaeoecology (or PALAEO3), Journal of Hydrology, Applied Geography, Journal of Rural Studies and *Geoforum*. Due to their quality and originality, some of those publications had significant impact in the international community. The Faculty of Science researchers are frequently invited lecturers at the leading international conferences in the areas of research conducted at the Faculty.

Current models of financing the research from European sources (e.g. H2020, formerly FP7, European Structural and Investment Funds) and from Croatian sources (e.g. Croatian Science Foundation, Unity Through Knowledge Fund (UKF), Ministry of Science and Education) are focused on **specific research projects within given terms**. This form of activity has become quite important and it is impossible to imagine experimental and theoretical activities, or supervision of doctoral candidates without project funding of scientific research. Also, project activities are especially important for the research infrastructure development. In that context, the Faculty of Science has applied with two projects for funding from the EU Structural and Investment funds: CeNIKS – Centre for Advanced Research of Complex Systems (http://ceniks.phy.hr), as well as CIUK – Centre of Research Excellence in Chemistry. Out of many projects conducted at the Faculty of Science, two projects of the European Research Council grants should be noted, as well as the Centre of Research Excellence for Quantum and Complex Systems and Representation of Lie Algebras, funded from the EU Structural and Investment Funds. Projects funded from FP7 from H2020 funds include: *Constraining Stellar Mass and Supermassive Black Hole Growth through Cosmic Times: Paving the way for the next generation sky surveys (ERC project), The Janus-face of the localized carrier in cuprates: Generating the pseudogap and high temperature superconductivity (ERC project), Systems medicine approach to chronic inflammatory disease (H2020), Innovative training in methods for future data (Marie Curie ITN), Comparative genomics of non-model invertebrates (Marie Curie ITN), Connectivity among Mediterranean fishery stakeholders and scientists resolves connectivity of fishery population (INTERREG), Marine Ecosystem Restoration in Changing European Seas (H2020), BIOengineered grafts for Cartilage Healing in Patients (H2020), Smart Integration of Genetics with Sciences of the Past in Croatia: Minding and Mending the Gap (H2020)*. The Faculty of Science researchers often participate in research projects as partners (where another institution is the project leader). Thus, for instance, the Faculty of Science researchers are active in six out of ten Centres of Research Excellence in STEM areas established in Croatia.

The third important form of activities are our doctoral study programmes. The Faculty of Science provides **seven doctoral programmes: Biology, Physics, Geology, Chemistry, Mathematics, Doctoral Programme in Geography: Space, Region, Environment, Landscape and the Interdisciplinary Doctoral Programme in Oceanology**. The doctoral programmes have several purposes. First, the doctoral candidates acquire expertise in a certain scientific branch as an important upgrade of the undergraduate and graduate study programme. Second, they are trained for independent research. Also, they are ready to accept and apply the state-of-the-art technologies resulting from the front-line research and are a significant asset for the sustainability of the Croatian universities and research institutes and for assisting the Croatian companies (in the public and private sector) to keep up with the cutting-edge technologies based on science. An example are medical physicists who are the only

ones with the expertise in certain segments of work on highly sophisticated equipment in hospitals and health institutes. A high number of the Faculty of Science doctoral programme candidates are employed at other institutions such as the *Ruđer Bošković Institute* or the universities in Split, Osijek and Rijeka. Therefore, the role of the Faculty of Science in this form of activity in Croatia is of exceptional importance and should be given special attention. An important part of the Faculty of Science scientific production is based on the doctoral candidates' research, as reflected in their research papers as well as doctoral theses.

The fourth important form of activities related to the research is the **international cooperation** with the researchers, scientific groups and institutions, as well as the researchers' **mobility**. The international cooperation has an impact on the international research as well as on the quality level of the research and the selection of topics dealt with by the researchers. The international cooperation has been subject of great attention from the beginnings of the Faculty of Science, as reflected in the existence of the International Cooperation Office and the position the Vice-Dean for International Cooperation has in the Faculty of Science structure. This form of activity includes bilateral projects, organisation of scientific conferences, and researchers' mobility, i.e. their visits abroad for short-term or long-term training courses.

The fifth important form of research related activities is **the applied research, i.e. professional work**. Through the research, the Faculty of Science researchers and teaching staff acquire the expertise and the credibility for professional projects of significance for a wide range of aspects affecting the Croatian society, among which particularly noteworthy is the sustainable development as well as environment and nature protection. One of the examples of the importance of their professional work is the cooperation with the Croatian Waters Authority. For instance, there are currently projects: Systematic Study of Hydromorphological Quality Elements in Rivers in 2016 and 2017 (client: Croatian Waters Authority, the project is conducted by the Department of Geography of the Faculty of Science and company *Elektroprojekt d.d.*), Development of Methods for Assessment of Hydromorphological Status in Lentic Waters and Hydromorphological Monitoring (both projects were ordered by the Croatian Waters Authority, and conducted by the Faculty of Science and *Elektroprojekt d.d.*), Analysis of Biological Methods of Ecological Status Assessment for Phytobentos, Macrophytes and Macrozoobentos in the European Intercalibration Rivers of the Pannonian and the Dinaride eco-region; Analysis of Impact of the Environment Factors and Anthropogenic Load on Biological Quality Elements (client: Croatian Waters Authority, the project is conducted by the Department of Biology of the Faculty of Science) and Classification System of the Ecological Potential for Artificial and Significantly Changed Bodies of the Surface Waters – Part I: Lentic Waters of the Pannonian Ecoregion and Part II: Lentic Waters of the Dinaride Ecoregion (client: Croatian Waters Authority; the project is conducted by the Department of Biology of the Faculty of Science and the Danube Research Institute). Within the scope of the Faculty of Science, there is the Seismological Service, engaged in the collection and analysis of macroseismic and microseismic data. Based on the recorded earthquakes, the population and various services are notified, and expert opinions are provided to builders, insurance companies and alike. The service also drafts the seismicity studies for the Croatian Power Distribution Company (HEP), Croatian Ministry of Defence and the Croatian Waters Authority, as well as studies in the field of engineering seismology, the results of which are applied in the design of structures of special interest (such as dams, bridges and terminals). Within the scope of the Faculty of Science, there is also the Botanical Garden, a popular destination of local people and tourists. Due to its major educational, cultural-historical and tourist value and its overall

significance for the University, the City of Zagreb, and the Republic of Croatia in general, since 1971 the Garden has been protected by law as a park architecture monument. The Garden has a significant role in the university teaching process, in the research and professional activities in the field of botany, as well as in the education of the general public about the importance of joint work on the protection and preservation of the rich Croatian flora. It cooperates with botanical gardens worldwide, sharing the experiences and developing the fundamental botanical garden activities in the 21st century, including education and protection of herbal biodiversity. The Faculty of Science researchers are involved in projects of significance for the preservation of the Croatian flora and fauna and, for instance, in cooperation with the Croatian Agency for the Environment and Nature, they participated in the production of many red books and red lists, important to identify the endangered species and habitats on the national level and to determine the priority measures for their protection. Finally, the Faculty of Science cooperates with the economy on continuous basis, through various expert studies ordered by various clients, related to the energetics, water supply, nature and environment protection, civil engineering and other commercial activities.

The sixth form of activities is the **cooperation with the real sector and positive influence on the economy**, where the essential role is played by the applied research and the transfer of technology. Modern universities have three significant roles. Two of them have already been mentioned, namely the research and teaching. The third role is the positive impact on the economy, which may run through several channels. One of them is flow of the human resources who acquired a certain level of expertise (having completed the undergraduate, graduate or doctoral programme) into the economic sector. The second is the cooperation with companies through participation in common projects or applied research. Such is, for instance, the cooperation with Pliva company (see more details below) and Genos (e.g. on H2020 project *Systems medicine approach to chronic inflammatory disease*). The Faculty of Science researchers have also led many Proof of Concept (PoC) projects, establishing connections with the economy. The third channel is through establishing spin-off and spin-out companies based on the scientific knowledge, i.e. transfer of technology. The Faculty of Science has until now had a significant influence through the first channel and there are certain activities in the second channel, while the third channel is a challenge that needs to be faced.

The seventh form of activity is **popularisation of science**. Popularisation activities have been successfully conducted at the Faculty of Science for years, through the exceptionally well visited Open Days of the Faculty of Science (once a year, usually in April) which have attracted large media attention (TV, radio, etc.) and the events such as Magic in Chemistry, Night of Biology, Physics Express. The purpose of popularisation is bringing our scientific activities closer to the wide audience who actually finances the public sector including our branch through payment of taxes. The aim is also to make the primary and secondary school children more sensitive to science, thus creating a wider and higher quality student base for the Faculty of Science.

There are many forms of activities that are in one way or another related to the scientific research. At the end of this chapter, we can also mention the publishing activities of the Faculty of Science. The Faculty of Science is the publisher of six journals: *Acta Botanica Croatica, Geofizika, Croatica Chemica Acta, Glasnik Matematički, Hrvatski geografski glasnik* and *Acta Geografica Croatica*; the first four of them are indexed in Web of Science, among total 42 Croatian journals indexed in that internationally recognizable bibliography base.

University of Zagreb Faculty of Science

Analysis of the scientific potential of the research organisation and its position in the scientific and commercial environment

The most important research resource of the Faculty of Science are its people. **There are 275 researchers in scientific-teaching titles and 157 researchers in associate titles at the Faculty, working at seven departments (November 2017)**. The Faculty of Science consists of the following departments:

- Department of Mathematics
- Department of Physics
- Department of Chemistry
- Department of Biology
- Department of Geology
- Department of Geography
- Department of Geophysics.

The departments are organized in several divisions, chairs and centres, including the Croatian Seismological Service and the Botanical Garden, for transparency. All the units are listed in Appendix A.

This strategy is for the most part focused on the strengthening of human resources, and thereby the capacities for conducting the projects and research at the Faculty of Science. Currently, there are 118 active projects at the Faculty, 83 of which are financed from domestic sources and 35 fully or partially financed from the international sources. More precisely, out of the mentioned 35 projects, there are seven projects funded from the H2020 programmes (one of them ERC project), two from FP7 programmes (one of them ERC project), one project from the European Structural and Investment Funds, one from the IRI programmes, one from INTERREG, one from Erasmus +, two from IAEA, two from AUF (Agence universitaire de la Francophonie), and the rest are bilateral projects. These figures do not include the research support (in 2017, 86 research supports were funded, with approximately HRK 2.7 million, which is the number approximately equal to the numbers from the previous two years). The share of the H2020 and FP7 projects is somewhat below 8% in the overall number of projects. The share of projects from the international funding sources, without inter-state projects, is therefore 16/118, which is between 13% and 14%. If that number is viewed through 275 researchers in the scientific-teaching titles, it clearly leads to certain items in the SWAT analysis below and certain objectives.

The Faculty of Science is located in highly motivating surroundings. In the vicinity of its several Departments (Mathematics, Physics, Chemistry, Geophysics, Geology Departments and a part of the Department of Biology), there is also the *Ruđer Bošković* Institute, the Faculty of Medicine, the Institute of Physics and the Institute for Medical Research and Occupational Health. **This large complex of science, biomedicine and biology in the north of Zagreb is often called the Northern Campus.** There are currently several infrastructural projects in progress that will be funded from the European Structural and Investment Funds, which will have a great influence on the scientific landscape of the Northern Campus, in which the Faculty of Science is either the direct factor (project leader) or its researchers participate as partners in conducting such projects.

University of Zagreb Faculty of Science

Among the projects funded from the European Structural and Investment Funds, below mentioned are those that will have a significant influence on the Faculty of Science research activity in the subsequent five years. **CeNIKS – Centre for Advanced Research of Complex Systems** (http://ceniks.phy.hr) project application was submitted for Infrastructural support financed from the European Regional Development Fund. The project worth EUR 8.2 million is conducted at the Department of Physics of the Faculty of Science. The application for the same European Regional Development Fund was also submitted for the **CIUK – Centre of Research Excellence in Chemistry** project. That project worth EUR 9.5 million is conducted at the Department of Chemistry of the Faculty of Science. The purpose of the project is development of the national research infrastructure contributing to the development of innovation capacities, both of individuals and of the society, to research excellence as well as diversity and modernization of the national economy. Through development of the Department of Chemistry of the Faculty of Science into the leading national and regional centre, in which superior applied and basic research is conducted in the field of chemistry, the research staff will be developed with specific knowledge and skills in this area. Such approach will provide, on long term basis, higher competitiveness and recognizability of the research and development related activities conducted within the scope of the University, both on the national and the international level. What should be noted among the specific goals of the project is the strengthening of the Croatian economy competitiveness based on the applicable results of research as well as stimulation of the new and expansion of the existing cooperation with the representatives of the economy. What should be noted is that there are currently preparations of the Department of Biology for application for the structural funds, which will be used to update the scientific equipment and renovate the existing premises to organize new laboratories. Finally, the strengthened infrastructure capacities are expected to significantly increase the research and innovation opportunities and thereby positively reflect on the teaching activity.

The contract has been signed for Superior Research Implementation project within the scope of the **Centre of Research Excellence (CoRE) for Quantum and Complex Systems and Representation of Lie Algebras** (http://bela.phy.hr/quantixlie/), also funded from the European Structural and Investment Funds, called in late 2016. The non-refundable funds have been approved in the amount of HRK 36,956,624.09 (about 5 MEUR). The project will significantly contribute to the development of human resources and raising the quality level of research in theoretical physics and mathematics. What should be noted is that the Faculty of Science researchers participate as partners (i.e. the Faculty takes part as a partner institution) in the activities of as many as five other Centres of Research Excellence (CoRE) led by the institutions in the Republic of Croatia: CoRE for Advanced Materials and Sensing Devices – CEMS (*Ruđer Bošković* Institute), CoRE for Biodiversity and Molecular Plant Breeding (University of Zagreb, Faculty of Agriculture), CoRE for Personalized Health Care (*J. J. Strossmayer* University in Osijek), CoRE for Basic, Clinical and Translational Neuroscience (University of Zagreb, Faculty of Medicine) and CoRE for Data Science and Cooperative Systems (University of Zagreb, Faculty of Electrical Engineering and Computing). Working at these centres of research excellence, the Faculty of Science researchers have the opportunity to intensify and exploit the cooperation with other Croatian scientists to raise the quality level of research throughout the country and to strengthen the interdisciplinary and multidisciplinary research.

Among the projects funded from the European Structural and Investment Funds, conducted at the neighbouring institutions, O-ZIP (Open Scientific Infrastructural Platforms for Innovative Applications in the Economy and Society, http://ozip.irb.hr/) projects are mentioned, which will be conducted at

University of Zagreb Faculty of Science

the *Ruđer Bošković* Institute, worth EUR 50 million as well as CALT – Centre for Advanced Laser Techniques project (http://calt.ifs.hr/), which will be conducted at the Institute of Physics. The Faculty of Science researchers will be able to use the O-ZIP and CALT infrastructure for their research. In addition to these two projects, which are declared strategically important, the financing of the Cryogenic Centre at the Institute of Physics is also expected (http://kacif.ifs.hr/).

By purchasing the capital assets and though project activities, the scientific infrastructure has been formed, including the laboratories and the appertaining equipment. The laboratories are structured in alignment with the structure of the Faculty of Science, by divisions, as described in detail in Appendix A. Drafting the Faculty of Science Scientific Equipment Catalogue is currently in progress to provide a detailed overview of the Faculty of Science capacities for experimental research and commercial services to the companies in business sector and other legal entities and natural persons. The current version of the Scientific Equipment Catalogue is provided in Appendix C and will if required be supplemented with new items. The Departments include the libraries with the reference works required for the research, subject to continuous upgrades, and providing access to the globally relevant journals in science.

The Faculty of Science researchers have intense cooperation with the *Ruđer Bošković* Institute, the Institute of Physics, the Meteorological and Hydrological Institute of Croatia, the Institute of Medical Research and Occupational Health, the Immunology Institute, the Faculty of Food Technology and Biotechnology, the Faculty of Pharmaceutics and Biochemistry, the Faculty of Textile Technology, the Faculty of Chemical Technology in Split, the Faculty of Mining, Geology and Oil Engineering, the Croatian Geological Survey, the *Ruđer Bošković* Centre of Marine Research in Rovinj, the Institute of Oceanography and Fisheries in Split, the Croatian Conservation Institute, the Croatian Institute of Brain Research, Faculty of Veterinary Medicine, Faculty of Science of the University of Split. We also cooperate with the City Office for Strategic Planning and Development of the City of Zagreb and the National Centre for External Evaluation of Education. The cooperation takes place through common projects and several partnership agreements have also been signed among which particularly noteworthy are the Partnership Agreements within six Centres of Research Excellence cited above, which makes our Faculty partner to all major stakeholders in the STEM area in Croatia.

The Faculty of Science researchers have very strong international cooperation. It partially takes place through common international projects. An example are the six projects of the Unity through Knowledge Fund, through which our researchers cooperated with the most prestigious world institutions such as the Massachusetts Institute of Technology and the Imperial College London. The Faculty cooperates with many other institutions as well: Caltech, University of Oxford, University of Cambridge, ETH Zurich, University of Chicago, University of Illinois Urbana-Champaign, Chemical Institute of Ljubljana, University of Ljubljana, University of Graz, University of Vienna, University of Prague, University of Florence, University of Manchester, Weizmann Institute of Science, Tübingen Proteome Centre, University of Portland, EMBL Grenoble, Technical University Berlin, Technical University Sydney, University of Stuttgart, University of Trieste, University of Warsaw, University of Heidelberg, University of Jyvaskyla, McGill University, University of Namur, LCC Toulouse, University of Maragheh, Universitat de les Illes Balears, East China Normal University, Kansas State University, Wrocław University of Technology, Universidade de Lisboa, Universität Bielefeld, Sorbonne Universités, University of Hamburg, University of York, University of Padua, Italian National Institute for Environmental Protection and Research (ISPRA), Max Planck Institute for Molecular Genetics

University of Zagreb Faculty of Science

Berlin Germany, University Ben-Gurion Beer-Sheva Israel, Centre for Genomic & Experimental Medicine MRC Institute of Genetics & Molecular Medicine, The University of Edinburgh Western General, Broad Institute of Harvard, Eawag, University of Washington, University of Utah, UCLA, University of Florida, Hong Kong University, Purdue University, Universidad Autonoma de Madrid, Universitaet Bonn and Danube Research Institute as well as Washington University in St Louis. In addition to the international projects, the Faculty of Science has the institutionalized cooperation in form of agreements with many international institutions. More precisely, the Faculty of Science has 131 Erasmus agreements with the international institutions and 14 cooperation agreements with the following institutions: A. P. Vinogradov Institute of Geochemistry, Siberian Branch of the Russian Academy of Sciences, Irkutsk, Russia; University of Trieste, Department of Education and Cultural Processes, Division of Geography and Politics of Territory, Trieste, Italy; University of Bihać, Faculty of Pedagogy, Bihać, Bosnia and Herzegovina; University of Padova, Department of Geosciences, Padova, Italy; International School for Advanced Studies (SISSA), Trieste, Italy; Basque Centre for Applied Mathematics (BCAM), Bilbao, Spain; University of Environment (UoE), Karaj, Iran; Saints Cyril and Methodius University of Skopje, Faculty of Science, Skopje, Macedonia; Institute of Nature Conservation of the Polish Academy of Sciences, Kraków, Poland; Paul Scherrer Institute, Villigen, Switzerland; Moscow Institute of Physics and Technology, Moscow, Russia; University of Pécs, Pécs, Hungary; Hungarian Natural History Museum, Budapest, Hungary; School of Science and University of Osaka, Osaka, Japan.

There is important cooperation with business entities in the applied research and transfer of technology. For instance, the researchers of the Faculty of Science Department of Chemistry have intensive cooperation with representatives of the pharmaceutical (PLIVA d. o. o, Fidelta d. o. o., Belupo d. d), chemical (Kemika d. d.) petrochemical (INA d. o. o) and food processing industry (Zvijezda d. o. o). Their common research is primarily focused on the development of new methods for chemical compound synthesis and methods of qualitative and quantitative analysis of their mixtures on examples encountered on daily basis by the researchers in the business sector. The research is partially focused also on the development of the so called green processes of chemical compounds preparation. Specifically, it refers to finding or optimisation of synthetic paths in which as little as possible quantities of hazardous solvents and energy sources are consumed. The scientific cooperation with the representatives of the economy has resulted in 29 scientific publications indexed by Current Contents, several doctoral theses (5) and diploma theses (3). The second part of the cooperation with the business sector so far includes the professional projects through which the Faculty of Science Department of Chemistry personnel use their scientific expertise and infrastructural capacities for resolution of specific problems encountered by representatives of the economy. In addition to the cooperation with the economy, particularly noteworthy is the cooperation of the Ministry of Science Department of Chemistry personnel with the Croatian Ministry of Interior. Namely, at a minimum fee, used partially to cover the NMR spectrometer operation costs, purchased within the Ministry of Science and Education call „Strengthening the Capacities for Research, Development and Innovations”, the NMR Centre staff of the Department of Chemistry analyse the complex mixtures of opiates confiscated in the Republic of Croatia.

The Faculty of Science has had a significant influence on a part of the hospital public sector through development of medical physics. In the Croatian health care system, there are currently 60 medical physicists performing daily clinical tasks in radiotherapy, nuclear medicine, diagnostic radiology and radiation safety, but also in the teaching process at the Faculty of Science. The Croatian healthcare is

currently facing a large and unavoidable need for development and application of medical physics in modern diagnostic and therapeutic procedures (radiotherapy– IMRT, VMAT, SRS, SABRT, diagnostic radiology – fMRI, dwMRI, tensor MRI tractography, msCT, nuclear medicine – SPECT, PET etc.). The Republic of Croatia has accepted and transposed to its legislation the EU Directive named EURATOM 2013/59, requiring the adequate application of knowledge in medical physics in medical procedures. On that basis, the number of medical physicists in Croatia will grow (more than 100 are expected) and their activities in such areas will deepen.

The doctoral study programmes need constant updating. One of the challenges the doctoral programmes are about to face is the model for financing the doctoral candidates, following the global trends, according to which mostly four years of the doctoral candidates are financed (e.g. by the Croatian Science Foundation), while until recently the junior researchers' system provided a significantly longer time (at least six years) for the doctoral thesis. There is a need to focus on a higher number of specialized elective courses and a smaller number of compulsory courses, to leave more time for research and to train doctoral candidates as well as possible through the courses covering the topics of their doctoral theses.

What should be noted is that the research at the Faculty of Science are **harmonized with the Smart Specialization Strategy of the Republic of Croatia for the period 2016 – 2020 (S3)**, i.e. with the **Strategy of Education in Science and Technology** and other **national strategic and sector documents**. All major projects financed from the European Structural and Investment Funds have passed the evaluation of their harmonization with the above-mentioned documents and their vertical and horizontal topics.

Specifically, **the QuantiXLie Center Of Excellence** is harmonized with the topics of the Smart Specialization Strategy: the project is in alignment with the Partnership Agreement and the Competitiveness and Cohesion Operational Programme 2014 – 2020 (CCOP), TO 1 – Strengthening the research, technology development and innovations, as it directly contributes to the strengthening of the capacities and creation of inventions and innovations in the field of the CoRE. The project is in alignment with the investment priority 1a of CCOP as it directly contributes to the capacities of the RDI sector for high quality research and for the needs of the economy. The links with the vertical Priority Thematic Areas (PTA), i.e. Subthematic Priority Areas (SPA) are: (i) PTA Energy and Sustainable Environment – SPA Energy Technologies, Systems and Equipment and SPA Environment Friendly Technologies, Equipment and Advanced Materials: research is conducted of topological photonic and condensed systems, focused on development of new generations of advanced materials; (ii) PTA Security – SPA Cybersecurity: within the scope of the project, elliptic curves are studied, particularly structure of elliptic curves with large torsion group and positive rank, which are of exceptional importance in the public key cryptography (indicative RDI topic are crypto-communication systems adjusted to the EU and NATO standards). (iii) PTA Safety – SPA Defence Technologies and Double Use Products: new photonic materials are studied which imitate the natural systems (like chameleon) and metamaterials (RDI topic Engineering of Materials (Protective Clothes and Equipment), related indicative topic within the horizontal KET topic Photonics and Advanced Optics). (iv) PTA Health and Life Quality – SPA Pharmaceutics, Biopharmaceutics, Medical Equipment and Devices: mechanism of chromosome division in mitosis is studied, to provide better insight into gene disorders as consequence of errors in cell division and possibilities of their treatment (RDI topic: Discovery and Development of Human and Animal Medications); (v) PTA Health and Life Quality –

University of Zagreb Faculty of Science

SPA Health Services and New Methods of Preventive Medicine and Diagnostics: exotic atomic nuclei are studied which are relevant in the medical diagnostics and therapy (RDI topic: Diagnostic and therapeutic tools and applications).

CIuK Project is related to the vertical Priority Thematic Areas (PTA) of the Smart Specialization Strategy: (i) Health and Life Quality (Subthematic Priority Areas (SPA): Pharmaceutics, Biopharmaceutics and Production of Medical Equipment and Devices); (ii) Energetics and Sustainable Environment: (SPA: Environment Friendly Technologies, Equipment and New Materials); (iii) Food and Biochemistry (SPA: Sustainable Food Production and Processing). The establishing of the Centre of Research Excellence at the Department of Chemistry will directly contribute to the effectuation of two investment priorities of the Competitiveness and Cohesion Operational Programme. These are: strengthening the research, technological development and innovations and investment in education, training and professional improvement and lifelong education. The first priority, related to the strengthening of the public research infrastructure, will contribute to better infrastructural and technological capacities available to the Department of Chemistry of the Faculty of Science, which are used in successful research projects of national and European interest. The same investment will improve the existing – obsolete and non-competitive infrastructure used for research in the field of chemistry and thus strengthen the link with the industry representatives (oil industry, pharmaceutical industry, construction industry, food processing industry). The intensified cooperation with the business sector will improve the cooperation that will enable the chemical research the results of which are applicable in the development of products and services of public and private interest. As the CIuK (Centre of Research Excellence in Chemistry) project, in addition to the infrastructure development, also covers the development of human capacities in the field of public research in chemistry, the project should contribute also to higher employment rates and strengthening the social cohesion in the country. This will take place through three specific goals: improvement of quality, relevance and efficacy of the higher education, increasing the rate of the acquired higher education and improvement of work conditions for the Croatian researchers.

CeNIKS Project is in alignment with the Smart Specialisation Strategy, overlapping with the following objectives: Objective 1. Increasing the research sector capacities for superior research projects corresponding to the needs of the economy; Objective 2. Overcoming the fragmentation of the innovation chain of value and large differences between the research and the business sector; Objective 3. Development of smart skills – improvement of qualifications of the existing and new labour force for smart specialization. Through the improvement of the scientific infrastructure and the organisational reform, the CeNIKS Project will create conditions for research excellence of the scientists, which will be reflected in a higher number of research projects and publications and in establishing the international cooperation. The project will improve the qualification of labour force that will form the basis of more innovative and more creative public sector cooperating with the economy. The project implementation will overcome and reduce the differences between the research sector and the business sector through cooperation in the selected Priority Thematic Areas. The priority areas represented in the project are health and life quality, energy and sustainable environment, traffic and mobility, safety, as well as food and biochemistry. The horizontal topics are (1) Key Development Technologies (KDT) and (2) Information and Communication Technologies (ICT). The main goal of the project is development of new materials and technologies and as such it fits into three different priority areas (i.e. sub-areas), namely: Health and Life Quality (health services and new methods of preventive medicine and diagnostics), Energy and Sustainable Environment

(environment friendly technologies, equipment and advanced materials) and horizontal area (KDT – Key Development Technologies). A part of the project, Laboratory for Optical Atomic Spectroscopy, is focused on the research of dielectric-barrier discharge (DBD), which may be used for change of characteristics of the surfaces of various materials, in medical and biomedical uses, for sterilisation of equipment and for cancer cell treatment. DBD of noble gas (helium, argon and others) plasma will be studied as discharge factors. The purpose is to determine the key parameters of plasma and completely understand the resulting processes to further adjust and increase the dissociation and ionisation efficacy of DBD. All this fits into the PTA Health and Life Quality (health services and new methods of preventive medicine and diagnostics). The project will provide the infrastructure for development and full characterisation of materials. Having that in mind, two new units are established: Laboratory for Synthesis and Preparation of Materials and Laboratory for Optical Spectroscopy and Ellipsometry. The first laboratory will be the central point provided with most advanced equipment for various synthesis processes and the second laboratory is characterised with the technology that does not exist yet in Croatia but is standard abroad and may provide quite a lot of new knowledge about the properties of the materials. The rest of the project is focused on various forms of characterisation of materials (magnetic, transport and electric properties, structural research and discovery of microscopic mechanisms) and ensuring stable research (unit for cryogenic liquids), for which currently the conditions are not met. All this contributes to PTA, i.e. SPA Energy and Sustainable Environment (Environment Friendly Technologies, Equipment and Advanced Materials) and horizontal areas KDT (Key Development Technologies) and ICT (Information and Communication Technologies). Namely, the ICT will serve for the integration and interpretation of data resulting from the research and for the organisation of research activities (software procurement). The former research topics of the project stakeholders were materials of significant impact on the environment sustainability such as high-temperature superconductors, but also new forms of nanoelectronics such as spintronics, and new materials for telecommunications such as topological insulators, etc. It is beyond doubt that these topics will be definitely worked upon but, what more importantly, the project will also open some new areas of research.

Here, the connections between the Faculty of Science major infrastructure projects with the national strategic and sector documents have been actualised, but the majority of the Faculty of Science research mentioned herein is mostly harmonized with those objectives.

In addition to the analysis of the form of activities of the Faculty of Science research and the description of the scientific potentials of the research organisation and its position in the research and the business environment, a definition of strategic objectives requires a SWOT analysis, determining the strengths, weaknesses, opportunities and threats in the performance of the strategic objectives.

SWOT analysis in the Development Strategy of the University of Zagreb Faculty of Science, prepared during the Faculty reaccreditation, serves as the basis for this SWOT analysis.

SWOT analysis

Strengths

- A long tradition and reputation of the Faculty of Science in university education, research and academic work in the field of natural sciences and mathematics.

University of Zagreb Faculty of Science

- Scientific excellence and international recognisability of individual researchers, competitive research groups and the results of their research.
- The intellectual potential of a great number of highly competent and motivated employees with scientific-teaching and associate titles and a good teacher-student ratio.
- Networking on the national and international level with a significant number of national and international scientific projects and the appertaining scientific infrastructure, library stock and periodicals.
- The vicinity of other organisational units of the University of Zagreb and the public scientific institutes, ensuring a stimulating environment for scientific, teaching and academic work.
- Dialogue and taking into consideration the needs of certain regions of the Republic of Croatia (Osijek, Split, Dubrovnik etc.) for expanding natural sciences, and primarily developing these regions in scientific fields and teaching activities.
- Established strong connections on the local and regional level in cooperating with public institutions (e.g. Croatian Waters Authority, Croatian Power Distribution Company, national parks, *Ruđer Bošković* Institute, Institute of Physics, Hydrological and Meteorological Institute of Croatia, etc.) in the field of sustainable development and computerisation.
- Active participation in the everyday life of the citizens of Zagreb and the Republic of Croatia (Seismological Service, Botanical Garden, etc.).
- Highly motivated, studious and diligent students at all study levels.

Weaknesses

- Current spatial detachment and inadequacy of the spatial position of some of the elements of science departments complicate the scientific and teaching activities and adequate administrative activities.
- The fragmentation of resources leads to a reduced connection between professions and scientific fields, which complicates severely the introduction of commons standards and criteria, has a negative effect on indicator (quality) effects, encouraging interdisciplinarity and establishing joint research in science.
- Insufficient reliance on the international funding sources i.e. international projects.
- An insufficient number of scientific-teaching and assistant positions as well as postdoctoral positions causes a working overload for teachers due to teaching and administrative obligations.
- Insufficient assessment of creating internationally recognizable research groups with large project funding sources, particularly those from EU funding sources.
- An insufficient number of high quality international postdoctoral candidates (partially related to the fact the postdoctoral salaries from domestic funding sources are listed in the national standard).
- A complex organisation leads to multiplication of procedures, the quality of project administration is not on an adequate level yet.
- Inadequate engagement on the public promotion of the Faculty of Science, ranging from website to the presentation of its researchers' results in the Croatian media.
- A lack of synergy among Departments weakens the possibilities to initiate interdisciplinary and multidisciplinary research.
- A lack of harmonisation among Departments in terms of study programmes leads to an illogical organisation of courses.

University of Zagreb Faculty of Science

- Insufficient connection with former students.
- A small interest among enrolment candidates for teaching programmes.

Opportunities

- Modernising the teaching and research programmes and balancing the existing enrolment capacities pursuant to modern achievements and societal needs.
- Harmonization with European systems in higher education, an internationalisation and increase in the competitiveness of educational programmes at the international level.
- Financing research projects and PhD students with the funds of the Croatian Science Foundation.
- Financing research projects with European Funds and joint project applications with other Croatian or foreign institutions.
- Improving the scientific infrastructure by projects applications for European Structural Funds and applications of joint projects with the industry (e.g. Met4Pharm).
- Increasing the number of arrival and departure mobilities of students and employees at the level of the university, the national and international level.
- Establishing functional connections with other stakeholders in the educational system, the economy and the media.
- Unifying the research capacities in science, mathematics and biomedicine in the Northern Campus of the University of Zagreb.

Threats

- Lack of spatial integration of the professions of Biology, Geology and Geography within a single location at Horvatovac.
- Reduced funding from the state budget and inadequate funds from non-budget sources.
- Insufficient number of new scientific-teaching and assistant positions as well as postdoctoral positions.
- Insufficient level of funds drawn for research from the EU funds may lead to a worse position of the Faculty of Science compared to the research institutions in its surroundings.
- Inadequate investment from the state budget for the maintenance of the existing infrastructure.
- Prolonging the project of constructing the Northern Campus of the University of Zagreb.
- Unfinished legal framework for developing research work.
- Departure of quality personnel outside the Republic of Croatia.
- Loss of interest for studying natural sciences and lack of attractiveness and bad social status of teaching professions.

Strategic Objectives

Objective 1	**To increase the Faculty of Science presence in the global and particularly EU science**
Objective 2	**To retain the leading role of the Faculty of Science in Croatia and to ensure its high ranking in the region**
Objective 3	**To increase interdisciplinarity, multidisciplinarity, connections with**

University of Zagreb Faculty of Science

	the economy
Objective 4	**To increase the quality level of the research staff**
Objective 5	**To increase the connections of the education process with research results**
Objective 6	**To build contemporary and advanced scientific infrastructure**

OBJECTIVE 1. To increase the Faculty of Science presence in the global and particularly EU science.

In the recent 25 years, the Faculty of Science researchers mostly relied on the funding sources from the Republic of Croatia, while only a small percentage of them made efforts to obtain funds on the international level. The assessment of research results was mostly related to counting the papers cited in certain databases (e.g. Current Contents; a certain improvement has been made considering the classification in quartiles). The cause is predominantly related to the policy of promotion in Croatia and to a great extent also consequence of the legal framework. The promotion policy has not sufficiently considered the international presence visible in the projects and the quality of research. Some qualitative breakthroughs happened occasionally, mostly through appearance of professors with local influence on raising the quality level of work and thereby generating certain improvements. Although the „paper counting" trend had a positive impact on the development of science at the Faculty of Science and Croatia in general, its relation to development of quality was not always high enough; sometimes the authors relied on the quantity increase at the expense of quality.

Therefore, this objective is particularly demanding and requires a certain improvement in the Faculty of Science research activities. In attaining this long-term goal in the subsequent (to some extent transitional) period, we would rely primarily on the incentives.

(1A) Stronger reliance on the international projects (simultaneously continuing to attract the project funds from domestic funding sources). What should be sought is that each department, in proportion to the number of the scientific-teaching personnel, reaches an optimum number of applications to the international research projects in a 5-year period (reference is here made to major projects with the budget exceeding a certain amount, e.g. HRK 500,000 approximately, and not to minor international projects, which are also important for fostering the international cooperation). This objective requires:

- Design and implementation of incentive system for applications to competitive international projects and the system of awarding and stimulating the researchers managing to obtain important international projects (the same procedure should design the way of stimulating and awarding the leaders of major domestic projects, such as the Croatian Science Foundation, as well as professional and development projects, although the Faculty of Science applications to the Croatian Science Foundation projects are quite successful)
- Creation of strong administrative and financial support for the application and implementation of international projects, including the systematic monitoring and regular reporting about the conditions for applications to international projects, assistance in drafting the financial plan and preparation of the financial statements, elaboration of the financial distribution of indirect costs to stimulate the project application

University of Zagreb Faculty of Science

- Adequately promoting the results of successfully implemented projects within the Faculty of Science and in the public (hiring a qualified PR professional).

(1B) Stimulating high quality papers and other elements of scientific research.

- High valuation and awarding of authors of quality papers (e.g. papers in Nature and Science journals) and high-quality papers (e.g. high-quality journals within the given area, so that 1-3 papers from each department are awarded every year), i.e. elaborating and implementing the Ordinance for awarding the excellence and quality
- Marking and recognition of all elements of internationally recognized results of our scientists (plenary and invited lectures at important conferences and/or leading institutions, international awards, memberships in foreign academies, highly cited papers, visits and stays at the leading institutions, editorship in journals, and alike).

(1C) Stimulating the creation of excellent researchers' groups and supervisors' work.

- Adequate evaluation of supervisors' work (supervision of doctoral theses, scientific publications published jointly with the student (undergraduate, graduate, doctoral))
- Valuation of creating an internationally recognized group of researchers (leading such a group includes project applications, supervision and successful scientific research)
- Monitoring the impact of the former doctoral candidates on the development of science and economy in the Republic of Croatia.

(1D) Stimulating the visibility and international cooperation.

- Stimulating the scientific cooperation with co-authors from the relevant global research centres
- Improving the Faculty and Department scientific news and notifications
- Systematic promotion of scientific discoveries and knowledge in the media and on the social networks.

Attainment of Objective 1 would mean stimulating and strengthening the atmosphere of 'positive competition' at the Faculty of Science.

OBJECTIVE 2. To retain the leading role of the Faculty of Science in Croatia and to ensure its high ranking in the region.

The Faculty of Science in Zagreb is the leading research and teaching institution for science in Croatia. It is important to retain that position in the forthcoming period. For that purpose, it needs to monitor its position in the region in a better way and in more details. The aim is that at the end of the 5-year period, each Department of the Faculty of Science is among the 10 best departments in the CSE region (Central-Southeastern Europe, defined here as: Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Kosovo, Macedonia, Bulgaria, Romania, Moldavia, Hungary, Czech Republic, Slovakia and Poland) according to the international rankings. The Faculty of Science should also systematically monitor its scientific output in comparison with several universities in the wider region, in the developed or significantly larger countries. More precisely, comparison is needed with the universities in Trieste, Ljubljana, Graz, Budapest, Athens, Thessaloniki and Istanbul. The second strategic objective is to retain and promote the role of the leading scientific and teaching institution in Croatia. The long-term goal is to be among „Top 5 Faculty of Science" in the Southeastern Europe.

University of Zagreb Faculty of Science

(2A) Stimulating the promotion on the international lists. Adequate measures should be taken to move to a better ranking on the international lists (Shanghai and Leiden as references) for each of the areas of research of the Faculty of Science. A small but important measure within 2A is to ensure accurate and adequate address listing (affiliation) of the Faculty of Science on research and other papers.

(2B) Systematic recognition and emphasis on successful projects in the performance of the measures under 2B and attaining the status and advancement on the adequate international rankings.

OBJECTIVE 3. To increase interdisciplinarity, multidisciplinarity, connections with the economy.

Until now, the Faculty of Science has relied on the basic research and will keep it as a priority. The basic research nowadays, in addition to individual work, often require teams of scientists of complementary expertise. One of the expected roles of the scientific research at the universities is development of the economy, e.g. through development of new technologies. More space should be given to such forms of scientific cooperation at the Faculty of Science and measures should be undertaken that include:

(3A) Influencing the legislative and university institutions to adequately evaluate the scientific research with impact on the economy.

(3B) Strengthening the research based commercial activities.

- Establishing and running in the channel for assistance to the Faculty of Science researchers in patent applications
- Establishing and running in the channel for opening spin-off (or spin-out) companies at the Faculty of Science
- Stimulating within the legal and university acceptable framework that the Faculty of Science researchers start their own companies based on the generated knowledge
- Establishing licence-based relations
- Stimulating the research aimed for the application of knowledge within the scope of development and/or applied projects
- Stimulating the involvement in R&D projects.

(3C) Strengthening the interdepartmental research activities.

- Particularly stimulating the projects/scientific papers involving several departments
- Common planning of the development of insufficiently present areas, with strong interdisciplinary potential: computer science, education research in the fields of the Faculty activities, medical physics
- Organising the Faculty scientific colloquia
- Strengthening the connections of the doctoral study programmes at the Faculty.

OBJECTIVE 4. To increase the quality level of the research staff.

Although the personnel policy depends to a large extent about the government institutions (Ordinance on Elections to Titles; Science and Higher Education Act) and the University (Rectors' Conference conditions), the Faculty of Science should adjust certain elements of the personnel policy in harmony with the global trends. Besides, the Faculty of Science researchers may act publicly

University of Zagreb Faculty of Science

toward the University, Croatian Parliament, Ministry of Science and Education and other relevant institutions to exert influence on the changes in the legal framework aimed to align that part of the system with the global trends.

(4A) Stimulating the hiring and promotions in accordance with these strategic objectives.

- Valuing of internationally recognized and visible research success and leadership of strong projects
- Valuing the creation of recognized groups of researchers
- Valuing the development of individual scientific professions of strategic national significance or value of direct importance for the Faculty of Science for retaining the leading position in science in Croatia
- Planning the development of certain areas: stimulating the education research in the fields of activity of the Faculty of Science for all levels and types of education and investment in development of computer sciences
- Actively seeking successful candidates in the Republic of Croatia and the European Union for project applications, increasing the visibility of calls.

(4B) Mobility and international presence in the personnel policy.

- Stimulating successful international cooperation (related to 1D)
- Strengthening the focus on personnel (postdoctoral staff, assistant professors, full professors) with international experience in the postdoctoral training abroad, as visiting scientists/professors; e.g. providing adequate substitute in the teaching process for the scientific-teaching personnel wishing to attend the training abroad.

OBJECTIVE 5. To increase the connections of the education process with research results.

The Faculty of Science has a large number of standard programmes which mostly cannot be changed too much. What should be used is the Faculty of Science positive brand (quality, high level, global relevance) in research, to develop new forms of education adjusting to trends and needs of the society (e.g. actuary mathematics study programme, organized in cooperation with the British actuarial experts, Croatian Actuarial Association and the Ministry of Finance of the Republic of Croatia is a good example of such cooperation). The following measures are planned:

(5A) Improving the organisation of doctoral study programmes; better connections of the professions, attracting international students.

(5B) Strengthening the impact of the recent scientific knowledge on the graduate study programmes and the final year of the integrated study programmes.

- Constant development of the courses and programmes, keeping up with the development of the fields of research, and elective courses responding to the needs for the development of interdisciplinarity and multidisciplinarity
- Monitoring the employment possibilities of students, assistance to development of the Republic of Croatia.

University of Zagreb Faculty of Science

(5C) Developing the education research in the fields of the Faculty activities (for all levels and types and education). Taking as an example the leading education research centres in Europe and comparing them with the development of education research in CSE.

(5D) Including the recent scientific knowledge and new technologies in the life-long education.

- Development of specialist study programmes
- Other forms of such relations.

OBJECTIVE 6. To build contemporary and advanced scientific infrastructure.

The strategic interest of the Faculty of Science in the subsequent 5-year period is to develop and maintain the scientific infrastructure in its field of activity, using the funds from the European funds and other projects. This includes the drafting of the Scientific Equipment Catalogue to ensure its high quality and extensive use by the Faculty of Science researchers as well as by other interested parties.

Through CIUK and CENIKS projects within several years, the Faculty of Science will significantly modernize and build its scientific infrastructure in the fields of chemistry and physics. In addition to such projects, it is important to invest maximum efforts to apply to the future calls for structural funds and other financing sources. Maximum efforts are required to ensure the spatial development of the Faculty of Science follows the construction of contemporary and advanced scientific equipment. Specifically, the construction of the BGG building should begin.

What should be noted is that the objectives are not numbered by order of importance so that e.g. Objective 1 is not considered more important than Objective 2, Objective 2 is not considered more important than Objective 3, etc. Further, the implementation of all objectives is planned simultaneously. However, for some of the research projects, reaching one objective may significantly facilitate the reaching of another objective. Specifically, this is the case with Objective 6, highlighting one of the weaknesses (Current spatial detachment and inadequacy of the spatial position of some of the elements for science departments complicate the scientific and teaching activities and adequate administrative activities). What should be noted is that not all departments are at equal position. The Department of Geography has been moved out, compared to the Departments of Mathematics, Physics, Chemistry and Geophysics, but it is at a single location in the same building. The Department of Biology is in an unfavourable situation being located on four different locations in four buildings; besides the premises of two Divisions of the Department of Biology are at several locations (Botany Division on three locations, Microbiology Division on two locations). For that reason, the contemporary development of certain research needs first the reaching of Objective 6, so that other objectives may be reached further. Reaching that objective would enable better connections between the Departments of Biology and Geography with others and facilitate the attainment of Objective 3.

Table of Measures/Activities with Planned Results

Table below presents the measures/activities with the corresponding results for each measure (if applicable) as well as the coordinators and authorities in charge of the activities.

The table contains the results related to the **organisational structure of the institution.** Specific plans include the project office or unit that will be engaged in the administrative management of major

projects and assistance during their application, and Centre for Advanced Computer Science, as measures directly contributing to the attainment of Objectives 1, 2 and 3. We do not find it necessary to restructure the departments at this moment but only the system functioning should be improved with minor amendments in the organisation.

The table contains also the **performance indicators related to scientific and professional training of the doctoral candidates and postdoctoral staff**. Namely, one of the performance indicators of the measures leading to Objective 1 (and thereby Objective 1 itself) is the increase in the number of doctoral candidates and postdoctoral staff trained at the Faculty of Science.

Activities/Measures – for Reaching of Strategic Objectives				
No.	Activity/Measure	Activity Coordinator; responsible persons and authorities	Final date for completion (from the Strategy adoption date)	Result/ Performance Indicator (5-year term target value, if applicable)
OBJECTIVE 1. To increase the Faculty of Science presence in the global and particularly EU science				
1.1.	Stronger reliance on the international projects (with continued funding from domestic projects)	Coordinator: Vice-Dean for Science and Doctoral Studies; Dean, Department Heads, Faculty Board, Department Councils	Continuously	
1.1.a	Design and implementation of incentive system for applications to competitive international projects; adoption of internal document on awarding excellence and quality	Coordinator: Vice-Dean for Science and Doctoral Studies; Dean, Department Heads, Faculty Board, Department Councils	1 year	System implemented, internal document adopted
			4 years	Increased number of researchers in associate titles (doctoral candidates and postdoctoral staff) by 5 to 10 %
1.1.b	Design and implementation of a system of incentives for the leaders of domestic research projects within the scope of the internal document on awarding excellence and quality	Coordinator: Vice-Dean for Science and Doctoral Studies; Dean, Department Heads, Faculty Board, Department Councils	1 year	System implemented; internal document adopted
			4 years	Increased number of researchers in associate titles (doctoral candidates and

				postdoctoral staff) by 5 to 10 %
1.1.c	Design and implementation of a system of incentives for leaders of all other projects related to the scientific research (professional, R&D, etc.), not mentioned in 1.1.a and 1.1.b	Coordinator: Vice-Dean for Science and Doctoral Studies; Dean, Department Heads, Faculty Board, Department Councils	1 year	System implemented; internal document adopted
1.1.d	Creation of strong administrative and financial support for the application and implementation of international projects; education of current employees, taking particular care of the new recruitments, design and implementation of adequately capacitated project office	Coordinator: Vice-Dean for Science and Doctoral Studies; Department Heads, Dean, Faculty Board, Department Boards	3 years	Project office, or established unit that will be engaged in administrative management of major projects and assistance in applications for such projects (or current Office of International Cooperation strengthened with human resources)
1.1.e	Adequate presentation and promotion of the results of successfully completed superior projects within the Faculty of Science and in the public; creation of a PR position and hiring a qualified person at that position	Coordinator: Vice-Dean for International Cooperation; Faculty Board	2 years	Hired qualified person
1.2.	Stimulating high quality papers	Coordinator: Vice-Dean for Science and Doctoral Studies; Dean, Department Heads, Faculty Board, Department Councils	Continuously	

1.2.a	High valuing and awarding of authors of quality papers, elaborating and implementing the Ordinance for awarding the excellence and quality (see 1.1.a)	Coordinator: Vice-Dean for Science and Doctoral Studies; Dean, Department Heads, Faculty Board, Department Councils	1 year	System implemented; Internal act on awarding the excellence adopted
1.2.b	Marking and recognition of all elements of internationally recognized results of our scientists	Department Heads	Continuously	Adequate design and maintenance of websites
1.3.	Stimulating creation of excellent researchers' groups and supervisors' work	Coordinator: Dean; Faculty Council, Faculty Board, Department Councils	Continuously	
1.3.a	Adequate valuing of supervisors' work; conducting a structured discussion about the ways of awarding the supervision of doctoral theses, and of diploma papers published in scientific publications, the Faculty of Science will conduct a structured discussion about it with the specific conclusions that will be subsequently implemented	Coordinator: Dean; Faculty Council, Faculty Board, Department Councils	1 year for the structured discussion and conclusions, 1 year for implementation of conclusions	Structured discussion implemented, conclusions adopted, conclusions implemented
1.3.b	Valuing of creation an internationally recognized group of researchers; conducting a structured discussion about the ways of awarding the creation and leading of an internationally recognized group through leading of competitive projects	Coordinator: Dean; Faculty Council, Faculty Board, Department Councils	1 year for the structured discussion and conclusions, 1 year for implementation of conclusions	Structured discussion implemented, conclusions adopted, conclusions implemented
1.3.c	Monitoring the impact of the former doctoral candidates on the development of science and economy in the Republic of Croatia	Coordinator: Department Heads; Faculty Board, Department Councils	3 years	Initiated alumni organisations for each department and organising of annual alumni meetings

1.4.	Visibility and international cooperation	Coordinator: Vice-Dean for International Cooperation; Faculty Board	Continuously	
1.4.a	Stimulating the scientific cooperation with co-authors from the relevant global research centres; e.g. organisation of the Days of International Cooperation at the Faculty of Science (once a year) where scientists cooperating with the most prestigious global centres would be noted	Coordinator: Vice-Dean for International Cooperation; Faculty Board	Continuously, once per year	Organized Days of International Cooperation
1.4.b	Improving the Faculty and Department scientific news and notifications	Coordinator: Vice-Dean for Science; Department Heads, Faculty and Department Boards	1 year	Upgraded and improved existing system of Department and Faculty notifications
OBJECTIVE 2. To retain the leading role of the Faculty of Science in Croatia and to ensure its high ranking in the region				
2.1.	Monitoring the position of the Faculty of Science professions at the international ranking lists with the analysis of the results which made certain progress; analysis of the measures with which each of the Faculty of Science areas could make progress to a better position on the international ranking lists (taking Shanghai and Leiden as reference); taking such measures	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	Continuously	
2.2.	Systematic recognition and emphasis on successful departments (professions) in advancement on the adequate international rankings. Proposal: Presenting the positions of the professions and the departments on the	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	Continuously	Once per year presenting the position of the professions in comparison with the institutions in the surroundings

	Faculty Day (see 2.2.a)			
2.2.a.	Using the Shanghai and Leiden lists, create a performance index of the departments (scaled to the number of people), with the understanding of the specific properties of the professions; this measure is required as the global rankings take into consideration not only the Faculty of Science departments but also a wider scale (same professions at the other faculties) and the contribution of the Faculty of Science departments at such rankings should be singled out	Coordinator: Vice-Dean for Science; Department Heads, Faculty Council, Department Councils and Boards	1 year	Accepted formula for performance index
2.2.b.	Comparison of the position of the professions with the universities in Trieste, Ljubljana, Graz, Budapest, Vienna, Athens, Thessaloniki and Istanbul	Coordinator: Vice-Dean for Science; Department Heads, Faculty Council, Department Councils and Boards	5 years	Relative promotion to a higher rank in the 5-year period for at least two of seven professions in comparison with the above-mentioned institutions
Objective 3. To increase interdisciplinarity, multidisciplinarity, connections with the economy				
3.1.	Influencing the legislative and university institutions to adequately value the scientific research with impact on the economy	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	Continuously	

3.1.a.	Organising the systematic discussion with the specific conclusions: How to value the influence of scientists to the economy in promotion and recruitment? How to value the start-ups and spin-offs? How to value in a higher quality manner the projects with commercial entities?	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	2 years	Drafted document with the conclusions on how to intensify the involvement of the scientific-teaching personnel and the research results into the commercial sector
3.2.	Strengthening the research based commercial activities	Coordinator: Vice-Dean for Science; Department Heads, Faculty Council, Department Councils and Boards	Continuously	
3.2.a.	Establishing and running in the channel for assistance to the Faculty of Science researchers in patent applications; organising workshops on intellectual property protection	Coordinator: Vice-Dean for Science; Department Heads, Faculty Council, Department Councils and Boards	Continuously	At least 2 workshops held
3.2.b.	Establishing and running in the channel for opening spin-off (or spin-out) companies at the Faculty of Science; organising the workshops on opening of such companies	Coordinator: Vice-Dean for Science; Department Heads, Faculty Council, Department Councils and Boards	Continuously	At least 2 workshops held

3.2.c.	Stimulating within the legal and university acceptable framework that the Faculty of Science researchers start their own companies based on the generated knowledge; establishing the licence related relations, for instance adoption of Faculty Council decision that authors of patents (Faculty of Science researchers as individuals) within the scope of projects conducted at the Faculty of Science, obtain certain percentage of finance (e.g. 30 – 50 %); the Faculty Council should adopt a decision enabling the patent authors to start private companies to which the Faculty of Science will provide free licences to such patents; the Faculty of Science will conduct a structured discussion about it with the specific conclusions that will be subsequently implemented	Coordinator: Dean; Faculty Board, Department Heads, Faculty Council, Department Councils and Boards	1 year	Structured discussion conducted with specific conclusions to be implemented subsequently (e.g. adopting the adequate decisions of the Faculty Board),
3.2.d.	Stimulating the research aimed for the application of knowledge within the scope of development and/or applied projects	Coordinators: Department Heads; Department Councils and Boards, Faculty Board	Continuously	Structured discussion conducted with specific conclusions to be implemented subsequently (e.g. adopting the adequate decisions of the Faculty Board)

3.3.	Strengthening the interdepartmental research activities	Coordinators: Department Heads; Vice-Dean for Science and Doctoral Studies, Department Councils and Boards, Faculty Board	Continuously	
3.3.a.	Particularly stimulating the projects/scientific papers involving several departments and several organisational units of the University of Zagreb, as well as common planning of the development of insufficiently present areas, with strong interdisciplinary potential: computer science, education research in the fields of the Faculty activities; constantly monitoring the number of projects involving several departments	Coordinators: Department Heads; Vice-Dean for Science and Doctoral Studies, Department Councils and Boards, Faculty Board	Continuously 2 years	5 common interdepartmental projects applied for in 5 years Centre for Advanced Computational Science established
3.3.b.	Organising the Faculty scientific colloquia	Vice-Dean for Science, Department Heads	6 months	Colloquia concept discussed, colloquia started
3.3.c.	Strengthening the connections of the doctoral study programmes at the Faculty; continuation of holding the days of doctoral studies and symposia of the doctoral students, increasing the students' information about the courses of the other study programmes	Vice-Dean for Science, Heads of Doctoral Programme	Continuously	Once in 2 years Day of Doctoral Programme and Symposium of doctoral students held
OBJECTIVE 4. To increase the quality level of research staff				

4.1.	Systematisation of the recruitment and promotion policy	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	2 years	
4.1.a.	Valuing of internationally recognized and visible research success and leadership of strong projects, by means of Measures 4.1.a, 4.1.b, 4.1.c and 4.1.d, a structured discussion will be organized with the Faculty authorities with the specific conclusions	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	2 years	Structured discussion conclusions adopted to be subsequently implemented
4.1.b.	Valuing the creation of recognized groups of researchers	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	2 years	Structured discussion conclusions adopted to be subsequently implemented
4.1.c.	Valuing the development of individual scientific professions of strategic national significance or value of direct importance for the Faculty of Science aimed to retaining the leading position in science in Croatia	Coordinator: Dean; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	Two years	Structured discussion conclusions adopted to be subsequently implemented
4.1.d.	Actively seeking successful candidates in the Republic of Croatia and the European Union for project applications, maximum use of returning scientists	Department Heads, Department Boards	Continuously	5 applications sent for returning scientists' positions in 5 years
4.1.f.	Planning the development of certain areas: stimulating the education research in the fields of activity of the Faculty of Science for all levels and types of education	Coordinator: Vice-Dean for Teaching; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	Continuously	

4.1.g.	Investing in development of computing sciences; stimulating the projects in the fields which the Faculty of Science is engaged in, which are closely related to the computer science	Coordinator: Vice-Dean for Science; Faculty Board, Faculty Council, Department Heads, Department Boards and Councils	Continuously	
4.2.	Mobility and international presence in the personnel policy	Coordinators: Department Heads and Vice-Dean for International Cooperation; Department Councils and Boards, Faculty Board		
4.2.a.	Stimulating successful international cooperation, particularly cooperation of superior quality (related to 1.4)	Coordinator: Vice-Dean for International Cooperation; Faculty Board, Department Councils and Boards	Continuously, once per year	Days of International Cooperation organised
4.2.b.	Strengthening the focus on personnel (postdoctoral staff, assistant professors, full professors) with international experience in the postdoctoral training abroad, as visiting scientists/professors; discussing within the scope of the measures under 4.1.	Coordinators: Department Heads; Department Councils and Boards	2 years	Structured discussion conducted, conclusions made and implemented, see 4.1.
OBJECTIVE 5. To increase the connections of the education process with research results				
5.1.	Improving the organisation of doctoral study programmes; better connections of the professions, attracting international students	Coordinator: Vice-Dean for Science and Doctoral Studies; Heads of Doctoral Studies, Department Councils	Continuously	Day of Doctoral Programmes organized once in 2 years
5.2.	Strengthening the impact of the recent scientific knowledge on the graduate study programmes and the final year of the integrated	Coordinator: Vice-Dean for Teaching; Department Heads, Department Boards and Councils	Continuously	

	study programmes			
5.2.a.	Constant development of the courses and programmes following the development of the fields of research, and elective courses responding to the needs for the development of interdisciplinarity and multidisciplinarity	Coordinator: Vice-Dean for Teaching and Vice-Dean for Science; Department Heads, Department Boards and Councils	Continuously	
5.2.b.	Monitoring the employment possibilities of students, assistance to development of the Republic of Croatia	Coordinator: Vice-Dean for Teaching; Department Heads, Department Boards and Councils	Continuously, once per year	At the Faculty Board and other relevant authorities, presented Bulletin of the Employment Service including the information on labour market needs
5.2.c.	Attracting the international students	Coordinator: Vice-Dean for Science; Department Heads, Department Boards and Councils	Continuously	
5.3.	Developing the education research in the fields of activities of the Faculty (for all levels and types and education); taking as an example the leading education research centres in Europe and comparing them with the development of education research in CSE	Coordinator: Vice-Dean for Teaching; Department Heads, Department Boards and Councils	Continuously	
5.4.	Development of the life-long education and science programmes; organisation of seminars and/or summer schools for primary and secondary school teachers	Coordinator: Vice-Dean for Teaching; Department Heads, Department Boards and Councils	Continuously	
5.4.a.	Development of specialist study programmes; analysing the market needs for specialist programmes and as	Coordinator: Vice-Dean for Teaching; Department Heads, Department Boards and Councils	Continuously	

	needed initiating the preparation of such study programmes			
OBJECTIVE 6. To build contemporary and advanced scientific infrastructure.				
6.1.	Drafting the Scientific Equipment Catalogue	Coordinator: Vice-Dean for International Cooperation; Department Heads	One year, continuously	Catalogue published
6.2.	Implementation of the CIUK Project	Head of Department of Chemistry	3 years	Project completed
6.3.	Implementation of the CENIKS Project	Head of Department of Physics	3 years	Project completed
6.4.	Application to the calls for funding from the European Structural Funds, H2020, FP7, Croatian Science Foundation and other funding sources	Department Heads, Vice-Dean for Science	Continuously	
6.5.	Construction of BGG building	Coordinator: Vice-Dean for Investment and Development; Dean, Faculty Board, Heads of BGG Department	3 years	Obtaining location permit and resolving the property matters on the land plot, drafting the main design

Intended Research Topics and Links with the Strategic Objectives

The Faculty of Science researchers have full academic freedom in the selection of their research topics. This opinion is in harmony with the principle that academic freedoms belong to all academic community members and encompass the freedom of scientific and artistic research and creation, teaching, cooperation and association. This strategy determines the strategic objectives and fields of research at the Faculty of Science. However, what should be noted is that if any individual selects a research topic out of the scope of this strategy, in alignment with the stated academic freedom, such research should be possible to conduct. Further, what should also be noted is that the Faculty of Science researchers should conduct their research in accordance with the University of Zagreb Code of Ethics, including ethical standards and rules. Most of the research to be conducted at the Faculty of Science in the forthcoming 5-year period will be within the scope of this strategy.

The text below and Appendix B include a detailed description of the strategy elements that refer to the specific Departments of the Faculty of Science. They set out specific directions of the scientific research and the activities conducted at the Departments. For all these activities, their contribution to and alignment with the six strategic objectives of the Faculty of Science are mentioned. The Faculty of Science will invest maximum efforts to perform the required measures in the following five

University of Zagreb Faculty of Science

years to reach the mentioned objectives, which will contribute to raising the quality of the research at the Faculty.

Department of Mathematics

The Department of Mathematics of the Faculty of Science is the centre of all mathematical research in the Republic of Croatia. It employs approximately a quarter of the active mathematical researchers in Croatia and coordinates more than two thirds of the research projects in mathematics. By that very fact, the Department of Mathematics has the obligation to care for the development of mathematics in the Republic of Croatia as a whole.

The research at the Department of Mathematics may be divided into three groups: Theoretical Mathematics, Applied Mathematics and Computing.

In each of these groups, many activities can be listed. Thus, within the scope of the Theoretical Mathematics, there are very important and internationally recognized groups for representation theory, Lie algebras, operator theory, number theory, mathematical logic, dynamical systems, differential equations and stochastic processes. Particularly noteworthy is the Centre of Research Excellence QuantiXLie as a good example of synergy of physics and mathematics in alignment with Objective 3.

Among the Applied Mathematics research, particularly noteworthy is numerical linear algebra, scientific computing, fluid mechanics, theory of elasticity, statistics, biomathematics and biostatistics, financial mathematics, numerical analysis of differential equations and mathematical modelling.

When it comes to Computing, here is particularly mentioned the research close to mathematics. Particularly this refers to development of distributed algorithms in optimisation on graphs and application of mathematical logic in the theoretical computing. The research related to mathematical logic has quite a long tradition at the Department of Mathematics, and the intention is to intensify such research for their application in the theoretical computing (formal programme verification and formal cooperation systems). Then, there is the research focusing on machine learning and data engineering, with the plans to establish a Centre for Advanced Computational Sciences, in cooperation with the Department of Physics, but also with the Department of Biology. The first step in that direction is the joint application for ERA Chair call, which is currently being thoroughly prepared.

There is intensified cooperation among the above-mentioned groups and a lot of overlapping among some of the mentioned topics. A good example of this is the above-mentioned research in the mathematical logic and theoretical computing or research by the group for applied mathematics, developing the mathematical models based on which numerical algorithms are developed by experts for numerical mathematics. Of course, in the analysis of such models, the basic mathematical knowledge about differential equations, dynamical systems, general topology, differential geometry and functional analysis are used. The research in biomathematics, biostatistics and financial mathematics are by their very nature interdisciplinary and are strongly connected to the basic research in probability and statistics. Further, biomedical mathematics is an enormous potential for interdepartmental cooperation on the scientific as well as on the teaching level, as we already mentioned in Objectives 3 and 5. In accordance with that, intensified cooperation has been initialized between the Department of Mathematics, the Department of Biology, the Faculty of Medicine of the

University of Zagreb Faculty of Science

University of Zagreb, and the *Ruđer Bošković* Institute to introduce a new programme in biomedical mathematics to be provided in English.

An important factor in the attainment of these objectives is the personnel policy systematically conducted by the Department Council for Promotions and Recruitment.

Department of Physics

In alignment with the Faculty of Science strategic objectives, the fundamental basis for the Development Strategy of the Department of Physics is to continue and further develop the established research in the field of physics (directly contributing to Objectives 1 and 2) which are unavoidably the starting point of the higher education at the Department (in accordance with Objective 5, the connections of the education process with research results should be increased additionally). We are witnessing great and fast changes in science, technology and higher education in today's society. The Department of Physics is open to such changes and is keeping up with them in reliance on its rich and long tradition.

Considering the need to systematically cover all important areas of research in the modern physics with our scientific activities, there are several areas of focus standing out as main strategic interests. In theoretical physics, that is primarily quantum physics of many particle systems, encompassing essentially the research in theoretical physics of condensed matter, nuclear and atomic physics, as well as research of complex systems in biophysics and photonics. The significance of such theoretical research at the Department of Physics is visible in the initiation of the Centre of Research Excellence for Quantum and Complex Systems and Representation of Lie Algebras – „QuantiXLie" – gathering also the physicists from other institutions as well as mathematicians from the Faculty of Science and its collaborating institutions. The Centre objectives include the building of cooperation among various fields of the theoretical research on the overlapping topics – thus automatically striving to fulfil Objective 3 of the Faculty of Science strategy (i.e. increasing the interdisciplinarity and multidisciplinarity), particularly Objective 3C, strengthening the interdepartmental research activities. Another strategic focus is the research in theoretical physics and, also with a long tradition, physics of elementary particles, gravitation and cosmology.

The areas of research within the scope of experimental physics, which would be strengthened as a strategic priority within the laboratories at the Department of Physics, are primarily physics of complex and functional materials (multiferroics, superconductors, quantum magnets, metallic glasses and alloys...). In that area, there are already well equipped and scientifically recognized laboratories for low temperatures and strong magnetic fields, for solid state NMR and high frequency measurements, for micro-structure research, for research of magnetic and electric phenomena, as well as for measurement of transport, magnetic and thermodynamic properties. The intention is to intensify the current research in near future with the CeNIKS project (which has met the criteria of project admissibility and quality assessment and has been forwarded to the next phase of the procedure for award of non-refundable finance) and then also with the Centre for Advanced Materials and Nanotechnology project (for which the application will be submitted for the RDI infrastructure projects of the European Regional Development Fund RCOP (Regional Competitiveness Operational Programme)), and partially with other projects (including H2020 and Croatian Science Foundation projects) – all of them directly fitting into Objective 6 of the Faculty of Science strategy, systematic building and maintenance of the research infrastructure. The CeNIKS project will also

serve to invest in the opening of new opportunities of research in complex materials: infrared spectroscopies and elipsometries and equipment for sample synthesis and processing. The research within experimental physics of other area (atomic physics, astrophysics, nuclear physics, physics of elementary particles, biophysics) would be conducted within the scope of the existing or new cooperation projects (Objective 3) with the institutes in the Republic of Croatia (primarily the *Ruđer Bošković* Institute and the Institute of Physics) and abroad, with small range measurements in the laboratories at the Department of Physics. Further development in this area is planned to be provided with the Centre for Advanced Materials and Nanotechnology project in cooperation with the Chemistry, Geology and other Departments of the Faculty of Science (in alignment with Objective 3C). The Centre is planned to expand the capacities required for closing the circle from the basic research to the development and application of high technology products. The Centre will also provide support to the companies in the sector of high added value, for transfer of technology into the knowledge-based commercial activities (in alignment with Objective 3). In cooperation with the Zagreb university hospital centres and the *Ruđer Bošković* Institute, the Department will continue improving the research in the field of medical physics (contributing thereby to Objectives 2, 3 and 5).

Significance of all research is in keeping and improving the expert opinion in all relevant areas of modern experimental physics, as a prerequisite for successful education of students at the highest level (Objective 5 – to increase the connections of the education process with the scientific research).

Projects such as QuantiXLie and CeNIKS, in addition to all mentioned above, are planned to increase the presence of the Department of Physics and the Faculty of Science in the European and the global science (Objective 1), to retain and strengthen the position of the Faculty of Science in the regional science (Objective 2), and to start systematically building and reconstructing the scientific infrastructure (Objective 6). The CeNIKS projects has obtained support from eleven companies in the commercial sector and has great chances in attaining Objective 3 (namely the part concerning the strengthening of the connections with the economy). In addition to these projects, which are already close to their implementation phase, there are preparations for many other project applications for international funding sources (Objective 1A) and there are also plans for active stimulation of young employees to propose projects funded by domestic (Croatian Science Foundation, University) and international institutions.

The Department of Physics will be particularly engaged in establishing the Centre for Advanced Computing Sciences at the Faculty of Science, in cooperation with the Mathematics, Biology and other Departments of the Faculty of Science (in alignment with Objective 3C), having in mind that the development and methods of advanced computing are universal in the field of science and that their application today is necessary not only for progress in modern theoretical research but also in experimental research. Within the scope of establishing the new centre, joint applications are planned with the Mathematics and other Departments of the Faculty of Science to Horizon 2020 calls but also to calls from the European Structural and Investment Funds. The first project application within the scope of establishing the Centre for Advanced Computational Science at 2020 ERA Chair call is strongly supported by the Ministry of Science and Education of the Republic of Croatia and the National Protection and Rescue Directorate, but also nine major IT and high technology companies, which confirms the strong development potential for participation in resolving relevant social challenges and cooperation with the economy (Objective 3B).

University of Zagreb Faculty of Science

An important factor in the attainment of these goals is the personnel policy systematically conducted by the Council of Department of Physics in its extended composition, thus contributing to Objective 4.

Department of Chemistry

The Development Strategy of the Department of Chemistry of the Faculty of Science, University of Zagreb, as a recognized scientific research institution in the field of chemistry, relies on its long tradition in the implementation of basic and applied research. In doing that, the Department of Chemistry has always made efforts to reach the standards of the research and teaching activity of the European and the global centres of research excellence, through adequate personnel policy (Objective 4 of the Faculty of Science Development Strategy), through inclusion of students into the research of the Department, but recently also through strengthening the students arrivals and departures mobility (Objective 5 of the Development Strategy). To continue providing high quality education and development of young researchers as the future stakeholders of research activity and to contribute to the development of the competitive economy through transfer of knowledge and technologies, the Department of Chemistry plans to strengthen the existing areas but also to stimulate some new research paths.

The research activity intended to be developed through the Department of Chemistry of the Faculty of Science encompasses several areas. One of them includes biochemical, bioinformation, computing, proteomic and genetic research of gene information transfer and protein biosynthesis in all three life areas and gaining a detailed insight into selected biochemically important processes. This area is naturally supplemented with the studies of interactions of pharmacologically active molecules with biomacromolecules in solution, *in vivo* biological research (Objective 3), as well as structural research of solid state biomacromolecules. Another important branch of research is based on the design and synthesis of functional organic and inorganic systems, with special attention focused on design of fast, environment friendly and energy efficient methods of their preparation. This unavoidably includes characterisation and testing the properties of prepared solid-state compounds and their behaviour in the solution, which joins the areas such as spectroscopy, thermodynamics, X-ray structure analysis, chemical kinetics, supramolecular chemistry, chemometrics, colloid and interface chemistry, electrochemistry and thermal analysis. Development of process analysis methods and development and application of adequate methods for analysis of real samples, such as those from the environment, is another important research path with the long tradition within the scope of the Department of Chemistry. Finally, an important part of the Department research is the research in the field of computational and theoretical chemistry which, in accordance with the global trends, becomes increasingly important. What should be noted is that the Department of Chemistry employees have participated for many years in the preparation and implementation of scientific projects (e.g. UKF, FP7, FIRCA-NIH, bilateral and Croatian Science Foundation projects) cooperating with the researchers in Croatia (University of Zagreb, University of Osijek, University of Split, *Ruđer Bošković* Institute, Institute of Medical Research and Occupational Health, Institute of Immunology, Maritime Technology Institute) as well as abroad (in the recent ten years, cooperation has been achieved with the researchers from more than 80 institutions from 20 countries of the world). The Department of Chemistry has scientific cooperation also with the researchers employed at the Biology, Geology and Department of Physics of the Faculty of Science. In alignment with Objectives 2 and 4 of the Faculty of Science Development Strategy, these forms of

cooperation are intended to be additionally strengthened, particularly in the area of multidisciplinary research.

In order to ensure competitiveness of the Department of Chemistry researchers on the international level, there are constant efforts on the strengthening and improvement of the current infrastructure, in favour of which speaks the successful Met4Pharm project in partnership with PLIVA d. o. o., funded from the European Regional Development Fund. Within the scope of that project, the Department of Chemistry was equipped with a high-performance NMR spectrometer. Noteworthy is also the CiUK project application submitted at the Ministry of Science and Education call, Preparation of a Stock of Infrastructure Projects for EFRR 2014 – 2020, which is currently in the evaluation process. Within the scope of that project, the Department of Chemistry should strengthen its infrastructure capacities (Objective 6 of the Faculty of Science Development Strategy). The Department of Chemistry employees intend to apply to similar public calls in future.

One of the major strategic objectives of the Department of Chemistry is the continuation of the former successful cooperation with partners in the commercial sector and its strengthening and expanding (Objective 3 of the Faculty of Science Development Strategy). Namely, in the recent 10 years, the Faculty of Science Department of Chemistry staff conducted 2 scientific and 23 professional projects in cooperation with the representatives of the economy. Besides, the cooperation with the representatives of the pharmaceutical, food processing and petrochemical industry has resulted in the publication of 28 research papers and 5 doctoral theses as well as three diploma theses, with the topics related to resolving the specific problems encountered in the commercial sector. Such a form of cooperation, which should be intensified after the planned strengthening of the structural capacities, contributes to the lifelong education of researchers in the commercial sector (Objective 5 of the Faculty of Science Development Strategy).

Department of Biology

The Department of Biology builds its Development Strategy, following the objectives of the Faculty of Science Strategy, on the link between the tradition and the contemporary research fields, developed in response to the changes in the science, economy and the social environment. In terms of teaching, the Department of Biology intends to remain a recognizable centre of education of biological and interdisciplinary university programmes in the Republic of Croatia with the constant improvement of the teaching process and the adequate flexibility in responding to the requirements of the current market demands, which fits into Objective 5 of the Faculty of Science. The plan is to continue the cooperation with other Departments within the Faculty of Science and to intensify the international cooperation and the cooperation with the public sector and the economy, in alignment with Objectives 1 and 3.

The main strategic interests at the Department of Biology in the period to come include several research areas. The research of the biodiversity of Croatia and the neighbouring biogeographically connected areas joins the phylogenetic, phylogeographic and ecological research with an intensified cooperation with the scientists from the neighbouring countries but also on a wider basis. The international significance of such research is visible in several Interreg projects in which the Department of Biology researchers are either leaders or partners and in participation in the COST action projects, as well as in a number of applications to international competitive projects, supporting Objectives 1 and 2 of the Strategy. Special attention will be paid to the research of global

climate changes and the impact of foreign species to the stability of the communities. The ecological research is deepened with the research in the fields of evolutionary ecology, ecological genomics, ecotoxicology and archeobotany.

One of the strategic topics of the research is the research of the impact of stressful conditions on plant and animal models, as well ecophysiological, ecotoxicological and phytochemical research and the research in the field of plant reproduction biology potentially applicable in the improvement of yield of commercially significant crops, discovery of new biomarkers, production of medications and preservation of biodiversity of the Republic of Croatia (Objective 3). An important contribution to the research is planned through the participation of the Department of Biology researchers in the Centre of Research Excellence for Biodiversity and Molecular Plant Breeding (CroP-BioDiv), led by the University of Zagreb Faculty of Agriculture. The research will continue of the forms of cell specialisation and differentiation during the reproductive development and embryogenesis, evolution of plant and animal genome on the molecular-cytogenetic level with the use of contemporary data analysis methods obtained through the new generation sequencing methods, as well as development and use of chromosome engineering methods in the plant breeding and manipulation of biosynthetic routes for the purpose of production of usable secondary metabolites through the application of plant tissue cultivation techniques. In accordance with that, the cooperation will continue with many domestic (University of Split, *Ruđer Bošković* Institute, etc.) and international research centres (University of Vienna, University of California Davis, Queen Mary University of London, University of Ljubljana, etc.). The plan is to continue the genetic analysis of the bacterial defence mechanisms with CRISPR-Cas system, which will be additionally deepened through the cooperation with the Faculty of Science Department of Chemistry and the associates from abroad.

Biomedical research in various fields will be systematically stimulated: neurophysiological, endocrinological, epigenetic and metagenomic, as well as the research of the impact of bioactive substances of plants and their impact on the cells and tissues of various organisms. The equipment and tools required for the research will be provided with the projects of the Centres of Research Excellence: CoRE for Basic, Clinical and Translational Neuroscience in which the Faculty of Science is a partner with other faculties, hospitals and commercial entities (in alignment with Objective 3). Also, through the Horizon 2020 projects (Objectives 1 and 6), the aim is to provide the new premises with safe work conditions including lentiviral vectors for introducing CRISPR/Cas9 constructs into various animal cells and to establish the so-called cleanroom. Exceptionally relevant is the research of flexible molecular tools for precise epigenetic modulation and modulation of gene expansion, as well as their application in the reprogramming of pathogenic into normal state of immunology system cells, research of the molecular biology of tumours, application of stem cells in the regenerative medicine and tissue engineering and development of methods for the analysis of data obtained by next-generation sequencing methods.

For years, the Department of Biology has been recognized in Croatia as the leading institution for education of persons working with experimental animals in form of LabAnim professional training course. This area of work, including the legal but also the ethical dimension of the work with animals, is intended to be strengthened, licenced on the international level, and expanded to the region. The scientific part of the bioethical discourse, including the biomedical research, is performed by the Department of Biology in cooperation with the CoRE for Integrative Bioethics.

University of Zagreb Faculty of Science

The research of molecular diversity and ecology of various microorganisms, viruses and subviral entities will be one of the strategic research fields in the forthcoming period. It includes the research of the microbial genomics, molecular epidemiology and microbial ecology. In alignment with Objectives 2 and 3, the cooperation on such research will continue with other Departments of the Faculty of Science, as well as with many domestic and international universities and research centres, such as ETH Zurich, Dutch Institute for Water Treatment B.V. and the *Ruđer Bošković* Institute.

In alignment with Objective 3B, the continuation of applied research will be stimulated, for instance within the scope of the National Programme of Monitoring Aquatic Ecosystems as the initial strategy in the context of the EU Water Framework Directive. Such research contributes to the drafting of the legal provisions significant for the nature and environment protection (Objective 4A), with the transfer of knowledge to the public sector. The development of the Flora Croatica database will continue as a part of the National Nature Protection Information System of the Republic of Croatia. The Department of Biology plans to continue the maintenance, improvement and digitalisation of the herbarium and zoological collections to make their contents more accessible to the scientific and general public. For instance, within the scope of the Botanical Institute, there are two herbarium collections registered in the world base Index Herbariorum – Herbarium Croaticum (ZA) and the Herbarium of Ivo and Marija Horvat (ZAHO) with total approximately 260,000 herbarium exhibits. One of the important organisational units of the Department of Biology is the Botanical Garden which conducts the activities on *ex situ* protection of the Croatian flora, with the permits and licences for collection on the natural habitats and breeding for the requirements of the collections of our rarest, legally protected and natural species.

The Faculty of Science Department of Biology is the centre of science research in the Republic of Croatia and in the wider region and intends to retain and strengthen that position (Objective 2) and the preparations are in progress for applications to domestic and international calls for research funding sources (Objective 1). Through our teaching activities, examples of the application of the recent research in biology and adult education, it is our desire to be recognized as a leader in the education (Objections 4 and 5). The Department of Biology intends to keep providing systematic support for applications to domestic and international projects through available mechanisms (Objective 1) and investing in the maintenance of the existing and procurement of the new scientific infrastructure (Objective 6) through applications to the structural funds.

Department of Geophysics

The Department of Geophysics Development Strategy is based on the need and ambition to continue the successful adjustment of the Department with its long tradition in research to the research, teaching, technological and socio-economic challenges and to contribute effectively to the fulfilment of the objectives set out in the Faculty of Science strategy elements.

Within the scope of meteorology, in alignment with Objective 3, the research will continue of atmospheric dynamics important for weather forecast, early announcement of dangerous weather phenomena, air quality, and for many commercial activities (agriculture, energetics, tourism, traffic, etc.). Advanced numerical models will be applied, and further developed and special measurements will be conducted, and their results analysed. The intention is to supplement the existing equipment. For that reason, there are currently preparations of the documents for an application to the Ministry of Science and Education call for the preparation of the stock of infrastructure projects of the

European Regional Development Fund (Objective 6). Cooperation will continue with international experts (Objective 1 – stays at leading institutions and stimulating the cooperation with the co-authors from such institutions) and the researchers of the Meteorological and Hydrological Institute of Croatia in the field of climate modelling (Objective 3b – Stimulating the research for the purpose of the application of knowledge within the scope of development and/or applied projects), which is because of the recent climate changes and the need for sustainable development of strategic significance for the wider community. The rich experience in the climate modelling on the global and the regional scale will be supplemented through micro-climate modelling (Objective 2A – Retaining and promoting the role of the leading institution in the Republic of Croatia).

In the research of hydrosphere, the development of operational oceanography and the establishing of the marine forecast system is of strategic interest for the Republic of Croatia. In cooperation with other national institutions, the Department will develop a numerical oceanographic model (Objective 2A – Retaining the role of the leading institution in the Republic of Croatia, Objective 3 – Strengthening the interdisciplinarity and multidisciplinarity and promoting the applied research). The measurements in the sea will continue, which are of significance for the operational oceanography, application in the maritime activities and geodesics, monitoring the climate changes and planning of the sustainable development of the coastal area, which due to its dense population and high commercial activity is particularly exposed to high pressure. The interdisciplinary research in cooperation with the marine chemists and biologists are of strategic significance (Objective 3 – interdisciplinarity and multidisciplinarity, particularly strengthening of interdepartmental research activities). In cooperation with the hydrologists and hydrogeochemists, the recently initiated limnological research will continue (Objective 2 – the leading role of the Faculty of Science in the Republic of Croatia and ensuring high regional ranking and Objective 3 – interdisciplinarity and multidisciplinarity), with the final aim of establishing the hydrodynamic model of the Plitvice Lakes system, which is of strategic significance for the protection of the national park that is part of the world natural heritage (UNESCO). The results of such research will serve to the further development of the newly introduced (academic year 2016/2017) course in Limnology (Objective 5).

Seismological research in Croatia has been conducted only at the Department of Geophysics, continuously for more than hundred years. The Seismological Service, as the organisational unit of the Department, provides highly professional services for the country. Therefore, the Department must care for all aspects of seismological research. Studies of seismicity of Croatia and the neighbouring countries are conducted as strategically important as well as the related earthquake risk assessments and the research of seismotectonic relations and structure of the inside of the Earth in the area of Adriatic, Dinarides and the Pannonian Basin (Objective 2 – the leading role of the Faculty of Science in Croatia and ensuring a high ranking in the region and Objective 3 – connections with the economy).

Within the scope of the geomagnetic research, the activities of the only geomagnetic observatory in Croatia will continue. It was established by the Department in 2012, and due to the quality of the data collected by it, it was admitted to the international INTERMAGNET network. The strategic research will include the modelling of the geomagnetic field on a restricted area and development of sophisticated techniques for the calibration curve construction (Objective 2 – the leading role of the Faculty of Science in Croatia and ensuring the high ranking in the region).

University of Zagreb Faculty of Science

Within the scope of the strategic research, the successful cooperation will continue with the domestic institutions (Faculty of Agriculture of the University of Zagreb, Meteorological and Hydrological Institute of Croatia, Faculty of Mechanical Engineering and Naval Architecture, Faculty of Electrical Engineering and Computing, Faculty of Mining, Geology and Oil Engineering, Faculty of Geotechnical Engineering of the University of Zagreb, Faculty of Civil Engineering of the University of Rijeka, Institute for Oceanography and Fisheries, Croatian Hydrographic Institute) and the international institutions (University of Virginia and New Mexico Tech, USA; University of Aegean, Greece; Universitat de les Illes Balears, Spain; Zentralanstalt für Meteorologie und Geodynamik, Austria; Helmholtz-Zentrum Potsdam, Germany; Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Germany; International Centre for Theoretical Physics, Italy; Geological and Geophysical Institute of Hungary), and, in alignment with Objectives 1, 2 and 3, the establishing of cooperation with other domestic and international institutions will be stimulated, as well as further fostering of the Department staff mobility (Objective 4B).

The interdepartmental cooperation will be stimulated in all geophysics disciplines (Objective 3). Also, further connections of the education process with the research results will be stimulated (Objective 5) through the modernisation of the course contents and through the introduction of new elective courses on the diploma and doctoral level, in alignment with the recent research topics.

Department of Geology

The baseline for the Development Strategy of the University of Zagreb Faculty of Science Department of Geology, in alignment with the Faculty of Science strategic objectives of increasing the connections of the education process with the research results, is to continue the further development of research in geology, as an unavoidable outcome of the higher education at the Department. The Department of Geology is open to and participates in the changes in geo-sciences, relying on its rich and important tradition, particularly in the basic sciences.

The Department of Geology will also stimulate the update of the research infrastructure and play an active role in the planning and building of new premises of the Department on the Horvatovac Campus, contributing to the improvement of the scientific research (Objective 6).

Keeping in mind the intention to cover all important research areas at the Department of Geology with its research activities, several basic topics come up as the main strategic interest.

At the Geology-Palaeontology Division, the foundations are the stratigraphic, paleontological, sedimentological and paleoecologic research of the Dinarides and the Pannonian region to contribute to the understanding of the structure, creation and evolution during the geological past. Particular emphasis in the research will be on the lithological, sedimentological and paleontological properties of the Dinaridic (Phanerozoic) and the Pannonian (particularly Neogene and Quaternary) area sediments, clastic sediments of the Dinarides (flysch, molasse), stressful events in the geological past (extinctions, impacts, glaciations), paleoichnological findings and their application in the paleogeographic reconstructions of such areas and the specific properties of the shallow marine carbonate environments during the Jurassic, Cretaceous and Paleogene periods. Within the scope of the research of the fossil records in the Phanerozoic rocks, the evolution of the life on the Earth will be studied. To explain the environmental changes in the geological past, the recent sediments and sedimentation in the Adriatic will be explored, as well as the dynamics of the coastal changes and the

reflection of the climate changes of the sea level to the coasts and the coastal processes. Part of the interest will be focused on zooarchaeological research as well.

At the Mineralogy-Petrography Division, the crystalochemical properties of the minerals will be studied as well as their application in the mineralogy, geology, materials science and environmental research. Special emphasis will be on the clay minerals, zeolites and oxides. Another area of scientific interest will be the research of formation and changes of rocks in the territory of the Republic of Croatia and the neighbouring countries, with a study of the sediment and evolution development models of the Pannonian, Dinaride and Adriatic region as well as of the Alpes and the Carpathians. In relation to that, geochemical research of lithostratigraphic units and geological structures will be conducted. Further, geochemical research of the environment will be conducted to differentiate between the geogenic and the anthropogenic factors of influence on the distribution of metals and other substances of importance for the environment, for the purpose of characterisation, remediation and management of endangered and sensitive environments. Finally, some of the research will be focused on geoarchaeology, i.e. the characterisation of archaeological materials by means of mineralogical methods.

Among the objectives of the Department of Geology is creating the synergy of various research institutions with similar research topics (e.g. the Doctoral Programme in Oceanology) – which automatically aims to fulfil Objective 3 of the Faculty of Science Strategy Elements (i.e. increasing the interdisciplinarity and multidisciplinarity), particularly Objective 3B, strengthening the research-based commercial activities, as well as to fulfil Objective 4 through the preparation and implementation of the personnel policy, which is in alignment with the requirements of each departmental division.

Projects such as the current Croatian Science Foundation project Cretaceous Geodynamic Evidence in the Area of Dinarides and the Pannonian Basin, public institution Plitvice Lakes National Park project Sedimentology, Stratigraphy and Structural-Geological Properties of the Plitvice Lakes, InterReg–DINOKRAS and the Croatian-Hungarian project Stratigraphy and Correlation of the Upper Miocene – Pliocene Sediments Along the Croatian-Hungarian Border, with all above mentioned, strengthen the role of the Faculty of Science in the regional science (Objective 2), while cooperation with the other organisational units of the University of Zagreb, other universities and higher education institutions in the Republic of Croatia and the international research institutions retains the significant role of the Faculty of Science Department of Geology in the international science (Objective 1).

Department of Geography

The geographic research in Croatia has a long tradition and therefore the Development Strategy of the Faculty of Science Department of Geography is based on the synergy of the long tradition and the contemporary research topics in alignment with the needs of the society and the fast development of science. The scientific research at the Department of Geography includes the physical geographic as well as social geographic research and covers all important research areas in geography, but some of the fields are still noted as the strategic interests of the Department of Geography development. The scientific research is conducted in 8 basic research groups (more details below).

Within the scope of the physical geography, there are 2 basic research groups engaged in the research of the environmental changes (climate, hydrological, geomorphological, changes in the land use / land cover – LULC). The social geographic research covers 6 research groups engaged in the

planning and the evaluation of demographic and commercial resources in the region and the research of cultural landscapes, processes and changes in the urban and rural areas as parts of the local, regional and national spatial identities.

The physical geographic and the social geographic research is currently conducted within the scope of the Croatian Science Foundation projects and supports from the University of Zagreb. In the forthcoming period, the applications are planned for the research projects in alignment with Objective 1 of the Faculty of Science Strategy. Establishing a more efficient system of funding search is proposed (Assistant Head for Science and Scientific Cooperation and the Department Coordinator for EU Fund Projects and finding new personnel solutions, in alignment with Objective 4 of the Faculty of Science) such as the European Social Fund, European Regional Development Fund, Unity through Knowledge Fund, JPI Europe, Ministry of Culture calls, Croatian Academy of Arts and Sciences, etc. Further, the applications by doctoral candidates and young researchers to the Croatian Science Foundation calls will be stimulated within the scope of the calls for Installation Research Projects, Partnership in Research, Young Researcher Career Development Project, and projects providing for employment of young people.

The Department of Geography has the strategy of stimulating the research excellence through incentives for the publication of high quality papers. The recognition and stimulation of excellence was conducted at the Department of Geography in 2015 and will definitely continue in alignment with Objective 1B of the Faculty of Science Strategy. Stimulating the excellence also contributes to the stimulation of creation of excellent research groups and supervisors' work (Objective 1C of the Faculty of Science Strategy) and connecting the education process with the research results (Objective 5 of the Faculty of Science).

The strategic objective of the Department of Geography in the forthcoming period is also the study of education resources, geography curriculum and lifelong education, which is directly in alignment with Objectives 5C and 5D of the Faculty of Science Strategy.

The cooperation among these research groups is intensified, including the associates from other Departments of the Faculty of Science (e.g. Department of Biology and Physics) but also of other institutions in the Republic of Croatia (University of Zadar, *Ruđer Bošković* Institute, Croatian Waters Authority, etc.) and from abroad. In the forthcoming period, the continuation of research is planned (explained in detail below) within the scope of the existing cooperation (research groups, associates) but the new cooperation is also planned with the other Faculty of Science Departments, partners from Croatia and from abroad, in alignment with Objective 3 of the Faculty of Science Strategy – increasing the interdisciplinarity and multidisciplinarity and the connections with the economy.

The Department of Geography has already taken many measures for updating its doctoral programme to provide better connections of the education process with the research results, stimulating the interdisciplinarity. The main focus of the programme is on the research with a wide selection of courses in alignment with the specific properties of individual research topics. The programme was approved by the University of Zagreb Senate Decision in 2014 and has until today attracted a high number of candidates from close similar professions (Objective 5a). New approaches to the programme have been introduced, such as the annual internal conferences for the doctoral candidates, the implementation of which will be worked upon in future, which is also in alignment with Objective 5 of the Faculty of Science Strategy.

University of Zagreb Faculty of Science

Modernisation of the Physical Geography Laboratory and GIS Laboratory is also planned (Objective 6 of the Faculty of Science Strategy) and their importance is reflected in the continuation of the research and student education.

The purpose of all the above-mentioned incentives is to retain the role of the leading institution in the region, in alignment with Objective 2 of the Faculty of Science.

University of Zagreb Faculty of Science

Appendix A – Organizational Structure of the Faculty of Science

For the clarity of the exposition of this strategical document, in this appendix we outline all units of the organizational structure (divisions, chairs, centers) that are operating within the departments. The professors of the Faculty of Science are working in these units and therefore this structure to some extent reflects the scientific potential of the faculty.

Department of Mathematics is a unit of the Faculty of Science formed to conduct activities in the field of Mathematics. Within the Department, the following units are active:

- Division for Algebra and Foundations of Mathematics
- Division for Geometry
- Division of Mathematical Analysis
- Division of Numerical Mathematics and Scientific Computing
- Institute for Applied Mathematics
- The Computer Science Division
- Division of Probability Theory and Mathematical Statistics
-
- Division of Topology
- Chair for didactics of mathematics and informatics

Division of Theoretical Condensed

Department of Physics is a unit of the Faculty of Science formed to conduct activities in the field of Physics. Within the Department, the following units are active:

- Experimental Physics Division
- Theoretical Physics Division of Particles and Fields
- Division of Theoretical Condensed Matter Physics
- Theoretical Physics Division

Department of Chemistry is a unit of the Faculty of Science formed to conduct activities in the field of Chemistry. Within the Department, the following units are active:

- Division of Organic Chemistry
- Division of Physical Chemistry
- Division of Analytical Chemistry
- Division of General and Inorganic Chemistry
- Division of Biochemistry

Department of Biology is a unit of the Faculty of Science formed to conduct activities in the field of Biology. Within the Department, the following units are active:

- Division of Botany
- Division of Zoology
- Division of Animal Phisiology
- Division of Molecular Biology
- Division of Microbiology
- Botanical garden

University of Zagreb Faculty of Science

Department of Geophysics is a unit of the Faculty of Science formed to conduct activities in the field of Geophysics. Within the Department, the following units are active:

- Division of Geophysics “Andrija Mohorovičić”
- Seismological Service

Department of Geology is a unit of the Faculty of Science formed to conduct activities in the field of Geology. Within the Department, the following units are active:

- Division of Geology and Paleontology
- Division of Mineralogy and Petrology

Department of Geography is a unit of the Faculty of Science formed to conduct activities in the field of Geography. Within the Department, the following units are active:

- Division of Physical Geography
- Division of Social Geography
- Division of Regional Geography and Methodics
- Cartographic Technical Center

University of Zagreb Faculty of Science

Appendix B – Detailed description of the scientific research topics to be investigated, with objectives for each topic

Department of Mathematics

Division for algebra and foundations of mathematics

Recently, there was a very important advancement in the Langlands program, namely, the proof of the existence of the endoscopic transfer of local and global discrete series representations from the split classical groups to GL(n), mainly due to Arthur. The research in our group is coordinated with that development. For example, we calculate Jacquet modules of the discrete series representations, which will enable the full understanding of the parabolically induced representations from the discrete series (generalized principal series). In the theory of automorphic forms, we develop explicit constructions based on the work of Arthur and Moeglin. In that way, we explicitly construct new series not only of the discrete series representations, but also of the isolated unitary representations.

The main topics of the research in the number theory group are the elliptic curves, modular forms, Diophantine equations, Diophantine approximations, and the application of the number theory in cryptography. We study the structure of the groups attached to the elliptic curves over rational numbers and over algebraic number fields. We examine the relations between arithmetic properties of the Fourier coefficients of the modular forms and arithmetic geometry. We research Diophantine m-tuples and their various generalizations, especially in the ring of integers of the fields of small degree. In area of Diophantine approximations we examine a problem of separation of the roots of polynomial and connections with the classifications of transcendental numbers. We also research into applications of the elliptic curves and Diophantine approximations in cryptography.

In this division there is group which studies vertex-algebra theory and related infinite-dimensional Lie algebras. We study C_2 finite vertex-algebras which are closely related with mathematical physics and quantum group theory. Special emphasis is on the construction of new vertex-algebras, their representations and intertwining operators. The vertex operator theory is also used in constructions of the new combinatorial basis of representations of affine Kac-Moody Lie algebras, and in proving combinatorial identities. We also examine embeddings of finite dimensional Lie algebras and related conformal embeddings of affine vertex algebras.

Division for geometry

Main directions of the research in the upcoming period for the Division of geometry could be divided in three topics that are natural continuation of the research done in last five years by the researches from the division.

- Differential geometry of curves and surfaces in different ambient spaces. Research goals include the study of differential-geometric properties of curves and surfaces in special ambient spaces like pseudo-Riemannian manifolds, e.g. Lorentz-Minkowski space or Lorentz's spatial forms, more general settings as affine spaces, spaces with degenerated metrics, e.g. isotropic spaces, and three-dimensional Thurston spaces. Deeper understanding of these geometries can be gained by studying their submanifolds of certain properties, for example, the special classes of the surface with prescribed curvature.

University of Zagreb Faculty of Science

- Finite geometries and design theory. In this line of research, existence and classification questions about block designs, t-designs, symmetric configurations, difference sets and designs over finite fields will be studied. In order to reduce the combinatorial complexity of the problems, additional constraints will often be imposed, such as the action of a suitably chosen automorphism group. Furthermore, various regular substructures of finite projective and polar spaces will be studied. Besides algebraic and other theoretical methods, the research heavily relies on computational techniques and methods. The development of algorithms and computer programs for the construction and classification of finite structures is an important goal of this research.
- Geometric properties and models of special classes of quasigroups. Geometric properties of some particularly interesting subclasses of idempotent medial (IM) quasigroups will be studied, with special emphasis on pentagonal quasigroups. One of the basic goals is to determine all possible orders of finite pentagonal quasigroups, to obtain similar results for some other subclasses, and to establish relationship with graphs, directed graphs and designs.

Division of mathematical analysis

The research of Division of mathematical analysis includes following topics:

- Various types of orthogonality in Hilbert C*-modules. The main goal is to continue research of various types of orthogonality in Hilbert C*-modules, in particular, the Birkhoff-James orthogonality, the strong Birkhoff-James orthogonality and the orthogonality with respect to the inner product. Study of this topic includes obtaining characterizations of various classes of elements of Hilbert C*-modules in terms of orthogonality, as well as characterizations of mappings between modules that preserve certain type of orthogonality, discussions of relations between different types of orthogonality and similar problems.
- Frames for Hilbert spaces and Hilbert C*-modules. The main goal consists of two parts: to continue the research of frame theory in Hilbert spaces and to extend the theory of frames in Hilbert C*-modules. In particular, we plan to develop the interrelations between frames and strict/outer frames in Hilbert C*-modules and to extend results on frame perturbations, finite extensions of Bessel sequences to frames, especially Parseval frames, Riesz bases, etc. in Hilbert C*-module setting.
- Dirac cohomology of Harish-Chandra modules and applications. Dirac cohomology is a relatively new invariant of Harish-Chandra modules, which contains a lot of interesting information. Research in the next period will be focused at the following problems: studying representations obtained by Dirac induction, in particular the discrete series representations; applications of Dirac cohomology to problems of restricting representations; attempts of strengthening the Dirac cohomology, with applications to unitary representations; computations of Dirac cohomology of unipotent representations; computations of Dirac cohomology of unitary highest weight modules.
- Inequalities for isotonic linear functionals. The objective is to obtain new inequalities for two isotonic linear functionals such as inequalities of Chebyshev and Gruss type and other converse type inequalities. Also, we will investigate properties of functionals related to certain inequalities. The investigation of properties of h-convex functions will be continued.

University of Zagreb Faculty of Science

Division of Numerical Mathematics and Scientific Computing

- Research interests of the Division and plans for the next period are related to development of theoretical background of scientific computing and the development and validation of mathematical software developed on these theoretical concepts. Research directions are based on recent activities and results within research projects. Due to the interdisciplinary applicability of the results of the planned research, we expect to be a good basis for stimulating interdepartmental cooperation and in the direction of achieving the strategic goal 3C. Our plans are also compatible with plans for establishing the Center for Advanced Computer Science (a joint interconnection project within the scope of 3C). For certain research directions we plan to develop special courses in PhD studies and educate PhDs in line with Goal 5 of the Strategy.
- Matrix spectral decomposition. It is planned to continue successful research in the development of numerical methods for classical and generalized spectrum and SVD decompositions. It has been shown that the class of Jacobian type robust methods for SVD decompositions and various reduction of the matrices to canon forms can be efficiently implemented on multiprocessor computers, and this development will continue in the next planning period. In addition to development of numerical algorithms, we work on the theory of perturbation and on the convergence proofs. The goal is to continue successful integration of our software into the LAPACK software package.
- Control theory. Some of the staff members of the Division deal with the control theory. Activities include both the development of theoretical and numerical aspects, and the application of control theory to concrete engineering problems. This research group focuses on important topics: the reduction of large control models, the control of network dynamic systems, the optimal control of the systems described by ordinary and partial differential equations and the cost of partial differential equation control. Over the next five years, it is planned to intensify co-operation with researchers from the United States and Germany and provide new theoretical methods and results, analyze relevant numerical issues, develop appropriate computing software, and validate the application of newly-developed methods on systems that arise from practical problems, thus bridging an interstitial between theoretical considerations and industrial applications.
- Reduction of dynamic system dimensions and data-driven methods. It is planned to intensify the development of methods of identification and approximation of dynamical systems to low-dimension models. We are anticipating progress and further development of the already achieved results, especially modern data-reduction modeling techniques (POD, DEIM, Vector Fitting, Dynamic Mode Decomposition, Koopman's Linearization) and implementation of the IRKA method on multi-processor computers.
- Operator equations. We plan to continue the development of algebraic methods of approximation of operator equations (Lyapunov and Riccati equations) by a low rank operator approximation, based on the Krylov type, as well as a modern approach based on random sampling in the operator image.
- Spectral analysis of mechanical systems. We plan continuation of already started research and development of numerical methods for solving linear and nonlinear eigenvalue problems in different applications. Arnoldius and Schur-Krylov type methods are of special interest, as well as modern methods based on numerical computation of Cauchy's integral. In this context, we will also deal with the development of finite elements based on operator

numerical analysis. As interesting areas of application, we will observe the probes in the theory of elasticity and optics (photonic crystals).

- Spline approximations. Some of the chair members deal with various problems of approximation associated with a special type of spline function, such as Chebyshev splines, cycloid splines, tension splines, and q-splines. In addition to the development of new numerical algorithms for efficient computing of these splines, the theory of their approximation properties is developed, and based on them, algorithms for specific applications. Over the next five years, a continuation of theoretical and practical work on these issues is planned to improve the appropriate algorithms, and to apply them in the problems of advection and diffusion in geophysics, and the image processing.
- Numerical algorithms for high dimension problems. Over the last decade, the advancement of data collection technology, as well as the requirements for building increasingly complex mathematical models, have dramatically increased the need for efficient numerical solution of the problems of high dimensions. These problems require an approach that is completely different from approach to the classical problems of numerical linear algebra. The data are typically represented by sparse matrices or tensors, or, on the other hand, allow the approximation by low rank matrices or tensors. The members of the Chair were involved in research projects dealing with high dimension issues from various aspects. As the focus of research in numerical mathematics increasingly shifted to the direction of the high dimension problem, as a significant strategic shift, intensive activity in the direction of the development of numerical methods for tensor calculus is planned. This direction of the research is particularly in line with the plans for the development of the Center for Advanced Computer Science.
- Development of mathematical (numerical) software. All planned research directions include the development of numerical algorithms and related software implementations. As the development of robust software tools for industrial applications is an important interdisciplinary branch of research, which plays a major role in modern technology, we will be, particularly and systematically, focused on software development at the level of industrial quality. This development may also have a commercial impact and is planned as a contribution to Strategic Goal 3B and the development of the Center for Advanced Computer Science

Institute for applied mathematics

Scientific activity of the Institute for applied mathematics is in the development of mathematical methods used in natural, technical and bio-technical sciences. The activity of the Institute is related to mathematical modelling and analysis of problems described by ordinary and partial differential equations, most often stemming from the continuum mechanics. This includes the setting of models, analysis of their properties (such as the existence, (non)uniqueness and the correctness of the problem), and the corresponding numerical analysis. The directions of the research are:

- Development of the techniques for partial differential equations: in particular the homogenisation theory and applications in optimal design and inverse problems for partial differential equations, the Friedrichs systems as a framework for investigation of partial differential equations of different type, analytical objects and tools for understanding of fundamental questions in the theory of partial differential equations, and the properties of pseudodifferential operators and other techniques of microlocal analysis, with applications

to velocity averaging, averaged controllability, compactness by compensation, semiclassical limits, etc.

- Fluid mechanics: mathematical modelling, analysis and numerical simulations of fluid flow in thin domains (pipes, cracks, etc.), or in porous media. The fluids considered will be Newtonian or micropolar, monophase or multiphase, while the physical processes will be convective, dispersive, conductive, isothermal or nonisothermal. The theoretical analysis is based on a priori estimates for starting equations and various concepts of convergence and compactness. We shall use asymptotic analysis and homogenisation.
- Elasticity theory: inference and justification of lower dimensional models from three-dimensional elasticity. Of interest are also models for viscoelastic, plastic and biodegradable materials. These models form a basis for the formulation of more complex models composed from several structures, possibly of different dimensions (e.g. a system of rods and shells).
- Interaction of fluids and structures: medical applications motivate the analysis of Newtonian fluids and elastic bodies modelled as thin (lower-dimensional) or thick (full three-dimensional) body. The questions of interest are existence, uniqueness, stability, regularity of solutions; design, implementation and analysis of numerical schemes; the analysis of parabolic-hyperbolic systems.

The Computer Science Division

- *On-line algorithms for combinatorial optimization*. Objective: to develop randomized algorithms for certain well-known on-line problems, especially the *k*-server problem. The new algorithms should be better than the existing ones, e.g. in terms of competitiveness or computational complexity. Important parameters of the new algorithms will be analyzed by mathematical methods. The same parameters will also be experimentally evaluated on computers.
- *Distributed heuristics for solving NP-hard problems*. Objective: to develop new distributed heuristics for various problems, e.g. vehicle routing, Hamiltonian completion, etc. Thanks to collaboration of many concurrent processes, such heuristics should be able to solve very large problem instances in a reasonable time. The new heuristics will be evaluated experimentally on a computer network. For each heuristic the following properties will be measured: accuracy (deviation from optimum), computing time and speedup.
- *Robust algorithms for combinatorial optimization*. Objective: to develop robust algorithms for chosen optimization problems posed in graphs or networks. Robust algorithms are designed to produce acceptable solutions in situations when problem parameter values are uncertain. Such uncertainty is expressed by a set of “scenarios”. For each considered robust problem variant, its computational complexity class will be determined. For each robust algorithm, a mathematical analysis of its computing time will be performed. Algorithms will also be evaluated experimentally on computers.
- *Automated translation*. Objective: preparation of monolingual and bilingual resources needed for automated translation. Analysis and evaluation of the prepared resources by graph algorithms and by using a relational database. Development of a system for universal tagging of words in a dictionary, in order to achieve correct tagging of word occurrences in a text.
- *Achieving top-level competences in computer science*. Objective: day-to-day monitoring of new trends and achievements in all computer-science disciplines that are relevant for

teaching at the Department of Mathematics. Disciplines of top interest are: programming languages, data structures and algorithms, database systems, computer networks, software engineering, parallel and distributed computing, formal languages and automata.

Division of Probability Theory and Mathematical Statistics

Many phenomena in science and everyday life exhibit inherent uncertainty. The researchers in the Division commonly use stochastic and dynamical models to describe such behavior and rely on stochastic methods to gain insights, make forecasts or inference about them.

The goal of the Division's research projects is to advance understanding of the role of randomness in each of the following five research areas:

- Analysis and potential theory of Markov processes. We plan to study several questions related to potential theory and analysis of path properties of Lévy, Lévy-type and Feller processes.
- Modelling heavy tailed phenomena. We plan to study the tail behavior of stationary processes, limit theorems for extremes and sums of random observations, and applications of those results in time series analysis, nonlife insurance and other areas.
- Stochastic methods in harmonic analysis. We plan to obtain a complete theory for more general "entangled" multilinear singular integral operators, and to use martingale methods in characterization of low-pass filters in wavelets.
- Stochastic methods in biomedical and social sciences problems. We plan to work (in collaboration): on developing a mathematical model of a growth of a biological lens (with S. Bassnett, WU in St. Louis), on analyzing modified branching process of telomere shortening (with I. Rubelj, IRB), to investigate local asymptotic properties of approximate MLE of diffusion drift parameters and to apply them in fitting the general von Bertalanffy model to the tumour spheroids data (with Ž. Bajzer, Mayo Clinic), and to improve collaborations from previous researches related to the problems from behavioral economy and innovation processes (with J. Cvitanić, CALTECH, D. Prelec, MIT, and S. Radas, EI in Zagreb).
- Ergodic properties of extended dynamical systems. The goal is to fully describe invariant probability measures of discrete and contionuous space extended differential equations, such as Frenkel-Kontovora models, reaction-diffusion equations, and the Navier-Stokes equation, and statistically describe their dynamics.

Division of Topology

Scientific interests of the Division belong to fundamental research in some areas of topology and dynamical systems. Planned research is focused around the following topics:

Study of certain classes of low dimensional discrete chaotic dynamical systems. Particular interest is directed to a better understanding of the dynamics of hyperbolic and partially hyperbolic maps on surfaces, the dynamics of families of homeomorphisms on surfaces (with homoclinic tangents) and the topological properties of strange attractors in chaotic dynamical systems. With these goals we plan to explore new conjugacy invariants and develop new methods of symbolic dynamics and kneading theory, topological entropy, rotational theory.

Discrete dynamical systems generated by germs of diffeomorphisms in R^n or C^n and their bifurcations. We will investigate analytic germs and germs with asymptotic expansions in power-

iterated logarithm scales (especially, Dulac germs). The goal: contribution to the theory of formal and analytic classification of diffeomorphisms and their families. Reading the intrinsic properties of generator functions, such as multiplicity, formal and analytical class, from epsilon-neighborhoods of orbits of the associated dynamical systems (i.e. from fractal properties of orbits). Applications in continuous dynamic systems within the Hilbert's 16th problem and the cyclicity question.

Fractal zeta functions and complex dimensions of fractal sets as generalizations of the box dimensions and the Minkowski content. Applications to dynamical systems. The interest of this research comes from the Riemann hypothesis and Weyl-Berry conjecture. The goal: to explore various types of singularities of zeta functions of fractal sets and to relate them to geometric properties of sets. Investigate which types of singularities occur in fractal zeta functions of orbits and trajectories of dynamical systems. Reading the properties of generators of dynamical systems from zeta functions and complex dimensions of their orbits. Complex dimensions of orbits in bifurcations.

Topology and computability. Investigation of the theory of computable metric and topological spaces and, in general, computable analysis and topology. Objective: Finding conditions under which a set is computable or contains computable points, determining properties of computability structures on metric spaces, studying relationships between computability, topology, geometry and analysis.

Chair for didactics of mathematics and informatics

The Chair for Didactics of Mathematics and Informatics performs fundamental research in mathematics and informatics education at all levels. In addition, its research interests include studies of understanding and applications of basic mathematical concepts in the context of mathematics and other school subjects, especially within the group of subjects of natural sciences.

- Research of mathematics and informatics education. The aim of this research is to identify, characterize and understand phenomena and processes that occur or may occur in learning and teaching of mathematics and informatics at all levels of education by applying existing or developing new theoretical frameworks. The emphasis will be on curriculum studies (planned and implemented curriculum), studies of concept images (including preconceptions and misconceptions) and mental processes that pupils and students of teacher study programs develop while learning mathematics and programming, or while solving problems.
- Research of understanding of fundamental mathematical concepts in the context of natural sciences. Today, in educational research worldwide, many basic mathematical concepts and skills have been identified whose understanding makes pupils and students a significant problem. At the same time, their understanding and application are important both for mathematics and physics or other subjects of natural sciences. In order to better combine mathematics with other teaching subjects, and to develop appropriate teaching contents and methods that enable more meaningful teaching, the aim is to explore these concepts and related difficulties in understanding within mathematics and other subjects of natural science, especially physics.

Department of Physics

Experimental Physics Division

- Experimental research in physics of condensed matter involves the synthesis and testing of structure and microscopic and macroscopic properties of a wide range of modern materials.

Inorganic and organic materials, low dimensional conductors, oxide heterostructures, topological insulators, Dirac semiconductors, Weyl semiconductors, materials exhibiting collective phenomena like superconductivity and quantum magnetism, heavy fermions, magnetic nanoparticles, single molecule magnets, complex compounds with magnetic ions, organic magnetic materials, multi-ferroics, high-entropic and amorphous alloys and compounds, complex magnetic structures, ionic conductors, ferromagnetic graphite, soft matter, metal cluster compounds and other materials of importance for basic and applied physics are being and will be studied. From a fundamental point of view, especially interesting are searches for new phases of matter and the study of critical phenomena at the borders of these phases. Different types of experimental methods are being used for the determination of microstructure (X-ray diffraction, electron microscopy), local properties (nuclear magnetic and quadrupole resonance) and macroscopic properties (magnetic and electrical properties, magnetotransport, thermoelectric and thermodynamic properties, high frequency transport) in a wide range of external conditions (including extreme conditions such as very low and high temperatures, strong magnetic fields, and high hydrostatic or uniaxial pressure). Methods for determining the macroscopic properties include measurements of static magnetization, magnetic momentum, AC susceptibility, electrical resistance, magnetoresistance, Hall effect, thermopower, Nernst effect, microwave conductivity, nonlinear radiofrequent conductivity, and magnetic properties in the electrical field.

- Experimental research in atomic and molecular physics focuses on the study of atomic and molecular processes in high-pressure discharges in metal vapors and in high-frequency discharges in noble gases, using classical and laser spectroscopic methods.
- Research within experimental nuclear physics include the study of the structure and properties of nuclei and hadrons, nuclear reactions of astrophysical and technological importance, and nuclear and particle processes of interest for fundamental questions of quantum mechanics and standard model. Research is done in laboratories in the country as well as in specialized European and world-wide accelerator centers. The essential component is the application of nuclear methods in the study of materials, the environment and medicine. Experimental physics of high-energy elementary particles focuses on quark-gluon plasma studies on RHIC and LHC accelerators facilities, as well as the structure of nucleon spin on RHIC collider.
- Research in astrophysics focuses on the following topics: (a) star structure, evolution and interactions, (b) formation and evolution of galaxies, and (c) properties of interstellar matter.
- Physics education research includes investigation of university and high school students' understanding of the basic physics concepts, research in the field of educational neuroscience, and the development and testing of new teaching strategies and materials for physics education.
- Neurobiological research uses neurodynamic methods for functional brain imaging to study sensory and cognitive processes, multi-sensory integration, and cortical plasticity in basic and translational studies.
- Experimental Physics Division gives a great deal of attention to the development of top instrumentation that enables the most demanding experiments to be performed and at the same time enables the development of technology at the highest level. Recent examples of such achievements are the development of an ultrasensitive multichannel pikoampermeter,

the development of a cryogenic radiofrequency amplifier, the development of an experimental setup for measurements under uniaxial pressures, or the development of detectors for fundamental and applied research. Such instrumentation finds its way to patenting and customers in developed western countries.

- The Division will continue, in collaboration with the University Hospital Centre Zagreb and the Ruđer Bošković Institute, to promote research in the field of medical physics. In the context of the growing need for medical physics in the Republic of Croatia, the Division is the natural core for the development of a scientific research strategy in medical physics; it is planned to develop such a strategy in cooperation with other scientific and clinical centers.

Theoretical Physics Division of Particles and Fields

- **Gravitation and black holes.** Theoretical investigations General research on parity violating effects in gravity by studying holography, anomalies, entropy, black holes. The focus is in particular on the natural candidates for parity violating gravity interactions – the Chern-Simons terms, both pure gravitational and mixed gauge-gravitational ones - using extra-dimension models such as those inspired by the string theory. The expected outcome is a significant increase in understanding the consequences of parity violating gravitational interactions, not only in relation with possible CP violations, but also for other effects, e.g. for corrections to black hole entropy. Also, research on general properties of classical scalar and electromagneticfield in a curved spacetime: question of symmetry inheritance and the interaction between the fields and black holes.
- **Phenomenology of elementary particles and fields.** Goal of this research is to study the fundamental strong force, as described by the theory of quantum chromodynamics (QCD) and physical processes happening at hadron accelerators, including electroweak production of as-yet-unseen particles at the large hadron collider (LHC). Thereby, we investigate models of new physics in which such new particles are introduced in attempts to explain neutrino masses and abundance of dark matter in the universe. To achieve these objectives we study specific hadronic processes, both in the high-energy regime where strong force is weak enough for perturbative approach, as well as in regimes where non-perturbative features of QCD, such as confinement and chiral symmetry breaking come to the fore. Our focus is on processes measured by the range of experimental collaborations which facilitates close contact with reality and immediate testing of our results and ideas.

Division of theoretical condensed matter physics

- **History of Physics.** The main research interest is the Croatian scientific community of mathematicians and physicists, especially the latter, between 1875. and 1950. The goal is to shed light on the extent, composition, and dynamics of that community, above all the consequences of the establishment of home-grown studies of natural sciences and mathematics, and its influence on Croatian society.
- **Graphene and related systems.** We investigate and model graphene systems, one- and multilayer, undoped, intercalated, and doped, especially those doped with alkaline and rare-earth metals, including mechanically deformed systems, nanoribbons, and carbon nanotubes. Investigations will encompass electron structures and excitation spectra, transport and optical properties (including ballistic conductivity and plasmon excitations), Raman spectra and magnetic properties, the effects of pseudo-magnetic fields induces by mechanical deformation, as well as spatially inhomogeneous systems with confinement of charge and/or spin. Some of these subjects are related to the investigations of

nanoelectromechanical systems, in which magnetic and pseudo-magnetic fields affect magnetomotoric couplings, and spin-controlled nanomechanics.

- **High-temperature superconductors and related materials.** The physical mechanisms behind the superconducting phase and other phenomena in these materials have remained largely unclear even after nearly thirty years of intensive investigations. We shall investigate collective, transport, and electromechanical properties, the dependence of the dynamical conductivity and relaxation functions on frequency and temperature, the dependence of transpot coefficients on tempareture, memory functions, and the role of electron-phonon couplings on electronic spectra, conductivity, and Raman scattering. The goal is to explain (i) the doping mechanism and appearance of free charge, (ii) nature of metallic response, (iii) appearance of the pseudogap in spectroscopy, and (iv) the nature of the magnetic responses. Investigations will extend to related materials, e.g. transition metal oxides, such as nickelates and iridates, aiming to design technologically desirable materials and to understand the appearance of superconductivity better across different classes of high-temperature superconductors.
- **Organic compounds deposited on surfaces and small metallic clusters.** The contribution of electronic spectra of organic molecules (benzene, terilene, fullerene, etc.) deposited on surfaces and small clusters of noble metals (e.g. Au(111) and Au47, respectively) to various spectroscopic functions (optical absorption, EELS, photoemission etc.) will be investigated. Because of the strong Coulomb interaction, the calculation of optical spectra requires the solution of the Bethe-Salpeter equation, which includes the creation of excitons, an the interaction of the excited electron and hole.
- **Layered transition-metal dichalcogenides.** In low-dimensional materials such as the layered transition-metal dichalcogenides, Coulomb and electron-phonon coupling leads to the appearance of various phases and phase transitions, such as charge- and spin-density waves, superconductivity, metal-insulator transition, Peierls instability, superstructures, magnetic ordering etc., which makes them interesting from not only the theoretical and experimental, but also technological point of view. The ground state, optimal crystal structures, electronic spectra, and optical, transport, and magnetic properties will be investigated
- **Theoretical investigations of new, mostly low-dimensional, materials.** The purpose of these investigations is understanding and modelling of fundamental properties and new phenomena with the aim of facilitating synthesis and furthering technological developments based on new future classes of materials.
- **Fundamental investigations into strongly correlated wave functions.** Recently acquired insights into the structure of many-body Hilbert space will be pursued with the specific goals of elucidating the ground-state compositions available to few-electron wave functions in the presence of strong correlations, such as the intra-atomic Coulomb interactions in (hybridized) d-orbitals of transition metals.

Division of theoretical physics

- **Nuclear structure.** The goal of the theoretical nuclear physics research activities conducted at the Faculty of Science is the development and application of a novel theoretical framework, based on the Density Functional theory, that will allow fully microscopic and accurate modelling of quantum systems at the femtometer scale. The energy density functional (EDF) based framework will also provide reliable predictions for exotic systems very far from stability that are not yet accessible in experiments. A new generation of semi-microscopic and fully microscopic functionals will, on the one hand, establish a link with the underlying theory of strong interactions – low-energy QCD and, on the other hand, provide accurate predictions for a wealth of new data on short-lived nuclei far from stability that are

produced at radioactive-beam facilities. In order to enable EDF-based models to make detailed predictions of excitation spectra and electromagnetic transition rates, it is crucial to perform full restoration of symmetries broken by the static mean-field and take into account fluctuations of collective variables (e.g. quadrupole and octupole deformations). The generator coordinate method and the collective Hamiltonian model have recenlty been applied to describe the the phenomena related to the evolution of shell structure, shape coexistence and shape phase transitions, structure of super-heavy nuclei, predictions of exotic modes of multipole response in exotic isotopes far from the valley of stability. Another important research topic includes microscopic modelling of the spontaneous and induced nuclear fission process, in particular the fission fragment distributions. Key component of our research is the utilization of computer resources to perform large-scale computational modelling and numerical simulation utilizing parallel algorithms on distributed systems. In order to make meaningful comparison between theoretical predictions and experimental results, it is necessary to provide realiable estimates of the theoretical uncertainties by employing the advanced methods of information geometry and Bayesian analysis.

- **Nuclear astrophysics.** The field of nuclear astrophysics originates from an intersection between nuclear physics, elementary particle physics and astrophysics, exploring the physical processes within the stellar environment. Nuclei far from stability might provide answers to some of the most important scientific questions on the origin of the elements, in particular how were the elements from iron to uranium made. Shedding some light on this problem will be crucial for understanding not only the origin and composition of Earth and other objects in the Solar system and the chemical evolution of galaxies, but also fundamental interactions within the atomic nuclei. Main goal of the nuclear astrophysics research conducted at the Faculty of Science is to develop and a comprehensive energy density functional based theoretical framework that can be applied to describe properties of atomic nuclei thus providing reliable input for the astrophysical models of stellar evolution. The nuclear properties, excitations and decays are explored at finite temperatures that characterize various stages of stellar evolution. Current focus in our research are reactions relevant for nucleosynthesis of heavy elements – netron capture, neutrino induced reactions and electrone capture – crucial for understanding the final stages of the evolution of extremly massive stars including the supernova explosion and formation of the neutron star. It is also important to study the beta-decay and beta-delayed neutron emission in exotic neutron rich nuclei. While beta-decays determine the dynamics of extreme astrophysical processes (e.g. supernovae explosion or neutron star mergers), the precise knowledge of the beta-delayed neutron emission is significant for resolving the problem of the reactor antineutrino anomaly. The astrophysical simulations often require calculations that involve the entire chart of nuclides. Therefore, advanced computational techniques represent an important aspect of our work, including optimisation and massive parallelisation of numerical algorithms. Finally, studies of the infinite nuclear matter symmetry energy combined with theoretical predictions of the collective excitations in finite nuclei could provide a link between finite femto-systems and infinite nuclear matter.
- **Optics and photonics.** The main goals of research that are conducted theoretically in the fields of optics and photonics is the design and development of novel photonic structures for the propagation of electromagnetic waves with intriguing properties such as emulation of artificial magnetic fields, research of optical nonlinearities in novel materials such as

graphene, and understanding of the novel nonlinear phenomena that occur in these structures. Next we develop novel plasmonic materials with the possibility of having great confinement of electromagnetic energy (in small volumes), on scales much smaller than the wavelength of the light in air at the same frequency. These goals are at the very front of the research in these fields in the world. We plan to continue and intensify our collaboration with the world's leading centers in these fields through joint projects and scientific papers. These research topics encompass classical electrodynamics, laser physics and condensed matter physics.

- **Ultracold atomic gases.** The main goals of research in the fields of ultracold atomic gases are design and development of novel methods and schemes for creating quasiparticle excitations with fractional statistics (so called anyons), theoretical understanding of these many body systems (ground states, observables that can provide a clear experimental signature of these states). These goals are closely related to the goals that we are working on for years; these are developments of synthetic magnetic fields for cold atomic gases, understanding of many body dynamics in the presence of these fields, understanding of novel topological phases of matter that are obtained with such synthetic magnetic fields. These topics are at the very front of research in ultracold atomic gases in the leading centers in the world. The investigations encompass many-body quantum physics, atomic molecular and optical physics, condensed matter physics. In all of the research directions we are exploring analogies between ultracold atomic gases and optical systems.
- **Biophysics of cells.** The main goal of theoretical biophysics at the Faculty of Science is revealing the physical principles that lead to self-organization of cellular interior. Living cells are basic building blocks of living organisms, in which the formation and maintenance of mitotic and meiotic spindles, the positioning and transport of organelles, and the movement of the cells, are of crucial importance for their functioning. Motor proteins together with microtubules and actins, are main building blocks in all these processes. To explore physical principles that underlie these processes, we introduce physical models in which use the properties of molecular motors and microtubules that are obtained from *in vitro* experiments, and basic knowledge of classical mechanics as well as statistical and nonlinear physics. Once developed, models are solved analytically and numerically, whereas the predictions are tested experimentally. This research is performed in close collaboration with the experimental groups at the Ruđer Bošković Institute and other institutions in the world.
- **Bioinformatics.** Tandem repeats constitute a large portion of eukaryotic genomes and could be found in centromeric and pericentromeric regions of heterochromatin. In human and higher primate genome tandem repeats are organized in the symmetric higher order repeat structures. Recent studies reveal that tandem repeats play an important role in the structural organization of chromosomes, cell metabolism, speciation, and gene expression regulation. However, the mechanism of tandem repeats origin as well as modes of their activity largely remains a mystery. The research of bioinformatics group is focused on development of algorithms and computer applications for identification, classification, and analyses of all kind of repetitions within the eukaryotic genome assemblies, with a focus on human, higher primates, and Neanderthal tandem repeats. The analysis includes development of new theoretical models of tandem repeats evolution, with emphasis on regions of abrupt structural changes and higher order structures. These models help us to gain deeper insight into the evolution of whole genome assembly, genome structural organization, and the role

of non-coding regions in the regulatory network of gene expression. This insight could lead to application of abovementioned algorithms as clinical tools for disease detection and diagnosis.

Department of Chemistry

Division of Analytical Chemistry

Various studies are planned to be performed at the Division of Analytical Chemistry for the purpose of developing sensitive and selective analytical methods. Analytical atomic spectrometry (AAS, ICP-AES, ICP-MS) will be applied for development of new methods for quantitative metal content determination. The methods will be guided in order to upgrade sample preparation steps and improve spectral control of matrix effects. Special focus will be payed on methods of spectrometric quantification of elemental and isotopic composition of biomaterials and nanomaterials. Developed analytical methodology will strength multidisciplinary researches and it will be implemented through existing and planned joint- projects with economic sector (strategic objectives 2 and 3, Development Strategy).

Structural analysis of inorganic, organic and biological compounds will be performed by using MS, NMR, UV-Vis, IR and Raman spectroscopies. Structure, interactions and binding modes of bioactive molecules will be investigated by spectroscopic, computational and other physico-chemical methods. Special attention will be devoted to design of novel bioactive compounds and drugs. Hydrogen bonds and their impact on stability, structure and reactivity of studied systems will be studied as well. Process analytical approaches to monitoring chemical and physical processes will be developed and implemented.

IR and Raman spectroscopy will be used for analysis of various synthetic and real samples. Within the vibrational spectroscopic methods, surface-enhanced Raman scattering (SERS) techniques will be developed, which will be applied for structural analysis as well as for study of intermolecular interactions and binding modes of small organic molecules with biomacromolecules. Development of SERS sensors for detection and quantification of various chemical species will include preparation and characterization of nanostructured metallic surfaces and spectra analysis by chemometric methods.

The HPLC and/or UHPLC chromatographic methods will be applied for analysis of real samples (food, dyes, farmaceuticals, etc.). Modern analytical procedures based on hyphenated methods such as LC-SPE-NMR and LC-MS for purity profiling of bioactive compounds, drugs and natural products will be developed. In that respect already established collaboration with industry will be extended (Strategic objective 3: PMF Strategy). Complex mixtures and aggregation processes in petroleum samples and derivatives will be evaluated.

It is worth highlighting the successful collaboration of scientists of the Division of Analytical Chemistry with several research groups from abroad which will be intensified in accordance with Strategy objectives 2 and 4.

University of Zagreb Faculty of Science

Division of Biochemistry

The accuracy of protein synthesis. The research aims in this area are to understand the molecular basis and the biological importance of cellular mechanisms that ensure the accuracy of protein biosynthesis (translation). Erroneously synthesized proteins affect cell viability and function and are therefore associated with cellular aging and the development of neurodegenerative diseases. Using biophysical, proteomic, biochemical, computational and genetic analysis of structure/function relationship of aminoacyl-tRNA synthetases (AARSs), the key proteins that control the accuracy of protein biosynthesis, together with analysis of kinetic models of AARSs catalytic functions, we shed more light on the mechanistic details, evolution and biological relevance of proofreading reactions of these enzymes, which are developed to ensure the appropriate level of translational accuracy. To understand the impact of the inaccurate protein biosynthesis on protein structure/function we will produce the mistranslated model proteins. Understanding of these processes provides a platform for the synthesis of inhibitors with pharmacological activity, additional components for multicomponent antibiotics, and the treatment of diseases associated with mistranslated proteins. Our research is highly competitive and it is conducted in collaboration with prominent international groups that have complementary expertise (structural biology, laboratory-directed protein evolution, bioinformatics). Research in the field of the accuracy in protein biosynthesis will also include proteomic research in order to analyze and understand the relevance or permissibility of translational accuracy on a global scale. The long-term goal is to include proteomic studies based on mass spectrometry (LC-MS / MS) and to obtain the required instrumentation at the Department of Biochemistry since modern biochemical research is increasingly dependent on this aspect.

Design of Proteins with New Properties. Research goals are to create proteins with novel/improved properties that have superior biotechnological or biomedical applications using methods of protein engineering. Moreover, protein redesign has important application in biochemical, biophysical and cellular-biological studies as it enables the creation of specific properties that can be used to analyze the structure and function of the protein and to track their localization in the cell. Research is focused on the incorporation of synthetic (artificial) amino acids into proteins to effectively extend the standard amino acid alphabet. Interesting candidates to expand Nature's alphabet are fluorinated amino acids because fluorinated therapeutic peptides can easily pass through the membrane and thus have a better pharmacological effect. On the other hand, an attractive biotechnological line of research may include redesigning the existing protein biosynthesis system to prevent incorporation of non-proteinogenic amino acids that accumulate in the cell. This problem is recognized in the process of production of therapeutic proteins in bacterial cells and as such poses a serious problem in the pharmaceutical industry. The research is international, multidisciplinary and is at the intersection of biochemistry, synthetic biology and biotechnology.

Aminoacyl-tRNA-synthetases as targets for antibiotics. The research goals in the field of antibiotic mechanisms of action are to shed light on the correlation between the structure/function of aminoacyl-tRNA synthetases (AARS) and their role of a target in the production of natural antibiotics and in the development of synthetic drugs. Emphasis is on the research related to antibiotic resistance, which is one of the biggest global health problem. Mupirocin is an antibiotic that inhibits protein biosynthesis by inhibition of isoleucyl-tRNA-synthetase (IleRS). Mupirocin resistance is a common problem among the hospital strains of the pathogenic *Staphylococcus aureus*. Resistance in hospital strains, but also in nature, develops through the evolution of IleRS that is less sensitive to mupirocin or through the acceptance of an additional IleRS, which is insensitive to mupirocin. Using biochemical, kinetic, computational and genetic research in collaboration with groups dealing with

biochemical evolution and structural biology, the goal is to address the key issues related to the mechanism of action and resistance to antibiotics as well as the connection of this process with the accuracy of the translation.

Novel noncanonical functions of aminoacyl-tRNA synthetase. Aminoacyl-tRNA synthetases often have additional functions in the cell and participate in a variety of cellular processes that are not directly related to protein biosynthesis. Noncanonical function studies will focus on poorly explored plant aminoacyl-tRNA synthetases, and will examine their role in cell response to abiotic stress using biochemical, molecular biology and genetic methods. At the same time, the protein interactors and the biological role of macromolecular complexes involving plant aminoacyl-tRNA synthetases and their influence on the growth and development of plants will be investigated. The subject of the study will be also amino acid:[carrier protein] ligases, bacterial homologues of aminoacyl-tRNA synthetases that evolved a new and unexpected substrate specificity towards aminoacylation of the carrier proteins instead of tRNAs. Their biological role is unknown, they do not participate in protein biosynthesis, but most likely in the biosynthesis of secondary metabolites or antibiotics.

Interactions of proteins with other biomolecules. Specific interactions between molecules are fundamental to all biological processes. To understand complex interacting systems in the cell, protein-protein interactions, interactions between protein and nucleic acids or with small ligands will be monitored. Various techniques and methods for analyzing macromolecular interactions will be used, with emphasis on quantitative determination of the binding free energy (thermophoresis, fluorescence spectrometry, isothermal titration calorimetry). Research has potential applications in biotechnology and biomedicine since many drugs act as inhibitors and modulators of biomacromolecules and their complexes.

Computational methods in biochemical research. Modern (bio)chemical research implies the use of computational methods in everyday work. Computational methods are used to study the structure, dynamics and energetics at the atomic level of biological macromolecules such as proteins, nucleic acids, and their complexes as well as their complexes with small compounds. In the absence of experimentally solved structures, computational methods are also used for predicting protein structures based on their amino acid sequence. Prediction of protein structures has been advanced in recent years because of methodological development and the exponentially growing number of experimentally solved structures that are used as structural templates. Therefore, computational methods complement experimental research and can significantly contribute to the following objectives: structure and function of erroneously synthesized model proteins and proteins with incorporated synthetic amino acids, modeling of aminoacyl-tRNA synthetases (AARS) to understand the mupirocin resistance. In addition to AARS-related research, computational methods will be used for modeling structure, function, dynamics, studying protein interaction networks and the catalytic mechanism of different enzymes involved in various metabolic pathways. Computational methods of different complexity such as molecular mechanics, molecular dynamics, quantum mechanical methods as well as their mutual combination and empirical valence bond (EVB) simulations will be used in the research.

Division of General and Inorganic Chemistry

The strategy of the Division of general and inorganic chemistry is based on the results and experience achieved and attained during the last decade of research through domestic and international research projects (objectives 2 and 4 of the Development Strategy). It is planned to continue research in the field of new organic and coordination compounds, solid state chemistry, supramolecular chemistry and protein chemistry (*H. Pylori* proteins and insulin derivatives) and other biologically active compounds. The research will encompass design, preparation and detailed

structural spectroscopic and thermal characterisation of the prepared compounds. Research on proteins will include cloning, purification, crystallisation, and structural characterisation. A variety of experimental methods shall be employed in order to study inter- and intramolecular interactions and their influence on molecular structure and properties. The main objectives of the above research are:

- Fundamental research in the field of development of new, environment-friendly, methods of preparation of organic, bioorganic and organometallic compounds;
- Potential application of novel methods of synthesis and materials with designer properties (e.g. optical, thermal or magnetic) in industry;
- New insight into the influence of study inter- and intramolecular interactions on the structure of solids;
- Structural characterisation of proteins for the purpose of obtaining new insight into the relationship between protein structure and function;
- Transfer of the obtained knowledge and experience into education an all levels from undergraduate to postgraduate study;
- Intensifying international collaboration though participation in European and bilateral research projects.

Along with the above scientific research one should point out also professional work of chemical synthesis as well as physical and chemical characterisation of pharmaceutically active solids which is performed as a collaboration with partners from industry. In line with objective 3 of the Development Strategy of scientific research at the Faculty of science, it is planned to additionally enhance this form of collaboration.

Division of Physical Chemistry

Scientific work in the Division of physical chemistry is an inseparable part of the teaching process and includes the research in the fields of theoretical and computational chemistry, thermodynamics, chemical kinetics, electrochemistry, colloid and interface chemistry, macromolecular chemistry, chemometrics and education.

In theoretical chemistry, quantum-chemical methods are used to calculate potential energy surfaces and dipole moment surfaces, which enables highly accurate determination of spectroscopic properties of molecules and reaction mechanisms. Interactions of biological macromolecules, as well as their structural and dynamical properties, are studied using force field based computational methods with purpose of understanding biochemical processes on molecular level. Quantitative structure-activity relationship models are generated for investigating biological activity of different classes of compounds.

Thermodynamic investigations involve equilibria of ion association and complex forming reactions in solutions and on the surface. Structures of complexes and relevant thermodynamic parameters are determined by means of experimental and computational chemistry methods. Parallel kinetic investigations provide an insight into the reaction mechanisms. The continuation and extension of already ongoing successful collaborations with pharmaceutical industry related to physico-chemical characterization and synthesis of pharmaceutically active compounds is planned (Strategic objective 3 of the Strategy of Faculty of Science).

University of Zagreb Faculty of Science

Investigations in the field of colloid and interface chemistry deal with the development of theoretical models and experimental techniques for the characterization of interfaces. Aggregation, adsorption and electrical interfacial layer at the solid/liquid interface will be studied. The above mentioned investigations will be performed in collaboration with several research groups from Croatia and abroad (objectives 2 and 4 of the Strategy).

In physical chemistry of macromolecules, properties of polyelectrolytes and proteins in solution are studied, as well as their adsorption on solid substrates. Formation and properties of polyelectrolyte complexes and multilayers are also investigated. Special emphasis in these investigations will be given on the study of their antibacterial properties and on the specific aspects of ionic condensation on polyions. For that purpose already fruitful collaboration with the researchers from the Faculty of Health Sciences and from the Faculty of Chemistry and Chemical Engineering, University of Ljubljana will be strengthen.

Chemometric methods are developed and applied to interpretation of complex experimental data and their reduction to significant parameters. Use is made of modern computer methods, chemometrics, spectrometry, (micro)calorimetry, potentiometry, conductometry, optical reflectometry, electrokinetics and acoustophoresis. Scientific work in the field of chemistry education is dedicated to developing a quantitative approach to chemical problems, based on clearly defined notions and their interrelations.

Division of organic chemistry

Scientific activities in organic chemistry are focused in two directions: organic synthesis and physical-organic chemistry. Synthetic organic chemistry is oriented towards design of new bioactive compounds containing heterocyclic aromatic and nonaromatic substructures as well as investigation of their interactions with enzymes, primarily cholinesterases. Research of pyridone derivatives is directed towards synthesis of compounds with antitumor effects, and synthesis of pyridone manozides with application in antiadhesion therapy. Medicinal chemistry studies include design of new molecular conjugates of modified immunomodulating peptides, comprising molecular modeling approach.

Physical-organic chemistry studies are focused towards development of new conceptual frameworks for explaining mechanisms of thermal organic reactions in condensed phases. Reaction mechanisms in solution are investigated with computational chemistry approach, and methodology of solid-state reactions investigations is based on study of aromatic C-nitroso compounds dimerization reactions. Since these systems show photo/thermochromic effects, corresponding molecular aggregates could in principle possess externally controlled dynamical properties allowing their use in field of molecular electronics. These molecules are also investigated as potential building blocks for self-assembling mono- and multilayers, as well as three-dimensional supramolecular systems.

Future activities in field of organic synthesis will be directed towards design and synthesis of new aromatic and supramolecular systems, their experimental and theoretical study, as well as possible applications (biosensors, molecular electronics, "smart" drugs, new materials, etc.). The second part of synthetic research will comprise design and synthesis of bioactive molecules, especially heterocyclic systems, glycoconjugates and peptides with possible antiproliferative, antibacterial, antitumor, immunomodulating, antioxidative and different inhibitory effects, using conventional as well as new, faster and ecologically more acceptable methods.

University of Zagreb Faculty of Science

Investigation of thermal and photochemical organic reactions mechanisms in condensed phases will be conducted simultaneously with theoretical and experimental approach. Computational results will help to better understand the intermolecular interactions in different solvents and polycrystalline systems. The study of solvation effects will be continued using newly developed computational approach. Experimental studies will be focused towards detailed investigations of kinetics and thermodynamics of organic reactions in solid phase, with emphasis to reactions in cryogenic conditions. New equipment will facilitate opening of new research directions based on mono- and multilayers formed on ordered surfaces.

Department of Biology

Division of Botany

Scientific research groups within Divison of Botany study algae and plants from different aspects. Plant Physiology group plans to: 1) investigate the biochemical and molecular responses of plants and lichens to stress conditions with the aim of identifying stress tolerance mechanisms, 2) determine indicators that are potentially applicable in assessing the effects of different pollutants in the environment and 3) explore the biological effects of plant bioactive substances. Scientific focus of Phytochemistry group comprises: 1) analysis of bioactive substances in plants, and food and beverages of plant origin, including their metabolism and mechanisms of biological effects, and 2) isolation of natural compounds with beneficial effects on human health. Plant systematics and Flora group will continue their research in the field of biodiversity, phylogeny and phylogeography, palynology and biogeography. Group of Archaeobotany and Geobotany will focus on: 1) investigation of flora and vegetation of different habitat types which, along with the basic knowledge of biodiversity and ecology of the explored habitats, is also important in management plans of protected areas and inland waters and 2) archeobotanical analyzes of carpological and anthracotomic remains collected at underwater and land archeological sites with the aim of reconstructing historical environments and settlements and insight into different aspects of plant use. Plant Ecology and Biogeography group will study the dynamics of vegetation cover and biodiversity with respect to the changes in abiotic factors and the use of space, with emphasis on the influence of invasive species and the analysis of indicator species for assessing and predicting environmental changes. Algology research group will focus on the biodiversity of phytoplankton and phytobenthos and their interactions with biological and physico-chemical indicators in situ with the aim to better understand the responses of communities to changes in marine and freshwater ecosystems. There are two herbarium collections registered in the world base of Index Herbariorum - Herbarium Croaticum (ZA) and Ivo and Marija Horvat Herbarium (ZAHO) which today number about 300.000 herbarium specimens. We plan to intensify intra- and inter-departmental scientific collaboration, to continue collaboration with other scientific institutions, the public and economic sectors, as well as to intensify international collaboration.
In the forthcoming period, the research will focus on:

- the effects of stress conditions on plants and ecophysiological, ecotoxicological and phytochemical studies that can potentially be used to improve the yield of economically important species, in the discovery of new biomarkers and drugs as well as preservation of plant biodiversity
- screening of natural compounds and herbal extracts with beneficial effects on human health
- diversity of Croatian flora and biogeographically related areas using phylogenetic, biogeographic, archeobotanic and palynological methods, the development of new generations of molecular markers and their application in plant protection, plant breeding and archeobotanics

University of Zagreb Faculty of Science

- developing online platform for species distribution modeling and generating dichotomous parallel and sequential, single- and multi-access keys for determining taxa, maintaining and developing Flora Croatica Database as part of the National Information System of Nature Protection of the Republic of Croatia
- exploring plant diversity and habitat conditions over space and time and application of gained knowledge in nature conservation, management of protected areas and inland waters, and reconstruction of historical environments and relationships between humans and plants
- maintaining, systematization and digitization of herbarium collections in order to conserve plant biodiversity and to make them accessible to the scientific community and public
- seed germination ecology of strictly protected plant species of Croatian flora
- ecophysiological features of plant species that allow their greater performance in certain environmental conditions with special emphasis on invasive plant species
- application of new methods to determine the biodiversity of marine and freshwater microalgae, experimental analysis of mixotrophy, investigation of the impacts of climate change on lakes and Adriatic Sea, and the development of the Croatian-Chinese Research Center for Environmental Protection

Division of Animal Physiology

Two directions of investigation are planned in the Division of Animal Physiology in the forthcoming period.

The first involves research into animal and cellular models with the aim of applying the results obtained to human population (translational research):

- As part of the CoRE for basic, clinical and translational neuroscience, in which members of the Division participate as associates, new experimental models will be developed to study the development and disorders of the central nervous system such as hypoxic ischemic lesions and Alzheimer's disease.
- Research in the field of immunology, oncology and physiology will be based on the application of new forms of delivery of bioactive components (polyphenols) via nanoparticles or nanocrystals on an animal model of peritoneal angiogenesis and their effectiveness in animal models of diabetes, osteoporosis, inflammatory skin and bowel disease and their association to the modulation of activity of intestinal microflora.
- Research in the field of endocrinology and reproduction, will investigate the impact of various *in vitro* manipulations of reproductive cells on oxidative stress and genome stability.
- In the field of metabolism and toxicology physiology, research will be carried out on the bioavailability of bioactive substances in the body, toxicological *in vivo* and *in vitro* research on bioactive substances and residues in food, and the effects of intracellular lipid metabolism on oxidative stress of cells and organs.

The second direction includes research in the field of ecophysiology, behavior and molecular ecology of wild species of vertebrates:

- The ecological, physiological, ontogenetic, genetic and epigenetic determinants of behavioral and cognitive characteristics of vertebrates will be investigated on the lizard as a model organism, in cooperation with the Zoological Gardens of the City of Zagreb and the University of Indiana.

University of Zagreb Faculty of Science

- Research on animal behavioral features that allow for survival in the environment will be conducted on the Balkan snow vole, an endemic rodent of the Western Balkans.
- In the field of molecular ecology, genetic diversity, population structure and processes relevant to the adaptive evolution of populations will be investigated on different vertebrate species such as common tern, roe deer, red deer, dolphin, wild boar and Eurasian otter using neutral and adaptive genetic markers.

Division of Microbiology

The Division of microbiology is conducting scientific research on various types of microbes, including fungi, bacteria, viruses and subviral pathogens. One of the strategic goals is investigation of microbial biodiversity, which is performed through basic microbiology methods and state of the art molecular techniques. Research encompasses samples collected from different ecological niches, such as surface waters, wastewaters, soil, sediments, forests, vineyards, and samples obtained from humans, plants and domestic animals.

Another strategic goal is the advancement of microbial ecology research through microbial genomics and molecular epidemiology studies. The achievement of this goal is also foreseen through investigations of microbial interactions with hosts and/or environments. The development of the latter type of research will also enable better collaboration of Division of microbiology personnel with experts from microbiological sub disciplines that deal with microbes primarily as pathogens. The pathogenic bacteria in the environment are investigated in collaboration with the Departments of Geology and Chemistry (Faculty of Science), Faculty of Mining, Geology and Petroleum Engineering (University of Zagreb), University of Split School of Medicine, Faculty of Technology and Metallurgy (University of Belgrade), Université Grenoble Alpes, University Hospital Centre Split, Croatian Institute of Public Health, and Zagreb Wastewater - Management and Operation Ltd. The plant pathogens are investigated in collaboration with international and national research centers (INRA, John Innes Center Norwich, Croatian Center for Agriculture, Food and Rural Affairs - Institute for Plant Protection). The latter enables implementation of the results, obtained through state of the art research techniques, in the Croatian national program for plant protection.

Research on fungi and oomycetes is mainly carried out through studies of the biodiversity of different plant pathogens and molecular interactions including bilateral (fungi - plant) and trilateral (fungal virus – fungi - plant) interactions. The research is done in co-operation with domestic and foreign universities and research institutions, like ETH Zurich, University of Osijek, Faculty of Forestry of the University of Zagreb, Faculty of Forestry of the University of Skopje and the Croatian Forest Research Institute.

Research of plant viruses has a long tradition at the Division of Microbiology. Although, the preservation of this heritage through functional laboratories, experimental greenhouses and a collection of viruses is one of our long-term goals, they have been extended to different topics of virus research including sub-viral pathogens (satellite viruses and viroids), environmental viruses as well as fungal and animal viruses as essential drivers and models in molecular evolution studies. Some of them are important regulators of biodiversity, biogeochemical cycles and play a role in health maintenance. Some could be used as a tool in nanotechnology with the important application in biomedicine (e.g. modified adenoviral vectors used in gene therapy). The results of research are disseminated through activities within professional associations, primarily the Croatian

University of Zagreb Faculty of Science

Microbiological Society and collaboration with different faculties and institutes (Faculty of Agriculture of the University of Zagreb, Ruđer Bošković Institute, National Institute of Biology in Ljubljana, Biotechnical Faculty of the University of Montenegro, Université de Liège, Università di Bari, Penn State etc.).

All afore mentioned positions the Division of Microbiology in the centre of microbiological research in the country and the region. However, it is our intention to further develop and improve both our activities and status. Through our teaching activities, diverse applications of our scientific results and our involvement in lifelong learning and other forms of education, we aim to achieve recognition as a leading institution for the application of modern microbiological methods and concepts in practise.

Division of Molecular Biology

Division of Molecular Biology comprises several scientific groups with different research topics.

Scientific interest of the Group for Stress Biology is the impact of the abiotic stress (salinity, osmotic and heat stress as well as heavy metal stress, including nanoparticles) on plants in order to elucidate mechanisms of plant response at the cellular level but also at the level of chromosomes, genes and proteins.

One of the oldest scientific groups at the Department of Molecular Biology works on organization and evolution of the plant genome at the cytogenetic and molecular level. The aim of their work is focused on application of chromosome markers in phylogenetic research and to study organization and evolution of repetitive DNA and their role in speciation.

A group working on plant development investigates the sexual and asexual reproduction of plants using the models of *Arabidopsis thaliana* and *Vitis vinifera*. Future studies will be focused on elucidation of reproductive capacity of the germinative and somatic cells using RNA sequencing methods, reverse genetics, and proteomics. Also, the plan is to apply the potential of somatic embryogenesis to obtain new agronomically desirable properties without the application of genetic engineering techniques.

Biomedical research groups are involved in research of tumor biology, regenerative medicine and tissue engineering, intercellular communication and microorganism effects on cellular mechanisms. The listed research topics involve analyses of transcriptional regulation in animal cells, communication networks between cells and microenvironment, regulation of plasminogen system activity in tissue remodelling, identification of selective cell death mechanism of tumor cells and virus effect on cell cycle. Research in the field of regenerative medicine and tissue engineering is focused on stem cell differentiation in 3D systems, formation of bone and cartilage tissue as well as the development of bioreactor systems, scaffolds, differentiation conditions and tissue analysis. The aims of the biomedical research groups are focused on the development of new methods and discovery of new processes that can be translated into clinical practice.

The research group for bioinformatics and computational biology uses quantitative systems-level analyses to study biological processes. The Bioinformatics group is most cited research group at the Department of Biology and among the most cited research groups in the Faculty of Science, and according to the number of published articles in leading journals in the field, one of the most successful groups in the University of Zagreb. Some of the group's research topics are: metagenomics

University of Zagreb Faculty of Science

- interaction of microbial communities and their environments (including the human body) at the genome level; genomics of multicellular organisms – processes involved in cell development and differentiation, as well as genetic conditions needed for the formation of multicellular organisms; Mammalian developmental genomics - processes at the level of transcription of coding and non-coding RNAs necessary for successful development of fertilized egg cells; epigenomics of malignantly transformed cells – studying mutation markers and their association with epigenetic factors in order to diagnose and classify tumor diseases; epigenomics of viral infections - mechanism of HIV-1 virus integration in human genome with emphasis on the epigenome and chromatin structure.
The research group for epigenetics primarily investigates regulation of protein glycosylation both in the normal physiologic state and in human chronic diseases. The goal is to elucidate how the variability in protein glycosylation (which is under epigenetic control) influences susceptibility and progression of diseases in human populations. To this end, we are using state-of-the-art methods of bisulfite pyrosequencing and chromatin immunoprecipitation. Another aim is to discover the functional role of GWAS hits in IgG glycosylation using cutting-edge methods for genome and epigenome engineering, including the TALEN/CRISPR technology.

The group of molecular bacterial genetics is interested in understanding the defence mechanism of Escherichia coli against foreign genetic elements (bacteriophages and plasmids) using the CRISPR–Cas system. The aim of this group is elucidating its regulation, specifically in understanding the role of the protein Cas3 as a key checkpoint for CRSIPR-Cas immunity. The research will cover all levels of gene regulation: from transcriptional and post-transcriptional control, protein stability, changes in protein conformation and finally the proteolytic degradation of the Cas3. We also plan to clarify the link between CRISPR-Cas immunity and DNA repair-recombination processes.

Division of Zoology

The Division of Zoology deals with the researches regarding diversity, distribution, ecology, taxonomy, ecotoxicology, reproductive biology, phylogeny and phylogeography, ecological evolution and genomics, evolution and biogeographic features of all segments of the Croatian fauna and processes leading to recent faunal community composition. This activity of the Division which has elements of professional and scientific work is carried out by the independent activities of the employees of the Division, but also in cooperation with related institutions in Croatia and abroad.
The basic directions of the research in the next period are:

- DNA encoding biodiversity of Croatian fauna. Phylogenetic and phylogeographic researches, biological-ecological aspects of present-day distribution, taxonomy and phylogeny of arthropods (insects, crustaceans) and fish, turbellarians, freshwater cnidarians and their endosymbionts, and research of evolutionary aspects of symbiosis.

- Ecological research, which should mention the development of tools and solutions for the regeneration of degraded marine habitats and the recovery of their biodiversity and functions. A special focus will be on research on the impact of global climate change and input of foreign species on freshwater communities and native species. Ecological research is deepened by research into ecological evolution and ecological genomics. The impact of anthropologically conditioned ecological changes (pollution, biological inputs, and fishing activities) on the rapid evolution of natural populations will be explored. It also continues

with synecological research on aquatic communities and features of various aquatic biotopes.

- Applied research under the National Program for Monitoring of Aquatic Ecosystems as an Initiative Strategy in the context of the EU Water Framework Directive. Investigations of different pressure impacts, and determination of bioindications. These research bases are for the preparation of legal acts and monitoring systems. Based on the above mentioned researches, the databases from which scientific papers are generated are also collected.
- Ecotoxicological research aimed at studying the effects of pollution on organisms living in such an environment and the development of specific biological methods for the faster and more accurate determination of negative anthropogenic activity. Also, laboratory research will investigate the effects of certain pollutants on the course of cell differentiation and the (ultra) cell structure in certain aquatic organisms.
- Professional projects (monitoring programs) as part of which the employment of assistants is planned

Department of Geophysics

- **Meteorology and climatology.** Research of micro-, meso- and macro-scale atmospheric processes will be maintained using standard geophysical approaches (measurements, monitoring, numerical simulations and theoretical examinations). Among other, following problems will be investigated: formation, transport, dispersion and settling of air pollutants, vertical structure of the urban and sub-urban boundary layer, turbulent eddy dissipation, budget of turbulent kinetic and potential energy over complex terrain and three main kinds of non-standard radio waves refraction. Furthermore, airflow over complex coastal and mountainous terrains will be explored altogether with phenomena like bora wind, sirocco wind, sea- and land- breeze, deep convection and fog formation. In view of atmosphere-sea interaction, regional and local weather and climate conditions will be investigated in cooperation with oceanographers by applying advanced statistical methods and using climate models of different complexity. Some of the models (i.e. simulators) will be modified in order to improve turbulence parameterisation. Furthermore, European climate variability and change will be explored as well. Of particular importance is impact of large-scale atmospheric modes and their potential time-delayed effect trough the interaction with slower components of the climate system (sea, soil and ice). Investigation and explanation of physical mechanisms which enable such connection will be examined by appropriate statistical methods applied to the results of global and regional climate model simulations. Analysis of urban heat island in the current and future climate conditions is planned in collaboration with Croatian Meteorological and Hydrological Service. For that purpose, numerical simulations with urban microclimate model MUKLIMO_3 will be performed. Also, different meteorological fields and vertical profiles of meteorological parameters together with spatial databases will be used (terrain, land-use and land-cover based on GIS data). Results will contribute to deeper understanding of small-scale atmospheric processes and will be utilized in undergraduate study programmes to provide state-of-the-art education for students.
- **Oceanography.** The research activity in oceanography will cover continuous sea-level measurement at the permanent tide gauge station at Bakar (founded in 1929), but also

measurements performed within targeted experiments, using pressure gauges, undulating vehicle and other available instruments. All the data will be analysed by standard as well as by self-developed statistical methods. In this, a wide range of ocean processes will be examined, from long-term sea-level changes, over storm surges and coastal seiches to processes related to river mouth plumes. Finally, various models will be applied or developed in order to reproduce the observed data. Semiempirical models will be used to study sea-level trends, two-dimensional barotrophic models will be applied to analyse the ocean response to atmospheric forcing, and three-dimensional baroclinic models will be applied to study hydrographic properties and ocean dynamics in the vicinity of river mouths.

- **Seismology.** The Department of Geophysics of the Faculty of Science is the only institution in Croatia where seismological research is nurtured and as such it is not focused on specific subject but takes interest in wide variety of research topics related to seismicity in Croatia. Croatian Seismological Survey will continue, in accordance with available financial support, to expand Croatian Seismological Network and will carry on its mission to register earthquakes, archive recorded seismograms, update Croatian Earthquake Catalogue and to exchange data with foreign partners. Scientific work will be more inclined towards regional and subregional areas (e.g. Velebit Mt.), with the main focus on investigating characteristics of the regional seismogenic faults and their role in the overall seismotectonic framework. Furthermore, at the Department studies of the structure and seismic properties of the crust and upper mantle beneath the Croatia will be continued using state-of-the-art seismic (e.g. receiver functions, travel time and ambient noise tomography, etc.) and inversion (e.g. Bayes framework) methods. In the field of engineering seismology and earthquake engineering, intention is to continue activities that will result in the improvement of the seismic hazard estimates in Croatia, as well as measurements of dynamic properties of important buildings in order to facilitate damage due to the ground-building resonance.
- **Geomagnetism.** Investigation of the geomagnetic field in Croatia will continue by collecting data at a single Croatian geomagnetic observatory, which runs from the beginning of July 2012 in Lonjsko polje. Data from this observatory will serve for a theoretical analysis of the distribution of all magnetic elements, producing geomagnetic maps, modeling and interpretation of the anomaly field over Croatia. Scientific work in geomagnetism would be strengthened by modeling of the geomagnetic field in a limited area using spherical cap harmonic analyses. In addition, special attention will be paid to the development of more sophisticated methods for constructing the calibration curve, (baselines) in cases of significant decrease in data quality that occurs mainly from thermal instability and errors in the absolute observations. It most often occurs in observatories, which, like ours, do not have insured stable temperature conditions for high quality measurements. Also, the aim is to continually improve the quality and standard of measurements at the observatory to reach the requirements of INTERMAGNET.

Department of Geology

University of Zagreb Faculty of Science

Research groups at the Department of Geology are engaged in study of rocks from the aspects of petrology, paleontology, mineralogy, geochemistry, paleo-environment and environment, ecology and paleo-ecology as well as geoarcheology.

Principal research topics at the divisions of the department are as follows:

Division of Geology and Paleontology

- Contribute to the understanding of the geological evolution of the Dinarides and Pannonian basin

The Internal Dinarides, as well as adjacent areas towards the External Dinarides contain numerous exposures of sedimentary rocks which store information related to the history of the orogen and paleogeographic evolution of the wider region. Biostratigraphic and sedimentological characteristics of largely deep-water deposits will be studied to determine paleogeographic and geodynamic relationships within the Dinarides themselves, as well as with neighboring segments of the Alpine orogenic belt (Croatia, Bosnia and Herzegovina, Slovenia, Austria, Serbia, Monte Negro). Dating of transgressive deposits will contribute to a better understanding of synorogenic basins in this area. Provenance studies of clastic material will constrain the composition, and potentially the petrogenesis and thermal history of source terrains, which is useful in the reconstruction of geodinamically active regions.

The study of Miocene deposits and biota of the Paratethys and surrounding land areas, with an emphasis on the relationship between global stress events and the response of organisms. Special attention will begiven to middle Miocene environments and transgressive-regressive cycles. Bioaccumulations of red algae and bryozoans and marginal shelf environments will be studied among shallow water deposits. Pelagic and benthic mollusks (with chemo symbionts), as well as less known groups of benthic organisms (e.g. crustaceans, deep sea urchins, sponges).

- Study of stress events in the geological past such as impact events, extinctions and glaciations

Investigations will largely deal with traces of glaciation in the Dinarides with emphasis on determining the extent of the Pleistocene ice cover, directions of its expansion and supply of detrital material, as well as understanding its dynamics, i.e. expansion and shrinkage with the goal of establishing a regional stratigraphic frame for the Pleistocene (subdivision into regional stages). Age determination of Plistocene deposits and determination of their paleontological content will be conducted in cooperation with interested scientists from abroad, and locally with the Institute for Quaternary Paleontology and Geology (Croatian Academy of Sciences and Arts) and the Ruđer Bošković Institute.

The study of geological traces of asteroid impacts has the goal of learning the characteristics and composition of impact materials and particles, determining the source of impact detritus and its chronostratigraphic age. These interdisciplinary investigations are performed in collaboration with researchers from the Chemistry Department of the Faculty of Science, Ruđer Bošković Institute and Institute for Quaternary Paleontology and Geology (Croatian Academy of Sciences and Arts).

These investigations will also include samples and extinctions recorded in the rocks from the Dinarides (for example the Guadalupian–Lopingian and Permian-Triassic boundaries).

University of Zagreb Faculty of Science

- Characteristics of shallow marine environments with carbonate sedimentation during the Mesozoic and Cenozoic with regards to their geographic distribution in Croatia

Mesozoic successions of largely shallow marine deposits will be studied in the External Dinarides, which encompass the Croatian coastal area south of Karlovac. They will be analyzed sedimentologically (structural and textural characteristics of limestones) and stratigraphically (based on biostratigraphic distribution of microfossils and absolute age dating based on strontium isotopes). Comparison of determined environmental characteristics, placed in the context of different types of sequences (from shallowing upward sequences to higher order sequences), will allow regional reconstructions of the External Dinarides. Furthermore, by comparisons with successions of Mesozoic siliciclastic-carbonate deposits of the Internal Dinarides and the Austoalpine area the paleogeography of the Internal and External Dinarides will be reconstructed (the exploration of which is partly included in the investigation of Mesozoic outcrops in the Pannonian Basin and Internal Dinarides). Within this established frame of research, the ichnology of terrestrial reptiles will be investigated, based on which the dimensions of the organisms will be determined and possible paleogeographic reconstructions will be based on the regional stratigraphic and environmental data derived from the research described above.

- Investigation of river mouths, coasts and coastal processes and marine sediments with the goal of determining changes in depositional environments during the Pleistocene and Holocene, as well as anthropogenic influences on the sediment

Research will be conducted along the eastern Adriatic coast and coastal area, with an emphasis on river mouths, estuaries and deltas of eastern Adriatic rivers. Sediment cores extracted from these areas will be used for sedimentological, micropaleontological and geochemical analyses with the goal of describing successions of depositional facies in karstic river mouths during the Pleistocene and Holocene. The geomorphological evolution of these areas will be reconstructed and understanding of sea level changes in the past, climatic changes and human activity which occurred following the last glacial maximum will be improved. Emphasis will be placed on the phenomena of drowned karst and indicators of sea level change (salt marshes, tidal notches, bioconstruction indicators, as well as archeological indicators).

Apart from sedimentary cores, sedimentological and paleontological investigations will also extend onto sea bottom sediments in the coastal and open sea areas with the goal of understanding the evolution and mapping of the sea bottom, as well as defining and describing of marine habitats. Furthermore, results of geochemical investigations of sea bottom sediments will be used to characterize the state of marine environments, especially those under considerable anthropogenic influence.

Detailed investigations of coastal morphology, as well as study and monitoring of coastal processes, especially on beaches, coastal cliffs and river mouths will contribute to the understanding of how these environments function (source-to-sink concept) and help establish a foundation for sustainable management of the coastal area.

The results of the research described above will considerably contribute to improving monitoring studies and appraisements of coastal and transitional aquatic environments which are conducted under the directives of the European Union.

University of Zagreb Faculty of Science

Division of Mineralogy and Petrology

- Crystal--chemical properties of minerals with applications in mineralogy, geology, material science and environmental science, special regard being given to clay minerals and zeolites.

Alongside basic research of crystal-chemical properties of minerals in order to determine known and new mineral species and their genesis in different geological environments, additional research will be directed towards interdisciplinary studies regarding the role of minerals in interaction with living organisms and the effect of minerals on the distribution of various elements and compounds in the environment. The latter is of particular importance in pollution prevention, as well as environment protection and remediation activities. Part of the research will focus on the application of minerals in state-of-the-art technological processes, supplemented with the efforts to strengthen the links with other disciplines involved in preparation and characterisation of novel materials, both on the Faculty and the University level and other research institutions in the country and abroad. Special attention will be given to clay minerals, zeolites and oxides.

- Genesis and alterations of rocks in Croatia and neighbouring countries with an overview of evolution models of Pannonian, Dinaric and Adriatic area development supplemented with geochemical studies of lithostratigraphic units and geological structures, as well as mineral deposits.

Fundamental scientific research encompassing igneous and metamorphic rocks including their role and importance in reconstructing geological events in the orogenic areas of the Carpathians, Dinarides and Alps, as well as the crystalline base of the Pannonian basin, will be directed towards determination of detailed chronological and petrogenetic conditions during the Pre-variscian, Variscian and Alpine orogeny, and postulating the cause and effect connections between these processes. The importance and spatial and temporal coverage of the oldest and the youngest orogeny on the Croatian territory have not been entirely resolved yet, and neither have the details of particular episodes of the Variscian orogeny. With this in mind, studies are foreseen in order to precisely define the petrological, mineralogical, structural, geochemical and isotopic properties of igneous and metamorphic rocks and the processes linked to them which occurred in various geotectonic environments and geodynamic units. The focus of the research will advance from studies at magmatic and metamorphic complexes level towards further three-dimensional structural, textural and microtectonic analyses of the rock complexes, determination of isotope composition of individual phases, inclusion studies and analyses of complex features and inner structures of accessory minerals, such as zircon, apatite, monazite and xenotime which occur in both types of rocks.
The research in question will predominately be conducted on Croatian territory. Simultaneously, thanks to numerous scientific collaborations, research in specific locations of central and eastern Europe will be continued and expanded, which is of utmost importance in studying rock complexes spanning outside Croatian borders and explaining the evolution of bigger geodynamic units.
Studies of sediments and sedimentary rocks will be focused on Neogene and Quaternary deposits in the Pannonian basin and the Quaternary deposits of the Adriatic area. Regarding the Pannonian area research, two main goals have been set for the upcoming time period. The first one is the definition of geochemical character and sedimentation time frame of the pyroclastic deposits and the accompanying sediments and sedimentary rocks. These deposits, under-represented in the studies so far, are key in defining the durations of emersion, lacustrine and marine phases in the basin development, as well as the point in time in which the transition from the syn-rift into the post-rift phase took place. The second goal is to define the sedimentation model of Late Miocene and Pliocene on the Croatian territory, which would, on one hand, contribute to a better definition of general evolution model for the whole Pannonian area and, on the other hand, be a crucial factor in hydrocarbons research. The investigations of the oil- and gas-rich areas of the Drava depression have already begun in collaboration with colleagues from the Croatian Geological Survey, INA and

universities from Budapest and Pécs. The area of research is planned to be expanded to other parts of the Pannonian territory. In the Adriatic area, the plan is to continue studying the provenance and age of Pleistocene sediments, as they represent the main source of material for the beaches on the islands and on the coast.

- Geoarchaeology - using mineralogical methods in characterisation of archaeological materials.

These studies will result in characterisation of archaeological materials and materials used in historical buildings using mineralogical methods. In the last fifteen years, the Division of Mineralogy and Petrology is more actively involved in archaeological research, notably in phase characterisation of ceramics, metal and stone artefacts and pigments, as well as in studying the stone weathering processes aimed at improving the methods of its prevention. With this respect, important collaboration with the Croatian Conservation Institute has been established. In the recent years, several other local museums and related institutions have recognised the value of the work being done at the Division of Mineralogy and Petrology, so the plan is to expand the existing research and use the obtained results to determine the provenance of the rocks used in making of artefacts found at archaeological sites and in construction of historic buildings.

- Geochemical environmental research aimed at differentiation of geogenic and anthropogenic factors in the distribution of metals and other elements and compounds in the environment in order to characterise or serve in remediation and management of endangered and sensitive environments.

Environmental research will be conducted in order to differentiate between geogenic and anthropogenic factors in the distribution of potentially toxic compounds and other substances in the environment. The results will be used in characterisation as well as remediation and management of endangered and sensitive environments, including risk models design. The research will be especially focused on the influence of individual segments of human activity on the environment (agriculture, industry, catastrophic events such as wildfires), where the distribution of key chemical elements and compounds which could influence ecosystems and organisms will be monitored. Part of the research will be directed towards the influence of the disposal of different types of waste on the environment, with respect to geological foundation and potentially toxic substances distribution. It will also deal with waste management and recycling strategies. In these studies, emphasis will be put on the link between the man and the environment, through the development of medical geology, which will be achieved through continuation of kidney stones research already in progress.

Department of Geography

- **Geomorphology and paleoenvironment.** The research group from the Department of Geography of the Faculty of Science traditionally deals with questions of the creation, evolution and the recent dynamics of karst relief, i.e. research of karst from geomorphological and paleoenvironmental perspectives. The most important research themes revolve around questions of the influence of the geological structure on the development of karst relief forms, climatic geomorphological research (e.g. measuring the intensity of karst denudation) of the development of morphometric methods, and geomorphological mapping in the GIS environment. Karst relief is also often under the influence of other morphogenetic processes, such as the glacial processes that were significant in the past. Therefore, one of the goals of the research is also to analyse glacial

karst, on the surface and within underground karstic forms - caves. These periods are directly linked to the different allotment of land and sea in the area of the Adriatic, which plays a very important role in the reconstruction of paleoenvironmental characteristics during the late Pleistocene and Holocene. For this reason, we employ different markers (geomorphological, biological, archaeological, etc.) in order to reconstruct paleoclimatic characteristics, as well as to define and explain fluctuations in sea level. Environmental and climatic change is also investigated, based on analysis of speleothems and tufa. The research is based on field work, however, the isotopic methods which are applied in conjunction with the Ruđer Bošković Institute, are of exceptional value. One of the more important goals within this research group is the continued development of the physical geography/geomorphology laboratory and its equipment.

- **Climatological, hydrogeographical, and geoecological research.** Research is directed toward the planning functional spatial organisation and sustainable development. Our strategy is directed toward fundamental and applied research, human resources development, transfer of knowledge, technological development, obtaining computers, GIS and research equipment, as well as increasing cooperation with both national and international partners. The research of this research group encompasses analysis of the influence of abiotic factors on ecosystems, whereby geomorphological, pedological, hydrological, hydrochemical, anthropogenic, and biological indicators are used in research and monitoring of the state of the environment. Additionally, the research activities encompass investigation of natural risks, microclimatic research, research of geodiversity and geoheritage, settlement ecosystems and anthropogenic geomorphology, as well as the geographic aspect of environmental protection and ecosystem services. Within the framework of hydrogeographical research, cataloguing and evaluation of the hydromorphological status of flowing and stagnant waters, riparian zones and watersheds, and flow regimes is conducted—all within the framework of implementing the Water Framework Directive of the EU. One of the goals is to create a hydrological atlas of Croatia, and ecologically acceptable flow calculations as well as water resource and water supply management in relation to sustainable development of regions are also being researched. Climatological research is directed toward regional climatic analyses, research of urban climate, analysis of climate change and the changeability of climatic elements in the instrumental period, as well as the influence of climate on geographic valorisation of space. An important goal of these research activities is regionalisation on the basis of the physical geographic elements of the landscape.
- **Urbanisation, urban social structure, and regional development.** The regional development of Croatia lies in its urban system; due to this, research attention will be especially aimed towards the urban network, and the functional classification and role of cities in the administrative-territorial organisation of the country. Furthermore, attempts to ascertain differing characteristics, development potentials, and limitations of city surroundings will be undertaken. Recommendations and development measures for the evaluation of the potentials of suburban areas in future development of urban regions will be given. An additional focus of the research is on the area of the city itself and its spatial structure (functional, morphological, social, and cultural characteristics), including the following themes: quality of life; problematic areas in the city; sustainable development of the city with emphasis on sustainable (alternative) transport; spatial mobility; socio-spatial and cultural differentiation, segregation, and the everyday environment. The methodological

instruments used in this research range from exact (GIS, field work) to qualitative (interviews, focus groups). Spatial imagination and mental maps are emphasised as products of daily spatial practices and therefore are essential elements of researching urban space. The obtained results are important for advancing spatial planning and regional development, evaluating spatial resources, functional integration, and problem-solving approaches for imbalanced regional development in Croatia. There is a broad spectrum of potential for the application of the research results in both the commercial and public sectors, as well as contributing to informing and improving the quality of public policies.

- **Sustainable development and planning of rural and periurban areas of Croatia.** Half of the population of Croatia lives in rural and periurban settlements and these areas take up almost 90% of the country's surface area. Apart from such areas found in larger urban regions, the Croatian countryside is often characterised by unfavourable development characteristics, negative demographic state and processes (depopulation, ageing), and a weaker infrastructural and economic development level in relation to urban areas. Concurrently, rural and periurban areas are of strategic interest because they are the most important areas for food production and contain crucial natural resources. They are also the pillars underpinning other important functions, e.g. housing, various business activities, environmental protection, locations of large infrastructural and energy facilities, and recreation. With predominantly negative development trends in one hand, and the task of harmonising the aforementioned functions in the other, dilemmas and conflicts often happen in relation to planning and sustainable development of these areas. The key research directions, derived from the aforementioned, are: models and development measures for different types of rural areas; various scenarios of possible future developments; the influence of new stakeholders and actors on demographic and socio-economic processes in rural areas; and comparative analysis of trends in rural areas in Croatia and in other European countries, especially those in transition.
- **Demographic aspects of the development of Croatia.** Contemporary demographic development of Croatia is characterised by unfavourable processes and structural characteristics, which have contributed to a reduction of total “human capital,” as the carrier of socio-economic development; and the consequences of these processes are also visible in the disparities in regional development, in maintaining and even deepening the inequalities between villages and cities, as well as between the peripheries and the centres, in uneven development of settlement networks, etc. Demographic potentials, i.e. the total qualitative and quantitative, real and potential, social and biological characteristics of the population, have a large role to play, on all levels, in the (re)valorisation of Croatian national space. In relation to the aforementioned, research will be directed toward the following: recent changes in spatial distribution, dynamic and structural characteristics of the population on all spatial levels; demographic development of marginal and problem areas; population development tendencies in settlements in urban regions; and the influence of demographic processes on the planning of education activities. The goals of this research are: the identification, evaluation, and projection of demographic potentials of Croatia and its regions; defining directives for forming a population policy and a strategy for balanced regional development of Croatia, and to form a recommendation of intervention in the network of schools and in the organisation of catchment areas of primary and secondary

schools, which would ensure the sustainability and rational organisation of education activities.

- **Cultural landscapes and spatial identities.** Investigation of environmental change in Croatia is planned, with emphasis on changes in land cover and land use. The goals of the research are deductive models, which include physical changes in the environment (landscape), as well as socio-geographic and physical geographic factors that influence the observed changes. Additionally, the possibility of including human behaviour and decision making processes in land cover and land use changes will be researched. A special aspect of this investigation is the coupling of social changes (e.g. depopulation and its consequences in an area), the manner and intensity of evaluation of a space through land use, and consequential changes in the environment. The aforementioned mechanisms also largely influence the increasing occurrence of environmental risks, such as fires. Cultural landscapes contain a link between the past and present, as well as between intangible and material values, and represent a part of Croatia's heritage. Spatial identities (local, regional, national) are constructed on the basis of these values. The research will also include perceptive aspects of spatial, and primarily regional, identities. Using historical maps as a source, previously-started research on border, vague regional identities in the past, specifically in the period from the early modern period to present day, will be continued; concurrently, on the basis of questionnaire survey and interviews, as well as analyses of media content, research of perceptive scope and structural elements of current traditional regions of Croatia will also continue.
- **Tourism and spatial development of Croatia.** Tourism is one of the most important branches of the Croatian economy with tendencies of ever increasing quantitative and qualitative growth, as well as ever more pronounced spatial dispersion from the leading coastal tourism destinations toward the country's interior. In the interdisciplinary approach to researching tourism, themes of interaction of space and tourism are of utmost importance given that all tourism attractions are strongly territorialised. Therefore, a key goal of the research, within the framework of this research theme, is researching the two-way interrelation of space and tourism, which is understood to include: a) identification and evaluation of natural and anthropogenic spatial resources in the attraction basis of Croatian tourism; b) analysis of spatial characteristics of tourism change; and c) defining the spatial implications of tourism in the transformation of tourism space in Croatia—tourism localities, tourism places, tourism regions, i.e. Croatian tourism destinations on all hierarchical levels. The significance of the research defined in this manner can be observed in the possibilities for developing optimal concepts of tourism products in the tourist supply of Croatian destinations, as well as directing the spatial development of Croatia in the context of tourism, in accord with characteristics of desired sustainable development. Rational planning and management of space and its resources is of exceptional importance in the turbulent period of transition of Croatian tourism following ever more pronounced globalisation in the context of the European Union, with the strengthening interest for use of space, primarily in many of the most touristically developed parts of Croatia, on the part of an ever increasing number of potential users.
- **Cognitive processes in geography teaching and the organisation of education.** In this area of research, four topics will be addressed. 1) Cognition in geographic education. Goal: researching efficiency of learning and teaching strategies, suitability of teaching resources in

generating learning outcomes, and forms and criteria of achievement evaluation. The results of the research will be implemented into the curriculum of geography in all educational cycles. 2) Subject curriculum of geography for primary and secondary education. Goal: harmonising education of geography in primary and secondary schools with the Croatian qualifications framework and the development of the scientific field of geography. Groups of learning outcomes will be classified on the basis of analyses of the state of the system, needs of the labour market, and in harmony with the goals of the Strategy for education, science, and technology. Contributions will be made regarding the implementation of the Croatian qualifications framework in the system of education. 3) Initial education, vocational training, and professional development of teachers and instructors of geography. Goal: contribute to creating professional standards, qualification standards, and advancement of competence for organising learning and teaching oriented towards students. 4) Educational resources and human resources in geography teaching. Goal: continue research of the influence of demographic development on change of the index of utilisation and the coefficient of encumbrance of human resources in geography teaching on the level of catchment areas and individual regions. GIS analyses will be used to create models applicable for redefining school networks, initial education of teachers and instructors of geography, managing human resources, and regional development

University of Zagreb Faculty of Science

Appendix C – Faculty of Science Catalogue of Equipment

The bilingual Croatian/English Catalogue of Scientific Equipment and Software of the Faculty of Science is available at the following link:

http://www.pmf.unizg.hr/_download/repository/PMF__Katalog_znanstvene_opreme_i_racunalnih_programa.pdf,

or by click on the Documents in the left menu on the Faculty of Science Homepage, and then by click on Other documents.

References

1. Faculty of Science Self-Evaluation, 2014
2. Faculty of Science Regulation on Job Structure