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ACADEMIA
SCIENTIARUM
LATVIENSIS

IVARS KALVIŅŠ
PRESIDENT OF THE LATVIAN ACADEMY OF SCIENCES

INTRODUCTORY REMARKS

Without question, the development of the Republic of Latvia over the past thirty years has impacted all areas of daily life, including education, research, and innovation. However, the changes have not come to fruition as rapidly as the people of Latvia and, in particular, members of science circles and the technical intelligentsia, might have wished. After the restoration of independence, the education and science system in Latvia faced the dilemma of transformation from a framework built for the needs of a Soviet superpower into one that would respond to the needs of a small independent country. At that time, science and research in Latvia were carried out in the scientific and research institutes of the Academy of Sciences, founded in 1946, as well as in laboratories and institutes of line ministries. Research at institutes was supported by the USSR State Committee for Science and Technology.

The institutions of higher education in Latvia, on the other hand, were rather limited in their scientific research, as they lacked either properly equipped laboratories, or the necessary funding. The end of this institutional framework for higher education and science in Latvia was marked by a decision, in 1992, of the General Assembly of the Latvian Academy of Sciences of transition to a personal academy of a classical type, bringing together not only scientific institutes, but also the most eminent scientists and other spiritual workers of the country, with provision also for foreign members. Most scientific institutions within the Latvian Academy of Sciences (LAS) either became legally independent, or joined Latvian universities, thus strengthening their scientific and research potential.

Unfortunately, this transition did not go smoothly, in the light of the Latvian state being faced with political, social, and financial difficulties in its own transformation from a planned socialist model for agriculture to a market economy.

Critically low investment in higher education, science and innovation has led to a dramatic decline in both the number of researchers and the holders of a PhD. Of course, under such circumstances, only a maximum mobilisation of all available resources in universities and state scientific institutions, including the LAS, has ensured that, despite the critically low level of state support, the institutions of higher education and science in Latvia have been able to demonstrate increasingly improved performance, especially after Latvia's accession to the European Union. Latvian scientists have significantly improved their performance in EU-wide competitions for financing of scientific projects, thereby obtaining funds not only for their research, but also for improvement of scientific and research infrastructure.

For Latvia, as a small country, it was essential to sustain growth, that Latvia define those areas of scientific and research specialisation that matched

its capabilities. On the recommendation of the LAS, a priority was identified for knowledge-intensive bioeconomy, biomedicine, medical technology, and biotechnology, as well as smart materials, technologies and engineering systems, smart energy and, as a horizontal priority, information and communication technologies. The Latvian Academy of Sciences is home to some of the foremost scientists and inventors in all of these areas.

Thanks to effective cooperation of the LAS with the Ministry of Economics of the Republic of Latvia, practice-oriented research programmes have been established, enabling EU Recovery and Resilience Facility funds to be channelled into scientific research, to promote technology transfer, and the development of innovative and commercially viable products and technologies responding to industrial demand in two (Research and Innovation strategy for smart specialisation) RIS3 areas: "Biomedicine, Medical Technologies, Pharmaceuticals" and "Photonics and Smart Materials".

We have selected articles for inclusion in this Yearbook focusing on the social impact of science on public thinking, advances in the life sciences, and energy security issues, including green energy. Some articles have been written by Latvian scientists who last year won the highest awards of the Latvian Academy of Sciences as the authors of the best scientific or innovative achievements of the year. This annual Yearbook also presents the ideas and proposed solutions on climate change presented at the 18th Baltic Intellectual Cooperation Conference, "Energy for the Future Society". Several articles are also devoted to the study of the complex challenges facing the Latvian economy and society in an international context, as well as to the tools needed for the development of a smart economy and society.

We hope that this Yearbook will give the reader an insight into the issues that Latvian scientists are dealing with, in addition to contributing to the global scientific landscape.

Translated by **Eduards Bruno Deksnis**

PETRO MYRONENKO
PRESIDENT OF THE ACADEMY OF POLITICAL AND LEGAL SCIENCES OF UKRAINE,
DOCTOR OF POLITICAL SCIENCES,
ACADEMICIAN-FOUNDER OF THE APLS OF UKRAINE

MANIFESTO OF SCIENTISTS OF THE ACADEMY OF POLITICAL AND LEGAL SCIENCES OF UKRAINE

On 24 February 2022, democratic, peaceful Ukraine, which has never attacked anyone and respects the sovereignty of other countries, was woken up by explosions of bombs and missiles. On this day, the Russian Federation unleashed a large-scale war against the people of Ukraine without any reason, guided by imperial ambitions, vilely disguising it as a "special military operation".

The Ukrainian people, with the support of democratic countries, have shown the world examples of true heroism and unbreakable spirit by defending Kyiv and liberating a significant part of their territory. The war, which has been going on for the second year in a row on the territory of Ukraine, has claimed countless victims. Every day, we bury those who were killed in the heat of war, including not only soldiers defending their country, but also civilians and, unfortunately, children. It is undeniable for us that this war has all the hallmarks of genocide against the Ukrainian people: the occupiers are looting our museums and libraries, blowing up churches, and persecuting Ukrainians for their desire to preserve their language and culture.

Since the annexation of Crimea and the occupation of part of Donbas in 2014, we, representatives of the Ukrainian scientific community, have consistently warned the world about the danger posed by one of the embodiments of evil – the Putin political regime, and the majority of the Russian population, whose consciousness has been distorted by inhuman mass propaganda. We have strong reason to believe that this war of darkness against light is directed against global democracy and already has all the hallmarks of the Third World War.

The international security mechanisms, including the UN and the OSCE, unfortunately, proved powerless to stop the Russian Federation either at the stage of preparation or during the implementation of its aggressive intentions. Ukraine, which has lost one-fifth of its territory and is engaged in a deadly battle with the enemy, is tired of "deep concerns" and "peace proposals" coming from different continents. The destruction of Ukrainians as a nation has become a reality of the 21st century. The ruins of Mariupol and Bakhmut, Kharkiv and Chernihiv, Bucha and Irpin, and dozens of other settlements are

soaked in the blood of murdered residents. However, the world, lulled by Russian media lies, mostly does not notice this. The so-called "realism" of some politicians does not object to contacts with Putin's regime and calls for "compromises" and "saving face" for barbarians of the new era.

Today's Russia will not stop with Ukraine. Moscow's plans include the annexation of other European countries, the seizure of new territories, the destruction of human rights and freedoms, dignity, humanism as the highest values of the democratic world. In order to achieve this goal, the Kremlin has legalised such means as bribery, blackmail, provocations, murders, hostage-taking, political subversion, historical manipulations, threats of nuclear strikes. The dumbfounded world still mostly remains obediently silent. The fear of a Russian invasion acts as a new paralytic substance, cutting off many people's desire to critically evaluate international realities and determine their place in protecting the best achievements of civilization.

This war can only be stopped by joint efforts. The world must not tolerate evil. Continuing to cooperate with people representing Russia in the current circumstances means nothing less than assisting international criminals. Based on this, we urge scientists all over the world to make it impossible for citizens of the Russian Federation to access international grant programmes and all scientific publishing houses, to restrict the education of Russian students in higher education institutions in democratic countries, and to refuse to participate in scientific events in the territory of the aggressor country.

We are deeply convinced that only decisive actions at all levels can stop Russia's bloody aggression against Ukraine and the threat to the entire progressive mankind.

ROSEMARIE WILCKENS
DR., MAYOR OF THE CITY OF WISMAR AD

COOPERATION FOR CULTURE IN EUROPE

For more than 800 years, bricks have been used for major building projects in the cities and communities of northern Europe. There is no doubt that this is a symbol of a common history in the Baltic Sea region. It is impossible to overlook the fact that this brick tradition has shaped the face of the Hanseatic cities on the North and Baltic Seas.

From 1150 onwards, building with brick spread rapidly in the common economic area of the Hanseatic League. It began with the Brick Gothic period and continued into the modern era. But it was the borderless Europe after 1990 that made co-operation between the individual regions and municipalities of the brick area possible.

Mecklenburg-Vorpommern lies at the centre of this cultural area, so it is not surprising that an important impetus for brick architecture has come from here in recent times. The reconstruction of the war-damaged St George's Church in Wismar between 1990 and 2010 played an important role as a model building site.

Initiated by the German Foundation for Monument Protection and its then Chairman of the Board, Prof. Dr. h.c. Gottfried Kiesow, an exhibit at the World Exhibition 2000 in Hanover was turned into a joint exhibition by the federal states of Mecklenburg-Western Pomerania and Schleswig-Holstein, the Hanseatic cities of Wismar, Lübeck, Stralsund, Rostock, and Greifswald, the North German Broadcasting Corporation, and the two regional churches entitled "Paths to Brick Gothic". The logical conclusion could only be the extension of the theme to the "Route to Brick Gothic". A success story between Denmark, Germany, Poland, and Latvia.

When dealing with brick construction, it also became clear that the artistic use of this simple material had never received the attention and appreciation it deserved in art history. Research and science had touched on brick architecture from time to time, but never systematically investigated it. Brick has yet to find its place in building culture and its categorisation in art history.

Since 2006, the Hanseatic cities on the southern Baltic Sea of Wismar, Lübeck, Rostock, and Stralsund, together with the German Foundation for Monument Protection and the European Centre for Brick Architecture e.V., have organised an annual congress on brick architecture in St George's Church in Wismar and published documentation on the subject. With 18 congresses in this series, an extensive collection

of material on building with brick has been created. The organisers are driven by amazement at the ingenious building material brick and its universal application possibilities. It is comparable to an act of creation when brickmakers and master builders have been performing the miracle of creating an artificial brick from clay for thousands of years and using it in an impressive variety of ways.

In 2005, the European Centre for Brick Architecture was founded on the initiative of the Chairman of the Board of the German Foundation for Monument Protection, Prof. Gottfried Kiesow, the Polish Conservator General, Prof. Dr. Andrzej Tomaszewski, the German architectural firm Angelis und Partner, the Danish brick manufacturer Falkenlöwe, and the Hanseatic City of Wismar.

What began with the German Foundation for Monument Protection and Prof. Gottfried Kiesow has continued to this day under his successor, the former mayor of Wismar. Although Dr. Wilcken has stepped down from the committees of the German Foundation due to age restrictions, she is still in charge of the conference series on brick architecture within the European Centre of Brick Architecture. The European Centre of Brick Architecture has set itself the task of collecting fundamental information on building with brick from all stylistic periods and networking today's players.

A vision like this can only be realised if you have people with ideas and supporters at your side. And so it cannot go unmentioned that Prof. Ojārs Spārītis has been part of the inner circle of the "Brick Architecture Family" since 2006 and continues to be today. His talent for inspiring and involving others has made European and Baltic brick architecture a focal point of our congress series.

The focus on brick has developed into a supra-regional and thematic co-operation with international specialist circles. The focus is on all aspects of brick building culture, building research, architecture and monument protection. What began 20 years ago as inter-communal co-operation has long since become a transnational project with a firm place in Europe's cultural landscape.

SCIENCE IN THE DISCOURSE. HUMANISM VERSUS PRAGMATISM

RUSSIAN–UKRAINIAN WAR: ORIGINS, PARADOXES, POLITICAL CONSEQUENCES

PETRO MYRONENKO
Academy of Political and Legal Sciences of Ukraine

Russian plans to conquer the world using the "Ukraine" detonator have been completely and irreversibly destroyed. Ukraine's strategic partnership with the USA, other NATO countries, and democratic countries in various regions of the planet has become a reality.

By supporting Ukraine to survive, united Europe proved to be reliably protected in the east of the continent from the Russian invasion. Despite this, NATO is expanding as one of the few supranational structures of the 20th century, the necessity of which is not disputed.

Russia cannot but fight. The meaning of the existence of this territorially largest country in the world is to prepare for wars, instigate wars, actively participate in hostilities and use the post-war situation to prepare for the next wars. Russia and democracy which is inherently opposed to wars were and remain mutually exclusive concepts. Short-term democratic implants in the authoritarian Russian body were rejected by the very nature of the Moscow government, whose basic slogans are *to attack, take away, destroy, threaten*.

Russia was formed over the centuries on a military basis, conquering new lands and imposing on them the developed military and power model of Kremlin ruling. In the 18th century, the Moscow state extended its power over most of modern Ukraine, beginning a long phase of plundering it for its own benefit.

Ukraine was simultaneously used, hated and feared by the neighbouring state. The latter used the incredibly rich natural resources of the Ukrainian region – from coal and gas to iron ore and bread, from Pechersk shrines to musical and literary masterpieces. It hated Ukraine for spiritual and cultural otherness which in many cases manifested itself as moral superiority. It hated for the historical primacy in the formation of centralised state and introduction of Christianity, for the Cossack heritage, for language, customs, value intransigence, democratisation of communication. It hated for the phrase "I will win" that cannot be literally translated into Russian. It was afraid because it saw proud and freedom-loving Ukrainians, their extremely high motivation in the armed defence of their land.

Russia envied the courage and intransigence of Ukrainians on the battlefield. In its historical books it is hard to find the fact that entry of the USSR into the armed struggle against the German invasion in 1941 took place when Ukrainian marshal (Semen Tymoshenko) was the Minister of Defence. It is knowingly forgotten that the Instrument of Surrender of Japan in 1945 was signed by Ukrainian general (Kuzma Derevianko). It is also not mentioned that Ukrainians were the best pilots ACE (Ivan Kozhedub), the best sniper (Ludmyla Pavlichenko). That half of the tank armies were commanded by Ukrainians (Pavlo Rybalko, Andrii Kravchenko, Dmytro Leliushenko). That the only national order of the Soviet award system in that war was the order of Bohdan Khmelnytskyi. The historical lie about Russia that is supposed to have won the Second World War singly, is rejected by the fact that the 1st, 2nd, 3rd, and 4th Ukrainian fronts, equipped with mobilisation resources primarily from the Ukrainian regions, triumphantly set foot in the territory of Czechoslovakia and Hungary, Romania, Bulgaria, Yugoslavia, Austria, Northern Greece. Russian version of the privatisation of victory collapses from the recognition of the truth that the 1st Ukrainian helped take Berlin. That the Ukrainian Insurgent Army, supported by the people, fought against the western and eastern occupiers (Nazis and Bolsheviks) for more than 20

years. The fact is ignored that Ukraine, but not the Russian Federation, voted for creation of the UN. With its vitality, historical significance, and civilizational subjectivity, Ukraine negates the efforts of Russian propaganda regarding the "superiority" and "right to dominate" of that Eurasian mix which is designated as "Russians" and so far is controlled from Moscow.

The economic development of Ukraine, imposed and controlled by the allied authorities, rather resembled Russian revenge. The Holodomor of 1932–1933 was the result of the forced seizure of grain stocks from Ukrainian laborers. Dnipro, walled up in cascades of six reservoirs, turned into a half-dead river. The first Soviet gas pipelines Dashava–Moscow and Dashava–Leningrad devastated the Carpathian energy fields. The world-famous Chornobyl NPP was built 110 kilometres from Kyiv on the initiative of the Soviet leadership.

In the post-Soviet period, Russian hatred of Ukraine acquired new features. Russia was annoyed by the Ukrainian revolutions of 1990 (Revolution on granite), 2004–2005 (Orange Revolution), and 2013–2014 (Revolution of Dignity), which prevented the usurpation of political power by the then ruling clans. No less acute moment of Russia's rejection of Ukraine was the radical difference in the development of the political systems of the two states. Democracy worked in Ukraine with enormous difficulties, with asymmetric failures, with elite abuses. Ukraine has chosen European and Euro-Atlantic integration as its strategic goals. Thanks to the visa-free regime, Ukrainian passport has become recognisable in dozens of countries. Having no energy advantages, the Ukrainian economy started working on the principles of the civilised world. In contrast, Russia was unable to consolidate the results of the democratic experiments of the 1990s and restored the usual barracks of authoritarianism, which quickly proposed the citizens of the Russian Federation a super-presidential model of absolute power in the hands of an artificially grown leader.

Fears of the ruling Russian political circles (preventing Maidans as in Ukraine, opposition as in Ukraine, media as in Ukraine, raising the standard of living as in Ukraine) were transformed into the newest version of Ukrainophobia, the logical continuation of which was the Ukrainocide. According to the Kremlin projects, Ukraine was supposed to disappear, dissolve in historical nothingness. It should be replaced by Novorosiia (awakened to life caricature copy of Malorosiia). The Ukrainian language as a "south-western dialect of the Great Russian language" had to dissolve in a muddy flow of imperial verbal surzhyk. The majority of the Ukrainian population was supposed to fill the territorial and demographic voids of the northern and Asian parts of Russia. "True" Russians were to be resettled in their place in order to maintain the Ukrainian agricultural and industrial, defence and industrial, transport and communication, recreational and tourist and other complexes in a working condition in the interests of the resurrected empire. Another war, hidden under the euphemisms "special military operation", "denazification" and "demilitarisation" of Ukraine, became the mechanism for implementing these and other Russian intentions.

The Russian dictator planned the attack on Ukraine as only the initial stage of a "great plan" aimed at gaining world leadership on the basis of the restoration of the Russian great power. It was planned that after the capture of Ukraine, the next victims would be the Baltic republics, Moldova, and the countries of Eastern Europe. Hoping for the effectiveness of nuclear blackmail, the Russian helmsman was expecting the weakness of the West which is unable to respond adequately to the Russian invasion, the declaration of conditional "Union – 2.0", the restoration of Russian dominance over the former socialist vassals (Poland, Slovakia, the Czech Republic, Hungary, Romania, Bulgaria), in the end – the rehabilitation of the status of a global political power which the Soviet state once sported. Moscow's revenge for the defeat in the Cold War was to take place. The "greatest geopolitical tragedy of the 20th century" had to be corrected, with which the current head of the Russian state marked the collapse of the USSR. Ukraine destroyed Russian offensive plans. The actions of the armed defenders of Ukraine are officially designated as carrying several operations: First strategic defence operation (24 February 2022 – April 2022); Second strategic defence operation (May – August 2022); Strategic offensive operation (September – December 2022); Third strategic de-

fence operation (January – February 2023); Fourth strategic defence operation (March – June 2023); Second strategic offensive operation alternating with defensive actions (from July 2023).

Details of these operations will be described by historians. However, some paradoxes of the Russian–Ukrainian war, which came as a surprise to most countries, may be pointed out:

- no modern army has been engaged in a war of such high intensity. The war that Russia unleashed against Ukraine has become the largest conflict in Europe since the Second World War. Ukraine is fighting on an equal footing with the nuclear state and the army which Russian propaganda defined as "the second in the world" until recently;
- front-line successes of Ukraine, supported by numerous allies, suspended Chinese plans to invade Taiwan;
- the Armed Forces of Ukraine extremely quickly mastered foreign high-tech weapons and military equipment. At the same time, Ukraine is actively reviving its own defence production;
- with basically no modern naval forces, Ukraine defeats the Black Sea Fleet of the Russian Federation, transforming its operational and strategic capabilities into operational and tactical ones (at the flotilla level);
- the offensive actions of the Armed Forces of Ukraine refuted one of the fundamental postulates of military science about the need for a numerical (3–5 times) superiority in manpower and weapons during the offensive. The Ukrainian army advances in conditions of enemy's superiority – both in weapons and in number of personnel.

Ukrainian logistics, the elements of which are located abroad, provide all the needs of the front. It has been successfully optimised while taking into account the threat of air and missile strikes.

Russia responded to Ukraine with battle stencils from 70–80 years ago "from Marshal Zhukov": the main striking force on the battlefield is armoured vehicles, primarily tanks; the infantry must advance behind a dense barrage fire created by artillery; to execute the order, commanders of all levels should not count on human losses; Russian mobilisation resources are inexhaustible, etc. As can be seen, the Present (from Ukraine), where every soldier, volunteer is valued, and the bloody Past (from Moscow–Russia) with its contemptuous attitude towards human life met on the Ukrainian battlefields.

In the rapidly changing maelstrom of military and political events, it is worth highlighting certain political consequences, which are already clearly marked today and offer a vision of the future, at least in a sketchy version.

Notably, Russian plans to conquer the world have been completely and irreversibly destroyed thanks to Ukraine's strategic partnership with the USA, other NATO countries, and democratic countries of the world. By supporting Ukraine to survive, the united Europe is reliably protected in the east part of the continent from the Russian invasion. However, NATO is expanding as one of the few supranational structures of the 20th century, the necessity of which is not disputed.

The world order that had been in place since 1945 has passed into historical oblivion. International and political decisions dating from former conferences no longer mean anything. The need to update the global political and communication system on a value basis is becoming necessary. And the removing of Russia from the UN Security Council is only the beginning of great cleaning of international institutions from the relics of Tehran, Yalta, or Potsdam treaties.

The first armed conflict between the circle of democratic countries and the camp of autocratic regimes is taking place at the civilisational level. The preliminary generalisation of the Russian–Ukrainian war provides grounds to assert that the global "axis of evil" (Russia, Iran, China, North Korea) is losing confidence in the rapid reformation of the world "for themselves". However, it is far from defeated. With a high probability, the "axis" will repeat attempts to destroy the democratic part of humanity. Especially since its participants are nuclear countries and the "almost nuclear" Islamic Republic of Iran.

The space of war has become material and virtual. The "hybridisation" of hostilities with the simultaneous involvement of numerous proxy structures (primarily private armies and religious and extremist organisations) in their course, involvement of

cyberspace in the sphere of armed struggle, end-to-end informatisation of defence management have erased the line between war and peace. The correlation between these social states was clear and understandable only a generation ago. Now it is filled with implications, exceptions, transitional situations, which are increasingly difficult to regulate not only on the basis of international law, but also common sense. As a result, security theory (national, regional, international) must break out of the cocoon of half-dead theories and weak recommendations.

Russia's large-scale aggression against Ukraine which began on 24 February 2022, sharpens the need to supplement NATO with new security structures capable of countering the latest threats. This idea is supported by Great Britain, Poland, Lithuania, and other countries. Having the experience of effective actions in the conditions of modern war, Ukraine claims to participate in the creation of a new architecture of European security, the institutional format of which remains uncertain so far.

Recent attempts of part of the American political elite to isolate the United States from world processes have not worked. Washington rehabilitated an internal sense of responsibility for freedom and democracy which should become organic elements of the internal policy of other states. This is exactly what Kyiv and Jerusalem heard, and even earlier – Taipei.

The starting cannonade (not the starting gun) sounded. The marathoners overcame the first kilometres. However, it is far from the finish line.

ON AWARENESS, PUBLIC OPINION, AND THE NEED OF KEEPING ALIVE WHAT IS STRICTLY HUMAN

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A 2018 interview with Robert Shank, one of the fathers of the so-called Artificial Intelligence (AI), appeared in CNN (https://youtu.be/PVb0OkRxRfc?si=cgIPXo6zm8oica2w) providing a synthesis of motivations at the basis of the actual buzz on AI. An enthusiastic journalist (while, at the bottom of the screen, flowed the news on the huge success in stock exchange of companies involved in AI) tried to give a miracle-working flavour to the spot, expecting Shank to sketch the huge trans-humanistic recasting of the world fostered by AI.

Shank's attitude was exactly the opposite: the scientist said that defining AI as 'Intelligence' was highly misleading and that it much better to use the term 'computer software'. This is nothing new to any scientist involved in mathematical modelling and data analysis: AI (whose mathematical bases were set more than 70 years ago) is not different from any other data analysis method like regression, discriminant analysis, neural networks, or cluster analysis. All these methods rely upon a data set made by many statistical units defined by a large set of descriptors, that do learn by experience by the progressive enlargement of the training data set and are able to make predictions on the outcome (dependent variables) of new entries (test set) not present in the training set.

Similar considerations hold for the so-called ChatBots (ChatGpt is the most popular of these algorithms) that are not different from the usual way of searching the web using some keywords of interest. When we ask a question to a ChatBot we receive an answer (generated by the copy-and-paste procedure) summing up different instances (texts stored in the web) based on their maximal superposition with the question wording. Even if it is relatively easy to detect the trick and the purely syntactical nature of the answer, many people think these machines mimic the human minds.

This misunderstanding is favoured by the names assigned to AI algorithms; by the way, one of the most fashionable AI architectures has the fascinating name of 'deep learning'. It is nothing else than a multi-layer neural network acting as a universal optimizer relying on the discovery of non-linear complex interactions among descriptors (x variables) to find the best approximation of the desired outcome. It is not by chance that nowadays the 'hottest' theme in AI research is the quest for 'explainability', i.e. the effort to make the algorithms transparent (and then allowing human experts to judge about the consistency and reliability of AI responses) making explicit the reasons behind their output choices [1]. This is a relatively easy task in the presence of an ordinary equation, in which the terms of the discriminant formula have a natural counterpart in established concepts (e.g., electromagnetic force, population density, concentration of a chemical), but it is much more difficult in the case of 'black box' discriminators like neural networks.

The need to check for the consistency and reliability of AI responses stems from two basic features:

1) Difference between syntactic and semantic information.

Like any computational approach, AI tools rely upon syntactical and not semantical information, with no relation to the context. In other words, the AI will necessarily consider two statistical units with the same values of a set of descriptors as equal (and thus necessarily ending up into an identical out-

come). Let us imagine two persons, A and B, having the same values of a set of clinical laboratory tests. But if person A had the tests as a routine procedure for being admitted to the hospital, while person B had the same tests following a specific intuition of a physician to verify his/her hypothesis on a specific disease, the situation is drastically different. In fact, it was recently demonstrated that these two (mathematically identical) persons (that in computational, syntactic terms are not distinguishable) have a difference in life expectation of around three years [2]. The semantic information that defines the different context from which the same results derive is a 'context' that is completely not accessible by a machine.

2) No sample can completely catch the 'whole'.

Not any training set (the ensemble of instances used to develop a model) can provide a complete and definitive picture of the real world, from where arise novelties that can abruptly change the general picture. This implies that the dream (nightmare?) of capturing the entire set of possibilities by inflating the set of information is bound to failure and could provoke the death of science whose progress relies upon the analysis of unexpected events. Recognition of 'exceptions' to established paradigms is possible if (and only if) our models rely on simple explanations with few parameters and not on the carbon copy of the already known.

A prophetic 1936 short tale of Jorge Luis Borges entitled "On the Exactitude of Science" (*El Rigor de la Ciencia*) perfectly describes the today's risk of extinction of any creative endeavour. It is worth reporting in its entirety the Borges tale that the author attributed to an imaginary 17th century explorer:

> …In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.
>
> Suarez Miranda, *Viajes devarones prudentes*, Libro IV, Cap. XLV, Lerida, 1658.

There is nothing wrong with maps (models of reality), but they become useless when they pretend to be definitive by encompassing any possible detail. On the contrary, the usefulness of a model comes from the focus on both a specific scale and a personal point of view (exactly like happens for Art).

In the same years of the imaginary Suarez Miranda, the extremely real Blaise Pascal (one of the major polymath geniuses of all times) clarified the need of both human (largely unexplainable) intuition (*esprit de finesse*) and the equally human but expressible in a symbolic formal way, mathematical thinking (*esprit de geometrie*). In his *Pensees*, written around the years 1655–1660, Pascal wrote (emphasis added):

> The DIFFERENCE between mathematical and intuitive mind. – In the one, the principles are palpable, but REMOVED FROM ORDINARY USE; so that for want of habit it is difficult to turn one's mind in that direction: but if one turns it thither ever so little, one sees the principles fully, and one must have a quite inaccurate mind who reasons wrongly from principles so plain that it is almost impossible they should escape notice […]. However, in the intuitive mind, THE PRINCIPLES ARE FOUND IN COMMON USE and are before the eyes of everybody. One has only to look, and no effort is necessary; it is only a question of GOOD EYESIGHT, but it must be good, for the principles are so subtle and so numerous that it is almost impossible but that some escape notice […]. These principles are so fine and so numerous that a very delicate and very clear sense is needed to perceive them and to judge rightly and justly when they are perceived, WITHOUT FOR THE MOST PART BEING ABLE TO DEMONSTRATE THEM in order as in mathematics; BECAUSE THE PRINCIPLES ARE NOT KNOWN TO US IN THE SAME WAY, AND BECAUSE IT WOULD BE AN ENDLESS MATTER TO UNDERTAKE IT.

> WE MUST SEE THE MATTER AT ONCE, AT ONE GLANCE, and not by a process of reasoning, at least to a certain degree [...].

It is worth noting that Pascal was neither a largely irrational hippie nor a theoretician far from scientific thinking, but one of the developers of probability calculus, the pioneer of fluid dynamics, the one that set the rules of automatic computation, the one that, at the age sixteen, established a fundamental theorem of projective geometry, not to mention other important achievements.

After almost four centuries, we have largely forgotten the evidence (very clear to Blaise Pascal) that the '*esprit de finesse*' does not correspond to irrational or purely emotional behaviour but is a form of knowledge of its own and, like any form of knowledge, can be fostered by education. It is what Michael Polanyi [3] calls 'Tacit Knowledge', i.e. what we know but cannot explain. Using a physical metaphor, we can equate tacit knowledge to a capacitor that progressively stores energy to be released when needed. This storage is made possible by our reflexive activity on our experiences, and is put at work when we must solve an incoming problem that in turn does not necessarily have an evident link with previous experiences. The tacit knowledge is the main source of 'awareness' [4]. The lack of recognition of the need of strictly human traits like tacit knowledge and awareness and the consequent reduction of human mind to its computational ability has dramatic social and psychological consequences. I do not want to enter into the causes of this bizarre (and somewhat tragic) state of affairs and prefer to comment a very recent brilliant paper by Shen et al. [5] that offers a very interesting perspective on the 'physical' genesis of the exaggerated hype on AI. The authors deal with the polarisation (and consequent public opinion oscillation) stemming from 'rumours' (i.e. not motivated and carefully analysed opinions) in the era of social media. This case is very similar to the pre-conceived opposition/magnification of AI caused by the lack of awareness of their nature of data analysis techniques, i.e. of their neutral nature of tools and not trans-human entities. After all, in the presence of a murder, we put in prison the killer and not the weapon.

The authors of the abovementioned paper [5] model the swinging of public opinion on the topic of the behaviour of a driven-damped pendulum (Fig. 1), the conditions to be satisfied by the system are:

1. The rod is massless, and the mass of the whole system is concentrated on the bob.
2. The rod is rigid, so the angle ϑ can exceed 90°, approach or reach 180° or even more.
3. The bob is subjected to periodic external forces in the direction of oscillation, which is always perpendicular to the pendulum.

If the solicitations exerted by external forces on the pendulum are small, the bob remains in close vicinity of its minimum energy position (angle ϑ = 0) and, when forces dissipate, remains stable in its position subject to force of gravity (mg). This extremely simple system can show a very complex behaviour when driving forces exceed a certain limit: the motion of the bob is not more confined to harmonic motion around its energy minimum with small changes of the angle, but enters in a strongly non-linear regime and many complex dynamical behaviours can emerge.

By the action of simple analogical reasoning, each feature in rumour propagation (especially in social media) has a counterpart in the pendulum model. For example, the direction of public opinion is anal-

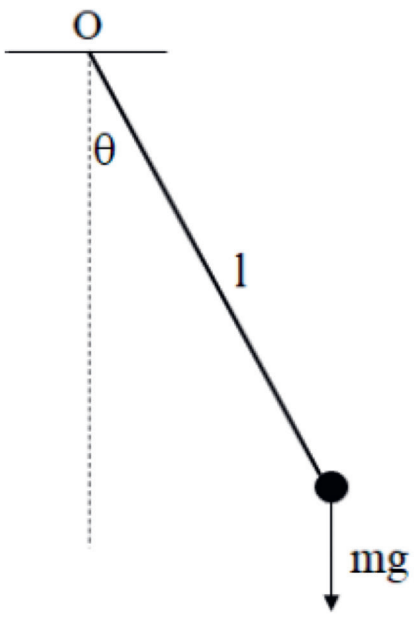

Fig. 1
A driven-damped pendulum

ogous to the angle of the pendulum; the 'heat' of the debate corresponds to the energy of the pendulum and so on.

In public opinion triggered by rumours (in the case of unmotivated opposition/adoration of AI) there are typically two directions that correspond to negative and positive values of ϑ. The ratio $d\vartheta/dt$ corresponds to the speed of the oscillations in public opinion, essentially reflecting the intensity of the argument between different opinions. When there are no external forces or damping acting on it, public opinion still oscillates spontaneously. This is because of diverse individuals who hold different opinions and seek to persuade or refuse others. The interaction between different opinions results in a constantly evolving preferred direction of motion that can change over time. As the pendulum swings back and forth with a small angle, this internal force is akin to gravity and generates a harmonic motion around the equilibrium position. In addition to the above internal force, external forces can impinge on the evolution of the system drastically changing the harmonic character of the system behaviour in time. Let us imagine that there is a strong commitment of economic (political) power to support the idea of the need of a drastic reduction of workforce in economic sectors as banking or public administration. This attitude could derive from purely economic motivations and generate the need to put the blame on 'unescapable consequences of the technology advancements' so to avoid opposition to these job reduction policies.

If this is the case (I do not take any position about this interpretation) the economic (political) power will drive the public opinion toward the direction of 'AI as intelligent agents that will substitute the human work' thus forcing the pendulum to assume a 'quasi-stable' position far from its gravity defined natural equilibrium. That is to say that manipulation of the public opinion is a relatively straightforward job when in the presence of largely dominant positions in the social media information arena.

The only antidote to this manipulation allowing us to exit the jail of 'public opinion' is to keep alive (not only in the specific case of AI) our critical thinking that necessarily stems from our tacit knowledge storage. This is the necessary role of any creative endeavour from Art and real Science to the conscious care of daughters and sons and relies on an education system that gives importance to apparently 'useless' matters as literature, art history, Latin and Greek language and culture, theoretical philosophy.

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SOME REMARKS ON THE RELATION OF THE NATURAL SCIENCES TO THE HUMANITIES

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It was with some trepidation that I accepted the invitation to deliver general remarks on the relation of the humanities (*sciences humaines, Geisteswissenschaften,* and their equivalents in other languages) to the natural sciences. This is an old and much debated question, most sharply defined by C. P. Snow when he proposed that two separate intellectual cultures existed that could not communicate with each other. This conference assumes the opposite, and I agree with many other subsequent critics of Snow who have argued that the sciences and the liberal arts or Humanities can communicate in a non-trivial way with each other. The question is how.

To paraphrase the invitation to the lecture I received, the suggestion that borrowing the analytic methods and tools of the natural sciences is the way communication or collaboration with the Humanities happens nevertheless seems to me to misstate the issue. The concept of method is very problematic, especially if the term be applied to define the distinctions and possible differences among disciplines. In teaching and writing I prefer to use historiography or the literature of art rather than methodology. To be sure we may still refer to the old Baconian notion of the scientific method that describes how empirical knowledge is gained, namely by induction from particulars following a certain order. But knowledge is not always gained simply by induction. As several noted philosophers of science have argued, it is not methods that define the growth of scientific knowledge. Rather the process may be one in which hypotheses (conjectures) are formulated that are proved or in one familiar philosophy of scientific discovery disproved. It has also been proposed that certain common assumptions (sometimes called normal science) are shared and that new theses or hypotheses (revolutionary science) may cause us to reject, reform, or amend them. In any case not only the natural sciences, but all procedures of knowledge formation share some features in common. Rather than the methods involved, it is the tools used (for example, iconography, on the one hand, statistics, on another) in approaching a problem that might help to differentiate between disciplines. While we don't change a tire with a saw, as the thrust of this symposium suggests, we may however also borrow tools, just as we might use someone else's tire wrench.

One area that does seem to distinguish the Humanities from either the natural or social (or applied sciences) are their comparative lack of use of mathematical models or systems of analysis. Perhaps this is because as has been said *individuum est ineffabile*, the individual is incommunicable. Whether or not this be so, exactly quantifiable data of significance such as are available for analysis in the supposedly exact sciences that allow for the determination of trends or testing generalisations are not usually identifiable in fields like art history or literature, or at least have not led to significant results. This does not mean that general works of art history/cultural cannot be written. Some non-trivial and quantifiable data does exist for analysis in the Humanities. I am thinking here of such sorts of approaches as those of other aspects of word frequency in prose or

poetry, syntactical repetition, and rhyme patterns in literature, and of the frequency of use of colors and patterns of design in art, for example. Data for some such questions may be assembled to be categorised and then examined by computation. Digital humanities has burgeoned, although what further effects and where it may lead is uncertain.

This however gets us to the crux of the matter. Is data analysis enough? Dilthey and others who founded modern philosophical hermeneutics argued that interpretation lay at the heart of what the Humanities were seeking, namely understanding. Hans Georg Gadamer made the distinction sharper when he differentiated between truth and method, as did writers of the Frankfurt School, when they attacked what they called positivism. We need not be positivist to see that the interpretation or understanding of objects also lead to the application of skills, or insights taken from other fields in the varied social and natural sciences that both provides information and helps identify and then perhaps subsequently formulate further argument. New approaches or understandings of material may help us not necessarily to acquire new knowledge, but to deepen, reinforce, or even correct interpretations.

I would like to adduce three examples in ways in which perspectives on cultural and art history have recently been enriched by the natural sciences. One involves the use of optics, and techniques of so-called scientific analysis of paintings. Here the use of infrared analysis has opened up a whole field that if not ineffable was previously invisible, namely the existence (and study) of underdrawings on paintings. Not every painting has underdrawings; many are not visible because only carbon based pigments allow them to be perceived; and some were already visible with the naked eye. Still, the study of the mass of underdrawings that may now be discerned can elucidate much. Of course, the empirical data revealed require further interpretation. This becomes clear if we read some of the common misunderstandings that art historians have had when they call upon the mere existence of an underdrawing to establish an attribution. But just as an artist who is a member of a workshop, either someone now known by or obscure to art historians, may have had a hand in executing a painting in an atelier, so an assistant may apply a cartoon to a panel or canvas, and that cartoon may be used to produce multiple examples of the same composition.

The use of DNA analysis may also prove fruitful. Here the application of genetic investigations to the dead – even to those long dead – has revealed many patterns of human geography, with applications for history and art history (or art geography). For example, DNA allows us to trace patterns of migration, kinship, and circulation of people in the past. To use a term taken from the social sciences, earlier arguments had argued on other bases than culture, like was diffused along with genomes, and this may now be confirmed. As has however most recently been revealed by studies of neolithic people in Africa, artefacts travelled much more and much farther than did people. As I have observed elsewhere this discrepancy indicates not only that trade and circulation existed from the earliest human times on the planet, but also that global (or at least regional) exchange can flourish even when (as in the existence of the silk route with many stops rather than a continuous silk road) people do not carry objects for long distances but transmit them over space and time.

Finally, Data Science itself. This recent development within the field of applied mathematics/computer science involves the procedure of mapping data and has many possible applications for the humanities (and social sciences). Art historians are involved in a similar process when they discuss a notion common to both fields, namely diffusion, to use the word in yet more contexts. The Humanities have however not hitherto applied concepts like cluster analysis very much if at all. The greater usefulness of this idea remains to be determined, but some applications of methods resembling data analysis already seem noteworthy. I refer to studies of network analysis of imperial ambassadors and visitors to the Porte, the court of the sultan in Istanbul (Constantinople) and of *alba amicorum* (*Stammbücher*, autograph albums) that have demonstrated the existence of hitherto unrecognised cultural connections and patterns. The scholars who have tracked them have specifically used data network analysis, if not specifically cluster analysis, although an interlocutor informs me that the technology has not reached

a level in which this sort of analysis could provide much more than simple graphing or mapping.

While the term network is widespread, it is however significant that when I have asked them neither the mathematician/computer scientists who analyse networks nor the historians who collaborate with such scientists seem to have been aware of the use of the term "network" as it has recently been applied by the sociologist and Parisian *maître à penser* Bruno Latour. Significantly, however, in his formulation of actor-network-theory Latour specifically eschews graphing or mapping networks.

In the end, the question of how much collaboration and crossover exist remains open. I leave it to those better informed (and most are) than I am to say. In any case efforts are now being made to try to devise theoretical models that may also be empirically tested and that have increased our knowledge of the universe from the most microscopic to most macroscopic scale. In this regard such models do not resemble the all too frequent and to my mind often fruitless interior conversations about method and theory that in the North American and to some extent Anglo-Continental World of art history often seem to have taken over large tracts of academic discourse. This has happened especially in those Humanities that deal with the twentieth century and contemporary cultural expression. It remains to be seen what comes next.

BIRTH OF A NATIONAL ELITE FROM THE SPIRIT OF HEINE

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The title of this essay intends to draw attention to a question that may seem strange only at first glance: what do sentimental love poems have to do with the emancipation of small national cultures in Central and Eastern Europe? I will seek to answer this question in order to provide insight into the debate how literary studies can help to understand research of social transformations.

In the five decades between the European revolutions of 1848 and the 1905 revolution in the Russian Empire, Latvian society experienced a significant turning point: a completely new and previously non-existing group – the ethnic Latvian intellectual elite – began to assert itself and laid claim to having a dominant role in Latvian culture. For centuries, Latvians had been seen as a peasant class whose literary and cultural life was taken care of by Baltic German intellectuals, mainly the Lutheran clergy. In the mid-19th century, this structure, with characteristics resembling a colonial situation, was undermined. It was partly related to the response to the revolutions of 1848, which fundamentally changed the way the elites looked at the possibility of social change. In an era in which the public space became firmly established and reading came to be more widespread than ever before, literature gradually gained a central position in the project of social reforms. The awareness of the potential influence of the new elite on social change was firstly shaped by developments in literature, which seemed welcome to some and almost apocalyptic to others.

The new Latvian elite were named the "Young Latvians" because outsiders saw it as a dangerous parallel to the revolutionary *Junges Deutschland* movement, but the term itself was offered not in the context of political or social issues, but in the context of a Latvian translation of a poem by Heinrich Heine.

Heinrich Heine's poem "Lorelei" (1824) not only gave voice to the Latvian intellectual elite but also made others aware of its dangers. The poem was published in 1856 in an anthology of translated poetry modestly titled *Little Songs* (*Dziesmiņas*) by Juris Alunāns, born in a Latvian peasant family and a student at the University of Tartu. It was the introductory poem of the whole collection. Work on this thin book (about 70 pages in length), published in a 500-copy edition, funded by donations obtained by the author began around 1848, when the author was 16 years old and was studying at the gymnasium. At that time, he had no intention of publishing the translations in a book, as they were written as a hobby and a practical exercise. In a sense, we can read them also as a form of teenage protest against the intellectual crisis in Courland at that time and the arrogance towards the Latvian language and Latvians in general. It is likely that it was Alunāns' encounter with similarly frustrated and subversive students from Courland living in Tartu, and perhaps also a sense of freedom inspired by the foreign environment that led him to publish 37 of his translations in a book. The vignette on the title page, with the harp motif which was popular at the time, is almost identical to the one that adorns the cover of *Buch der Lieder* (1827) by Heine. It contains only one poem by Alunāns himself; most of the translations (mainly from German, but also poems by Greek and Latin, Czech and Russian authors) are accompanied by the original texts.

The structure of the collection is reminiscent of Victorian music hall productions, in which disconnected episodes alternate in a confused order. Alongside Heine, Goethe, Schiller, Herder there are, for example, Blumauer, Usteri or Zedlitz (names that even some of their contemporaries would need to look up in a lexicon). These are followed by the Romantic greats Hölderlin and Hauff, but also Enlightenment marginals such as Langbein and Hölty. The revolutionary romanticism of Herwegh, Körner, Rückert is accompanied by a Minnesänger Vogelweide. The texts of Horace and Ovid are interspersed with the poetry of Pushkin, Lermontov, and Zhukovsky. For many scholars, Alunāns' chaotic stroll through the lighter and darker corners of the European literary canon has proved to be a hard nut to crack.

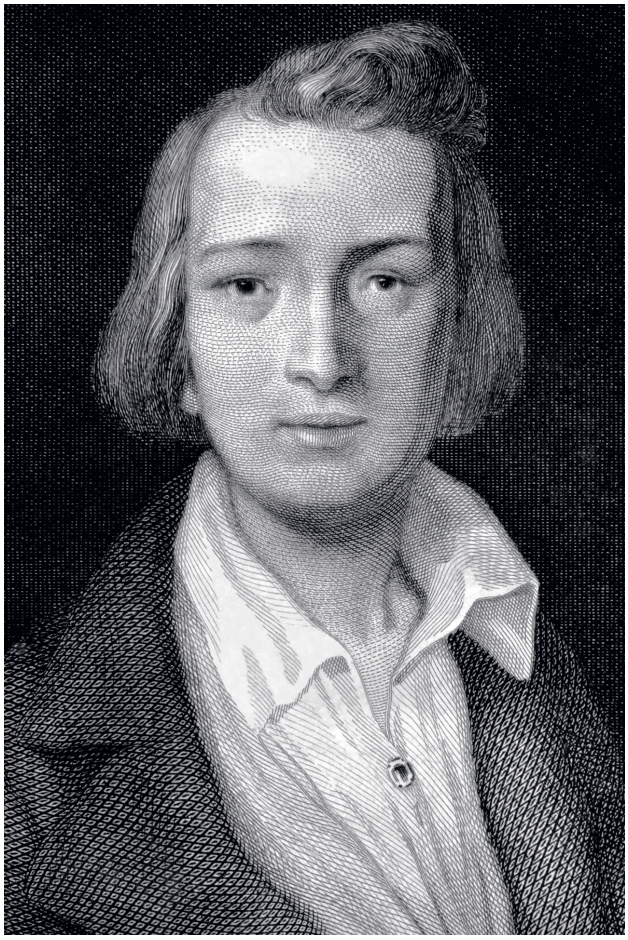

Fig. 1
Heinrich Heine

Fig. 2
Juris Alunāns

Alunāns framed his anthology not within a political or social framework, but rather as a more neutral discussion about the orthography of the Latvian language as demonstrated in the preface and afterword. The linguistic framing provided for the anthology itself to be read as an experiment with the poetic possibilities and aesthetic horizon of the Latvian language. At that time, the attitude of the wider Baltic society towards the Latvian language was similar to that in Germany towards the Low German: it was a language of everyday life, but not one of culture, literature, or education. Experiments were usually rather academic, which in itself did not have the aims of achieving cultural equality.

However, to more attentive readers it was apparent that exactly these aims lay behind the neutral facade of linguistic debate. Firstly, Alunāns wrote his preface and afterword about the problems of Latvian orthography in Latvian, not in German as was the custom. By doing so, he alluded to the fact that the book was not intended for German intellectuals, but for the general Latvian reading audience.

Today it is hard to imagine the explosiveness of the first two words in the collection – the address in the preface: "Honourable readers!". The standard form of addressing Latvians was "dear readers"; Alunāns' choice of words in the subtext implied a completely different idea of his public, and this did not go unnoticed among his contemporaries. In signing the preface, Alunāns did not use his baptised name 'Georg', but its Latvian form 'Juris', also adding the Latvian masculine ending 's' to the surname, which sounds unusual to German ears.

In his afterword, using not only German and Russian but also Greek, Latin, and Hebrew examples, Alunāns expressed interest in orthography that might have raised the eyebrows of his contemporaries. How should 'Europe' be spelled? How to adapt the names of Isaac Newton and Thomas Jefferson in accordance with Latvian orthography? How should Sappho, Calypso, and Xenophon be spelled in Latvian? How

Fig. 3
Poster with Juris Alunāns' poem, published in 1873 in honor of the Latvian Song Festival (from the collection of the National Library of Latvia)

should they call the Americans, French, and English? The serious manner in which Alunāns tackled these problems led one to suspect that his interest was not merely academic, but that he was imagining a Latvian public space in which these names might be required for communication purposes. Members of the Latvian elite wished to talk about topics that concerned them in Latvian, not in German.

The contemporaries did not know whether to be angry or laugh. Or to shrug their shoulders, as one reviewer did when he wrote in *Das Inland* (09.10.1856): "The more important question for us is: for whom was Alunāns writing? Not for the Latvians apparently." And yet he guessed that those for whom Alunāns had written this book were in a sense where Heine's *die schönste Jungfrau ... dort oben wunderbar* – in the translator's imagination; that this was the imagined Latvian community of the future. It is no coincidence that the Rhine was translated as the Daugava, a river in Latvia. In translating Heine, Alunāns did not long for a fair maiden, but for readers who would be able to read Heine in Latvian. It was with this thought in mind that the reviewer wrote perhaps the most famous sentence in the history of 19th century Latvian culture: "Könnte es aber Leute geben, denen etwa ein junges Lettland 'als schönste Jungfrau sitzet dort oben wunderbar', die möchten wir doch von Herzen vor der Lorelei gewarnet haben." ("But if there are people for whom the young Latvia 'like a beautiful maiden sits up there, looking so delightful', then we should warn them earnestly for Lorelei.")

Only those with a very clear recollection of the recent revolutions could read the threat behind this sentence, as well as an evidently new national meaning of the word *Lettland* (previously it was used only for the Latvian part of Livland).

Alunāns' book may not have been intended as a manifesto, but it was read and perceived as such, first within a narrow circle, then an increasingly wider society. We cannot really approach its meaning by looking through the book's content: there is no unifying theme or message. Even an analysis of the aesthetic innovations and experiments in form will leave the question of the book's meaning unanswered. In fact, Alunāns did not create anything fundamentally new on a textual level, but he did create a new frame of reference for Latvian literary culture. Prior to 1856, writing in Latvian and writing for the elite were perceived as two different activities. By bringing them together, Alunāns framed Latvian culture within a framework that did not exist at the time, yet could serve as a compass for the future. In this sense, the actual act of writing in Latvian, the choice of language, became the message. Alunāns' 70 pages instantly made previous Latvian secular literature "low literature" as opposed to "high literature" – a distinction that had not existed before.

According to an often quoted saying, literature can move furniture in the mind of the reader, provided that such furniture had already been there before. Alunāns relocated the existing furniture of Latvian literary culture, thus creating a new framework in which the cultural ideas of the Latvian elite could be expressed. This episode in the 19th century sheds light on the potential of literature which is usually hidden: not only to reflect, but also to create change. The transfer of Lorelei's route from the Rhine to the Daugava marked a turning point in the history of Latvian emancipation, creating preconditions for the cultural space that ultimately made it possible to redraw the map of Eastern Europe after the First World War.

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THE FORGOTTEN LAST BASTION OF LATE IDEALISM

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Personal identity is a major topic in discussions in Western society today. Is an immutable essence at the core of an identity? Does belonging to different groups construct a personality? Some postmodernists believe that we have lost the concept of a stable individual identity. These questions involve significant challenges of a metaphysical nature. More than a century ago, the late idealists sought to address these issues. When the revolution took place in the Russian Empire and the ideological settings changed, some philosophical traditions fell into oblivion. Marxist–Leninist ideology violently disrupted the late tradition of idealism in the Empire. Many philosophers died or were forced to leave the Soviet Russia during the civil war. The thinkers who defended the idea of the unique value of the person had to give in to the forces that assigned the central role to class affiliation in the construction of a person's identity. Although Georg Wilhelm Friedrich Hegel (1770–1831) famously stated: "What experience and history teach is this – that peoples and governments never have learned anything from history or acted on principles deduced from it" [1, S. 9], looking into the fates of philosophers of late idealism can provide food for thought in the modern world as well.

German philosopher Gustav Teichmüller (1832–1888) founded the personalism school when he came to Tartu in 1871. Previously, Teichmüller had held a position as a private docent at the University of Göttingen. He established close ties with Rudolf Hermann Lotze (1817–1881) and Wilhelm Dilthey (1833–1911). He also had a close relationship with Rudolf Christopher Eucken (1846–1926). Teichmüller turned to the analysis of Aristotle's works under the guidance of philosophy professor Friedrich Adolf Trendelenburg (1802–1872). Teichmüller was invited to the University of Tartu as a prominent specialist in ancient philosophy.

In the 18th century, Paul I of Russia (1754–1801) issued a ban on sending the younger generation to study abroad. He worried that studying abroad could introduce young people to French Revolution ideas. The University of Tartu was reopened to compensate for the tsar's ban. Its goal was to train the Baltic German elite and provide dependable state workers. New challenges arose in the 19th century. Despite the Russification policy, German was still the main language at the University of Tartu. In 1863, the Minister of Education of the Russian Empire, Alexander Golovnin (1821–1886), stated the following: "The University of Tartu is in an exceptional position: because the teaching is in German, it would be easy to make it one of the best European universities by inviting some of the most outstanding European scientists" [2, c. 510]. At the same time, revolutionary movements began to emerge throughout the empire. Students organised illegal groups and staged protests. Students who were rejected by other universities for participating in rallies were admitted to the University of Tartu. Naturally, Tartu soon became one of the centres of revolutionary currents in the empire. Student organisations emerged that embraced Marxism. Under these conditions, "the Russian government found the Teichmüllers professorship useful as a shield against Marxist currents" [3, 6. lpp.]. Adherents to positivism and Marxism often attended the professor's lectures. The philosopher willingly engaged in discussions with them, demonstrating his pedagogical talent.

A small group of like-minded people began to gather around Teichmüller. The core of the group consisted of the first Latvian philosopher Jēkabs

Jēkabs Osis

Osis (1860–1920), the Russian philosopher Yevgeni Bobrov (1867–1933), the Lithuanian Włodzimierz Szyłkarski (1884–1960), and the Polish thinker Wincenty Lutosławski (1863–1954). This group of philosophers came together to revise German idealism and fight materialistic tendencies. After Hegel's death, philosophy split and connections between schools weakened, leading to decreased public interest in philosophical questions. Teichmüller was aware of this crisis in philosophy. In the introduction to his work titled *The Real and the Apparent World: New Foundation of Metaphysics*, he writes that the well-educated "know of the sorry state of the philosophy, where all systems have gone bankrupt, and they will gladly welcome any attempt to give philosophy a new foundation" [4, S. 16]. Teichmüller followed a line of thought described by Professor of Philosophy Herbert Schnädelbach as the "rebirth of metaphysics". Metaphysics "has been reborn as ontology, charging against the empirical sciences occupying reality" [5, S. 233]. Teichmüller criticised Hegel and Kant's followers. He believed in a new doctrine that would reveal and justify the importance of an individual personality as the only true source of existence. Teichmüller named this new philosophy "personalism'".

After Teichmüller died, Osis became a professor. At his friend and teacher's funeral, he expressed the hope that in the future, representatives of the ruling schools of thought would recognise the uniqueness of personalist ideas. Ten years later, Osis was the acting rector of the University of Tartu. He witnessed how students inspired by socialist and Marxist ideologies refused to attend lectures, instead gathering in rallies. The army and secret police calmed the revolutionary feelings at the turn of the 19th and 20th centuries. However, the Latvian philosopher experienced intense and chaotic events during the Russian Civil War. In 1917, Tartu University was moved to Voronezh and Osis helped set up the new university. For almost half a century, philosophy professors at the University of Tartu were representatives of the personalist tradition.

Osis was hoping to leave the city devastated by the epidemic and the war. In 1917, the philosopher participated in the commission that developed the plan for establishing the Latvian University. Colleagues planned to elect the philosopher as the first rector of the University of Latvia. However, when the Latvian University Council in Riga elected Osis as a professor, the philosopher had already passed away. In March 1920, he fell a victim to the typhus epidemic in Voronezh.

In the first years of independence, the leadership of the Latvian University planned to take care of the philosopher's legacy. The intention was to organise the reburial of the philosopher in Latvia. The colleagues decided to bring back the professor's manuscripts and personal library to his home country. However, these plans were not realised. The professor's legacy vanished into the dark layers of perception. During the first half of the 20th century, personalism was regarded as a resonance of an old idealistic tradition that had been overshadowed by emerging movements such as neo-Kantianism, phenomenology, existentialism, Marxism, positivism, and critical theory.

The house where Osis was born in Kabile, Latvia, has turned into ruins. There is no indication that it is the place, where the first Latvian philosopher's life began. Nevertheless, the ruins can serve as a

meaningful symbol to delve into the context of the philosopher's quest. Professor of philosophy Robert Ginsberg once wrote that: "philosophy is an art of living with ruins" [6, p. 276]. The task of a historian of philosophy can be described as translating the ruins of a bygone era.

In the view of many historians of philosophy, the period of idealism ended with Hegel's death, so the late idealists sort of "dropped out" of the narrative. Several historians of philosophy have stated that for a long time, and even nowadays, dominates the tendency in essays on 19th century philosophy to ignore representatives of academic philosophy. Researchers have written about the necessity to "fill in the blanks" and revive historical justice. The monograph *Person and Personalism: Enduring the Collapse of Idealism. The First Latvian Philosopher Jēkabs Osis* by Andris Hiršs is a small contribution to this effort to tell the forgotten.

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SOCIETY WITHOUT A WORLD AND *BEYOND HUMAN*

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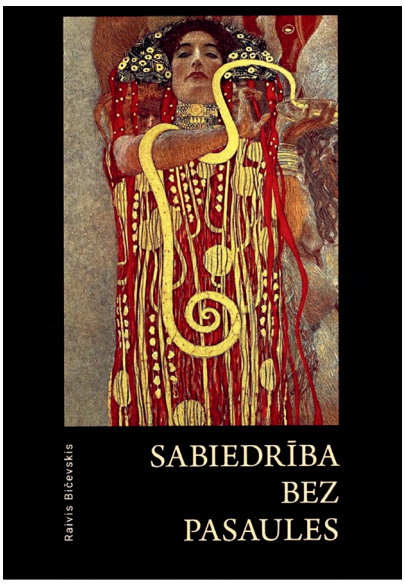
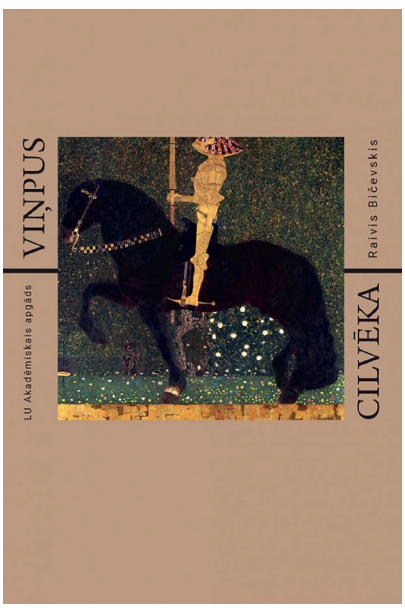
This article is a summary of a several-year research programme, the realisation of which was possible thanks to the Fundamental and Applied Research Competition of the Latvian Council of Science. As part of the fundamental research on the Herder Institute in Riga (Institutum Herderianum Rigense: Herder Institute in Riga as a science network in the European Science Network, lzp-2020/2-0083) and on the competing discourses of nature in Latvia (Competing discourses of nature in Latvia and ecological solidarity as a consensus-building strategy, lzp-2020/1-0304), a very broad research programme of modern society and culture was worked on, the results of which can be found in two books by Raivis Bičevskis: *Society without a World* and *Beyond Human*. The article reflects the position of the research questions and some main theses.

In Part I of Friedrich Nietzsche's *Beyond Good and Evil*, "On the prejudices of philosophers" (§ 9), one can read about the will of philosophers to "create the world" and to do so in their own image and likeness. The main thesis of books *Society without a World* and *Beyond Human* – as two parts of the current research programme – states that society creates the world in its own image, or, to put it more correctly, society (and this is probably what Nietzsche meant regarding the philosophers' intentions) replaces the world with itself: the world is society. This critical thesis, already expressed in the book *Society without a World*, is complemented in the book *Beyond Human by* reflections on the consequences of a society without the world for man's understanding of himself, the orientation of various cultural fields (art, politics, science, philosophy, literature) in the age of modernity, the existence and exploration of strategies, ways and possibilities for recovering the world – called 'substructures' as a central concept of the research programme.





With the notion of the purpose of life as immanent to society, i.e. defined as society itself, the world as an entity beyond society disappears: if the purpose is, as sociologist Alexandra Schauer in *The Man without World* (2023) puts it, the world as a "space

of understanding and making" and "to discover the world" means "to become aware of the collective existence" then it is clear that society itself is now also "the world". Asking questions such as "what is happening in the world?" can no longer be understood in any other way than "what is happening in society?". The meaning and content of the world has become a mere correlate of society, which has turned the world into its own set of actions, communications, desires and fears, in short: society has no other world than society itself. The relationship between human and the world beyond society pales in this way. Without exception, this relationship has become a social or socio-politically constructed relationship.

The two parts of the research programme – which resulted in books *Society without a World* and *Beyond Human* – seek to describe the relationship between the man and the world in modernity, the tensions and nature of which are indications of a way of relating in which there is an "abrasiveness of the world with society", and consequently, a particular way of relating to society that replaces the relationship with the world. To put a conceptual name to this process of substitution, one can speak of the socialisation of the world. It has an impact on human self-understanding, for which the world as a social construction appears more and more definitively and unquestionably in place of a relationship with the world. Karl Marx rightly states in his *Theses on Feuerbach*: "But the human essence is no abstraction inherent in each single individual. In its reality it is the ensemble of the social relations." No longer leaving the essence of humanity solely to the power of internal "abstraction", Marx immediately "fills" this essence with social relations. In a society without a world, man can think of himself – either confidently or, on the contrary, despairingly – as a merely socialised self, i.e. a "self" whose pole of relation is society, but no longer the world. Relations with the world, on the other hand, in such a constellation, can be thought as non-existent or, more precisely, humanly self-affirming: thought moves within a framework in which nature is mute, the world as society – too talkative.

Does the world itself as beyond man have nothing to say anymore? This can be the case if "language" and "say-ability" are reserved exclusively for human beings, and if hearing is tuned only to the voices of a society that has taken its place in the world. The first thesis of the research programme therefore aims to relativise man's apparently self-sufficient (and inevitable) orientation towards himself as a consequence of a society without a world, looking not at the relativity of some cultural techniques of the past in relation to the new possibilities and practices of today's internet and social networks, but at the totality of human culture as relative to natural processes. The question of education, constantly renewed in the framework of modernity, is expanded as the question of the "pendulum of education". The pendulum, once set in motion, cannot swing only to one side from the centre of motion: the human self cannot be the centre of the pendulum, but only the opposite point of motion to the world. This movement must begin. The philosophical reminiscences of Late German Idealism (Schelling) and Early European Romanticism (Friedrich Schlegel, Novalis) therefore describe the liberation of the substructive, i.e. setting the world back into the relational and grounding trajectory of the "world-abundance". This trajectory also proceeds from phenomena otherwise regarded as only specifically "human": language and perception. The research programme shows (in a treatment of socio-political issues already deeply immanent to the modern age) the forms of "political religion" (Eric Voegelin) as a particular obsession with the self of a society without a world.

The second part of the research programme – "Substructions" (more explicitly discussed in the book *Beyond Human*) deals with the possibilities of transformations of the ways in which the worldless society holds sway over human self-understanding that appeared in the first part, but which do not have to be found outside the world, i.e. which suggest a world that reveals itself in various ways as the pole of these relations that has always been "here" but is therefore far from being "mute". These trajectories of re-cognition and rediscovery of the world as modes of world-saturation are referred to as substructures. Some of them appear in the engagement with German continental philosophy and in the discussion with the new generation of the Frankfurt

School. The books not only aim at uncovering substructures in the thought of the philosophers invoked, but also at reconstructing 20th-century German thinkers as thinkers of the world and of man's relation to the world.

The fact that the 20th century was an era of countless attempts to "reclaim the world", in which course the expression "societies without a world" was divergently developed, is strikingly evident in the fields of modern natural sciences and humanities. Approaches to "reality" and "nature" are examined in a particular perspective on the Baltic and Latvian cultural and scientific spheres: the activities of the Herder Institute in Riga and the changes in the understanding of reality demonstrated in Riga during this period (in the 1920s–1930s) by Max Planck, Jakob J. von Uexküll, and Joseph Nadler in their lectures and texts. The change in the understanding of reality finds its articulation in Emile Du Bois-Reymond's lecture *On the Limits of Natural Scientific Knowledge* (1872), a thesis on the unknowability of the deepest essence of nature and consciousness ("ignoramus et ignorabimus" – "we do not know and we will never know"). This text by Du Bois-Reymond was published in the same year as Nietzsche'a *Birth of Tragedy*, a work that at that time still straddled the border between philosophy and classical philology, and which undoubtedly belongs to the project of "recovering the world".

The Du Bois-Reymond thesis and its effects can be seen not only in the self-reflexivity of the sciences, but also in their relation to the liberated forces of the sciences: "science and technology" is a theme that forms a transition to the question of technology – not only the power of the anonymous forces of technology, but also the "step back" (Martin Heidegger) that "transcends" man in a very different way than the transhumanist possibilities unleashed by technology. Thus, two parts of the research programme – *Society without a World* and *Beyond Human* – imply the title of a multidimensional thought exercise to glimpse the variations and versions of "beyond" in the neo-, trans-, meta-, hyper- and post-humanist era, whose other designation "Anthropocene" is consistent within the framework of a worldless society, yet no less illusory for that. The many "non"-humanisms fit into the history of humanist transformations and the fate of modernity with its twists and longings. The research programme is therefore an attempt to point to the possibilities of other and older dimensions of "beyond" man, forgotten by the various "-humanisms" in the frame of a society without a world. The third part of the research programme completes a circle whose line has started to be drawn not only in the chapters of *Beyond Human*: the last act of the book revisits the notion of a "society without a world" in the context of the latest socio-philosophical developments of the Frankfurt School (Hartmut Rosa, Alexandra Schauer, Stephan Lessenich a.o.) and cultural critics (Sven Hillenkamp, Andreas Weber, Volker Demuth, Peter Trawny, Peter Sloterdijk a.o.), in which the profiling of the notion of the world appears quite sharply outlined.

Society without a World and *Beyond Human* is an attempt to look at an epoch and its historical fate, and yet also – in the medium of such a look – to further develop and consolidate the perspective of a "society without a world". But the research programme's main task today is to ask: what is man's relationship to the world? Where is the "world beyond society" and the "world without society" to be found? The titles *Society without a World* and *Beyond Human* imply a question about man between the world and society – about a relationship with the world that would also benefit society if it stopped trying to take the place of "given human" from the position of "beyond human".

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ON THE CULTURAL HOMOGENEITY OF THE BALTIC SEA REGION IN THE MIDDLE AGES: MYTHICAL CREATURES, DRAGONS AND MASKS

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In today's age of globalisation and close economic cooperation within the European Union, it may have been forgotten that even before the unstable times of the Reformation, which divided Europe into opposing camps for centuries, the Baltic Sea region formed an impressively homogeneous cultural and economic unity. The Baltic Sea as a unifying element brought together the pagan peoples living on its coasts as early as in the 8th and 9th centuries along trade routes that were maintained even after the Christianisation of the southern and eastern Baltic Sea region. This development intensified even more when the Abodrites, Rans, Pomeranians, Prussians, Couronians, Semigallians, Livs and many other tribes inhabiting the southern and eastern Baltic region were gradually Christianised during the 12th and early 13th centuries. This took place on the initiative of German dukes and bishops and was implemented by German as well as Danish clergy and by German knight orders. These, however, did not encounter empty space, but peoples shaped by natural religions, who continued to oppose the new faith with reluctance for a long time and cultivated their old rites, which faced the missionaries with relevant challenges. This religious transformation was accompanied by intensive settlement by immigrating colonists from the German lands – nobles, merchants, craftsmen, and farmers. Soon the rule of the entire western, southern, and eastern Baltic Sea region was in the hands of Christian, German-speaking elites, which gave rise to a unified cultural area whose unity was supported by the Middle Low German language generally represented in it.

This state of cultural homogeneity, which was, however, accompanied throughout the area by the same need for appropriate actions to assimilate and root the new religion with all its rites and truths of faith in the native population, can be clearly seen in the surviving works of medieval sacred architecture in what are now the coastal regions of northeastern Germany, Poland, Lithuania, Latvia, Estonia, and Finland. With the new religion came new building techniques in these regions, monumental edifices made of masonry (stone or brick) were erected to testify to the power of the Catholic Church and its mighty patrons. Important pioneers in this field were the orders that had immigrated from Germany and Denmark – the Premonstratensians and especially the Cistercians, who brought with them technical innovations and knowledge of brick building. A little later, a special role in the spread of brick masonry in the cities was played by the mendicant orders – the Franciscans and Dominicans, whose spacious churches, as important places of pastoral care, shaped the sacral topography of the cities and often became the inspiration for the citizens' parish churches. Thus, the architectural landscape of the Baltic Sea region was essentially shaped by brick, but there are also regions where ashlar predominates – among others, the island of Gotland, whose limestone sources were not only used for local sacral buildings, but also exported to the entire Baltic Sea region, and also to the northern part of Estonia with today's capital Tallinn – the old Hanseatic city of Reval [1].

Since there were often close family ties between the new inhabitants of the Baltic area, especially among

the elites of the patrician class, but also craftsmen and builders, the cities in this area became closely linked. Economic reasons made the merchants of the Baltic cities cooperate closely and negotiate common privileges on markets in England, Flanders, Norway, Denmark, as well as in Russia, from which all merchants of the German-speaking trading cities in the southern and eastern Baltic region benefited. This led to the establishment of a strong alliance of cities – the so-called German Hanseatic League, in which merchants closely allied and created an excellently functioning network through which not only trade goods and the latest information on political and economic developments in distant markets were exchanged, but also works of art, artists, craftsmen, and architects were transferred. [2] This close network between the elites of the Hanseatic cities and the migration of building craftsmen throughout the Baltic region contributed decisively to the fact that the character of the medieval architecture of this macro-region is so remarkably homogenous.

The close community of this specific cultural area is also particularly evident in architectural detail, especially in the figurative architectural sculpture of the church buildings, which decorates their portals, consoles, and capitals in particular. If one travels through the coastal areas in the southern and eastern Baltic Sea region, the attentive observer will notice the motifs recurring even in the most distant places. For example, the mythical creatures, dragons, centaurs, sirens, and fantastic animals appear frequently on church portals; their meaning is hidden to us today, but was generally understandable to the people of the time and had didactic functions. Medieval art very often operated with animal symbolism, which was mainly embodied in the very popular bestiaries from the 13th century onwards, i.e. written works in which individual animals, but also mythical creatures, were described in detail, depicted and their characteristics interpreted in the context of Christian salvation history. The contents conveyed therein were largely taken from the "Physiologus", a manuscript written in Greek in the 2nd century AD, which was widely read in medieval Europe and is the key to understanding Christian animal symbolism. The animal motifs that appear in the architectural decoration of medieval churches in a multitude of forms usually embody virtues and vices: for example, dogs – envy and immodesty, billy goats – lechery, monkeys, and lions – evil [3], pigs – impurity, hares – wakefulness, geese – marital fidelity [4]; deer often symbolised the person of Christ. Animal motifs appear usually on consoles, capitals, and above all in the capital zone of the portal jambs, most frequently on a church's southern side, as in the parish church in Dobiegniew (German Woldenberg, Poland) and in St Anthony's Chapel at St Nicholas Church in Tallinn (German Reval), and were intended to have an educating and moralising effect on the visitors to the church (Fig. 1).

Of negative connotation were also hybrid figures – half human, half animal, appearing frequently on portal jambs: centaurs (ex. Lübeck, Germany, St Mary's Church; Drawsko Pomorskie / German Dramburg, Poland, St Mary's Church; Vänge, Gotland), sirens (ex. Eberswalde, Germany, St Mary's Church; Prenzlau, Germany, St Marys Church; Drawsko Pomorskie), griffins (ex. Greifswald, Germany, St. Mary's Church and St Jacob's Church; Prenzlau, St Mary's Church). Sometimes, these wear a triangular headdress – a so-called Jewish hat – and thus represent a pejorative personification of non-believers, pagans, heretics (ex. in the St Mary's Churches in Lübeck, Prenzlau, and Drawsko Pomorskie; Fig. 2).

Especially the figural decoration of the north and west portals gives us a good insight into man's conception of the world at that time, which understood life as a constant struggle between good and evil. Even in the 13th and early 14th centuries, life was filled with great fear of diabolical forces. Sacred places were considered particularly endangered, and people tried to protect them in various ways. Evil was said to lurk especially on the "midnight side" (=north) and on the "side of the setting sun" (=west). Windows and doorways through which the devilish powers could enter the church were considered to be particular sources of danger. For this reason, apotropaic motifs (i.e. motifs that protect against evil) were usually used on north and west portals. For example, in Drawsko Pomorskie (St Mary's Church), Tallin (St Catherine's Church), and Cēsis (German Wenden, Latvia, parish church) dragon figures [5] on the portal jambs and in Drawsko

Fig. 1
Animal motifs: Tallinn, St Catherine's Dominican Church, west portal (photo by Christofer Herrmann); Greifswald, St Jacob's Church, west portal; Dobiegniew, Parish Church, south portal (both photos by Marek Fiedorowicz); Tallinn, St Nicholas' Church, St Anthony's Chapel, south portal (photo by Christofer Herrmann)

Fig. 2
Hybrid figures: Drawsko Pomorskie, St Mary's Church, south portal; Lübeck, St Mary's Church, south portal; Prenzlau, St Mary's Church, south and north portal (all photos by Agnieszka Lindenhayn- Fiedorowicz)

Fig. 3
Dragons: Tallin, St Catherine's Church, west portal; Cēsis, Parish Church, west portal (both photos by Christofer Herrmann); Drawsko Pomorskie, St Mary's Church, north portal, dragons and manticores (both photos by Marek Fiedorowicz)

Pomorskie additionally also manticores secure the entrance to the church (Fig. 3). On the north portal of Riga Cathedral, the heads of wild beasts appear under the capital zone. These monsters were supposed to ward off devilish dangers according to the basilisk principle: When evil beholds its reflection, it falls under its own spell and is incapacitated.

In church interiors and monastery cloisters, too, people tried to tame the evil forces by carving them in stone. Thus, monkey heads, grimace faces, sometimes even devil heads are found in a serving function on consoles and capitals supporting the vault load (ex. Kamień Pomorski / German Cammin, Cathedral, Bishop's Chapel; Bierzwnik / German Marienwalde, Cistercian abbey, cloister, both in Poland). A similar, apotropaic and at the same time moralising effect had the human masks and heads, which are widespread in medieval churches throughout Europe and also occur frequently in the Baltic region, and which can be found especially on consoles, but also on portal imposts and exterior façades. These serious, often ugly, but also deformed faces expressing horror, grief, or despair embody the suffering of damned souls. From the huge number of examples, we may mention at random the masks: in the cloister of Riga Cathedral [6]; on the southwest portal of St Catherine's Church in Tallinn, on the cloister consoles in the Cistercian monastery of Bierzwnik, in the St Gertrud's Chapel in Myślibórz (German Soldin, Poland) and in the sacristy of St Mary's Church in Prenzlau (Fig. 4).

In contrast to the widespread masks, half- or full-body representations were rarer in the churches and monasteries of the southern and eastern Baltic region. In this context, attention should be drawn mainly to a most interesting cycle of capitals of Gotlandic origin from the Pomeranian Cistercian monastery of Kołbacz (German Kolbatz, Poland), depicting scenes from the life of monks (Fig. 5) [7]. Their style is strongly related to the rich narrative

Fig. 4
Masks: Bierzwnik, Cistercian monastery, cloister; Prenzlau, St Mary's Church, sacristy; Myślibórz, St Gertrude's Chapel (photos by Agnieszka Lindenhayn-Fiedorowicz); Riga, Cathedral, cloister, human and animal heads (photo by Christofer Herrmann)

Fig. 5
Monks (?): Capital in the church of St Mary Magdalene in Koeru (photo by Christofer Herrmann), console in the Franciscan church in Szczecin (photo by Marek Fiedorowicz); two capitals from the Cistercian monastery of Kołbacz, today in the National Museum in Szczecin (both photos by Agnieszka Lindenhayn-Fiedorowicz)

figurative cycles on the portals of numerous Gotlandic churches, including those in Martebo, Gammelgarn, and Dalhem. A unique example in the whole of Livonia, although stylistically hardly comparable, is again a capital preserved on the north-western pillar of St Mary Magdalene's Church in Koeru (Koero) in Estonia, with the half-figure of a bearded man with a hood on his head (possibly a Cistercian lay brother) pointing with his hands to his head [8]. Different in meaning, certainly moralising in character, are representations of two half-body monks imagined as atlases on consoles in the bishop's chapel of the cathedral in Kamień Pomorski and in the Franciscan church in Szczecin (German Stettin, Poland), which, as parts of the wall responds, symbolically support the vault of the church forming a symbolical image of the heavenly kingdom (Fig. 5).

The wide dispersion of these motifs, which recur throughout the cultural area analysed here and which were intended to convey religious content to the viewers of the time using a generally comprehensible language of signs, testifies to the cultural uniformity of these regions, which were Christianised relatively late in relation to Western Europe, but also to the great challenge that these areas still faced in terms of consolidating the new faith into the 14th century. The motifs chosen, which are often linked to pagan symbols in order to convey Christian religious truths in a more comprehensible way, show that architectural sculpture obviously had the task here of strengthening the still relatively fresh faith [9].

Finally, an absolutely unique example of medieval architectural sculpture in the Baltic region must be mentioned here: the impressively rich terracotta decoration cycle of St John's Church in Tartu, Estonia, the former Hanseatic city of Dorpat. Built from the end of the 13th century, this parish church received an extraordinarily wealthy figural architectural decoration, both inside and outside, in the form of full-body representations and half-figures of saints, as well as masks, which run in friezes around the entire church. This decoration forms a comprehensive pictorial programme that combines the biblical content with aspects of urban representation as well as moralising and apotropaic functions. In a distant form, the full-body representations of saints placed in the interior of St John's Church at the foot of the clerestory windows in a kind of triforium zone under gabled niches remind of the decoration of St Mary's Church in the Pomeranian Hanseatic city of Stargard (German Stargard, Poland), whose choir and Lady Chapel have a rich exterior decoration in the form of gabled niches, where originally figures of saints were placed. The choir piers of this church have a similar decoration, surrounded by a wreath of gabled niches that once held terracotta sculptures. The placement of figures under baldachin niches is reminiscent of the exterior decoration of French and English cathedrals of the Rayonnant and Decorated styles, respectively. In English cathedrals, gabled niche systems also appeared inside the church and were sometimes even filled with sculptures. The pseudo-triforium of St John's Church in Tartu and the decorative gabled niches at St. Mary's Church in Stargard, as well as the decorations of the numerous churches in Pomerania and Mark Brandenburg that followed their example, were certainly a realisation of this design idea in brick. Here, various inspirations from the Western-European cathedral architecture were combined and further developed into an imaginative creation of impressive richness of its own. This shows how varied was the reception of the Western cathedral models in the Baltic region and testifies to the importance this area had as a contact zone and exchange platform. It also bears witness to the creativity of various master craftsmen who, drawing from the same sources of inspiration, arrived at stylistically different results. Thus, all regions of the southern and eastern Baltic Sea area show their individual character and yet in their diversity testify to the impressively close artistic interconnectedness in the Middle Ages, which makes this homogeneous cultural area a unique architectural landscape in Europe.

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2. Jahnke, C. Handelsnetze im Ostseeraum. In: *Netzwerke im europäischen Handel des Mittelalters*. V. Gerhard Fouquet and Hans-Jörg Gilomen (eds.). Ostfildern: J. Thorbecke, 2010, pp. 189–212; Jahnke C. Zu Ehren Gottes und zum Wohle der Kasse. Religiöse und soziale Netzwerke in den spätmittelalterlichen Hansestädten und deren Funktionen. In: *Raumbildung durch Netzwerke? Der Ostseeraum zwischen Wikingerzeit und Spätmittelalter aus archäologischer und gesellschaftspolitischer Perspektive*. Kiel, 2010, pp. 165–182; Jahnke C. Die Hanse. Stuttgart, 2014. On the migration and exchange of architects in the Baltic region with concrete examples: see Hermann 2007 (note 1), pp. 82–83; Hermann C. Mittelalterliche Architektur in Livland – Übersicht und Einführung. In: *Livland im Mittelalter. Geschichte und Architektur.* Petersberg, 2022, pp. 32–75, here p. 40.

3. The symbolism of the lion was ambivalent in Christian iconography. On the one hand, it was considered as a symbol of the devil and evil forces, but on the other hand, it also had a Christological symbolism and was also considered – on the basis of an early Christian tradition that these animals sleep with their eyelids open – an attentive guardian. Cf. *Der Physiologus. Tiere und ihre Symbolik*, Köln, 2005, pp. 7–9. On the symbolism of lion portals, among others, see: Dinzelbacher P. *Köpfe und Masken. Symbolische Bauplastik an mittelalterlichen Kirchen.* Verlag Anton Pustet. Salzburg, 2014, pp. 72–77. On the duality of lion symbolism and the difficulties in interpreting medieval architectural sculpture, see: Sparitis O. Mundus simbolicus – von Himmel und Menschen. Zu den Symbolen an mittelalterlichen Kirchen des Baltikums. In: *Ecclesiae Ornatae. Kirchenausstattungen des Mittelalters und frühen Neuzeit zwischen Denkmalwert und Funktionalität*. Eimer V. G., Gierlich E., Müller M. (eds.). Bonn, 2009, S. 349–371.

4. For detailed information on animal symbolism in Christian iconography, see, among others: Darcheville P. *Bestiaire de l'art sacré*. Paris, 2011.

5. In Christian iconography, dragons – certainly influenced by the dragon figure in the Apocalypse of John – were consistently regarded as symbols of the evil. Cf. among others, Darcheville 2011, pp. 101–106 (note 4); Dinzelbacher, 2017, pp. 78–80 (note 3).

6. For details on the architectural sculpture at Riga Cathedral: Bergholde A. *Rīgas Doma viduslaiku arhitektūra un būvplastika eiropeisko analoģiju kontekstā*. Rīga, 2015; Bergholde-Wolf A. Der Rigaer Dom und seine Bauskulptur. In: *Livland im Mittelalter,* 2022, pp. 76–91 (note 2).

7. Recently on the Kolbatz capitals in the holdings of the National Museum in Szczecin: Krasnodębska K. Elementy wystroju architektonicznego z Kołbacza, Szadzka i Nowogardu. In: *Mysterium des Lichts. Mittelalterliche Kunst in Pommern / Misterium światła. Sztuka średniowieczna na Pomorzu*. Exhibition catalogue of the National Museum Szczecin, Szczecin, 2022, pp. 85–114. https://wspolne-dziedzictwo.muzeum.szczecin.pl/images/interreg/wydawnictwa/Katalogi/Misterium-Swiatla_katalog/MISTERIUM-SWIATLA-katalog-interet-z-okladka-1.pdf (accessed 16.10.2023)

8. Randla A. Koeru / Koero. In: *Forschungsprojekt zur mittelalterlichen Baukunst in Livland (Estland und Lettland). Die Architektur einer historischen Grenzregion im Nordosten Europas*. Projektbericht, Leitung: Christofer Herrmann, Anneli Randla, Ieva Ose, Rainer Atzbach. https://www.academia.edu/42174736/Mittelalterliche_Architektur_in_LIvland_Estland_Lettland_ Projektbericht, pp. 70, 72. Ojārs Spārītis sees in this figure "a mimicking, mocking, grim-nosed fool with a pointed cap and hands raised to his head" as a personification of barbarism (Sparitis O., 2009, pp. 369–370, note 3), which shows the difficulties of interpretation that today's researchers often face when analysing figural architectural sculpture.

9. On the didactic role of figural architectural sculpture, especially in Livonia and the Baltic islands as far as Gotland, see: Sparitis O., 2009, passim (note 3).

VILHELMS PURVĪTIS AND VOLDEMĀRS ZELTIŅŠ – MODERNISERS OF LATVIAN PAINTING AROUND 1900 IN THE LIGHT OF NEW MONOGRAPHIC STUDIES

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In 2022, Latvia celebrated the 150th anniversary since the birth of the landscape painter Vilhelms Purvītis (1872–1945). A student of the Imperial Academy of Art in St Petersburg, graduate of the landscape painter Arkhip Kuindzhi's (1841–1910) master class, the internationally most acclaimed painter in the Baltic Provinces at the turn of the 20th century, director of the Riga City Art School until the First World War, founder and first rector of the Art Academy of Latvia, head of its Landscape Master Class, director of the Riga City Art Museum, organiser and manager of the General Art Studios at the Faculty of Architecture, University of Latvia, chief curator of Latvian art exhibition abroad – for more than a half-century since the beginning of his art studies, Vilhelms Purvītis was a principal figure of two important periods in the art of Latvia. His work became one of the key axes in the rise of national painting and the institutional progress of the young state, but it also continued in the period of totalitarian occupations when the artist died and most of his artworks perished at the end of the Second World War. The central event of the national Purvītis Year undeniably was the anniversary exhibition at the Latvian National Museum of Art (LNMA), curated by *Dr. art.* Aija Brasliņa and staged by artist Sandra Krastiņa. With its almost 76,000 visitors it became the second most attended art show at LNMA since the reestablishment of Latvia's independence.

Parallel to the exhibition the publishing house *Neputns* produced a book containing an album of artworks compiled by *Dr. h. c.* Laima Slava and a new extensive monographic study entitled *Landscape with a Painter* by the author of this report [1]. The book was introduced by LNMA director Māra Lāce and completed with an English essay on Purvītis' life and work by *Dr. habil. art.* Eduards Kļaviņš. Six months before the launch of this volume, just on the eve of the Purvītis Year, *Neputns* published a monograph about another Latvian painter of the early 20th century, Voldemārs Zeltiņš (1879–1909) [2]. In terms of previous representation in Latvian art writing, these two figures are extreme opposites to each other: a library section on Purvītis contains numerous titles whereas his younger colleague Zeltiņš by then did not have even a small catalogue featuring his name on the title-page. Nevertheless, both of them deserve prominence for their innovative contribution to Latvian painting in the early 20th century – the focal aspect uniting these two monographic studies elaborated by the same researcher and released by the same publisher.

Fig. 1
Vilhelms Purvītis painting in Mārciena. 1943
Photo by Jānis Maršāns. Art Academy of Latvia Information Centre

Fig. 2
Voldemārs Zeltiņš at his easel in the studio of Burtnieki House. 1908–1909. Unknown photographer. From: Siliņš, Jānis. Voldemārs Zeltiņš (1879. 13./I. v. st. – 1909. 31./VIII). *Ilustrēts Žurnāls*, 1925, No. 2, 40. lpp.

In 2014, when Eduards Kļaviņš as the editor of the multi-volume publication *Art History of Latvia* and the leading contributor of its "firstling" about the period of 1890–1915 was asked to name turn-of-the-20th-century artists who would deserve more recognition besides the widely known central figures Vilhelms Purvītis, Janis Rozentāls, and Johann Walter, the answer was prompt and precise: "Voldemārs Zeltiņš. Unfortunately, very few works by him survive, and his life was very short. […] His style is surprisingly pervaded with an authentic dramatism that is not characteristic to others. He is not a restrained artist but a budding Expressionist. Latvians have never had pure Expressionism. Zeltiņš, however, had the potential of becoming a Latvian Van Gogh." [3]. Although there was no doubt that this painter deserves a substantial, detailed treatise, Kļaviņš himself had previously declared that it is next to impossible to write a comprehensive monograph about him due to the shortage of relevant sources. These conflicting statements eventually became the internal driving force of research and narrative, crossing the rift between Zeltiņš' short presence on the scene of Latvian early-20th-century culture and the lasting impact of his bold and daring self-expression in painting.

While Purvītis epitomised a rare partnership of painterly innovations and academic success, Zeltiņš turned out unsuited for the routine of institutionalised training and abandoned both the Venyamin Bluhm's Riga Drawing and Painting School in Riga and the Imperial Academy of Art in St Petersburg without receiving official qualifications. The art of Purvītis around 1900 was an important and fascinating point of departure in Zeltiņš' quests for painterly freedom, but in the last years he dreamt about surpassing Purvītis and moving even further. Unfortunately, the young painter's aspirations were ruined by his suicide in 1909, the year when Purvītis was appointed director of Riga City Art School, thus becoming both the chief architect and a life-long main pillar of Latvian art education. The School of Purvītis in Latvian landscape painting is a rather widely explored phenomenon. However, the artistic heritage of Zeltiņš, too, inspired other Latvian painters throughout the 20th century, allowing to trace the continuity of the once innovatory expression and to view Zeltiņš' oeuvre as an important source of painterly vigour. Although just a couple of originals were publicly available for a closer scrutiny, these models ultimately stimulated the so-called tube period of Boriss Bērziņš and Edgars Iltners in Soviet Latvia of the 1960s and merged with the mighty gestural language of American Abstract Expressionism in the works of the New York-based diaspora artist Edvīns Strautmanis who obviously appreciated that one of the roots of the expression that any connoisseur of Western art would associate with world-famed examples, reached back to his own people's artistic experience.

The research about Zeltiņš required serious consideration of every smallest factual and visual evidence in sources helping to reconstruct a piece in the picture of his life, art, environment and connections. This meticulous approach apparently contradicted to his self-declared neglect of artisanal accuracy. The new biography of Purvītis, on its turn, had to retain a persistent balance between the background of previous studies and such discoveries that shed new light on particular episodes or entire periods in the career of the great painter, enabling either

Fig. 3
Voldemārs Zeltiņš. Landscape. Ca. 1906–1909. Oil on canvas. 55 × 73 cm.
Latvian National Museum of Art, coll. No. GL–449
Photo by Normunds Brasliņš, courtesy of the museum

Fig. 4
Vilhelms Purvītis. Boats. Early 1930s. Oil on cardboard. 56.2 × 73.5 cm. Museum of Fine Arts in Budapest, Collection of International Art after 1800, coll. No. 2022.5.1.B.
Photo: courtesy of the museum

to correct erroneous assumptions or to provide more accurate answers to questions that had puzzled researchers for generations. Thus, a number of mysteries of his early historiography were revealed, including the identity and biographical details of Mary Illyne, originally Maria Ilyina who authored an important feature article about Purvītis' art in the British magazine *The Studio* in 1905. Collecting reviews of his works exhibited outside the territory of Latvia and the Russian metropolises since a 1898 tour of Russian art shows across Germany and the 1900 World Exhibition in Paris until 1939 exhibitions of contemporary Latvian art in Paris and London, useful information was found in German, Austrian, Estonian, Finnish, Swedish, Norwegian, French, British, Polish, Lithuanian, Czech and other sources.

Surprisingly, the most challenging task was a properly thorough interpretation of Purvītis' late painting of the 1920s–1940s, the period of Latvia's independence and the following totalitarian occupations. For various general and individual reasons, researchers used to pass this quarter of a century in the artist's work very quickly and superficially focusing on his public duties. This lasting disbalance was largely due to irrecoverable war-time losses of Purvītis oeuvre. Presumably up to 90% of his paintings that he had hoped to donate to the city of Riga or the Latvian state were doomed to perish. However, investigation of Latvian international exhibition routes of the 1920s and 1930s helped to establish that several prominent paintings by Purvītis were purchased by foreign museums and are preserved in these collections or relocated to others. Although the long shadow of COVID-19 and the Russian full-scale invasion in Ukraine made LNMA to stage the anniversary exhibition without international loans, it was possible to bring his paintings from various countries together in the book where reproductions of works from Latvian museums and private collections were joined by images of paintings from the Finnish National Gallery in Helsinki, the Modern Museum in Stockholm, the Malmö Museum, Centre Georges Pompidou in Paris, the Benešov Museum of Arts and Design in the Czech Republic, and other places. The series of rediscoveries continued still after the book went to print as the Museum of Fine Arts in Budapest recalled their previous information about Purvītis' painting *Boats* being lost during the Second World War and shared photos of this happy find.

Research for the *Landscape with a Painter* benefited from close collaboration and exchange with colleagues already mentioned above and still many others but the result was dedicated to two outstanding women from the past – the artist's wife Karolīne Purvīte (born Caroline Stellmacher, 1877–1955) and his thorough biographer Tatjana Kačalova (born Rosenschild-Paulin, 1915–2010), in order to honour and commemorate their very special role in the life and posthumous reception of the artist. The monographic study ends with a chapter *Not in Vain* as a reply to chagrin and despair experienced by Purvītis facing the loss of his whole artistic estate. Against the background of the ongoing warfare in Ukraine, this epilogue reminds that research of art history, too, first of all means intellectual and aesthetic resistance against death and destruction.

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DEPOPULATION IN LATVIA

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This article outlines evolution of the total population of Latvia after the restoration of Latvia's independence. The term "depopulation" is increasingly used by specialists to describe a systematic decline in the absolute number of inhabitants due to an excess of deaths over births. Depopulation sometimes denotes a situation wherein the natural increase is sustained, but the total population shrinks due to a negative balance of in-migration and out-migration. Latvia is one of the few countries in the world, where year on year the number of deaths exceeds the number of births, while at the same time there is also a negative balance of international migration processes. Determining the causes of this phenomenon and ascertaining consequences of profound depopulation is one of the most important tasks falling to social science.

Before the First World War, the population of Latvia grew very rapidly both intrinsically and as a result of immigration. The First World War was responsible for a considerable loss in the number of inhabitants with a number lost during the ensuing freedom struggle. Occupation of Latvia by the Soviet Union gave rise to a major decrease in the number of residents, but throughout the Soviet period the number of residents tended to increase systematically, chiefly due to immigration from other Soviet republics, especially from the Russian Federation, Ukraine, and Belarus. In 1940, Latvia counted fewer than 2 million people living within its borders, but by 1978 this number already exceeded 2,500,000, while by the late 1980s it was rapidly approaching 2,700,000. The post-independence period has been characterised by an annual decline in population, taking into due account the departure of Soviet (Russian) army servicemen and their families during 1992–1994.

A low birth rate is a characteristic feature of demographic developments in Latvia. The transition from high fertility to lower fertility is a progressive feature of population reproduction. Initially, in a pre-transition period, most populations do not limit their fertility; the rate of increase is close to a physiologically feasible level. Mortality is also very high during this period, so that total natural increase of the population is rather slow, but episodically the number of deaths may exceed the number of births. This type of reproduction is called primitive and existed in Western Europe up until the 17th–18th centuries, and in Eastern Europe, up until the end of the 19th century. A decline in fertility and mortality is indicative of a qualitative change in reproductive types, i.e. an increasingly rational way of replacing generations, brought about by industrialisation and the modernisation of society.

It is evident from data shown in Figure 1 that during the years of restored independence, more than a half of the depopulation process has been due to international migration; a significant excess of deaths over births also was evident. The highest levels of emigration were recorded during both the first half of the 1990s and the economic crisis of 2008–2010 (Fig. 2).

Fertility is central to the mechanism of population reproduction. Already at the end of the pre-war period of the Republic of Latvia, the birth rate was insufficient fully to replace succeeding generations; by the mid-1930s replacement was only at 80–85%, and there was even a threat of depopulation, which was not typical of other European countries at that time. Low fertility rates persisted during the period of Soviet occupation, especially during the mid-1960s, when the total fertility rate (TFR) was only 1.7, one of the lowest rates in the world.

In the 1970s, the number of births of Latvians fell below the number of deaths, signalling, for the first time, extinction of a major ethnic group. In the 1980s, a number of measures were implemented to stimulate the birth rate, which resulted in an increase to

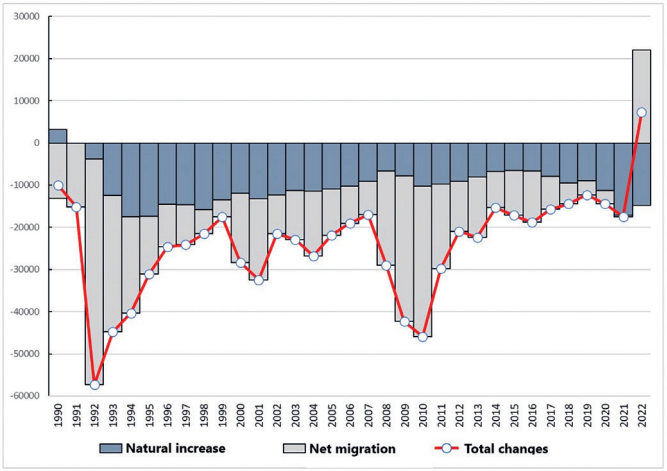

Fig. 1
Annual changes in total population due to natural change and international migration, 1990–2022 (individuals). Source: Database of the Central Statistics Bureau of the Republic of Latvia (CSB)

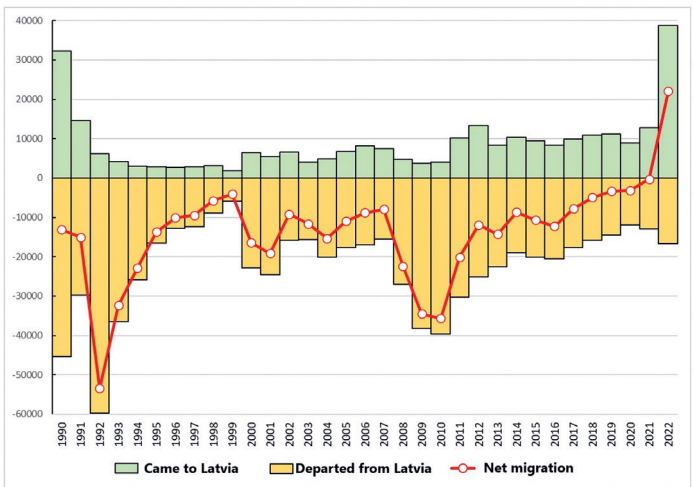

Fig. 2
Annual change in total population due to international migration processes for the period 1990–2022 (individuals). Source: Database of the CSB

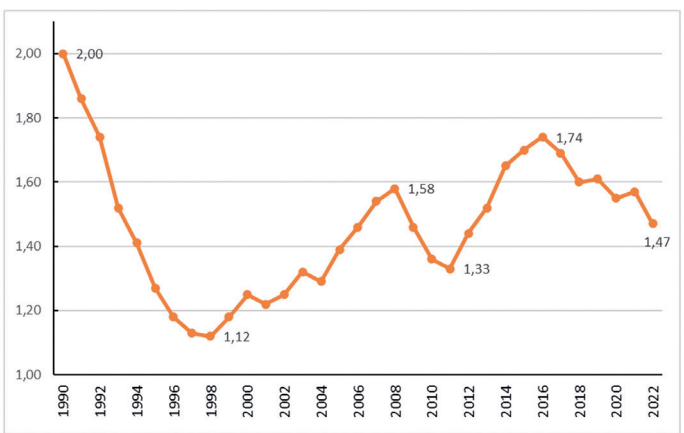

Fig. 3
The total fertility rate for the period 1990–2022. Source: Demogrāfija 2023, published by the CSB

simple replacement level of 2.1–2.2. The number of births fell from 38,000 in 1990 to 18,000 in 1998, while the TFR reached a record low value of 1.1 (see Fig. 3), which is only half of what is needed for generational replacement. The fertility rate has increased slightly since 2017, but the value is still one quarter below the level necessary for simple replacement, or twice the level required to prevent depopulation.

Mortality is one of the two main demographic processes. Viability defined as is the capacity for self-reproduction, adaptation and improvement of individuals and the total population of a country, in addition to being a measure of well-being. Today, objective indicators have been developed to measure and assess vitality and rates of mortality. Typically, the origin of the science of demography can be traced back to mortality studies carried out at the dawn of capitalism in the 17th–18th centuries. The contributions by the statistician and demographer Kārlis Balodis are particularly noteworthy, beginning with internationally recognised studies in the mid-19th century. He also ascertained the fact that ethnic Latvians had one of the highest life expectancies in Europe, while mortality in the Baltic provinces was lower than the average in Russia and Germany.

Let us look at the principal mortality indicators in Latvia today. An estimate based on the first census carried out in Latvia during the Soviet period shows that the average life expectancy at that time was 69 years, approximately ten years more than in 1940. During the following years, this figure stabilised or even declined. At the beginning of the period of independence restored, the value was 74.6 years for women and only 64.2 years for men, lagging far behind the situation in the most economically advanced countries and even in many developing countries. It is only in our present century that the situation has improved noticeably (see Table 1). In recent years, there has also been a substantial increase in mortality, including the contribution accruing to the incidence of COVID-19 and the impact of the Russian invasion of Ukraine.

The largest increase in the annual number of deaths was observed in 2021, when there was a significant increase of 20% when compared to the situation in 2020. In summary, the prevalence of premature mortality, especially for men, is the basis for the increase in the rate of depopulation. Comparing data country by country, the gap in rates of vitality for Latvia is even more pronounced than the ranking of the country in terms of fertility.

Recently, immigration has increased, including return migration, together with a drop in outmigration. A positive migration balance has been recorded in 2022 wherein the net balance exceeded 22,000 individuals. The number of new arrivals in 2022–2023 reached maximum, mainly due to the influx of Ukrainian war refugees and their acquisition of temporary protection status (Table 2).

The means of improving demographic indicators and tackling depopulation is an important challenge for both the country and for society as a whole. Based on an analysis of demographic processes and projections of key indicators, it may be calculated that the population will continue to decline in number throughout the coming years. Moreover, this rate of decline is likely to be one of the fastest in the EU, and also globally. According to the most recent Eurostat projections, the fertility rate in Latvia will remain basically at its current very low level (TFR 2022: 1.47), resulting in a decrease of the total number of inhabitants from 1.88 million today, to 1.76 million in 2030, with a further falling off to 1.47 million by the middle of this century.

The main scenarios for Latvia as published by the UN Population Division are slightly more optimistic, subject to the hypothesis that mortality will decline slowly, while fertility will increase (to 1.7), and also that immigration and out migration will be similar. An article published three years ago in the international medical journal, *The Lancet*, forecast that Latvia could have the highest depopulation rate in the world over the next few decades.

Demographic projections depend to a large extent on national social and demographic policies. In general, these have been passive, out of step with the situation that has developed in certain areas of the development of the population. The inhabitants themselves, as has been shown by surveys, have a rather high self-assessment of the support available to deal with the problems that have arisen. About half of the support providers identify the family/neighbourhood as the means for further solving demographic problems in the country. Support to promote fertility is

***Table 1*. Life expectancy in years, from 1990 to 2022**

	1990	2018	2019	2020	2021	2022	Less in 2022 than in 2018
Both sexes	69.5	75.0	75.6	75.1	73.1	74.4	–0.6
Males	64.2	70.0	70.8	70.4	68.2	69.4	–0.6
Females	74.6	79.6	79.9	79.5	77.6	79.3	–0.3

***Table 2*. The extent of international migration for Latvia, 1990–2022**

Years	Immigration		Emigration		Migration balance	
	total	average per year	total	average per year	total	average per year
1990–1994	60,328	12,066	197,099	39,418	–136,760	–27,352
1995–1999	13,395	2679	56,445	11,289	–34,050	–8610
2000–2004	27,408	5482	99,101	19,820	–71,693	–14,339
2005–2009	30,829	6166	115,378	23,076	–84,549	–16,190
2010–2014	46,212	9242	136,703	27,341	–90,491	–18,098
2015–2019	48,872	9974	88,814	17,763	–38,942	–7788
2020–2021	21,529	10,765	24,963	12,483	–3436	–1718
2022	38,708	38,708	16,680	16,680	22,028	22,028
1990–2022	288,281	8736	735,172	22,278	–446,893	–13,542

mentioned most often. Measures to reduce out migration and encourage return migration are ranked second in importance. Respondents have also referred relatively frequently to strengthening provisions for health care, with a view to increasing the expectancy of years of active life of residents.

Development of a recovery programme was foreseen in the 2014–2016 government Declaration on the planned activities of the Cabinet of Ministers (CM) featuring creation of a Demographic Affairs Council; however, only several measures have actually been implemented, most notably in the area of provision for family support.

The evident rapid depopulation of Latvia cannot but be but a source of great concern in scientific circles, including the Latvian Academy of Sciences, whose Senate held special sessions in 1997 and 2012 on the theme of a demographic crisis, calling for the need to activate public policies. The extent of depopulation is progressing, threatening the existence of the Latvian nation. Decisions and actions taken thus far do not inspire optimism about any tangible improvement in the near future with respect to population reproduction.

It is the opinion of this author that one of the shortcomings in the regulation of demographic processes is the fact that there is no unified national policy to address demographic issues, nor is there an institution to develop such policy. High hopes were placed on the Demographic Affairs Council, which started its work successfully in 2011 under the leadership of previous Prime Ministers, but it has never met during the time K. Kariņš led the government (2019–2023), i.e. effectively not in conformity with the statute of the said Council that provides for regular meetings to address tasks of national importance.

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SCIENCE FOR LIFE. LIFE SCIENCES

INSTITUTE OF BIOMATERIALS AND BIOENGINEERING, RIGA TECHNICAL UNIVERSITY

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The Institute of Biomaterials and Bioengineering (IBB) of Riga Technical University (RTU) (former Institute of General Chemical Engineering of RTU) is the largest and the most modern research centre in the Baltic States. IBB is developing cutting-edge biomaterials and bioengineering technologies by combining chemistry, materials science, and engineering tools for biomedical applications, including bone regeneration and bone tissue engineering.

The IBB was founded in 2010 as the Institute of General Chemical Engineering by merging the research structural unit of Rūdolfs Cimdiņš Riga Biomaterials Innovations and Development Centre and the study process structural unit of the RTU Department of General Chemical Engineering. In the late 2023, as a result of implementing structural reforms at RTU, the Institute of General Chemical Engineering was restructured. Starting from 1 January 2024, it is called RTU Institute of Biomaterials and Bioengineering.

RTU IBB is proud of its history and the people who have worked tirelessly to build the institute as we know it today. The creation of the IBB would not be possible without the lifelong work invested by Prof. Rūdolfs Cimdiņš and Prof. Līga Bērziņa-Cimdiņa and the long-term multidisciplinary cooperation between the RTU Biomaterials Research Laboratory and the Institute of Stomatology (IS) of Riga Stradiņš University (RSU), since the 1990s.

Today, IBB is an internationally recognised, university-based scientific institution that provides a multicultural and multidisciplinary platform for excellent science and research-based studying. The main aims of IBB are to train a new generation of highly qualified researchers and professionals and contribute to developing biomedical technologies and products for health, society, and welfare.

More than 60 employees work and do their academic and scientific work in the institute. IBB staff comprises 30 PhD holders, 20 staff members with Master's/Bachelor's degrees, and 10 undergraduate students. In 2020, RTU IBB started attracting foreign scientists. From more than 100 applications, the best candidates have already been selected for heads of scientific groups, postdoctoral fellows and doctoral students. Thus, in 2023, ten scientists from eight countries (Bosnia, China, Greece, Iran, Pakistan, Turkey, India, and Austria) are working at RTU IBB. The doors of the IBB are always open for developing PhD theses, Bachelor's and Master's theses, and high school children's scientific projects. During the last five years, 68 Bachelor's and 36 Master's theses have been developed and defended within the institute. In 2023, 21 PhD students are developing their PhD theses, seven of whom are foreign PhD students.

The IBB staff is involved in the study curriculum of the RTU Faculty of Natural Sciences and Technology (former Faculty of Material Science and Applied Chemistry) for all levels of students in the following study programmes: Bachelor and Master study programmes "Chemistry and Chemical Technology", Bachelor study programme "Materials Engineering", Master study programme "Material Science and Nanotechnologies", and Doctoral study programme

Fig. 1
STEM activities for school children during the European Researchers' Night 2019

"Chemistry, Materials Science, and Engineering". Additionally, IBB staff is involved in the study courses in other RTU faculties and scientific universities.

All institute's teaching staff and scientific staff actively work in science, leading and executing scientific projects financed by Latvian institutions and projects financed by international and European funds. IBB has extensive experience implementing national and international research and research management projects. In 2023, the institute continues to implement and achieve the set scientific research goals within the framework of three "Horizon 2020" projects, one "Horizon Europe" project, two ERA-NET projects, two State Research Programmes, one EEA and Norway grant, and three Fundamental and Applied Research projects of the Latvian Council of Science.

Furthermore, IBB has attracted funding from the H2020 project – "Rising Competitiveness of Early Stage Researchers and Research Management in Latvia" – RISEus2 (GA No 952347) to increase the research capacity of early-stage researchers, strengthen the research management capacity of leading staff, and to reinforce cooperation with industry by promoting technology transfer and delivery of the new products into the market.

In 2022, the IBB team published the results of their scientific research in 32 scientific articles, with an average impact factor of 4.98. Up to now, the IBB has developed and received nine Latvian patents and two European patents for new innovative materials and their acquisition technologies for medical applications and solving environmental protection problems.

The institute's staff is actively involved in participating and organising popular science events and STEM field activities (development of scientific research works, training, lectures, seminars, and competitions) for Latvian children, young people and society in general. The IBB aims to spotlight the importance of engineering and STEM fields, scientific careers and the contribution of Latvian science to society. Every year, the IBB team participates in events dedicated to the career days, RTU "Open Door Days", "European Researchers' Night", and "Shadow Days"(see Fig. 1). Participation in these events raises interest in engineering studies among a broad audience of prospective Latvian students.

The IBB has extensively contributed to enhancing the national level multidisciplinary/intersectoral collaboration network to promote cooperation between Latvian higher education institutions, scientific institutes, innovative companies and healthcare organisations – the University of Latvia, Institute of Solid State Physics of the University of Latvia, Riga Stradiņš University, the Institute of Stomatology of Riga Stradiņš University, Rēzekne Academy of Technologies, the Latvian State Institute of Wood Chemistry, the Latvian Institute of Organic Synthesis, Riga 2nd Hospital, etc. This national-level collaboration has contributed to the high quality of preparation and implementation of many scientific projects. Due to the existing cooperation, many Doctoral theses have been developed with a pronounced interdisciplinary character. In the field of biomaterials research, this cooperation has ensured the systematicity and continuity of the research and, through implementation in Latvian national programmes, has enhanced the quality of life for several thousand patients.

Fig. 2
Multinational and multidisciplinary research team of Baltic Biomaterials Centre of Excellence

Fig. 3
The new building of the Baltic Biomaterials Centre of Excellence that will be open at the summer of 2024

RTU IBB cooperates with international universities and research organisations in Germany, Switzerland, Finland, France, Argentina, Poland, the United Kingdom, Israel, Norway, Iceland, Italy, Turkey, the Czech Republic, Lithuania, and Estonia. Joint international projects have been implemented, high-ranking scientific articles published, guest lectures of teaching staff organised, summer and winter schools have been organised, and the international mobility of doctoral students has been promoted. International cooperation has resulted in an ambitious scientific capacity-building project – the Baltic Biomaterials Centre of Excellence (BBCE), which promotes excellence in research and development of new biomaterials for bone tissue regeneration, face, mouth and jaw surgery, orthopaedics and other fields (see Fig. 2). BBCE's establishment has succeeded due to the close long-term collaboration and two-way knowledge transfer between local and foreign partners and industry, combining competencies and developing the biomaterials industry. BBCE is a project financed by the EU "Horizon 2020" (GA No. 857287). An international team of scientists from Switzerland (AO Research Institute Davos), Germany (Friedrich-Alexander University of Erlangen-Nuremberg), Riga Stradiņš University (RSU), RSU Institute of Stomatology and Latvian Institute of Organic Synthesis are involved in project, providing the full cycle of biomaterial development, from laboratory to clinic (https://bbcentre.eu).

Although the RTU IBB is already equipped with up-to-date technological infrastructure, the IBB plans to move to a new modern facility in the RTU Campus in Ķīpsala next year (see Fig. 3). The BBCE project finances the construction of the facility. On 24 November 2023, the topping ceremony of the new BBCE building was celebrated, and the work on biomaterials R&D in the new laboratories will start in the summer of 2024.

For the fourth year in a row, BBCE project partners from Latvian institutions are organising an erudition competition for students – BIO-GO-Higher. The purpose of the BIO-GO-Higher competition is to raise the level of knowledge of 10th and 11th-grade students in engineering and natural sciences, providing them with a quality self-education model. For the main prize, the most successful student teams can visit BBCE's foreign partners in Germany or Switzerland, accompanied by a mentor, and participate in biomaterials' research and development process in the world's leading research centres in this field.

The staff of IBB are highly motivated to continue to direct scientific activities towards the growth of Latvia's national economy and the increase of competitiveness in Europe and the world.

Prof. Jānis Ločs, Director of the RTU Institute of Biomaterials and Bioengineering and Full Member of the Latvian Academy of Sciences, has always emphasised that Latvian scientists should pay significant attention to international cooperation and building a network of professionals from different fields. We wish everyone infinite energy in realising their scientific ambitions!

THE FACULTY OF PHARMACY OF RĪGA STRADIŅŠ UNIVERSITY

DACE BANDERE
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INTRODUCTION

The beginnings of the Faculty of Pharmacy (FP) of Riga Stradiņš University (RSU) date back to 1919, when graduates of the University of Tartu established the Department of Pharmacy at the Faculty of Chemistry, University of Latvia. Latvia established its own system of higher pharmaceutical education, which was one of the best in Europe at that time. Over the years, the Faculty of Pharmacy has continued its activities as a faculty of both Riga Medical Institute and the Medical Academy of Latvia, and until now it is an integral part of Riga Stradiņš University.
The Faculty of Pharmacy includes three departments: the Department of Pharmaceutical Chemistry, the Department of Pharmacology, and the Department of Applied Pharmacy, as well as the Laboratory of Finished Dosage Forms (LFDF), which was established in 2022.
The Faculty employs more than 60 professionals – pharmacists, chemists, biologists, physicians, engineers, as well as academic and research support staff. The faculty has considerable academic and research experience and qualifications, which are used to spread knowledge to students, and the faculty staff are also actively involved in promoting the development of the pharmaceutical industry. The activities of the Faculty of Pharmacy are in line with the RSU Development Strategy and the aims of the University of Science.

ACADEMIC ACTIVITIES

Academic work is provided by departments, where knowledge, skills, and competences are acquired not only by future pharmacists, but also by medical doctors, dentists, and other healthcare professionals. Each year, more than 30–40 future pharmacists are enrolled in the 2nd level professional study programme "Pharmacy" at the Faculty of Pharmacy. In addition, the Faculty also offers two Master's degree study programmes – "Clinical Pharmacy" and "Industrial Pharmacy". Doctoral students of the sub-programme "Pharmacy" of the Doctoral study programme "Health Care" work on their research theses in the Faculty's laboratories.
The Department of Pharmaceutical Chemistry (Head of the Department: Assistant Professor Inga Urtāne) provides all specific chemistry courses necessary for pharmacists' work in pharmacy, manufacture of medicinal products, quality control, and research. The Department of Applied Pharmacy (Head of the Department: Associate Professor Baiba Mauriņa) provides study courses related to the manufacturing of medicinal products in pharmacy and industry, clinical research of medicinal products, analysis and use of medicinal plants, as well as pharmaceutical care, pharmacoeconomics, and pharmaceutical legislation. Department of Pharmacology (Head of the Department: Associate Professor Inga Stuķēna) provides pharmacology training to all future healthcare professionals at RSU.
Employers of pharmacies, pharmaceutical manufacturers, hospitals, as well as employees of the State Agency of Medicines and members of the Pharmacists' Society of Latvia are actively involved in implementing the study programme. They all participate in the faculty management, provide placement for students, and work as lecturers in individual courses or lectures.
Both the pharmaceutical industry and pharmaceutical science are well developed in Latvia. It should be noted that the Faculty of Pharmacy has established very good cooperation with industry both in the teaching process, as, for example, classes for

students are held in cooperation with pharmaceutical manufacturers Grindeks, Olainfarm, LMP, and others, and in science, working on research theses at Latvian Institute of Organic Synthesis (LIOS), Latvian Biomedical Research and Study Centre (LBMC), manufacturing facilities and pharmacies.
According to the databases of Central Statistical Bureau, State Revenue Service, and State Employment Agency, 100% of RSU Faculty of Pharmacy graduates are employed. Graduates work in pharmacies, pharmaceutical wholesalers, pharmaceutical manufacturers, and scientific institutions. Especially in recent years, many graduates end up in international contract organisations for clinical trials, research laboratories, pharmaceutical manufacturers, and companies for the registration of medicinal products.

DEVELOPMENT

In recent years, the scientific activity of the academic staff has grown rapidly, which has also stimulated the participation of students in research, an increase in the number of doctoral students, an increase in the number of scientific projects and international scientific publications.
Mostly research areas related to clinical pharmacy, pharmacology, pharmacognosy, pharmacokinetics, as well as drug use and availability problems are being studied at the Departments. With the establishment of the LFDF, a strong focus is being placed on pharmaceutical formulation and drug delivery, as well as respective manufacturing and analytical methods.
The rapid development of the Faculty of Pharmacy in recent years has helped attract external funding (ERDF funding of more than EUR 9 million), which in turn has enabled both the construction of a new Pharmaceutical Education and Research Centre and the purchase of equipment and technology for study and research. Modern facilities, a comfortable, safe, and stimulating environment for students, and the opportunity to study and work with the latest analytical and technological equipment contribute to the further development of both staff and students in the field of science and enable them to acquire the knowledge and skills needed for the labour market. The LFDF provides a technology platform for study courses and is a platform for scientific research; it is a place of activity of research groups and projects and it also provides services needed by the pharmaceutical industry.

RSU Pharmaceutical Education and Research Centre

The new Pharmaceutical Education and Research Centre and the LFDF were launched at the beginning of 2023. The laboratories are equipped with new analytical equipment such as HPLC - FD/UV-Vis/PDA/RI, HPLC - MS/MS, GC/HS-FID, GC-FID, ICP-MS/MS, DSC, PSD, Rheometer, Dissolution apparatus, FTIR and UV-Vis spectrophotometers, TLC/HPTLC, RAMAN, XRD as well as modern technological equipment: micronizer, fluid-bed processor, roller compactor, compaction simulator, vacuum-compression-molding device, hot-melt extruder, rotary tablet press, capsule filling machine, tablet coater, blistering machine, providing wide formulation possibilities for research and development process of solid dosage forms.
Currently, the Faculty staff and students are involved in several projects that are taking place in cooperation with other universities of Latvia – Riga Technical University, Latvia University of Life Sciences and Technologies, and scientific institutions – LIOS and LBMC. Academic and scientific cooperation has been established with universities and science centres in Lithuania, Italy, Finland, Germany, Switzerland, India, Japan, Ukraine, and other countries.

STAFF

Faculty staff represent all sub-disciplines of pharmacy – pharmacology, pharmacognosy, dosage form technology, pharmaceutical chemistry, clinical pharmacy, and social pharmacy. Faculty staff also share their scientific results in their study courses, produce internationally-cited publications, and review scientific articles.

Several teams of researchers operate in the Faculty in different areas of pharmacy:

• Agnese Brangule – biomaterials, drug delivery systems

• Dace Bandere – pharmacokinetics, antimicrobial agents, antimicrobial properties of medicinal plants

• Maija Dambrova – preclinical drug discovery, cardiometabolic, CNS, mitochondria, biomarkers, energy metabolism

• Reinis Vilšķērsts – preclinical drug discovery, energy metabolism, cardioprotection, heart failure with preserved ejection fraction, vasoprotection

• Māra Plotniece – 1,4-dihydropyridines, pyridinium derivatives, lipids, nanoparticles, structure-activity relationships

• Aiva Plotniece – synthetic lipids, liposomes, fluorescent cell imaging, structure-activity relationships

• Inga Urtāne – clinical pharmacy, analysis of problems with patient adherence to pharmaceutical therapy

• Elita Poplavska – access to medicines, policy related to circulation of medicinal products

• Renāte Ranka – pharmacogenetics, personalised medicine

• Baiba Mauriņa – pharmaceutical formulations, medicinal plants

• Līga Lauberte – phytochemistry, expertise in development and validation of chemical analyse methods, direction of health promoting natural agent chemistry

• Konstantīns Logviss – pharmaceutical formulations, drug delivery systems, orphan drugs.

• Valentyn Mohylyuk – scientific direction related to improving the solubility and bioavailability of poorly soluble drugs of oral dosage forms, optimisation of the pharmacokinetics and custom/personalised properties of oral dosage forms, drug-loaded long-acting parenteral implants.

Professor Maija Dambrova, who has received several important national and scientific awards for her achievements in pharmacology, is co-author of the scientific monograph *Scientific Writing and Dissemination of Research Results* and also the lecturer with the highest number of publications at RSU – more than 165 Scopus publications.

The Faculty of Pharmacy being one of the smallest faculties at RSU, every year the faculty staff publish their research results in scientific journals, making a significant contribution to the total number of RSU scientific research. The number of international publications (indexed in Scopus or Web of Science) increases every year. For example, the Faculty of Pharmacy staff as authors and co-authors had 23 publications in 2019, 30 in 2020, 37 in 2021 and 25 in 2022, and 48 publications in 2023. Faculty staff publish their research results in distinguished journals such as *British Journal of Clinical Pharmacology, Basic and Clinical Pharmacology and Toxicology, Toxicology Letters, Pharmacological Research, Biochemical Journal, Nutrients, Journal of Infection and Chemotherapy, Medicina, Molecules, Nanomaterials, Journal of Ethnopharmacology, Plants, BMC Primary Care, BMC Medical Education, BMJ (Online), Journal of Pharmaceutical Policy and Practice, Journal of Drug Delivery Science and Technology, International Journal of Pharmaceutics*.

Several lecturers are members of editorial boards of international scientific journals, participate in funded research projects, including as experts, and are members of Latvian and international professional organisations. The academic staff also participate in several COST activities, creating new networks of scientists, and searching for cooperation partners. The participation of academic staff in numerous projects contributes to the development of scientific capacity and competitiveness, which is also characterised by an increase in the number of scientific articles in Scopus or Web of Science journals, as a result of which the authority and recognition of RSU as a Centre for studies and science is strengthened. Faculty staff are also actively involved in public education activities – they give interviews on radio and TV, publish articles in popular science magazines, and social media.

Currently, Faculty staff and students are involved in several projects: Horizon 2020 project No. 857287 "Baltic Biomaterials Centre of Excellence (BBCE)" headed by Professor D. Bandere with the involvement of the following scientific staff representatives: Assist. Prof. A. Brangule, Assoc. Prof. B. Mauriņa, Assoc. Prof. I. Skadiņš, PhD J. Amirian, PhD S. Singh Hallan, as well as doctoral students and students; RSU LFDF is involved in the BBCE project to complement the knowledge of the project consortium and integrate its expertise in

the field of pharmaceutical technologies. The LFDF is gradually expanding its research focus from oral solid dosage forms to biomaterials as drug delivery systems. The project was created in cooperation with RTU, LIOS, RSU Institute of Stomatology, as well as the AO Research Institute in Davos (Switzerland) and Friedrich-Alexander University Erlangen-Nürnberg (Germany) in accordance with Latvian Smart Specialisation Strategy in the field of biomedicine, medical technology, biopharmaceutics, and biotechnology. The project offers a wide range of training opportunities for Faculty staff, doctoral students, and students.
Scientists from the Faculty of Pharmacy are implementing the Latvian Council of Science project in the field of tuberculosis pharmacogenetics, projects funded by the European Agricultural Fund for Rural Development and the Rural Support Service on the use of medicinal plants in agriculture for the treatment and prevention of various antibacterial and parasitic diseases.

LABORATORY OF FINISHED DOSAGE FORMS

Established in 2022, the LFDF international and multidisciplinary team is made up of professional and creative experts with a wide range of experience and diverse backgrounds. The Laboratory employs pharmacists, chemists, technologists, engineers, and actively involves students and future professionals. The long-term goal of the LFDF is to become an international research and intellectual centre, developing new research directions and building knowledge of pharmaceutical formulations, drug delivery systems, and relevant analytical methods. With the establishment of the LFDF, the range of research areas in the development of different dosage forms has expanded. Valentyn Mohylyuk (PhD), the scientific manager of the Laboratory, together with lead professionals Līga Lauberte (PhD), and Konstantīns Logviss (PhD), is developing research to improve the solubility of poorly soluble drug substances and increase the bioavailability of oral dosage forms using micronisation, hot-melt extrusion, fluid-bed coatings, porous carriers, coprecipitation, microwaves, and other options.
The Laboratory will also work on optimising the pharmacokinetic properties of oral dosage forms by formulating them as easy-to-swallow, taste-masked, delayed-release or modified-release dosage forms

The LFDF Tablet Laboratory

in granules and tablets using fluid-bed coating, as well as matrix tablets prepared by roll compaction or hot-melt extrusion. The LFDF will also develop special oral dosage forms such as sustained-release tablets resistant to mechanical contractions, alcohol-resistant long-acting tablets and pellets, and abuse-deterrent dosage forms. The Laboratory will focus on continuous manufacturing processes for solid dosage forms, including continuous processing steps such as hot-melt extrusion, granulation, roll compaction, tableting, and encapsulation (into hard capsules). The LFDF is also expanding its expertise in long-acting parenteral implants through emulsification, solidification, and polymerisation processes, microfluidics, hot-melt extrusion, and 3D printing, as well as personalised dosage forms developed with 3D printing technologies.
The LFDF conducts research on extraction and analytical characterisation of herbal substances and development of health-promoting products based on them. Using state-of-the-art analytical equipment, the LFDF performs solid-state characterisation of substances, compaction simulation, vacuum-compression-moulding sample preparation, and mechanical, particle size distribution, spectroscopic and chromatographic testing methods to support Laboratory's research activities. The Laboratory is open to collaboration in the above or related fields, participates in joint research projects, enhances its reputation by publishing articles in internationally peer-reviewed journals and participates in prestigious international pharmaceutical events.

BIOTECHNOLOGY FACILITY AT THE LATVIAN INSTITUTE OF ORGANIC SYNTHESIS

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Since the day of its establishment back in 1957, the Latvian Institute of Organic Synthesis (LIOS) was focusing on drug discovery and development. Now LIOS is known as the largest drug discovery centre of the Baltic and as such possesses a broad spectrum of drug discovery and development process expertise including medicinal chemistry, organic synthesis, *in vitro* and *in vivo* pharmacology, bioanalytical studies, computational modelling, and process chemistry. Striving for scientific excellence, LIOS has set an ambitious goal to become a leading EU research centre in the field of drug discovery already by 2030. According to the LIOS Strategy for 2022–2027, the vision of LIOS as an institution is to become one of the European leaders in chemistry and biomedicine, in which vivid personalities, scientific ideas, and new products are created and developed.

To reach this strategic goal, permanent development of the necessary set of competences and capacities is the necessary element to bring the drug discovery research to the top-level and in line with the global trends. It is generally recognised that "integrated biotechnology tools are playing an increasing role in small–molecule drug development" [1]. Based on that, already back in 2018, LIOS Scientific Council acknowledged the biotechnology as a missing expertise that should be integrated with the existing areas of competence such as organic synthesis, pharmacology, and biophysical chemistry, to address all major tasks of preclinical drug discovery and development. Consequently, both the establishment of a biotechnology facility and formation of a dedicated group of biotechnology were identified as the logical steps forward to establish a high performance integrated LIOS drug discovery (LIOS-DD) platform. Hiring of a researcher with high expertise in drug discovery related biotechnology and proven leadership skills was the key element for this initiative. A top-level scientist with excellent track record would not only establish a research group but would also transfer her/his experience to other LIOS research groups, thus enhancing the performance of the LIOS drug discovery platform.

To tackle this task an ERA-Chair [2] project proposal was submitted aiming to achieve excellence of LIOS in drug discovery and chemical biology on sustainable basis by establishing a high-performance drug discovery (LIOS-DD) platform at the Institute. To achieve this goal, the establishment of the Biotechnology group and its integration with other research groups to form LIOS-DD platform was proposed. Among others, the following objectives were set:

1) recruitment of top-level principal investigator as the head of the Biotechnology group;

2) establishment of the Biotechnology group;

3) development and implementation of the training programme for the research staff;

4) formation of LIOS-DD platform by integration of the Biotechnology group with other research groups of LIOS;

5) achieving sustainable funding of Biotechnology group as part of LIOS-DD platform from external competitive research projects.

The project named BioDrug received a Seal of Excellence and was refinanced by the European Structural and Investment Fund (project No. 1.1.1.5/19/A/004).

In 2019, Prof. Emilio Parisini took up a Principal Investigator (ERA-chair holder) position at the Latvian Institute of Organic Synthesis and started to form the Biotechnology group. Simultaneously, Prof. Kristaps Jaudzems started to develop his independent research activities in the field of drug discovery related structural biology. Both scientists had certain common research interests, and a strategic decision was made to construct a new specialised facility at LIOS. To achieve the highest possible suitability of the new facility to the research needs of the two researchers, both Emilio and Kristaps were heavily involved in the design phase of the new laboratory building.

The design was started in January 2020 and lasted for one year. The construction work was started in May 2021 and on 29 March 2023 the grand opening of the new facility took place. In total more than 2.7 MEUR investments were made in design and construction of the new facility. About 2 MEUR investment was made in research infrastructure. The funding was obtained from the European Structural and Investment Fund (project No. 1.1.1.4/17/I/007).

Currently, the Biotechnology facility hosts two groups. The Biotechnology group is headed by Prof. Emilio Parisini and consists of ten members:

1) Prof. Emilio Parisini, group leader
2) Dr. Nikhil Agrawal, principal researcher
3) Dr. Teodors Panteļejevs, researcher
4) Dr. Rosella Castagna, researcher
5) Ambreen Kauser, research assistant
6) Anastasija Rudņickiha, research assistant
7) Atis Jēkabsons, research assistant
8) Shapla Bhattacharya, research assistant
9) Leonid Rozanov, laboratory technician
10) Linda Legzdiņa, laboratory technician

The Biotechnology group is involved in different advanced research areas, mostly related to structural biology, drug discovery, enzyme engineering, and in the development of biohybrid functional materials. It features a diverse set of expertise, ranging from molecular biology and biochemistry to X-ray crystallography, biophysics, molecular modelling, and material science. By performing cutting-edge research, the group is contributing to 1) the functional and structural characterisation of adhesion proteins that play a key role in cell homeostasis; 2) drug discovery against a diverse set of protein targets related to different pathological conditions; 3) the design and the production of novel enzymes for biomedical and biotechnological applications; 4) the design and the production of photoactive materials and other functional biohybrid materials.

The building of the Biotechnology facility

One of the main foci of the group is on the functional and structural characterisation of members of the cadherin family of cell adhesion proteins. Over the years, the group has made great contributions to the understanding of the activation mechanism of different cadherin family members, and has pioneered the development of small molecule inhibitors/modulators of the cell adhesion process. This is a highly innovative research field that is contributing to the development of inhibitors of protein-protein interactions and to the druggability of proteins previously considered undruggable. These small molecules may not only offer novel therapeutic opportunities, but also provide great research tools for mechanobiology studies.

The group also performs a wide range of drug discovery studies against several more traditional drug targets (kinases, phosphodiesterases, aminoacyl t-RNA synthetases, etc). This part of the

The opening ceremony of the Biotechnology facility. From left to right: Prof. Kristaps Jaudzems; President of the Latvian Academy of Sciences, Prof. Ivars Kalvinsh; Prof. Emilio Parisini; Minister of Economics of the Republic of Latvia, Mrs. Ilze Indriksone; Prime Minister of the Republic of Latvia, Mr. Krišjānis Kariņš; Minister of Education and Science of the Republic of Latvia, Mrs. Anda Čakša; Rector of Riga Stradiņš University, Prof. Aigars Pētersons; Director of the LIOS, Dr. Osvalds Pugovičs

research activity is done in collaboration with several medicinal chemistry groups in Latvia and abroad. Cancer, malaria, Alzheimer's disease are some of the therapeutic areas that the group is contributing to.

Another major focus in our group is on enzyme engineering. We are focusing on two major classes of enzymes, one involving a class of deglycating enzymes called fructosyl peptide oxidases (FPOX), which find potential application in the management of diabetes, and the other involving different cutinases (LLC) for the degradation of polyethylene terephthalate (PET) products. By using a combination of computational and experimental techniques, we are developing novel and more efficient enzymes for a wide range of biomedical and environmental applications.

Over a period from 2019 to 2023, the group has published 23 original research papers in journals indexed by SCOPUS.

Another research unit located in the Biotechnology facility is the Laboratory of Structural Biology and Drug Design headed by Prof. Kristaps Jaudzems. The laboratory consists of eight members and is the youngest research unit of the LIOS:

1) Prof. Dr. Kristaps Jaudzems, Head of the laboratory
2) Dr. Raitis Bobrovs, principal researcher
3) Dr. Diāna Zeļencova-Gopejenko, researcher
4) Iveta Kaņepe, researcher
5) Kristīne Kitoka, research assistant
6) Laura Drunka, research assistant
7) Anna Līna Bula, laboratory technician
8) Kristīne Kramēna, laboratory technician

The Laboratory of Structural Biology and Drug Design is involved in cutting-edge scientific research in two related areas: structural biology and drug design. These areas are essential for understanding biological processes, developing novel biomaterials, and creating effective treatments to address diverse health challenges. Led by Professor Kristaps Jaudzems in structural biology and Dr. Raitis Bobrovs in drug design, the laboratory's diverse expertise in biophysical chemistry, particularly in biomolecular nuclear magnetic resonance (NMR), molecular modelling, protein sample preparation, structural and interaction studies, significantly contributes to understanding fundamental biological mechanisms and advancing innovative drug and biomaterial development.

Working process in the Biotechnology facility

In the field of Structural Biology, the research focuses on protein aggregation studies related to spider silk formation and neurodegenerative diseases. The laboratory has made substantial progress in unravelling the mechanisms of spider silk formation and developing a method for producing chemically modified artificial spider silk. These results stem from NMR studies in solution and solid state, allowing the replication of conditions experienced by silk proteins in the spider's gland towards fibre formation. It should be mentioned that the results of the spider silk research laid ground to establishment of a spin-off company PrintyMed [3]. This is a medicine company focusing on the development of artificial spider silk for different medical applications, in particular the company works to produce a material that can be used to create 3D printed living tissue.

Additionally, the lab has investigated proteins like amyloid beta and tau, associated with Alzheimer's disease, gaining insights into the molecular mechanisms of neurodegeneration. This work holds the potential for future therapeutic interventions, including vaccine development, pursued in collaboration with Professor Kaspars Tārs from the Latvian Biomedical Research and Study Centre.

In Drug Design, the lab actively participates in collaborative medicinal chemistry projects with the institute's synthetic chemistry groups. It plays key roles in elucidating compound structure-activity relationships and designing highly active molecules targeting various drug targets for infectious diseases (malaria, bacterial infections, SARS-CoV-2), and cancer. This underscores the lab's dedication to advancing innovative approaches in drug discovery at the Latvian Institute of Organic Synthesis.

The establishment of the Biotechnology facility is another milestone on the way of the Latvian Institute of Organic Synthesis to its strategic goal – to become one of the leading centres of drug discovery and development in Europe. We are implementing the frontier technologies allowing us to stay at the forefront of biomedical research.

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INSERTING THE "FUNCTIONAL" INTO THE "PRECISION MEDICINE/ONCOLOGY" – CANCER CELL RESEARCH AT RIGA STRADIŅŠ UNIVERSITY

INESE ČAKSTIŅA-DZĒRVE
PhD, Laboratory of Cell and Tissue Culture, Institute of Microbiology and Virology; Science Centre "Kleisi"; Riga Stradinš University; Faculty of Medicine, Riga Stradiņš University

THE BEGINNINGS

The cancer cell research group at the Laboratory of Molecular Genetics, Institute of Oncology, Riga Stradiņš University, was developed in 2014–2015 in an empty, renovated space at the Institute of Oncology. The group started the first projects investigating the effects of different media on the gene expression in breast cancer cell lines. Through years, the group's focus was drug resistance and hypoxia effects in breast cancer cell lines that resulted in the financed project "Hypoxia-induced molecular alterations and druggable targets in triple negative breast cancer cell lines – HipTNBC". The group has an expertise in cell cultivation in prolonged chronic (long-term) hypoxia conditions and assessment of relative telomere-length, and also developed its skills in cultivating breast cancer organoids in 3D cultures (based on the method by Sachs et al. [1]), isolation and characterisation of breast cancer cell line-derived extracellular vesicles (EV's).

SABBATICAL AT DANA FARBER CANCER INSTITUTE (DFCI) AND HARVARD MEDICAL SCHOOL (HMS)

The head of the group, Inese Čakstiņa-Dzērve, went on sabbatical in year 2022/2023. Receiving Fulbright visiting researcher fellowship, she chose to join Prof. Anthony Letai group and learn new approaches to investigate different mitochondrial anti-apoptotic pathways the cancer cells use to avoid cell death. During the time in DFCI and HMS, she joined Patrick Bhola in the investigation of dynamic BH3 profiling applications for solid tumours (Fig. 1).

BH3 PROFILING AS ONE OF THE FUNCTIONAL TESTS FOR CANCER CELL RESPONSE TO DRUGS

Programmed cell death via the pathway called apoptosis is a normal process during the development and maintenance of every multicellular organism. In addition, apoptosis of cancer cells is the aim of cancer therapies. Apoptosis has two distinct major pathways: extrinsic (death receptor mediated) and intrinsic (mitochondrial mediated) as well as the perforin/granzyme pathway (cytotoxic T-cell mediate [2] (Fig. 2).

The extrinsic pathway conducts a signal for self-destruction from outside of the cell and is the target in several immunotherapies. It is initiated by ligation of transmembrane death receptors (CD95, TNF receptor, and TRAIL receptor) to activate membrane-proximal (activator) caspase-8 via the adaptor molecule FADD. This in turn cleaves and activates effector caspase-3 leading to activation of the caspase cascade resulting in activation of proteins that cleave other cell proteins inside the cell, thus destroying the cell [3].

In contrast, most chemotherapies involve the activation of intrinsic pathway in tumour cells. Various stimuli, e.g., radiation, toxins, free radicals, viral infections, DNA damage and oncogene activation etc., can cause changes in the outer mitochondrial membrane leading to release of normally seques-

A

B

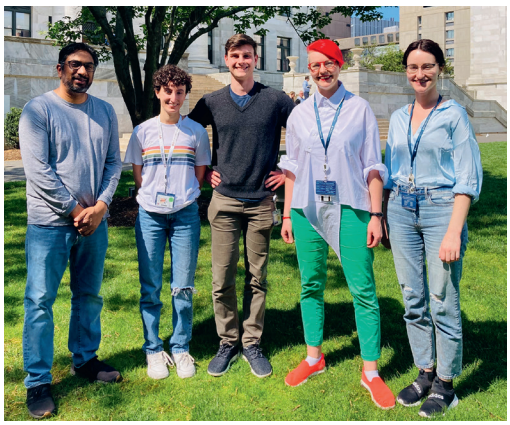

Fig. 1
A, Inese Čakstina-Dzērve with colleague Michael C. Yorsz after experimental part at HMS (in total we used approx. 400 of 384-well plates).
B, part of the Laboratory for Functional Medicine lead by Patrick Bhola (instructor of Prof. A. Letai group), from the left: Patrick Bhola, Gabriella Antonellis, Michael C..Yorsz, Inese Čakstiņa-Dzērve, Maria Davern

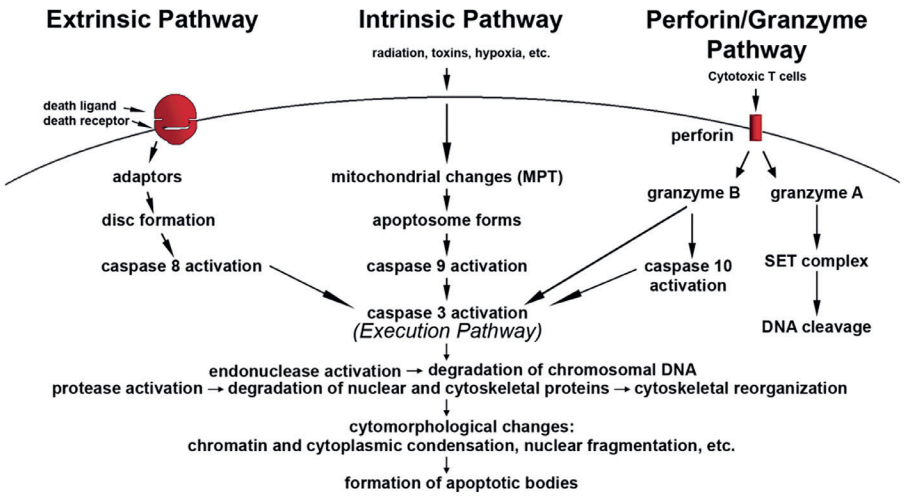

Fig. 2
Schematic representation of apoptotic events (Elmore, 2007)

tered pro-apoptotic proteins into the cytosol [4]. Cytochrome c, one of the pro-apoptotic proteins released, activates caspases by binding and activating Apaf-1 and procaspase-9, forming an "apoptosome". Such clustering of procaspase-9 activates caspase-9 [5]. Bcl-2 family of proteins are major key players in the regulation and control of these apoptotic mitochondrial events by regulating mitochondrial outer membrane permeabilization and hence release of cytochrome c [2].

The Bcl-2 family consists of up to 25 proteins and they fall into three groups based on Bcl-2 homology domains (BH). Some, like BCL2, BCL-X, BCL-W (which have BH1, BH2, BH3, and BH4 domains) inhibit apoptosis, while other relatives, like BAX, BAK (have BH1, BH3, and BH4 domains), and distant relatives like BIM, PUMA, BID (which have only BH3 domain), etc., promote apoptosis [6]. The induction of apoptosis requires activation of members from all these protein groups. BH3-only proteins are effectors of canonical mitochondrial apoptosis, and they play a critical role in restraining the cancer and other diseases. Exposure to stress induces BH3-only proteins which neutralise pro-survival or anti-apoptotic proteins, subsequently leading to activation of BAX and BAK. They undergo conformational changes and homo-oligomerisation (binding together) on the mitochondrial outer membrane leading to permeabilisation (making holes in the mitochondrial membrane) allowing the release of cytochrome c into the cytosol [7].

To benefit cancer patient survival and life quality, there is constant search for the best treatments possible. A treatment must be able to kill cancer cells, but not affect healthy cells, thus minimising side-effects for patients undergoing the treatment. Nowadays, treatment possibilities are mainly based on information about the tumour histological and molecular typing. However, often it might not be enough. The Letai laboratory has developed a func-

tional assay that measures how primed a cell is for apoptosis, called basic BH3 profiling (https://letailab.dana-farber.org/bh3-profiling.html). Drug-induced apoptotic signalling is an excellent predictor of response to therapy and can be measured with dynamic BH3 profiling (Fig. 3) [8].

The method called high-throughput dynamic BH3 profiling is developed by Prof. A. Letai's group and tested not only on "liquid" (such as blood) cancers, but also on solid tumour material. This method answers the question of how short (up to 24 hour) ex vivo treatments increase apoptotic priming in patient tumour cells [9].

DESCRIPTION OF THE BH3 PROFILING METHOD

There are various apoptosis assays available nowadays and they fall into six groups: (i) cytomorphological alterations; (ii) DNA fragmentation, (iii) detection of caspases, cleaved substrates, regulators, and inhibitors, (iv) membrane alterations, (v) detection of apoptosis in whole mounts, and (vi) mitochondrial assays.

BH3 profiling belongs to the mitochondrial assays. It is fast and technically less challenging than others. Also, it does not require expensive equipment and extensive labour hours. Application of this method on tumour cells that are exposed to various possible drugs (that could be used for treatment) can give an answer about which drugs will be most effective in killing cancer cells, but unaffecting healthy cells.

The workflow for dynamic BH3 profiling is visualised in Figure 4.

After cell incubation with drugs for up to 24 h, cells are permeabilised with digitonin to expose mitochondria followed by subsequent treatment with synthetic BH3 peptides (designed based on Bcl-2 family proteins). If the drugs do not affect apoptotic sensitivity, cytochrome c is retained within the mitochondria of the cells. If the drug has an impact on apoptotic sensitivity of the cell, the BH3 peptide treatment leads to the release of cytochrome c in cytoplasm. Mitochondrial outer membrane permeabilisation (MOMP) is measured by immunofluorescent staining of endogenous cytochrome c [9].

BH3 PROFILING IN RESEARCH APPLICATION (LATVIAN SCIENCE COUNCIL GRANT)

Over the past decade, the field of oncology has witnessed substantial advancements, not only in the development of new technologies and drugs, but also in the emergence of numerous assays tailored for precision medicine. Contrary to a prevailing misconception associating precision medicine solely with genomic data, a burgeoning domain known as functional precision medicine is gaining prominence. This approach involves making treatment decisions based on an individual patient's unique cellular response to drugs. Along with genomics data, it can serve as a more precise and effective tool for choosing the right drug for a specific patient.

BH3 profiling involves assessing interactions between pro- and anti-apoptotic proteins, providing a comprehensive view of the apoptotic potential of cancer cells. This technique has gained prominence due to its ability to identify the vulnerabilities of cancer cells, paving the way for the development of targeted therapies. In the context of the HipTN-BC project, BH3 profiling will serve as a critical tool for understanding the apoptotic response in triple negative breast cancer cell lines under hypoxic conditions. The nationally financed project, illustrated in Figure 5, focuses on unravelling the molecular alterations induced by hypoxia in triple negative breast cancer.

Despite remarkable strides in the treatment landscape of triple negative breast cancer (TNBC), patient outcomes often fall short of optimal due to the inherent heterogeneity of tumours. A significant contributor to this clinical challenge is hypoxia, a condition characterised by insufficient oxygen supply to tissues and cells. The impact of hypoxia-associated alterations hinges on the nuanced pattern of exposure, necessitating an understanding of specific molecular changes induced by various forms of hypoxia.

The primary objective of our proposed research is to meticulously identify and validate molecular alterations and druggable targets associated with acute, cycling, and chronic hypoxia in TNBC. This ambitious endeavour involves a comprehensive exploration of hypoxia-induced molecular alterations,

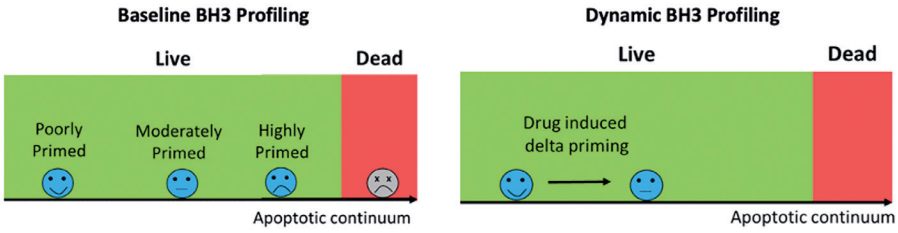

Fig. 3
Schematic visualisation of baseline BH3 profiling (different types of cells in context to their proximity to the apoptotic threshold) and dynamic BH3 profiling (different drug induced cell response) [9].

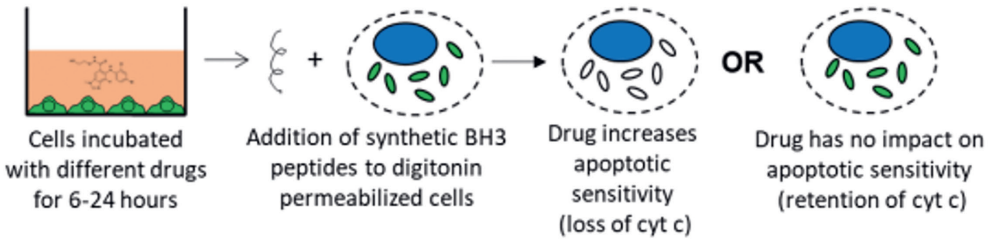

Fig. 4
Workflow for dynamic BH3 profiling [9]

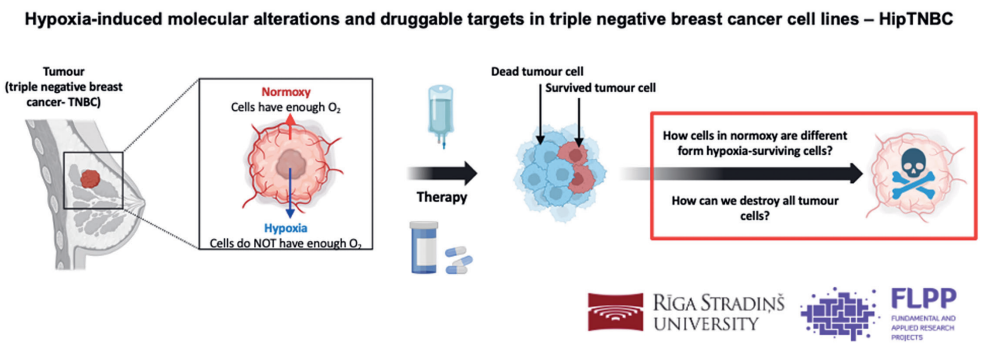

Fig. 5
Graphical abstract of HipTNBC project

spanning somatic genomic alterations, mRNA, miRNA, protein expression, and DNA methylation.

The identification of druggable targets, including BH3 mimetics, rooted in mitochondrial apoptotic dependencies in TNBC, constitutes a pivotal aspect of this research initiative. Leveraging advanced bioinformatics analyses on publicly available multi-omics datasets, we aim to delineate hypoxia-related mRNA signatures that hold the key to unravelling the intricacies of TNBC in the context of hypoxic stress.

The subsequent phase of our research involves the rigorous validation of the identified molecular alterations and druggable targets. TNBC reference cell lines will be systematically exposed to acute, cycling, and chronic hypoxia to mirror the diverse hypoxic conditions encountered *in vivo*. This robust validation process is poised to provide insights that bridge the translational gap between theoretical findings and practical therapeutic applications.

The outcomes of this research endeavour are poised to furnish a comprehensive repository of potential tumour-hypoxia related indicators and a curated list of promising therapeutic agents. This invaluable information holds the promise of catalysing the development of personalised therapeutic strategies in the field of TNBC.

FUNCTIONAL PRECISION MEDICINE/ONCOLOGY

The functional assays assessing cancer cell responses currently exist at diverse developmental stages regarding their proximity to clinical application. Notably, the imminent integration of BH3 profiling into clinical practice is more foreseeable for haematological neoplasms compared to solid tumours. Despite the variance in translational progress, these functional tests hold considerable promise for prospective therapeutic modalities. This is particularly noteworthy in instances of cancer recurrence, wherein the elucidation of cancer cell responses through functional assessments may pave the way for innovative treatment strategies with enhanced clinical efficacy.

As part of the annual initiatives aimed at promoting precision medicine, Riga hosts a Precision Medicine Networking Forum, featuring a specialised session dedicated to Functional Precision Medicine, curated by I. Čakstiņa-Dzērve. For detailed information, refer to www.pmnetforum.com, which houses recordings from the forum sessions conducted in 2023.

Furthermore, individuals are cordially invited to participate in the Society for Functional Precision Medicine (SFPM), a global organisation dedicated to advancing patient care and outcomes through the incorporation of functional assays into clinical practice. The mission of SFPM encompasses various objectives, including the cultivation of research and development endeavours in the realm of functional precision medicine across diverse medical domains. The society is committed to expediting the dissemination of contemporary research findings to interested stakeholders, promoting educational initiatives and training pertaining to functional precision medicine, fostering the development of solutions for clinical testing of functional precision medicine approaches, and enhancing the efficiency of adopting such solutions through engagement with academia, regulatory bodies, industry, and patient communities. Membership in SFPM offers exclusive access to high-quality recordings of monthly seminars, providing valuable insights and updates in the dynamic field of functional precision medicine. Enlisting as a member not only facilitates personal enrichment but also contributes to the collective effort aimed at advancing the application of functional precision medicine for the betterment of patient care globally. For those inclined to join this endeavour, further details can be found at www.sfpm.io.

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RESEARCH ON CROP BREEDING FOR ORGANIC FARMING AND HETEROGENEOUS POPULATIONS

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Institute of Agricultural Resources and Economics (AREI) is a fairly new institution in Latvia, established in 2016 by joining two crop breeding institutes, around one century old, and an institute dealing with economics of agriculture. Important breeder's interest since the beginning of this century was research and breeding for organic farming, since the share of organic production was rising in Latvia continuously during the past two decades. The work started with testing of breeding material and growing methods in research fields certified for organic farming, international networking in COST Action 860 "Sustainable Low-Input Cereal Production: Required Varietal Characteristics and Crop Diversity" (2004–2008) and continued with the development of specific breeding methods for development of varieties adapted for organic growing conditions in the framework of the EU Social Fund co-financed project (2008–2012). The breeding programme for organic farming for several crops was financed by the Ministry of Agriculture of Latvia since 2012, and finally our first varieties for organic farming are entering the registration process.

Plant diversity play a significant role in sustainable and, in particular, organic farming. Diversity can be increased in several ways: by increasing the number of crop species including underutilised ones; by choosing a larger number of different varieties per species; and within a crop field – by growing mixtures of several species or variety mixtures/cultivars consisting of diverse plants of the same species. For around one century, the main goal of plant breeders and also farmers was to create/grow completely homogeneous varieties consisting of completely identical plants. It was due to regulations, ensuring variety protection only to uniform varieties. Now the situation is changing and we re-discover the value of diversity that already existed in agriculture before in the form of farmer-grown landraces. One of our research topics at AREI for the past decade was creation and investigation of heterogeneous populations of self-pollinating cereals, namely barley and wheat, which is a way to obtain large diversity within a field of one species. We focused on composite cross populations (CCPs) composed of bi-parental crosses between around ten different parental varieties/lines. Populations are subject to natural selection, able to evolve and adapt to particular growing environments during repeated cultivation, and therefore also have a valuable potential in the

context of climate change. Latvia participated in EC temporary experiment on population marketing with our very first spring barley population 'Mirga' (Fig. 1), providing bases for EU regulations allowing production and marketing of organic heterogeneous material (OHM) seed starting from 2022.

Our research on heterogeneous materials was performed within two national projects funded by the Latvian Council of Science (2013–2017 and 2018–2022) and also in the frame of EU HORIZON 2020 project LIVESEED (2018–2021) in cooperation with several European partners. Co-authors from the Latvian State Forest Research Institute "Silava" Genetic Resources Centre were involved in the genetic analysis. Our latest experiments involved testing the agronomic performance of local and foreign heterogeneous barley and wheat populations in organic and conventional research fields as well as in several organic farms; investigations on phenotypic and genotypic changes in populations due to cultivation under organic versus conventional farming fields as well as due to cultivation for a number of years under the same farming system; and experiments on population improvement techniques.

We compared essential agronomic traits of heterogeneous spring barley populations during three seasons (2019–2021) in three organic and one conventional trial locations to those of currently grown homogeneous varieties and mixtures of population parental varieties/lines. When comparing heterogeneous materials (CCPs and mixtures) to homogeneous varieties, we found significant advantages for yield in organic and conventional stress environments, yield stability across contrasting environments, nitrogen utilisation efficiency, grain protein content, 1000-grain weight (TGW), and leaf disease net blotch (*Pyrenophora teres*) severity as well as some positive trends for nitrogen use efficiency (NUE), and competitive ability against weeds.

Heterogeneous material ranked highest for grain yield, on average, in organic management, whereas the two higher yielding homogeneous check varieties ranked highest under conventional management. Some extreme differences in ranking order between organic and conventional crop management systems with opposite trends for uniform varieties and populations indicate differences in adaptability

Fig. 1
Diversity of spike morphology in spring barley composite cross population 'Mirga'

of both types of material. In organic environments, the average yield of CCPs was highest, followed by mixtures and checks, whereas in conventional farming, the trend was the opposite (Fig. 2, chart), with an exception of drought and late sowing that caused stress conditions in 2021. The yield of homogeneous checks was most unstable due to specific adaptability to more productive conditions, whereas the CCPs were stable yielding over the 12 different environments. Nitrogen use efficiency (NUE) of heterogeneous materials and homogeneous check varieties did not differ significantly; however, higher values were found among heterogeneous materials. One of NUE components, N utilisation efficiency, showed significant differences, and higher average values were found in the heterogeneous materials, compared with the homogeneous varieties. For weed competitiveness, trends were observed that CCPs slightly surpassed check varieties. Especially during earlier crop growth stages, CCPs had higher crop ground cover and weed suppression ability. Net blotch (*Pyrenophora teres*) was the most severe leaf disease during the study period. Heterogeneous materials were significantly less infected than the homogeneous check varieties. All local populations and mixtures showed significantly less infection than the three most susceptible check varieties. All local heterogeneous materials showed significantly less infection than the most susceptible check variety with important seed-born disease loose smut

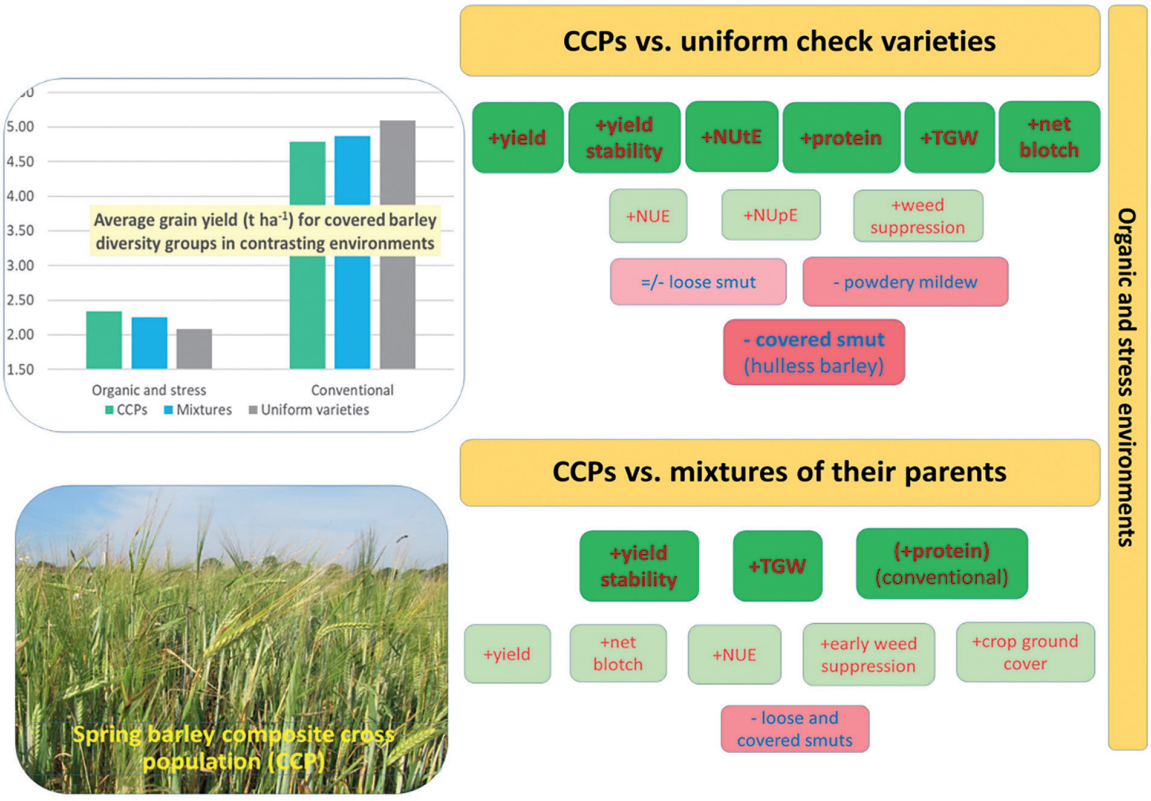

Fig. 2
Summary of spring barley experimental results on agronomic performance of composite cross populations, mixtures of their parents and uniform check varieties (on the right: dark green boxes – plant traits with significant advantages, light green boxes– insignificant advantages, red boxes– disadvantages)

(*Ustilago nuda*), and in most cases, slightly higher than most resistant check. Our experience shows, that loose smut susceptibility can be a problem for barley CCPs if highly susceptible parents were used. Therefore, careful choice of resistant parents is crucial. Hulless barley populations were highly susceptible to another seed-born disease, covered smut (*Ustilago hordei*) indicating, that resistance needs to be improved by further breeding.

We found significant differences between populations and mixtures of their parents, indicating advantages for CCPs in protein content and 1000-grain weight. In addition, there was a small yield gain mainly in low-yield and stress environments, higher yield stability in most cases, and some other minor positive trends. The differences can be explained by the considerably lower diversity level of mixtures compared to CCPs.

Field experiments with spring wheat showed, that grain yield and most of other investigated traits of populations (Fig. 3) were comparable to local check variety. Some significant advantages for grain quality characteristics and trends for better weed competitiveness and NUE over homogeneous varieties were found. Local CCPs and their parental mixtures had a tendency to suppress weeds better than homogeneous varieties. To compare CCPs and the respective mixtures of parental genotypes, the yield was equal, but there was a trend to higher TGW, protein and gluten content. Winter wheat populations from Germany, Denmark, and Hungary were compared to local checks while local CCPs were still under development. Danish population was superior for yield, which was similar to best yielding local variety. Winter hardiness of populations during three trial seasons was in general satisfactory but the grain quality was low. Some populations provided notably higher NUE in comparison to local check varieties.

While testing the effect of farming system on population development in three barley CCPs, no clear differences were identified in genetic diversity parameters between barley sub-populations cultivated under either organic or conventional farming system for seven generations. To compare pairs of organically and conventionally cultivated sub-populations

Fig. 3
Spring wheat heterogeneous population

for agronomical traits, we found the most significant effects on leaf disease net blotch (*Pyrenophora teres*) severity. Organic sub-populations were less infected with net blotch than conventional ones indicating a positive effect of natural selection in organic conditions, where the disease pressure was on average significantly higher. The proportion of powdery mildew (*Blumeria graminis*) resistant plants was in most cases higher in conventionally cultivated sub-populations than in organic ones, which can be the result of higher disease pressure in conventional conditions. Diversity index for plant morphological traits was comparatively higher for organic sub-populations in most of the cases (except for number of tillers) indicating a possibly positive effect of organic farming to promotion of diversity.

To evaluate changes over several generations (cultivation years), F4/F5, and F9 generation sub-populations of three CCPs were compared. No significant differences in the number of effective alleles, information index or expected heterozygosity (gene diversity) were observed between samples of one population taken from different generations. The observed heterozygosity was decreased. A proportion of plants with powdery mildew resistance alleles was decreased with time in most of the cases. In respect to agronomic traits, net blotch severity showed significant effects of natural selection over generations. A slight improvement of grain yield in organic sites, and positive trends for powdery mildew severity and grain volume weight were found. The diversity index for plant height was slightly reduced in all three CCPs, but for other traits there were opposite trends between the populations.

First results on improvement of breeding methods in barley populations indicated successful mass selection using molecular marker linked to resistance gene for harmful seed-born disease loose smut (*Ustilago nuda*). We compared two populations developed from similar parents by using two different crossing methods: regular bi-parental crosses and crosses to several lines with male sterility, which is applied in order to make easier the time-consuming crossing process (no manual castration is needed). We found negative effects of male-sterile parents on grain yield and susceptibility to powdery mildew, however, grain protein content and nitrogen use efficiency were improved. We also crossed existing CCP to three advanced lines in order to improve its performance and found a trend for improved yield, early vigour and traits related to weed suppressive ability, mildew severity, protein content, and NUE. Another approach was tested by selecting pure lines out of four CCPs and comparing mixtures of ten best performing lines to initial populations. Preliminary results showed yield advantage of line mixtures only in case of male-sterile cross derived CCP, indicating that natural selection was more effective than human selection in other populations. For wheat a population was created by crossing four foreign populations to two local varieties in order to obtain suitability to local growing conditions, high grain quality and resistance to seed-born disease common bunt (*Ustilago tritici*).

To summarise our results, we suggest heterogeneous populations as valuable alternative to traditional uniform varieties for organic farming as well as poor and stress cultivation environments. Populations were tested in several organic farms in production environments and first two applications for registration were submitted in 2023.

Since the importance of biodiversity is globally increasing, we are looking forward to continue this research direction, possibly in cooperation with international partners, by involvement in relevant consortium. More crops could be involved. Unprocessed and unpublished data from previous projects is still in our stock to be utilised as a start for a new investigation.

CARDIOMETABOLIC BIOMARKER RESEARCH IN LATVIA: FROM LABORATORY TO CLINICS AND BACK

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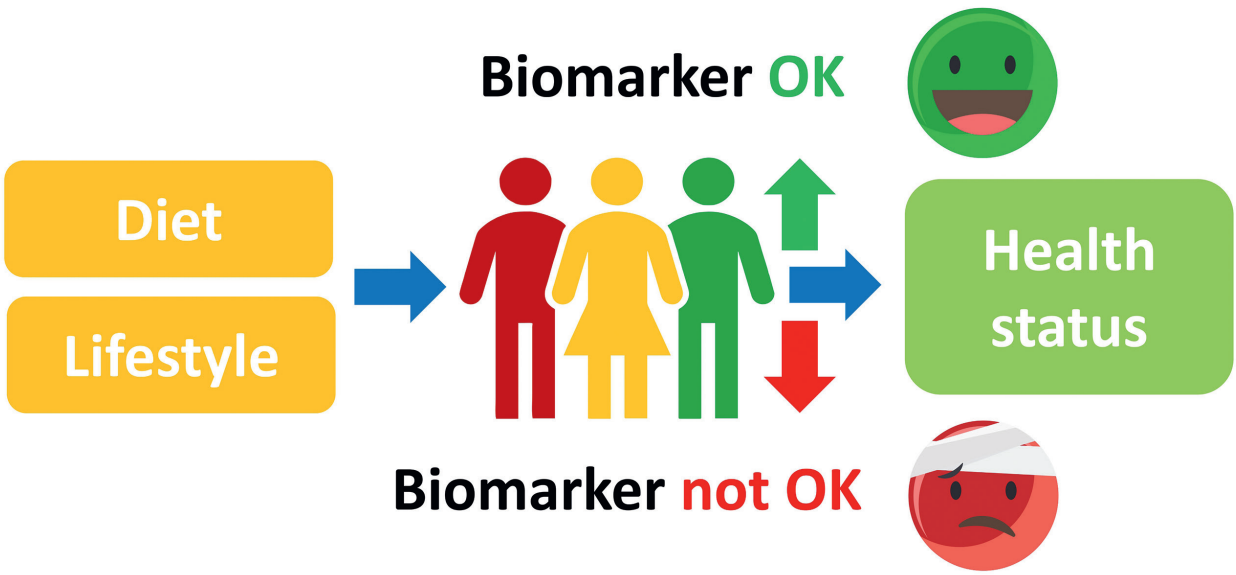
Some difficult questions, like, why not all patients respond to therapy, and how their diet, food supplements, and lifestyle affect the drug response can be answered by measuring biomarkers – quantitative indicators of the severity of a disease and the efficiency of a treatment or intervention. For decades, patients are directed to testing laboratories where their samples are analysed to support diagnosis. Nowadays biomarker analysis plays an important role also in all phases of drug discovery, development, and clinical use. Inclusion of biomarker testing in drug development can improve the success rates threefold, thus speeding up the path of new therapies to clinical applications. Benefits of using a biomarker-driven approach include early go/no-go decisions in proof-of-concept studies and early assessment of drug efficacy before reaching lengthy clinical endpoints. In addition, biomarker measurements can help to stratify patient populations thus advancing precision medicine approaches. This is very important in such noncommunicable diseases as diabetes, obesity, and heart failure – collectively called cardiometabolic diseases which are widespread in Latvia and worldwide.



Biomarkers are measured in patient blood samples and serve as objective indicators of medical state

The Latvian Institute of Organic Synthesis (LIOS), the leading drug discovery and development centre in the Baltic, specialises in fundamental and applied research in organic chemistry, pharmaceutical biosciences, and molecular biology. Its advanced research infrastructure comprises also a wide range of bioanalytical equipment that can be used to detect small-molecular biomarkers in biological samples emerging from preclinical drug discovery and drug target evaluation studies, as well as clinical research projects. Researchers from LIOS, Riga Stradiņš University, Riga Eastern Clinical University Hospital, and Pauls Stradiņš Clinical University Hospital have identified several cardiometabolic disease biomarkers that are used to identify novel compounds that might be used as treatments for cardiometabolic diseases, as well as follow dietary interventions that are suggested to improve cardiometabolic health.

The link between diet and the risk of cardiovascular disease has been well established and known for decades, but only in 2011 Hazen and colleagues made the seminal discovery of three metabolites of dietary phosphatidylcholine (choline, trimethylamine-N-oxide (TMAO) and betaine) predicting the risk for cardiovascular disease in an independent large clinical cohort [1]. TMAO was proposed as a diet- and microbiota-derived cardiometabolic risk marker and an important pathophysiological mechanism linking ingestion of unhealthy foods, such as beef (containing carnitine) and eggs (containing choline), and the development of atherosclerosis. Interestingly, among the authors of this first study, we find Latvian-speaking researcher Aldons J. Lusis who works in the USA and has lectured in Latvia several times about the immense role of gut microbiota in cardiovascular diseases and liver-heart cross-communication.

The research team from LIOS together with clinical partners in hospitals provided the first clinical evidence for the pharmacological lowering of plasma levels of TMAO in healthy volunteers by the cardioprotective drug meldonium, which increases urinary excretion of TMAO and thus decreases its plasma concentration [2]. Latvian scientists were also among the first ones to publish the association between TMAO and diabetes/obesity, thus, providing evidence that age, diabetes, and BMI are associated with higher TMAO levels [3] – this study has been cited more than 200 times since then. In a recent study researchers from RSU and LIOS investigated a fasting-mimicking diet which is a variation of intermittent fasting [4]. This dietary intervention is characterised by cyclicity (five subsequent days a month), reduced caloric intake (~1100 kCal during the first day, ~800 kCal – the remaining four days), and elimination of animal protein sources from the diet, mainly using products of plant origin. Such a dietary regimen allows a sufficient intake of macronutrients while mimicking the molecular effects of prolonged fasting. Surprisingly, it was found that this short-term dietary strategy significantly improved not only well-known plasma metabolic indicators (fasting plasma glucose, c-peptide, tissue insulin sensitivity index, plasma triglycerides), but also helped to decrease the levels of TMAO [4]. The obtained research results show that following a fasting-mimicking diet provides important benefits for maintaining cardiometabolic health. Moreover, the cyclical nature of this dietary intervention could help to ensure better compliance with the diet compared to other plant-based diets.

Another research line is related to fatty acid metabolites acylcarnitines, which comprise a moiety of a natural compound and popular food supplement – L-carnitine, with a lipophilic "tail" of fatty acids. Many types of fatty acids exist with short-, medium-, and long-chain, and LIOS researchers have participated in sorting out differences between varieties of corresponding acylcarnitines [5]. Latvian scientists have succeeded in proving that the accumulation of long-chain acylcarnitines in the case of heart attack and diabetes damages tissues and disrupts energy circulation, and accordingly, the reduction of long-chain acylcarnitine content prevents tissue damage and insulin resistance. For the first time, LIOS researchers created a preclinical rodent model of trimethyl-lysine hydroxylase knock-out that confirms the therapeutic potential of reduced concentration of long-chain acylcarnitines [6]. Using the possibilities of reducing the levels of long-chain acylcarnitines with drugs or genetically inactivating trimethyl-lysine hydroxylase in a preclinical mouse model, the protective effect of such an approach in the treatment of cardiovascular diseases and diabetes has been shown [7; 8]. In international collaboration with researchers from Sweden, Germany, and Canada, the classification of acylcarni-

Melita Ozola defended her PhD thesis on the topic "Regulation of TMAO in Treatment of Cardiometabolic Diseases" in 2023

tines was created [9]. This information updated the Human Metabolome Database, which now includes the chemical structures, properties, and pathways for a total of 1240 acylcarnitines, which will help to explain the results obtained in metabolome studies on acylcarnitine measurements [5]. In addition, the involvement of acylcarnitines with different lengths of fatty acid chains in biochemical signal transmission cascades and the selectivity of transport proteins and enzymes have been analysed to highlight the variability of metabolic states. Based on the research results and the proposed fundamental view on acylcarnitines as biomarkers, new opportunities are opened for early diagnosis of cardiometabolic diseases, as well as researching new drug targets for the treatment of diseases related to problems with energy metabolism.

Cardiometabolic biomarker research in Latvia is ongoing in the framework of the BioMedPharm consortium project, financed by the State Research Programme funding in Latvia – the Innovation Fund Programme of the Ministry of Economics. This project aims at the development of a National Biomedicine Research Platform addressing public health challenges in the RIS3 domain, which supports activities related to the identification of new biomarkers and the development of new solutions for precision medicine. Latvian Institute of Organic Synthesis, Latvian Biomedical Research and Study Centre, Riga Stradiņš University, and the University of Latvia have joined forces in biomarker investigation from preclinical, bioanalytical, and clinical perspectives, and co-authored highly cited publications on cardiometabolic risk markers TMAO and acylcarnitines. These results represent the strength of this fruitful collaboration and hold strong promises for the future.

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BACTERIOPHAGE-DERIVED DOUBLE-STRANDED RNA (LARIFAN) EXERTS ANTI-SARS-COV-2 ACTIVITY *IN VITRO* AND IN GOLDEN SYRIAN HAMSTERS *IN VIVO*

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Since the emergence of the COVID-19 pandemic, many efforts have been introduced to fight the virus and the consequences it may cause. Like many others, our lab rose to the challenge and utilised its knowledge to end the spread of the virus. This will not be another never-ending story about a fight between a living animal and a parasitic virus. This might be a story of success.

For some time, our lab has studied this antiviral medication, commonly known as Larifan, which promotes the immune system to protect it from viruses. Larifan consists of naturally obtained double-stranded (ds) ribonucleic acid (RNA) strains. Usually, all living things have RNA in the form of single strands. However, viruses, during their replication cycle, can have a dsRNA stage, which is quickly recognised by our immune system. Evolutionally, special receptors have been developed to sense and identify such "unnatural" forms of RNA. Upon encounter, our immune cells get to work and produce signalling molecules that can fight the virus, also known as cytokines, particularly interferons. Once activated, the immune system can efficiently battle the unwelcome intruders. In a way, Larifan mimics a viral infection and prepares our immune system for a virus attack so it is ready to fight once needed. Larifan has been known to alleviate multiple virus-caused symptoms, such as herpes and influenza (https://larifan.eu/en/). Thus, we wanted to test its activity against the newly emerged SARS-CoV-2. To archive this, we set up two types of models – one *in vitro* (meaning usage of human cells in a culture dish) and the other *in vivo* (involving laboratory animals) (Fig. 1) [1].

To begin with, we set up an experiment to test Larifans' effect on cells SARS-CoV-2 would infect in a human, such as lung tissue (human lung adenocarcinoma cell line (Calu3)) or airway epithelium (primary human small airway epithelial cells (HSAEC)). The cells were cultured in a Petri dish, and Larifan was added either before the SARS-CoV-2 infection, or after, or kept within the culture throughout the length of the experiment. We then measured the amount of virus particles present, and found that the addition of Larifan reduced the amount of SARS-CoV-2 (example visualised in Fig. 2).

Next, we wanted to test Larifan's effect within a living organism, so we set up a Golden Syrian hamster experiment. SARS-CoV-2 usually does not infect rodents, such as mice or rats; however, it infects hamsters, who develop a mild to moderate disease and recover in a few days, similarly to humans. Larifan was either introduced systemically (subcutaneous injection) or locally (intranasal administration) before or after the SARS-CoV-2 infection. Subsequently, we evaluated the presence of the virus within and the level of damage to the lungs. The amount of virus particles present was reduced once Larifan was added, and the lung tissue was visually less damaged in the treated hamsters, especially the ones administered locally (Fig. 3). We may conclude that the nationally well-known antiviral medica-

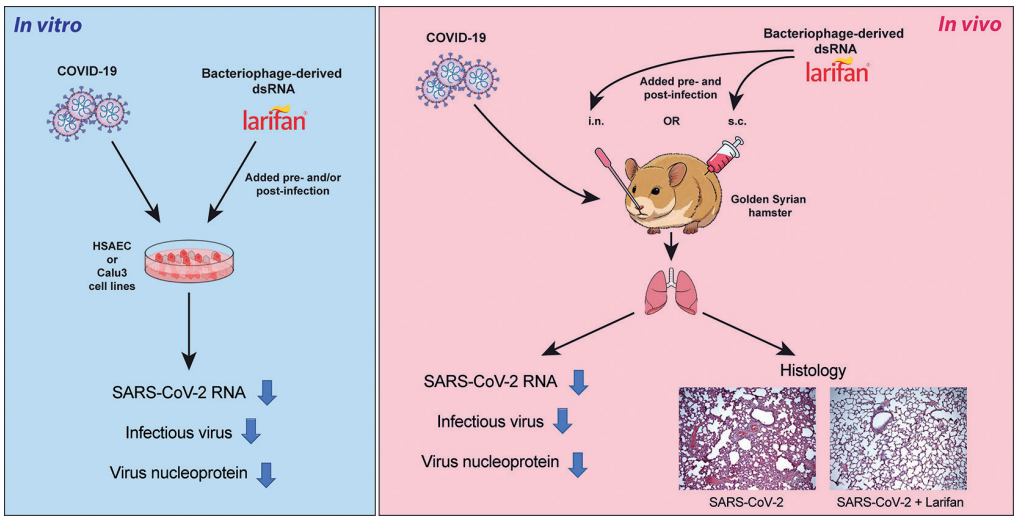

Fig. 1
Experimental design *in vitro* (blue) and *in vivo* (pink). Human airway epithelial cells (HSAECs) and lung tissue culture (Calu3) were infected with SARS-CoV-2 either before or after Larifan addition, and SARS-CoV-2 genetic material, nucleoprotein presence and infectiousness was estimated. In parallel, separate groups of Golden Sirayan hamsters were infected with SARS-CoV-2 either before or after Larifan injection systemically (subcutaneous) or locally (intranasal). Animal material was analysed for viral RNA or protein presence, infectiousness by titration and histopathologically

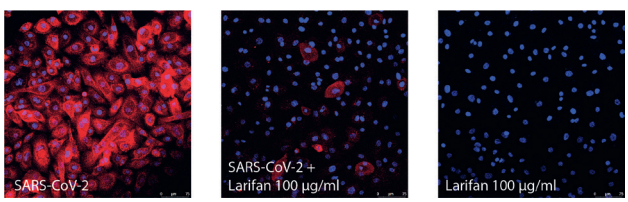

Fig. 2.
Representative pictures of SARS-CoV-2 NP (red) detection by immunocytochemistry in HSAEC upon treatment with 100 µg/ml Larifan. Nuclei are counterstained with DAPI. Scale bars 100 µm. (Picture adapted from Vaivode et al. 2022, [1])

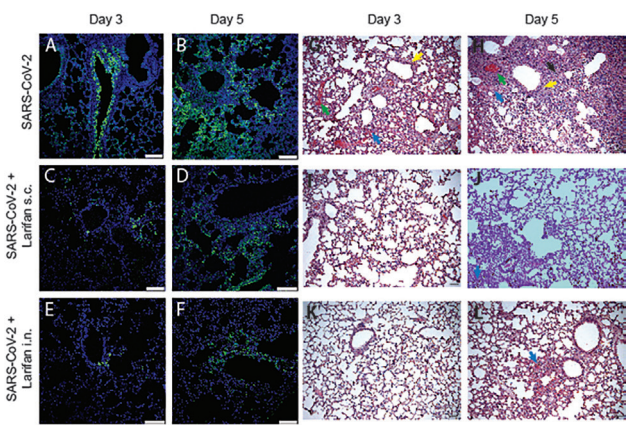

Fig. 3
Larifan treatment reduces SARS-CoV-2 antigen in the lungs and improves lung histopathological features in infected animals. Representative immunohistopathology for SARS-CoV-2 NP (green) (**A-F**) and hematoxylin and eosin stained (**G-L**) images of lungs of infected and infected Larifan treated hamsters (image taken from Vaivode et al. 2022, [1])

tion, Larifan, can be effective against many viruses, including COVID-19.

This is intriguing data, but much is still unknown, so our work continues. Out of curiosity, we recently tested the effect of Larifan on mice specifically designed to be susceptible to SARS-CoV-2 (K18-hACE2 transgenic mouse). To our surprise, the mice injected intranasally with Larifan six hours before the virus infection, were less symptomatic and survived much longer (unpublished data). Consequently, we may declare that Larifan exerts an antiviral effect *in vitro* and *in vivo* against SARS-CoV-2 and might potentially be used against other emerging viruses. Nonetheless, further research is needed to evaluate our findings with particular emphasis on the immune system's involvement in the clearance of such viruses, and the molecules, cells and pathways responsible for the representative success.

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ENERGETICS AND ENERGY OF NATURAL SCIENCES

PAST AND PRESENT OF THE BALTIC CONFERENCES ON INTELLECTUAL COOPERATION

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SHORT HISTORY OF THE BALTIC CONFERENCES ON INTELLECTUAL COOPERATION

The tradition of the Baltic Conferences on Intellectual Cooperation started almost a century ago. In the beginning, the conferences were organised by the Institute of Intellectual Cooperation (Paris) at the League of Nations. Since the 1920s, the International Committee on Intellectual Cooperation (ICIC) of the League of Nations promoted international understanding and functioned as a cultural centre for international communication, and later became one of founders of UNESCO (https://unesco.libguides.com/IICI).

Estonia, Latvia, Lithuania, and Finland regularly participated in the Conferences on Intellectual Cooperation.

Before the Second World War, altogether six Conferences on Intellectual Cooperation had been held in Finland and Baltic countries: the first conference took place in 1935 in Kaunas, Lithuania, in 1936 – Tartu, Estonia, in 1937 – Helsinki, Finland, in 1938 – Riga, Latvia and in 1939 again in Kaunas. The last pre-war conference was convened in Tallinn on 15–17 June 1940, in conjunction with the "Baltic Week". However, the deliberations were interrupted by the USSR aggression against the Baltic States. Almost 60 years later, in 1999, the seventh Baltic conference on intellectual co-operation was organised in Riga, and was convened by the Latvian Academy of Sciences. Since then, 11 conferences have been organised by Baltic and Finnish partner Academies. Conferences always offer a forum for science policy discussion. The topics of the conferences have been rather diverse – from (humanities) history, pedagogy and science policy to mathematics, genome development and energetics. The 18th Baltic Conference on Intellectual Cooperation was devoted to energy for the future society. This time the conference agenda consisted of several directions – three aspects of energetics for society (energy harvesting and sources, energy storage, transmission and secure energy supply, efficient and sustainable energy use), energy policy discussion (lead by Assistant Professor Olga Bogdanova), awarding the medals of the Baltic Science Academies to the best scientists for research results and stimulating Baltic science cooperation, the meeting of the Presidents of the Academies. Besides this agenda, the Academies organised also a meeting of the young Baltic Academies (associations of the young scientists) and offered the workshop on HIAS Research Fellowships, lead by Sonja Gräber-Magocsi, PhD (Germany).

AWARDING MEDALS OF THE BALTIC ACADEMIES

The laureates of the Medal of the Baltic Academies of Sciences were announced on 21 April 2023, at the 18th Baltic Conference on Intellectual Cooperation, "Energy for the Future Society", taking place at the Latvian Academy of Sciences. The author of the medal is sculptor Jānis Strupulis, honorary member of the Latvian Academy of Sciences. In total, seven applications from Estonia, Latvia, and Lithuania were received, and international Medal committee (Protocol No. 3, 28 March 2023, Latvian Academy of Sciences) awarded the medals to the best applicants. According to the decision of the Medal awarding competition commission (28 March 2023),

the Medal of the Baltic Academies of Sciences, in 2023, was awarded to:
Dr. **Arvi Hamburg** (Estonia) for his substantial contribution to energy transition and for shaping of future energy policy for the entire Baltic region.
Academician *Dr.* **Baiba Rivža** (Latvia) for strengthening the cooperation between the Baltic Academies of Sciences, and outstanding research achievements in economics.
Academician *Dr.* **Jūras Banys** (Lithuania) for strengthening cooperation between the academies of sciences in the Baltic region, and for his outstanding scientific achievements in physics.

MEETING OF THE PRESIDENTS OF THE BALTIC ACADEMIES OF SCIENCES

After the conference, a meeting of the Presidents of the Academies of Sciences took place. Presidents of the Academies of Sciences, academicians Tarmo Soomere (Estonia), academician Ivars Kalviņš (Latvia), Jūras Banys (Lithuania), Edwin Kreuzer (Hamburg Academy of Sciences and Letters), and Mats Gyllenberg (Permanent Secretary of the Finnish Society of Sciences and Letters) discussed the directions of further cooperation and adopted the Resolution on the Energy for Future Society. Presidents also discussed the next conferences in Hamburg (2024) and the 19th Baltic Conference of the Intellectual Cooperation. Presidents of the Academies adopted a Resolution on the Conference.

RESOLUTION OF THE 18th BALTIC CONFERENCE ON INTELLECTUAL COOPERATION, "ENERGY FOR THE FUTURE SOCIETY"

As we gather for this important conference, let us reaffirm our commitment to building a sustainable future for ourselves and for future generations. The future of energy will be defined by our ability to address the complex challenges of sustainable development, climate change, and energy security. Acknowledging the importance of energy for the future society and recognizing the need for a sustainable and secure energy system, the participants of the Baltic Conference on Intellectual cooperation on Energy for the future society resolve to take the following actions:

1. Foster collaboration and dialogue between researchers, policymakers, industry leaders, and other stakeholders to develop and implement effective energy policies that support sustainable development.
2. Promote the use of renewable and clean energy sources, such as solar, wind, and hydropower, as well as energy efficiency measures, to reduce greenhouse gas emissions and mitigate the impact of climate change.
3. Calls for the adoption of energy efficiency measures to reduce energy consumption and waste, including the use of smart grids, energy-efficient appliances, and building insulation.
4. Invest in research and development of new and emerging energy technologies, such as energy storage, carbon capture and storage, and fusion, to improve the efficiency and sustainability of energy systems.
5. Encourages the promotion of energy education and awareness to increase public understanding and support for sustainable energy practices.
6. Encourage the development of innovative business models and financing mechanisms that can support the deployment of new energy technologies and help to bridge the gap between research and commercialization
7. Calls for the establishment of closer international cooperation and collaboration to address the global energy challenges and ensure the sustainable development of energy systems.

MORE ABOUT THE BALTIC INTELLECTUAL COOPERATION CONFERENCES

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XVIII BALTIC CONFERENCE ON INTELLECTUAL COOPERATION, "ENERGY FOR THE FUTURE SOCIETY"

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On 20–21 April 2023, the presidents of the Academies of Sciences of the Baltic Sea countries, representatives of European research institutes and academic organisations, as well as specialists in the energy sector, policy makers and entrepreneurs gathered in Riga for the XVIII Baltic Conference on Intellectual Cooperation (XVIII BCIC). The conference was organised by the Latvian Academy of Sciences together with the Estonian and Lithuanian Academies of Sciences and cooperation partners in Latvia – AS "Olainfarm" and AS "Latvenergo".

On 20 April, at 11.00, XVIII BCIC was opened by Prof., *Dr. habil. oec.* **Baiba Rivža**, Secretary General of the Latvian Academy of Sciences, Prof., *Dr. habil. chem.*, **Ivars Kalviņš**, President of the Latvian Academy of Sciences, Prof., *Dr.* **Jūras Banys**, president of the Lithuanian Academy of Sciences, and Prof., *Dr.* **Tarmo Soomere**, President of the Estonian Academy of Sciences.

The following persons also spoke at the opening ceremony: *Dr.* **Edwin Kreuzer**, President of the Academy of Sciences and Humanities in Hamburg, Prof. *Dr.* **Mats Gyllenberg**, Permanent Secretary of the Finnish Society of Sciences and Letters, **Didzis Solims**, Director of Research & Innovation, JSC Latvenergo, and Assoc. Prof. **Olga Bogdanova**, President of Latvian Member Committee of the World Energy Council.

The chairman of the Plenary Session was Prof. Ivars Kalviņš, President of the LAS. According to the programme, reports were presented in the session by:

Dr. **William Gillett**, Director of Energy Programme, European Academies Science Advisory Council (EASAC), "Science-based advice on policies to reduce greenhouse gas emissions from the EU energy sector to net zero by 2050". Experts from the national science academies of Europe have been working through EASAC to provide European and national policy makers with independent science-based advice on these policies and legislation. Reports containing EASAC's advice are freely available for downloading from the EASAC website on forest bioenergy and carbon neutrality, electricity storage, decarbonisation of transport, hydrogen and synthetic fuels, decarbonisation of buildings, and a new report is about to be published on the future of gas. The main messages in these reports for policy makers will be presented.

Prof. **Peter Lund**, Aalto University, Finland, "Deep decarbonisation of energy systems through advanced systems solutions". The energy sector will play a central role in the transition due to its high share of emissions. In particular, the rapid development of new renewable technologies helps to cut emissions not only in the power sector but also in other sectors such as heating, mobility, and fuels through strong electrification. However, this does not come without challenges such as increased balancing needs of power, huge material demand, co-evolving of the new and old energy systems, etc., which call for advanced solutions such as artificial intelligence, material and energy efficiency, smart materials, behavioural changes, etc. For example, complex systems control with AI could help building resilient energy systems, end-use energy efficiency could halve the energy production investments, novel battery chemistries can avoid critical material bottlenecks, etc. The complexity of the energy transition will benefit from stronger science and evidence-based policies in formulating the necessary solutions for the deep decarbonisation pathways required.

From the left: Prof., *Dr. habil. oec.* Baiba Rivža, Prof., *Dr. habil. chem.*, Ivars Kalviņš, Prof., *Dr.* Jūras Banys, and Prof., *Dr.* Tarmo Soomere

Prof. **Enn Lust**, Tartu University, member of the EAS, "Development of hydrogen and fuel cell technologies in Estonia". On 18 September 2018, Estonia joined the European Hydrogen Initiative in Linz; in 2019 – European Green Deal; later – Carbon Neutral Economy 2050, Fit for 55 and other initiatives. There was progress in recent years. In 2001, the solid oxide fuel cell research was started at the Institute of Chemistry, University of Tartu (UTIC), funded mainly by Elcogen 00, nowadays known as an EU market leader and innovation prize winner. In 2015, the Estonian Centre of Excellence in Science, "Advanced materials and high-technology devices for energy recuperation systems", was started (2015–2023). Based on the experience gained in the field of green energy technology, the sustainable energy complex, consisting of 60 kW photovoltaic panels, Pb/PbO2 batteries (5600 Ah) for storage, 10 kW alkaline electrolyser, hydrogen storage (300 bar), and fuel cells for regeneration of electricity and heat was completed in Chemicum in 2018. In 2019, UTIC joint with European Hydrogen and Fuel Cell Technology Platform (FCHU), the Botnia Hydrogen Backbone project, the T-TENT Corridors project. In 2021, we signed a contract with H2Electro00 for development of 300 W solid oxide electrolysis cell based on ceramic materials.

Prof. **Algirdas Kaliatka**, Lithuanian Energy Institute (LEI), member of the Lithuanian AS, "Research in Lithuanian Energy Institute for the energy sector development". The following scientific activities related to energy sector are performed at LEI: 1) Research on renewable energy and enabling technologies (Laboratory of Combustion Processes, Laboratory of Heat-Equipment Research and Testing, Centre for Hydrogen Energy Technologies, Plasma Processing Laboratory, Nuclear Engineering Laboratory); 2) Energy systems modelling and control research (Laboratory of Energy Systems Research, Smart Grids and Renewable Energy Laboratory, Laboratory of Nuclear Installation Safety); 3) Safety and reliability studies on industrial and energy facilities (Laboratory of Nuclear Installation Safety); 4) Research on decommissioning of nuclear installations and radioactive waste management (Nuclear Engineering Laboratory). This presentation will provide

a brief overview of some examples of energy sector research carried out in LEI.

Prof. **Andris Piebalgs**, European University, EU Commissioner for Energy (2004–2009), "Are pipelines and ships an 'either or' infrastructure decision for Europe's hydrogen economy?" Tanker shipment deliveries do present competitive economic and strategic advantages relative to pipelines in some cases, with very compelling prospects in the mid to long term, particularly for very long distances. Moreover, hydrogen derivatives, most interestingly ammonia and methanol, have standalone markets of their own in Europe totalling in the tens of millions of tonnes. The recommendations therefore are that rather than importing these derivatives with a view to converting them back to hydrogen, they are rather sold directly into the derivative markets, displacing the incumbent fossil alternatives. The EU and its wider neighbourhood region can leverage an almost unparalleled network of transmission infrastructure, comfortably capable of delivering the large volumes of cost-effective hydrogen required. Although pipelines risk overreliance on a few suppliers, at 1% of primary energy demand in 2030, imported hydrogen is arguably not likely to be a major security of supply concern.

The chairman of the session "Energy Harvesting and Sources", was Prof. Tarmo Soomere, President of the Estonian AS. According to the programme, papers were presented in the session by:

Dr. **Gediminas Stankonas**, Lithuanian Energy Institute; member of Young Academy of the Lithuanian AS, "How close are we to obtaining nuclear fusion's 'limitless' energy?" The Joint European Torus (JET) fusion experiment, which can produce plasmas hitting temperatures of 150 million degrees Celsius, 10 times hotter than the centre of the Sun. JET is the only working tokamak in the world that can use the same deuterium-tritium (D-T) fuel mix designed for ITER and future fusion power plants, because it can achieve circumstances comparable to those in those facilities. JET recently set a record by producing 59 Megajoules of heat energy from fusion over a five-second (the duration of the fusion experiment) interval.

Prof. **Maarja Grossberg-Kuusk**, Tallinn University of Technology, School of Engineering; President of Estonian Young Academy, "Development of next generation photovoltaic technologies in Estonia". The development of thin film photovoltaic technologies in Estonia is concentrated to Tallinn University of Technology, where two research groups with decades of experience develop next-generation sustainable PV technologies for building integrated applications. One of the technologies, namely unique monograin layer PV technology (MGL) based on environmentally friendly kesterite Cu2ZnSnS4 (CZTS) absorber material has already reached TRL7. MGL PV technology provides a way to prepare lightweight, semi-transparent, and flexible photovoltaics.

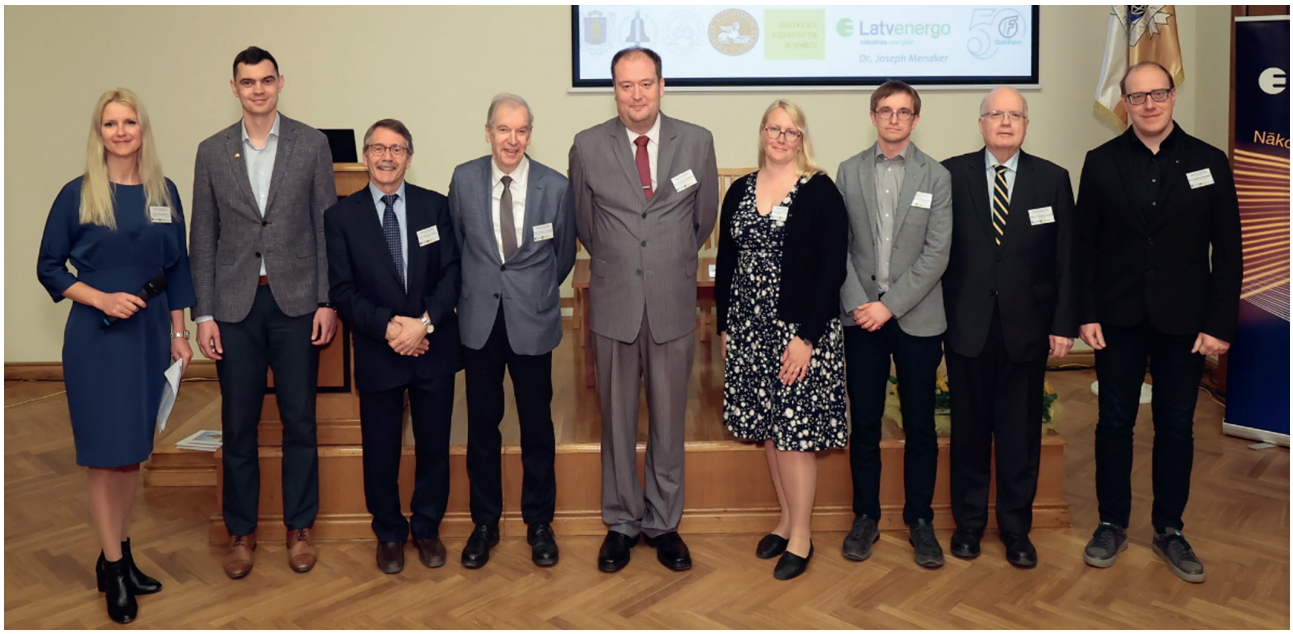
Prof. **Andris Šternbergs**, Institute of Solid-State Physics, University of Latvia, member of LAS, "Challenging scientific issues for sustainable future energetics raised by the energy crisis". *Solar power* is one of the "green" alternatives to fossil fuels that will help our world address its energy needs. In one hour, the Sun hits the Earth with more energy than is consumed worldwide in a year. Yet harnessing this solar energy are complex engineering solutions including both Solar Photovoltaics (Solar PV) technology and solar thermal methods such as Concentrated Solar Power (CSP). *Wind energy* is mostly the use of wind turbines to generate electricity. Wind power is a popular, sustainable, renewable energy source that has a much smaller impact on the environment than fossil fuels. Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network. *Clean hydrogen*, produced by electricity from renewable sources (e.g., wind, solar power) to split water, can be used as a feedstock, a fuel or energy carrier, or storage medium (by H2 storage in low pressure containers). A thermoelectric generator (TEG) is a solid-state device that converts heat flux directly into electrical energy through a phenomenon called effect. Nuclear energy like solar cells, wind generators, hydrogen energy (including the use ofH2 in fuel cells) exploitation reduces carbon dioxide emissions. *Nuclear energy* is an important pillar in electricity system, power plants are the only source of carbon-free energy that can provide stable electricity day and night at any time of the year in almost any place on the planet. In this regard "green" nuclear energy as a long-term solution for baseload capacity is proposed as a complementary low-carbon renewable energy source.

Dr. **Vidas Lekavicius**, Lithuanian Energy Institute, member of Young Academy of the Lithuanian AS, "Energy poverty in the Baltic states". Energy poverty is caused by a combination of three factors: high energy prices, high energy consumption (low efficiency) and low incomes. Energy poverty is closely linked to justice, as the energy transition and other major changes inevitably have distributional effects. It is vital to ensure the just distribution of energy transition costs and benefits among the members of society. While the importance of energy poverty is widely recognised and increasingly included in legislative initiatives, assessing the level of energy poverty remains problematic, even with the use of EU-wide surveys. This is particularly noticeable when analysing more detailed data on individual groups in society or comparing indicators related to energy poverty in different countries. If the Baltic countries are similar by arrears on utility bills indicator, significant differences can be observed in the population's ability to keep homes adequately warm. This and similar inconsistencies can be explained not only by objective differences among the countries but also by the peculiarities of the survey methodology used. Overall, the energy poverty-related indicators in the Baltic countries have been improving steadily for some time.

The chairman of the session "Energy Storage, Transmission and Secure Energy Supply" was *Dr*. Edwin Kreuzer, President of the Academy of Sciences and Humanities in Hamburg. According to the programme, papers were presented in the session by:

Prof. *Dr. ing. habil*. **Detlef Schulz**, Helmut Schmidt University Hamburg; member of the Academy of Sciences and Humanities in Hamburg, "Hydrogen-based Smart Energy System – a way out of the energy crisis?". The presentation describes the boundary conditions of energy supply, i.e. generation structures, energy balances, and import dependencies in Germany as well as the future development towards a hydrogen-based Smart Energy System. A resilient future energy system must enable a high level of security of supply with climate-friendly energy sources. Even then, there will be import dependencies, especially for hydrogen.

Prof. **Anna Mutule**, Riga Technical University; Head of Smart Grid Research Centre, Institute of Physical Energetics (IPE), "The evolution towards smart grids: drivers and potential impacts". The key political priority in the energy sector of the three Baltic States is the synchronisation of our electricity grids with the continental European network by 2025. This process is technically complex and challenging, and therefore, it could be treated as a main driver for Smart Grid technologies development in Baltic region. These advanced technologies include



Panellists of the closing discussion

advanced sensors known as Phasor Measurement Units (PMUs) that allow operators to assess grid stability, advanced digital meters that give consumers better information and automatically report outages, relays that sense and recover from faults in the substation automatically, automated feeder switches that re-route power around problems, and batteries that store excess energy and make it available later to the grid to meet customer demand and many other. The high-precision time synchronisation via the Global Positioning System (GPS) allows comparing measured values (synchrophasors) from different substations far apart and drawing conclusions as to the system state and dynamic events such as power swing conditions. Latvian researchers representing IPE have gained experience in developing tools for grid operation and control with focus on PMU/WAMS by participating in international collaborative projects, specifically the STRONg2rid. The project's application developments covered the following areas: power oscillation damping, voltage stability monitoring, system state estimation including estimation of transmission line temperature, sag and losses (development of IPE), identifying cascading outages and new ICT solutions.

Prof. **Dmitri Vinnikov**, Tallinn University of Technology; visiting Prof. at Riga Technical University; member of Estonian AS, "Future-proof power electronic systems for residential micro grids". Power Electronics Group of TalTech is leading European research on DC power distribution in energy-efficient buildings. This keynote explored the essence of residential DC distribution technology, and provided insight into recent development trends, standardisation, and challenges. Also, it gave an overview of the innovative technologies developed by TalTech Power Electronics Group to boost the uptake of the up-and-coming residential DC distribution technology, provide high efficiency and reliability of power supply, facilitate high flexibility by implementing plug-and-play features, and ensure the safety of residents.

Prof. **Andris Šutka**, Riga Technical University; member of the LAS, "Innovative amphoteric decoupled water electrolysis – a simple concept to split water and produce H2 with high efficiency in a cheap and safe way": "We report membrane-less decoupled amphoteric water electrolysis concept. We are combining a separate acid and alkaline cell. Both cells are connected with the primary Pt electrodes and auxiliary electrodes (AE). For acid cell the WO3 AE electrode is used while for the alkaline cell – Ni(OH)2. In the proposed electrolysis concept, the potential for gas generation depends on the polarity of the applied potential due to different chemical processes occur at different polarities. In both applied potential polarities, hydrogen and oxygen are generated in separate cells. In the first cycle, simultaneous water splitting and ion accumulation in AEs occur at 2.96 V potential with the Faradaic efficiency of 98% and energetical efficiency of 43%. In the second cycle, the hydrogen and oxygen are generated in acid and alkaline cells, respectively, from ions released from AEs at 0.68 V potential with the Faradaic efficiency of 98% and energetical efficiency of 201%. The total energetical efficiency of the provided electrolysis concept is 71%".

The chairman of the session "Efficient and Sustainable Energy Use" was Prof. Dr. Mats Gyllenberg, Permanent Secretary of the Finnish Society of Sciences and Letters. According to the programme, papers were presented in the session by:

Prof. **Mikael Collan**, LUT University, Director of the Finnish State Institute for Economic Research; Member of the Finnish Society of Sciences and Letters, "The Finnish price of electricity transfer dilemma – pricing driven by the regulation model". Electricity transfer is infrastructure-based service-business that operates under a natural monopoly. The risk-level that faces the business is low and the industry is regulated. The circumstance would under typical expectations point to return levels that lie under the return levels of companies that operate with a similar risk level on competitive markets. Interestingly and importantly, this is not the status quo in Finland, where the observed returns of Finnish distribution system operators are comparatively higher than those of European indices composed of companies operating in competitive markets used as benchmark. The main reason for this apparent returns-related dilemma seems to be the regulation model used that allows the relatively high returns. The regulation model is based on using a specific and separate balance sheet as the basis for the calculation of the accepted reasonable return. The regulation-balance

sheet is based on usage value and not on the accounting value of the networks in place. Furthermore, the accepted costs of borrowed capital, interests, are not considered according to the actual paid interest costs, but according to a constructed value. In addition to resulting in very high relative returns, the regulation model and especially the treatment of costs of capital is problematic from the EU regulation requirement of cost reflective pricing.

Prof. **Modris Greitāns**, Institute of Electronics and Computer Sciences; member of the LAS, "Energy efficiency: artificial versus human intelligence". The main directions in which research should be carried out in order to make AI more effective are related to the following aspects: *Event-driven activity and sparsity*. In the brain on average less than 2% of neurons become active in response to sensory stimuli, as well as neuron receives often less than 5% excitatory inputs from most surrounding neurons. Similarly, in a neural network, if the weights and activations are sparse, then a large fraction of computations can be eliminated. *Structured data*. The model of the world in our brain has a 3-D structure that is acquired through sensory information flows and movements. Such a model allows us to move, rotate and change objects in our head. Operating on structured data requires significantly smaller datasets to be trained to recognize objects in alternative views without special training for those views. *Incremental and multi-task learning*. Due to simplifications of the mathematical neuron model AI overwrites many of its connections in each learning iteration and loses acquired knowledge, and therefore AI requires significantly more training processes and iterations in each of them. *Appropriative hardware*. In the future we need to work on AI that works smarter, not harder. In the long term, we can envision an architecture optimised for brain principles that strives to the performance of human intelligence and at the same time has energy consumption close to what our brain uses

Dipl. eng. **Ralfas Lukosevicius**, Director, Ltd. Addeco, "Development of the biomethane sector in Lithuania: future-proof power electronic systems for residential micro grids". This presentation gave a review of biomethane market situation in Lithuania. Current biogas and biomethane production, state strategies, legal measures, investment support instruments, business environment and other important questions were presented. Development of biomethane production and utilisation technologies themselves gives an additional added value to Lithuanian society. Thus, achievements of Lithuanian research institutions and business companies in this field were also introduced.

Prof. **Jarek Kurnitski**, Tallinn University of Technology; Adj. prof. Aalto University, member, Estonian AS, "Towards zero-emission building stock". Major development steps and main outcomes achieved by Energy Performance Building Directive (EPBD) may be classified as follows: 2006–2008, energy frame and requirements based on the primary energy and energy performance certificates were taken into use in all Member States; 2012–2013, so-called cost optimal calculations were conducted for the first time to determine performance-based energy performance minimum requirements based on the lowest possible life cycle cost calculated with net present value method for 30 years in residential and 20 years in non-residential buildings. This performance-based approach, repeated with a five-year interval (2018 and 2023), has led to market-driven energy performance improvement progress that is also easy to measure. Nearly zero energy buildings (NZEB) targets in force 12/2018 in public and 12/2020 in all new buildings, NZEB performance level was finally set as at least the 2021 cost optimal level. In 2018, EPBD introduced long-term renovation strategy & smart readiness indicator were revised putting the focus to renovation of existing building stock and starting to treat buildings as an active part in energy system.

The final discussion was moderated by Assoc. Prof. Olga Bogdanova, President of Latvian Member Committee of the World Energy Council.

The closing speech of the conference was given by Prof. Ivars Kalviņš, President of the Latvian Academy of Sciences.

Conference livestreaming on YouTube:

April 20: https://youtube.com/live/6nmkeiSXxGg?feature=share PHOTO GALLERY

April 21: https://youtube.com/live/oTkv7eLgYgY?feature=share PHOTO GALLERY

SCIENCE-BASED ADVICE ON POLICIES TO REDUCE GREENHOUSE GAS EMISSIONS FROM EU ENERGY SECTOR TO NET ZERO BY 2050

WILLIAM GILLETT
PhD, European Academies' Science Advisory Council

BACKGROUND

Experts from the national science academies of Europe work through European Academies' Science Advisory Council (EASAC) to provide European and national policy makers with independent science-based advice. Reports containing EASAC's advice are freely available from the EASAC website (www.easac.eu).
This paper reflects the advice for policy makers that was presented in April 2023 on behalf of EASAC to the Baltic conference on Energy for the Future Society.

EU GREEN DEAL

Building on its earlier policies, the European Commission has been working since December 2019 with EU Member States and the European Parliament to develop and implement an EU Green Deal for tackling the challenges of climate change (see Fig. 1). New climate and energy policies and legislation have been introduced and existing policies have been strengthened to reduce greenhouse gas (GHG) emissions. At the same time, new initiatives have been launched to provide financing for the investments required to deliver the transition to a sustainable, low GHG emission economy, to support low-income groups, and to ensure that no one is left behind.
The EU played a leading role in the preparations for the Paris Agreement, which was signed in 2015, and the EU has enshrined its commitments to that agreement in the EU Climate Law which was formally adopted in 2021 and sets a legally binding target of net zero GHG emissions by 2050.

STOPPING THE USE OF RUSSIAN GAS

Since February 2022, the task of reducing GHG emissions has been made more challenging by the Russian invasion of Ukraine, which has led to an EU wide commitment to stop using Russian gas. To deliver this goal, the EU adopted, in May 2022, an ambitious new initiative REPowerEU, which calls for urgent actions to reduce energy demand, increase renewable energy production and diversify EU energy supplies.
Good progress was achieved in 2022, with a 15% reduction in EU demand for natural gas, 80% of Russian pipeline gas replaced in less than eight months, and 39% of electricity coming from renewables (EC 2022). To build on this success, it will be important to decarbonise Europe's energy supplies by phasing out the use of fossil fuels and rapidly increasing supplies of renewable energies. As explained in the REPowerEU initiative, energy demands must be progressively reduced by improving energy efficiency in each of the three main energy demand sectors, namely buildings, transport and industry and this will become easier to achieve as Europe moves towards a more circular economy.

REDUCING EMISSIONS OF METHANE

In 2021, at COP 26 in Glasgow, President Ursula von der Leyen together with President Biden launched a Global Methane Pledge (GMP) to reduce methane emissions by 30% by 2030. More than 150 countries signed up to the GMP, and the EU has since proposed

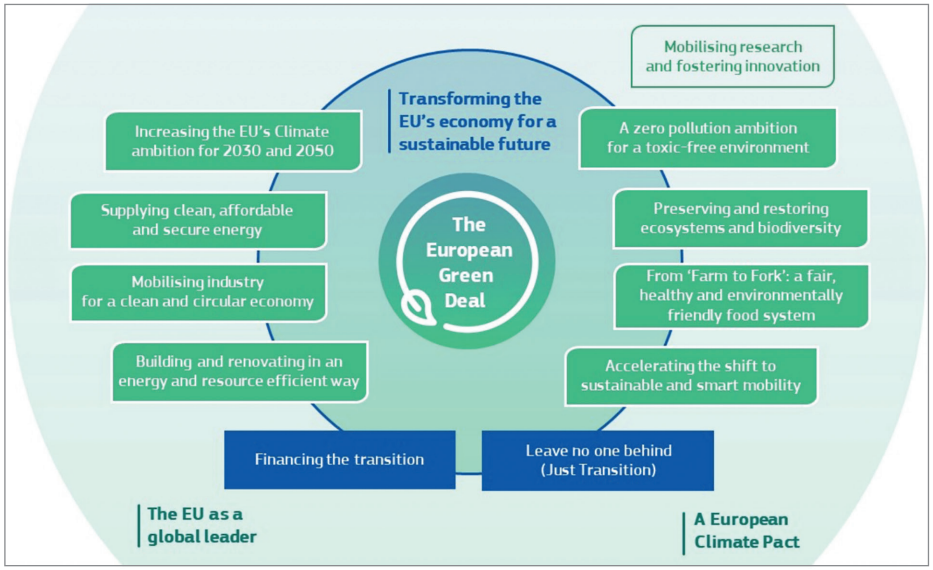


Fig. 1
Overview of EU Green Deal

a new Regulation (EU 2021) for reducing methane emissions that raises the level of ambition for methane emission reduction from the EU energy sector to around 58% by 2030 (compared to 2020 levels). Steps are also being taken in the EU to reduce methane emissions from agriculture and waste.

Until recently, it has been widely assumed that it is cleaner to burn natural gas than to burn coal for electricity generation. However, this assumption is no longer valid since satellite monitoring has shown that the leakage of methane during the extraction of natural gas from many sources, especially those where fracking is used, is much higher than previously assumed. In addition, for limiting global warming to less than the 1.5 °C goal set in the Paris agreement, it is the 20-year global warming potential (GWP) of methane that is important and this is three times higher than the previously used 100-year GWP value, making methane 80 times more powerful than carbon dioxide at causing global warming.

The main messages on methane for policy makers are that there is an urgent need for tighter regulations and policing of methane leakages from the extraction of natural gas, and that the use of natural gas for energy must be phased out as soon as possible alongside other fossil fuels (EASAC 2023).

BIOENERGY IS NOT ALWAYS RENEWABLE

Biomass resources include sewage, food wastes, and municipal and agricultural wastes but the largest potential biomass resource comes from forestry, namely wood. In the long term, sustainably managed forests are potentially renewable because new trees are planted when old trees are harvested. However, in the context of today's climate crisis with expectations that global temperature rises will exceed 1.5 °C within less than the next ten years, it is misleading to label bioenergy from trees with typical lifetimes of 60 to 100 years as renewable.

To minimise GHG emissions from forestry over the next ten years in an effort to limit the short-term risks of global temperatures exceeding 1.5 °C, as many trees as possible should be left in the forest as a valuable carbon sink. In addition, the wood from those trees that needs to be harvested, for example to maintain jobs for foresters or to address diseases or other forestry management requirements, should be used primarily for the manufacture of wood-based products with long lifetimes. Only after wood has been used for long lifetime applications, reused, and recycled should it eventually be used for energy, as illustrated in the biomass cascade in Figure 2.

INTEGRATED ENERGY POLICIES

Coordinated policies, regulations and incentives are needed to deliver cost-efficient reductions in GHG emissions from the buildings, transport, and industry sectors as well as for phasing out energy supplies from fossil fuels. An integrated approach is needed because there will be growing competition

Fig. 2
Biomass cascade: use forest biomass first for wood-based products with long lifetimes, then applications with highest economic and environmental value (EC 2021)

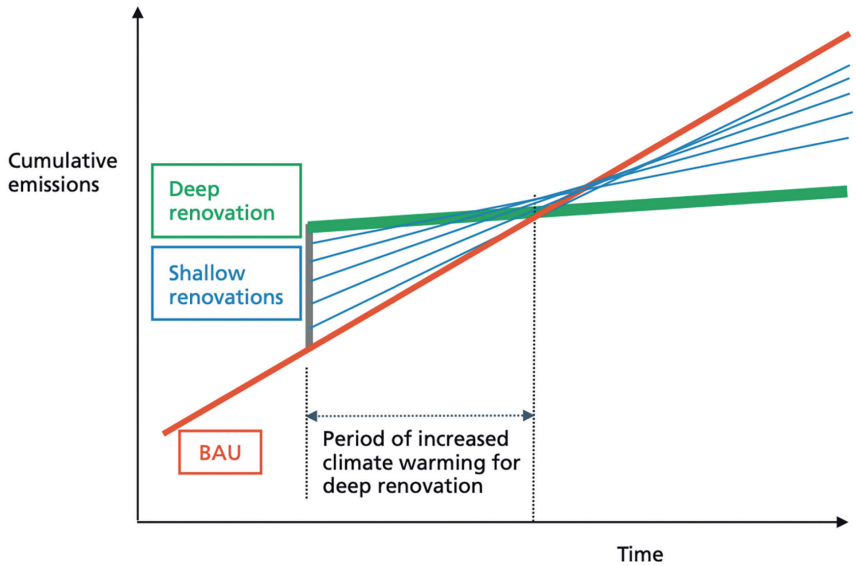


Fig. 3
Renovation reduces operational emissions but adds embodied emissions (BAU = business as usual; cumulative emissions = embodied + operational GHG emissions)

for supplies of low-carbon electricity, mainly from renewable energy sources, as fossil fuels are phased out.

Reducing operational and embodied GHG emissions from buildings. Buildings contributed about 35% of EU energy related GHG emissions in 2021 (EEA 2023), with about 2/3 coming from residential buildings and 1/3 from non-residential buildings. Around a half of the GHG emissions from EU buildings is produced directly (on site) by burning fossil fuels for heating and hot water. The other half is produced indirectly when buildings use district heating and grid electricity generated by fossil fuels for heating, cooling, lighting, appliances, and other equipment.

Most of Europe's ~250 million existing buildings are expected to be still in use in 2050, and the construction rates of new buildings are low so, to reduce building emissions, the focus must be on renovating existing buildings and stopping their use of fossil fuels. EASAC has shown that average renovation rates of 2% to 3% would be required for 30 years to address those buildings in the EU that will still be in use in 2050 (EASAC 2021). In other words, the current renovation rates of ~1%, will need to be increased by a factor of 2–3 (depending on the Member State) to deliver decarbonisation of all EU buildings by 2050.

In addition to GHG emissions caused by the operation of buildings, embodied GHG emissions are produced when building materials and components are made and transported to site, and by the machinery used to construct, renovate and eventually to demolish buildings.

When buildings are renovated, the amount of embodied emissions depends on the depth of renovation (see Fig. 3) and, for today's buildings, this typically corresponds to between two and five years of operational energy emissions. The embodied emissions of buildings can be substantially reduced by

increasing the use of wood, repurposed previously used building components, and recycled materials instead of new steel, concrete and bricks.

Public investment in building renovation to address energy poverty. To motivate homeowners to invest in renovating their buildings is a big challenge. Grants and incentives can be used to trigger, leverage and de-risk private financing for energy related building renovations, but public funding is limited so its use must be prioritised. The EU Green Deal includes a commitment to a fair energy transition in which no one is left behind. This implies that public funding should be used to renovate buildings for vulnerable groups who risk falling into energy poverty, rather than to subsidise building owners who can afford to pay for their renovations.

Using public funding to renovate buildings for energy-poor households, in place of long-term social welfare support for paying high energy bills in inefficient homes, not only tackles energy poverty, it also reduces GHG emissions. Moreover, social housing organisations can recover investments in renovation without increasing the monthly rents of residents by combining rent increases with reduced energy bills. Note: energy poverty is most prevalent in Central, Eastern, and Mediterranean EU countries.

Renovation improves health and wellbeing of building occupants. Renovating the envelope of a building can improve internal air quality, increase access to daylight, and avoid draughts and overheating as well as reduce GHG emissions. The resulting health and wellbeing benefits can therefore help to convince policymakers, social housing providers and investors to renovate buildings.

Good indoor air quality is particularly important in healthcare and school buildings, because young people typically breathe in more air per unit weight and are more sensitive than adults to heat, cold, and moisture. A healthy learning environment reduces absence rates, improves test scores, and enhances learning.

Reducing GHG emissions from transport. GHG emissions from transport represent 24% of all GHG emissions from the EU and, of this 24%, road transport contributes nearly three-quarters of the total (EASAC 2019).

To reduce GHG emissions from the transport sector, policy makers should put in place coordinated measures to 'avoid, shift, and improve' motorised transport in the EU, as follows:

Avoid – the demand for conventional motorised transport and reverse the EU policy that "curbing mobility is not an option". For example, encourage healthy walking and cycling by providing safe and attractive infrastructure, and promote the use of video conferencing and working from home to reduce unnecessary commuting between home and places of work.

Shift – passengers from private cars and aeroplanes to more efficient transport modes, such as public transport services (trains, buses, trams, etc), and shift freight off the road and onto railways or waterways. To make this happen, digital information systems and promotion campaigns are needed as well as investments in high quality public transport infrastructure.

Improve – the energy and GHG emissions performance of vehicles, for example by light weighting, and improving vehicle aerodynamics and rolling resistance. Incentives and regulations should be used to decrease consumer demand for oversized vehicles and oversized engines. Regulations are already being used to reduce the average GHG emissions of passenger cars and light duty vehicles. This is particularly important during the next 10 to 15 years, which is a crucial period for limiting global warming.

Other important steps that must be taken to reduce GHG emissions from transport include rapidly increasing renewable electricity generation on the grid, and accelerating the market penetration of battery electric vehicles and plug-in hybrid electric vehicles by increasing the numbers of vehicle charging points and adapting electricity markets and tariffs that apply to electric vehicles, so that costs are minimised for all consumers.

Hydrogen and synthetic fuels may be needed for long-haul heavy-duty vehicles but, because of inefficiencies in the fuel production processes, these fuels will not be competitive for passenger cars and light duty vehicles which can easily be electrified, as shown in Figure 4.

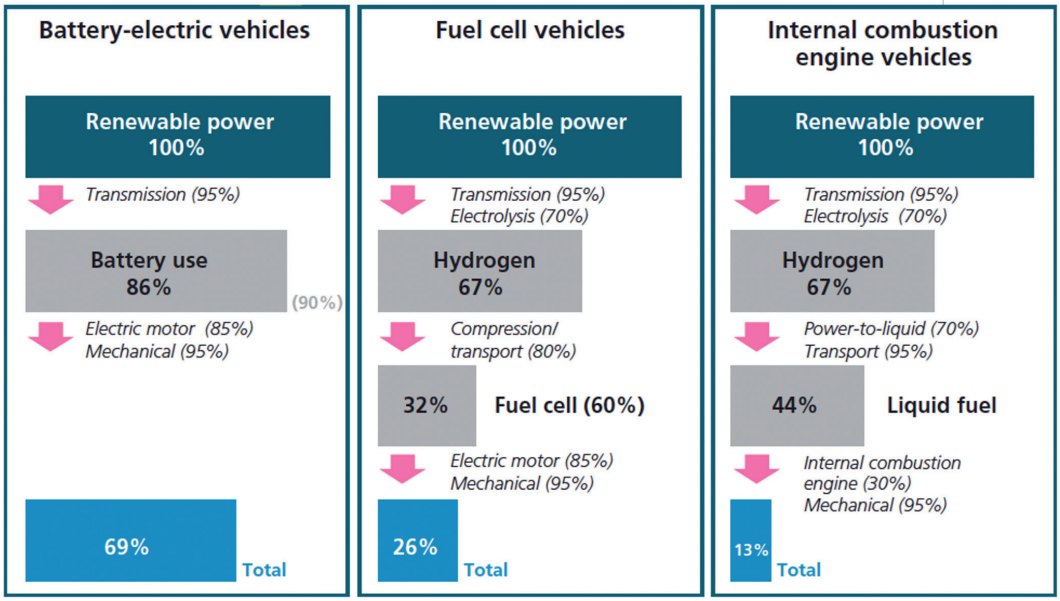


Fig. 4
Conversion efficiency comparison for electricity used in battery electric vehicles, fuel cell electric vehicles, and synthetic liquid fuels in internal combustion engine vehicles

CONCLUDING REMARKS

The transition to a sustainable EU energy economy and to net zero by 2050 will involve substantial investments, but these can also be expected to create growth and better-quality jobs, and to boost the competitiveness of industries in the EU.

Energy and climate policies must be regularly updated to reflect changes in the climate, technology, ICT, people's attitudes, business models, and geopolitics. As policies and regulations evolve, administrative burdens must be minimised, and reporting streamlined.

Growing concerns about the impacts of global warming and the increasing frequency of extreme weather conditions have led to a Green Deal with highly ambitious targets. However, it is important to recognise that the implementation and delivery in Member States of highly ambitious EU policies and targets will be challenging and may need financial support.

The transition to a sustainable energy system with zero GHG emissions will involve the electrification of many processes and systems that are supplied today by fossil fuels. An integrated approach will therefore be needed to deliver policy coherence between the energy sectors, and to make optimal use of investments in sustainable energy sources, in the infrastructure (network and storage systems) through which energy will be supplied, in the plant that will consume energy, and in energy management systems.

Policy makers must balance many different issues when making decisions, but it is the responsibility of the scientific community to peer review and provide independent (without commercial or political bias), objective, science-based advice in readily understandable terms for policy makers. EASAC and its member Academies are pleased to offer such advice.

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DECOUPLED AMPHOTERIC ELECTROLYSIS

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Green transition is crucial to reaching EU goals for sustainable development and a carbon-neutral society. This transition relies on cheap and available energy; the most commonly used renewable sources are hydrothermal, geothermal, solar, and wind energy. However, wind and solar energy have large dropbacks regarding peak consumption and production cycle mismatches. We need cheap and easily convertible storage media to store excess energy in peak production times and release it when the electricity demand exceeds production capacity. Traditionally, different battery technologies have been used, but most common Li-ion batteries are unsafe, and demand for lithium could exceed our production needs. Hydrogen is easily convertible and cheap storage media; however, before its full implementation in the energy grid, we must solve a few problems. For now, most of the commercially available hydrogen is produced through natural gas reformation. This method produces a lot of CO_2 and is not scalable due to its devastating environmental impact. For now, only 4% of hydrogen is produced in an environmentally friendly way – using electrolysis. Due to its high costs and efficiency, water electrolysis cannot compete with black hydrogen, produced from fossil fuel.

Conventional electrolysis produces hydrogen and oxygen simultaneously, which could lead to the formation of explosive gas mixtures [1]. Manufacturers use different polymer membranes to separate oxygen and hydrogen flow in electrolysers. Membrane electrolysers have many problems based on pressure imbalance on both sides of membranes (there is two times more hydrogen than oxygen), high resistance of ion diffusion through the membrane, and high material costs. Manufacturers use expensive and extensive pressure equalising systems to avoid membrane rapture and possible formation of combustible gas mixture. High ion diffusion resistance causes an increase in electrolysers' overpotential, lowering efficiency and increasing hydrogen costs. It is possible to limit this resistance by reducing membrane thickness; however, the membrane becomes more fragile and susceptible to chemical degradation. Water is split at 1.8 – 2.4V in membrane electrolysers, much higher than the standard potential at 1.23 V [2]. Commonly used electrolysers must operate below 80 °C to avoid membrane degradation. Still, it lowers total efficiency due to electrolyte resistance and the need for cooling systems.

In our proposed concept, we combine separate acidic and alkaline cells (Fig. 1) [3]. The standard potential of water splitting can be reduced if H_2 is released in an acidic cell and O_2 in an alkaline media. Both cells use Pt electrodes as primary electrodes and auxilia-

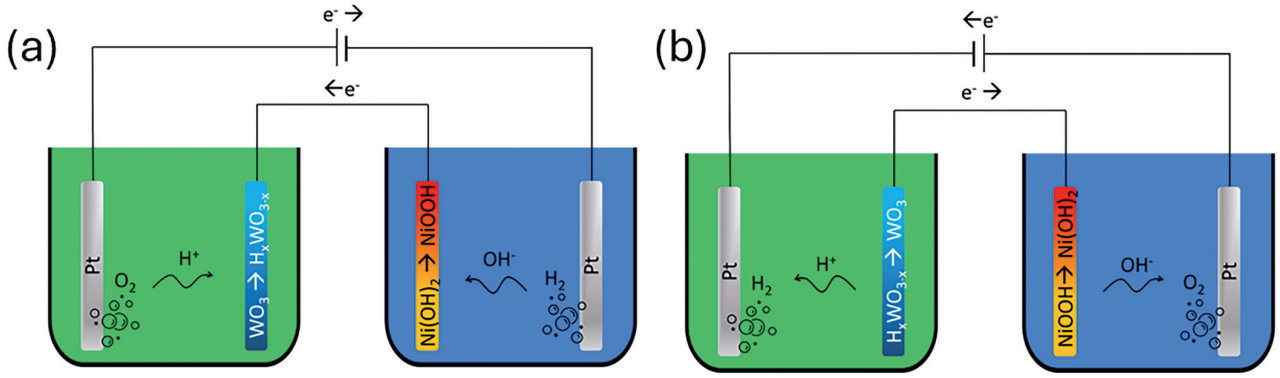

Fig. 1
Working principle of decoupled amphoteric water electrolysis at different current polarities. A green cell represents an acidic environment, and blue – alkaline. Water splitting is seen in the first step (a), and gas production from auxiliary electrode ions (b) in the second step

ry electrodes with active material. WO_3 and $Ni(OH)_2$ auxiliary electrodes are used in acidic and alkaline media, respectively. The gas production potential depends on the polarity of the applied bias voltage due to various electrochemical processes. During water splitting, WO_3 is protonated in the first cycle and forms tungsten bronze H_xWO_3 ($WO_3+xe^-+xH^+ \rightarrow H_xWO_3$) in the acidic cell. In alkaline media, nickel hydroxide is transformed to nickel oxyhydroxide NiOOH ($Ni(OH)_2 + OH^- \rightarrow NiOOH+e^-+H_2O$). This step is energetically disadvantageous because oxygen evolution reaction (OER) occurs on Pt electrode in acidic cell ($2H_2O \rightarrow O_2\uparrow+4e^-+4H^+$), but hydrogen evolution reaction (HER) ($2H_2O+2e^- \rightarrow H_2\uparrow+2OH^-$) in the alkaline cell [4]. When current flows from the Pt electrode to the cathode, HER ($2H^++2e^- \rightarrow H_2\uparrow$) happens in acidic cel. H_xWO_3 auxiliary electrode provides H^+ ions. When H^+ is transformed to H_2, H_xWO_3 decomposes, forming WO_3. Simultaneously, OER happens in an alkaline cell ($4OH^- \rightarrow O_2+2H_2O+4e^-$), converting OH^- ions provided by NiOOH auxiliarly electrode. During the OER reaction, NiOOH is turned back into $Ni(OH)_2$ ($NiOOH+e^-+H_2O \rightarrow Ni(OH)_2$). OER and HER happen until all H_xWO_3 and NiOOH are converted to their original compounds: WO_3 and $Ni(OH)_2$. In the second step, gases are produced from auxiliary electrode ions.

Hydrogen and oxygen are produced in separate cells without gas mixing and the formation of explosive mixtures. In the first step, water splitting and ion intercalation in auxiliary electrodes happen simultaneously at the potential of 2.96 V with a Faradaic efficiency of 98% and energetical efficiency of 43%. In the second step, hydrogen and oxygen are generated in the acidic and alkaline cell from auxiliary electron ions at the potential of 0.68 V with a Faradaic efficiency of 98% and energetical efficiency of astounding 201%. The total efficiency of our concept electrolyser is 71%, which is compatible with commercially available electrolysers with an efficiency of 70% [5]. Gas purity in acidic and alkaline cells exceeded 99.9% in both steps.

In our concept, we can produce 1 MWh using 1 kg of active material at an auxiliary electrode in 1000 cycles, with a cycle duration of four hours. Our concept is easily scalable and does not require expensive and rare materials. This concept can help to expand the hydrogen energy market and is usable to balance renewable energy grid, leading to faster green transition.

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MAGNETIC CAPILLARITY

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People have been trying to understand the variety of forms existing in the living world for centuries. This is the point of the famous book by D'Arcy Wentworth Thompson, *On Growth and Form* [1], where the author says: "The terms Growth and Form, which make up the title of this book, are to be understood, as I need hardly say, in their relation to the study of organisms. We want to see how, in some cases at least, the form of living things, and of the parts of living things, can be explained by physical considerations, and to realise that in general no organic forms exist save such as are in conformity with physical and mathematical laws" ([1], p. 15). The beauty of forms which exist in Nature have inspired the arts (Art Nouveau) and architecture (entrance gate to the Paris World Exhibition in 1900) [2].

As the physical force, which determines the growth and form, D' A. W. Thompson considers the surface tension which comes from the cohesion of the particles of matter and the energy of which is proportional to the surface area. The proportionality coefficient is called surface tension, which in known cases, as it was remarked by J. C. Maxwell in his famous review paper "Capillary action" [3], is positive. J. C. Maxwell says: "If this quantity (auth. surface tension) is positive, the surface of contact will tend to contract and the liquids will remain distinct. If, however, it were negative, the displacement of the liquids which tends to enlarge the surface of contact would be aided by the molecular forces, so that the liquids, if not kept separate by gravity, would at length become thoroughly mixed. No instance, however, of a phenomenon of this kind has been discovered, for those liquids which mix of themselves do so by the process of diffusion, which is a molecular motion, and not by the spontaneous puckering and replication of the bounding surface as would be the case if T (auth. surface tension) were negative." We see that J. C. Maxwell does not exclude the possibility of negative surface tension, which now, after 100 years, has been confirmed experimentally by the discovery in 1979 of labyrinthine pattern formation by magnetic liquids [4].

In the experiment an annulus of magnetic liquid enclosed the bubble in a circular Hele-Shaw cell (space between two close transparent discs). When the magnetic field was applied perpendicularly to the cell at some critical value of the field strength fingers formed on the bubble interface, which grew in length as the field was increased, sometimes experiencing beautiful bending deformations (Fig. 1). The finger propagation looks as if they pull themselves out by magnetic forces acting on their tips. Finally, a beautiful labyrinthine pattern is formed with a significant increase in the surface area between the magnetic fluid and air just as J. C. Maxwell predicted in the case of negative surface tension.

It should be mentioned that the discovery of these patterns happily took place due to some slips of experiment which was aimed at the study of the equilibrium shapes of bubbles in an infinite layer of magnetic liquid. Since for the introduction of the magnetic fluid in the circular Hele-Shaw cell only one hole on its upper surface was made, only a small amount of magnetic liquid could be introduced in the cell and as a result a large bubble with a surrounding annulus of magnetic fluid was formed. In this case the described formation of the labyrinthine pattern was observed.

We should mention that there are different cases in nature when similar patterns are observed. Here we may note domain structures in thin films of ferromagnets (domains distinguished by opposite directions of magnetisation), in superconductors of the I kind the

Fig. 1
Labyrinthine patterns formation in Hele-Shaw cell [4]

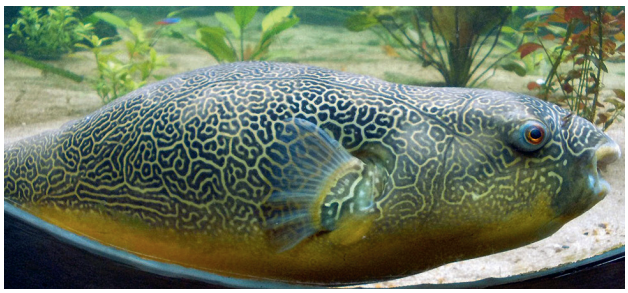

Fig. 2
Colour pattern of puffer fish (https://en.wikipedia.org/wiki/Tetraodontidae)

superconducting phase forms labyrinthine patterns. One essential difference of these patterns compared to those described above is that in these cases the structure is formed by the change of the order (magnetisation, order parameter of superconductor) while in the case of the magnetic fluid the amount of the pattern forming agent (magnetic fluid) due to the volume conservation remains constant. Thus, we may say that magnetic fluid carries out labyrinthine pattern formation with a conserved order parameter. In the other cases we mentioned the order parameter is not conserved (state of magnetisation, for example).

The story of labyrinthine patterns will not be complete if we do not mention the colour patterns of many tropical fishes, colour patterns of zebra, the colour patterns of tigers are also from this class of phenomena. This is the class of phenomena that was described by A. Turing, who considered reaction-diffusion systems. There are some species which propagate by diffusion and have chemical reactions between them. In the case when one species (activator) autocatalytically activates its own production and also produces an inhibitor which impedes activator production, as long as inhibitor diffusion is much faster than that of the activator, the activator patterns (including labyrinthine patterns) are produced. This model describes the colour patterns observed in nature (Fig. 2) quite well. Then the topic of investigation becomes finding out what plays the role of activator and inhibitor in these biological systems.

In describing the labyrinthine pattern formation, the problem of equilibrium shapes was mentioned, which is one of main problems discussed in *On Growth and Form*. In the present context it is the problem of the figures of equilibrium formed by the balance of surface tension and magnetic forces. The figures of equilibrium formed under the action of surface tension forces are well-known. They are spheres, cylinders, unduloids (in a special case catenoids) and one more complex shape (nodoids). For these shapes it is characteristic that the mean curvature $\frac{1}{R_1}+\frac{1}{R_2}$ ($\frac{1}{R_1}, \frac{1}{R_2}$ are the minimal and maximal curvatures of the curves formed at the section of the surface by the plane containing the normal of the surface) is constant. Since according to the Laplace law the surface tension creates additional pressure $\sigma\left(\frac{1}{R_1}+\frac{1}{R_2}\right)$ on the medium enclosed by the surface then at equilibrium when the pressure is the same everywhere the mean curvature should be constant.

In the book by D. W. Thompson the example of four equally sized bubbles in contact is considered. The internal boundaries between the bubbles make a fourfold vertex. To reduce their energy, it is advantageous to split this fourfold vertex into two threefold vertices, thereby decreasing the contact surface area. This simple example illustrates the famous and difficult Steiner problem of finding the path with the minimal length between the given number of points. For the four points on the vertices of a square, the path connecting the vertices may be the diagonals of the square, which intersects at a fourfold vertex. This solution is not the best one. The fourfold vertex splitting into two threefold vertices, where the paths make an angle of 120° with each other, gives a small-

er total length as observed in two dimensional foams minimising their surface energy. This angle is formed by soap films between a different number of pins (Steiner trees), which is a popular demonstration experiment in different audiences and more – it attracts serious interest from the point of view of mathematics related to optimisation problems [5].

The concept of the instability of the fourfold vertex allows one to understand why the fingers (for example, see Fig. 1) never split. To split the finger, which we may consider as a stripe, peristaltic deformations of the stripe should develop. In this case the fourfold vertex will form, which as we know is unstable with respect to the formation of two threefold vertices. As a result, the development of peristaltic deformation is stabilised. This is observed both experimentally and numerically (Fig. 3, [6]).

In the case of magnetic fluids, the condition of equilibrium besides the surface tension force also contains a shape dependent magnetic force which makes the problem of determining the figures of equilibrium much more complicated. The concept of negative or small effective surface tension may be fruitful to consider. For example, the concept of negative or zero surface tension allows one to consider an interesting analogy with 2D smectics (materials formed by equidistant parallel layers). It is possible to show that if a periodic system of magnetic fluid stripes in the Hele-Shaw cell is formed with an equilibrium distance between them that decreases as the magnetic field is increased then the effective surface tension of the stripes is exactly equal to zero [7]. It means that as the magnetic field is increased and the equilibrium distance between the stripes correspondingly reduced, the stripes may adjust to it by bending (Fig. 4). Since the effective surface tension is zero, there is no energy cost due to the increase of the surface area. As a result, beautiful so-called chevron patterns arise as observed in the experiment [8]. Another demonstration of negative effective surface tension behaviour is a foam in magnetic liquid [9], where the films separating air bubbles buckle as the field is increased since it is energetically advantageous to increase the surface area due to negative surface tension.

The problem of figures of equilibrium is one of the most complex in the physics. In the case of astronomical scales, large in comparison to the scales of living

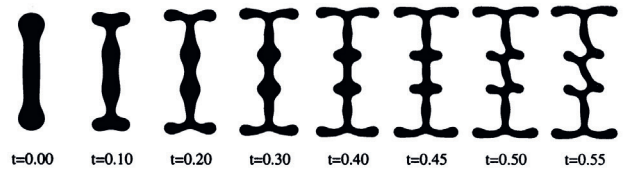

Fig. 3
Fourfold vertex instability (numerics, in experiment similar things happen) [6]

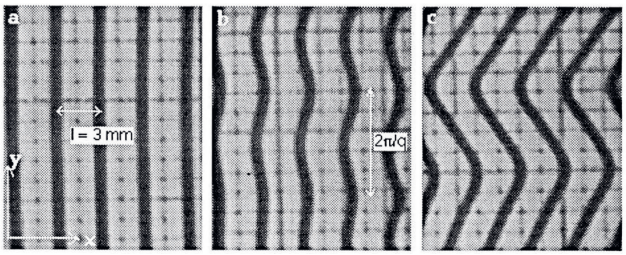

Fig. 4
Chevron pattern in the system of magnetic stripes [8]

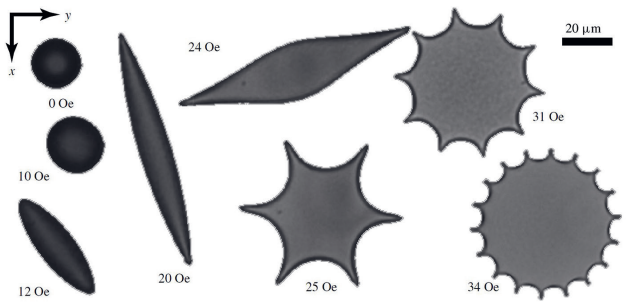

Fig. 5
Sequence of shapes in high frequency rotating field [10]

systems, gravity plays the main role. Significant attention has been given to the problem of determining the figures of equilibrium of self-gravitating rotating masses in the context of the evolution of planetary systems and stars. The following sequence of equilibrium shapes was found – oblate axisymmetric ellipsoids (Maclaurin), non-axisymmetric ellipsoids (Jacobi), bifurcation (abrupt changes of the characteristics of shapes) of the pear-like shapes (Poincare). The bifurcation to the pear-like shape was considered as the formation of a planet with one satellite. Other bifurcations gave the formation of a planet with two satellites and so on. The shape bifurcations of self-gravitating rotating masses have an analogy with the bifurcations of the magnetic liquid drops under the action of high-frequency rotating fields. In

this case all directions in the plane of a rotating field are equivalent and the resulting shapes are shapes of equilibrium (do not rotate). The following sequence of the shapes is observed – an oblate shape (compressed along the normal to the rotating field plane), a worm-like shape (may be approximately described as a non-axisymmetric ellipsoid) and back to an oblate pancake-like shape, only much more compressed, as the magnetic field increases further (Fig. 5) [10]. Fingering is observed on the perimeter of the pancakes with the formation of shapes that are reminiscent of living organisms – starfish. It is interesting that the starfish have five fingers, in some rare cases 10. Magnetic droplets have any number of fingers increasing with the field.

The few examples mentioned above illustrate the story of magnetic capillarity over the last several decades. Latvian researchers have notably contributed in advancing it, what was acknowledged by the President of the Latvian Academy of Sciences in 2022. However, the story is not over. In fact, it is just beginning. During the last decade, gases of atoms with large magnetic moments (dysprosium) cooled to low temperatures (quantum fluids) have been found to exhibit the labyrinthine patterns of the magnetic liquids described above (see, for example, Fig. 6, where the pattern of the magnetic colloid formed at field induced demixing in the range of concentrations corresponding to the transition from the stripe phase to the droplet phase (above) may be compared with the pattern of atom gas (dysprosium) (below)).

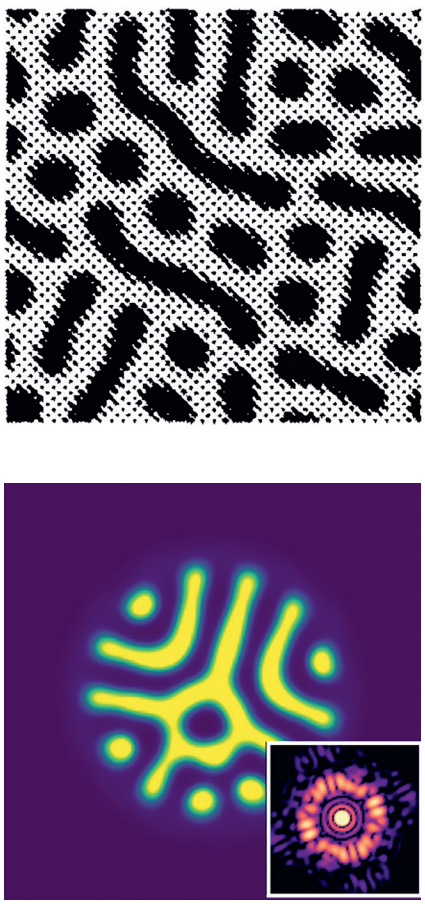

Fig. 6
Labyrinthine patterns (magnetic colloid (above [11]), quantum fluid (below [12]))

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DEEP DECARBONISATION THROUGH ADVANCED ENERGY SYSTEMS SOLUTIONS

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THE ENERGY TRANSITION AHEAD

Sustainability and climate change (mitigation) will define this century. The Paris Climate Agreement from December 2015 urges to reach net-zero emissions (i.e. carbon emissions-carbon sinks=0) by the middle of this century to limit the global temperature rise to 1.5 °C from the pre-industrial time [1]. Eight years later, in December 2023, in Dubai, the UN Climate Change Conference (COP28) finally succeed to adopt a fossil fuel phase-out agreement to transition away from fossil fuels in energy systems, "in a just, orderly, and equitable manner", to achieve the Paris goals by 2050. Energy stands in the focus of emission reductions as around 80% of all energy is still fossil fuel based and three-quarters of all greenhouse gas emissions originate from fossil fuels, notably coal and oil. The European Union has earlier on committed to the carbon neutrality target by 2050, which binds all member states.

The energy transition ahead will be very challenging as the emissions are still slowly growing and are projected to reach a record level in 2023. To cut, e.g., 80% of all emissions by 2050, would require an average yearly cut of 6% till 2050 – and if the turnaround is delayed to 2030, the gradient need to be steeper close to 7.5% a year. The climate quest becomes even more worrying when considering the geographical distribution of present emissions: by far, the most emissions come from poor and emerging economies, e.g., 60% from Asia, whereas the rich and industrialised countries stand for a declining share of the global emissions, e.g., European Union represent ca 7% of all emissions. In addition, nations have quite different starting points for cutting emissions based on their present energy base influenced by the investments and decisions made in the past prior to the climate crisis and based on their natural conditions. For example, the northern part of Europe has typically enjoyed extensive hydropower and bioenergy resources, whereas the traditional domestic energy sources in central and southern Europe are mainly fossil fuels (e.g., coal). The carbon intensity (CO_2/GNP) of nations vis-à-vis their level of wealth (GNP/cap), which is also influenced by the history, gives some indication of the effort needed to reach the climate targets: the highest economic burden in relative terms will be on low-income high carbon-intensive countries, and vice-versa, high-income low carbon-intensive countries could manage the transition the easiest. For example, in the European Union, the difference between the Nordic and eastern Central-European countries could be more than an order of magnitude on the scale ~CO_2/GDP x GDP/cap, with both terms scaled by their max. values [2].

Considering the magnitude of the climate problem on the one hand, and nonuniform efforts required to reach the climate goals on the other hand, shows that the net-zero transition is not a singular problem (i.e. just reducing GHG emissions), but need also consider the well-being of the society. This in turn, adds three important objectives to the execution of the transition: affordability, industrial competitiveness, and reliability [3]. The last factor relates closely to energy security and supply chains which are strained by the Russian invasion to Ukraine and geopolitical tensions globally. The four interdependent objectives above are of high importance for both climate and security and will put more emphasis on the energy systems themselves, and in particular on what kind of development could be

expected to provide more effective advanced energy technology and systems solutions. Naturally, the whole transition requires a socially just approach addressing the other sustainable development goals (SDG).

ENERGY SYSTEM SOLUTIONS – ADDRESSING BOTH THE DEMAND AND SUPPLY OF ENERGY

The energy transition touches all parts of the energy framework. To reach carbon neutrality, massive introduction of clean energy will be required, but also more effective use of energy will be necessary. Actually, energy efficiency is considered vital as reducing the demand will have major positive system effects throughout the whole energy and supply chains reducing the need of energy supply, investments (financing), materials, infrastructure, etc. Though the potential for energy efficiency is huge, in particular in the built environment, and new technologies such as digitalisation offer further efficiency benefits, strong policy measures and behavioural changes are necessary to realise these possibilities. International Energy Agency (IEA) calls for doubling the energy efficiency goals by 2030 to stay on track with the Paris climate goals (and tripling the solar wind capacity at the same time). The losses in the energy supply chain are illustrated in more detail in Figure 1.

The spread in future energy demand with or without energy efficiency measures is large. For example, the EU final energy demand could decrease by 67%, or, increase by 40% by 2050. Such an uncertainty in demand could have major effects on how the future energy systems and supply are conceptualised. For example, in case of Finland, energy system modelling indicates that a half a per cent decrease a year in the energy consumption instead of an increase would result in huge energy system differences by 2050 – in a scenario striving for >90% reduction in the emissions from energy (negative total emissions) and relying much on wind power and hydrogen/synthetic gas (PtG, power-to-gas), the higher energy demand would require almost double the wind power capacity and more than twice the amount of PtG than the lower energy demand case [4]. In addition to economic and environmental benefits, energy efficiency would also improve resilience and security. Through the "energy efficiency first"-principle, the energy system solutions would clearly be eased.

On the supply side, the key strategy to reduce emissions will be strong electrification of the final energy use. The share of electricity is presently some 20% of end-use, but it could increase to 50% and even beyond by 2050. Most of end-use energy is still in form of heat (>50%) the rest being fuels e.g. for transport. The rationale for focusing so strongly on electricity lies in the commercial breakthrough of new renewable electricity forms, wind and solar power. They are the cheapest forms of electricity and can reach the scale necessary to cut emissions globally. Wind and solar together represented 12% of all electricity 2022 (nuclear less than 10%, hydropower 15%, the rest fossil-fuels and other), but their share could reach to 70% by 2050 [5]. Cheap and clean electricity could help other sectors, which are difficult to decarbonise such as transport (e.g., electric vehicles, synthetic fuels), heating (e.g., heat pumps), industries (synthetic fuels, heat pumps), to reach their climate goals.

An energy system employing much solar and wind makes the electricity production more weather-dependent and decentralised, which has its benefits (e.g.. free fuel, less vulnerable), but it has also major drawbacks to traditional fuel-based centralised production, which benefit from better control of power production as fuel functions as an energy storage. To make solar and wind more fuel-like, their flexibility deficit needs to be addressed, i.e. when building more wind and solar, their integration to the energy system and adding flexibility elements to accomplish a secure energy system will be increasingly important. Present market mechanisms, legislation, and policies often overlook these aspects as most of the energy is still fuel not requiring such measures. There are several options to increase energy system flexibility to ease integration of large-scale solar and/or wind power schemes ranging from elements in the demand to the supply side. For example, demand response, demand side management, energy efficiency, prosumer schemes, digitalisation, virtual inertia, better weather forecasting, energy storage, synthetic fuels, multi-fuel engine plants, sector coupling (Power-to-X, PtX), among others, are examples of available options. The required flexibility needs to be determined case-by-

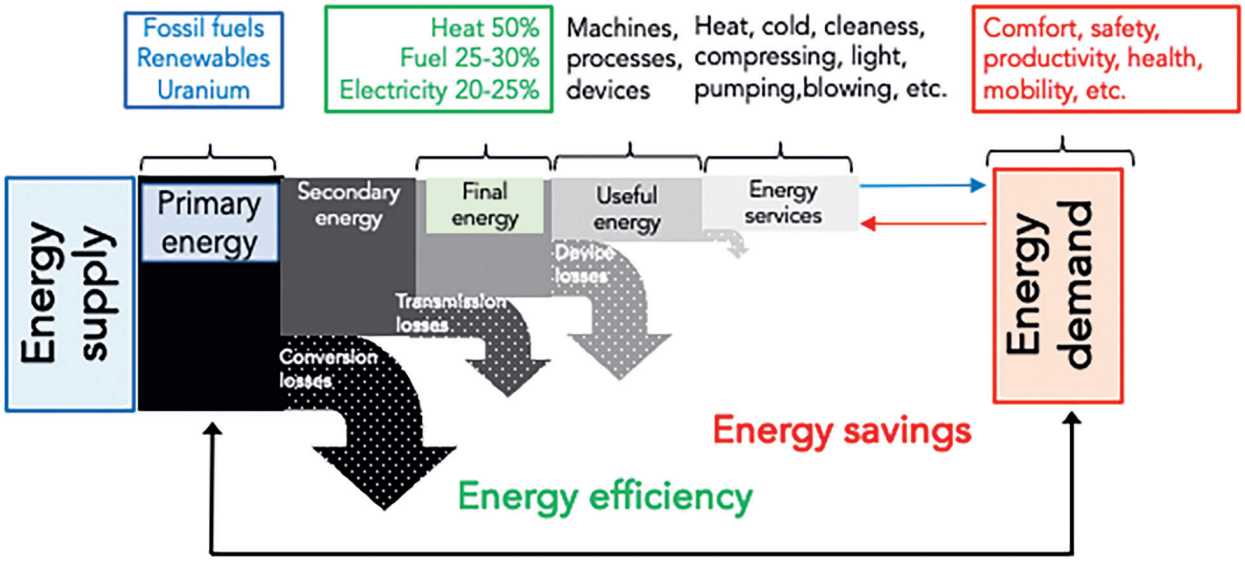

Fig. 1
Illustration of losses in the energy delivery chain from supply to demand

case as it depends on the local conditions meaning that the increased flexibility could be a portfolio of measures tailored for the site in question.

Sector coupling in which renewable electricity is turned into other final energy forms such as heat or fuel, could be a powerful flexibility measure. For example, power-to-heat (PtH) can provide much energy system flexibility in northern countries with high heat demand enabling even to oversize, e.g., wind power plants and turn the access to heat [6]. Heat is also much cheaper to store for a longer time than electricity in case there is oversupply of electricity. A study for Helsinki, capital of Finland, showed that 60% of the electricity and 20% of the heat demand could be delivered through a large-scale wind and PtH+thermal storage scheme without the need to feed wind surplus into the grid [7]. Recent studies in Australia show that solar and wind including their integration costs would be cheaper than fossil fuel or nuclear based power production [8].

An ultimate solution to overcome the variability of solar and wind could be to use the excess electricity to produce hydrogen through water electrolysis and further to make synthetic fuels (methanol, methane, ammonia, etc.) with hydrogen. This would transform variable solar and wind power into a storable fuel and for later use. A lot of development is under way to accelerate hydrogen production and use, e.g. scaling up and improving electrolysis, creating H_2 networks etc., but the cost of electrolytic H_2 is still 3–4 times more expensive than H_2 from natural gas limiting its use. Global efforts strive to make renewable based 'green' H_2 competitive by around 2030. A key factor for cheaper hydrogen in the future will be the cost of electricity for the electrolysis which favours 'green energy' options as their present cost is favourable and the prospects for reducing their costs further are good [9]. Reaching a sensible cost level would in addition require achieving at least some 4000 full-hours of operation of the electrolyser-unit, which is already feasible with wind power in the Baltic Sea region.

The optimism around hydrogen has also spurred large-scale plans for hydrogen production in northern Europe, e.g., Baltic countries incl. Finland. Some scenarios foresee this region as a H_2 deliverer to Central Europe with less possibilities for indigenous H_2 production. Hydrogen from the north would require massive investments into hydrogen networks and in offshore wind power hubs, which could also mean an economic boost in the countries involved. Within EU, transport via pipe networks is considered more optimal for large-scale H_2 transport than using liquid H_2. For example, Germany and the Netherlands are already starting to convert some parts of their natural gas network for H_2 transport.

Next generation nuclear power in the form of so-called Small Modular Reactors (SMRs) is viewed by some countries promising for their carbon-free

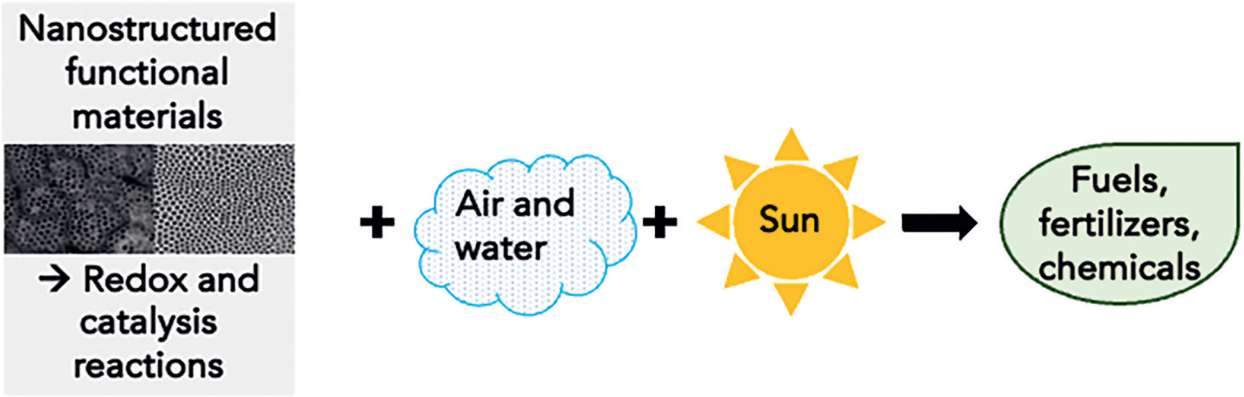

Fig. 2
Principle of solar fuels and chemicals

electricity production. For example, France and Finland, both already having a high share of nuclear power, are strongly pushing this option forward. One argument for SMR is the 'fuel'-based and continuous power production from nuclear vis-à-vis variable renewable production. However, as the demand is also getting more weather dependent through the electrification of other sectors, large nuclear share would also require additional flexibility, which has been the case e.g. in France where over 70% of the electricity originates from nuclear base-load plants. In addition, challenges to be addressed with SMR includes the high cost (even in mass production in the 2030s twice as expensive electricity as from wind power today in Finland), supply chains, nuclear waste, safety issues, etc. Overcoming these factors will require major RDI efforts in the coming years supporting new innovations and new technologies.

BEYOND THE STATE-OF-THE-ART – NEW TECHNOLOGIES IN SIGHT

Science will offer a range of interesting developments for energy systems in the future. Through material science and digitalisation in particular, improved solutions are expected. For example, the next wave of digitalisation comprising 6G for ultra-rapid communication, quantum computers for fast computation, and artificial intelligence with effective deep-learning algorithms combined with other disciplines and applications could open up radical pathways in energy. For example, digital twins of energy systems enabling real-time simulation and optimisation of and link to physical systems for different conditions could help to manage complex problems such as balancing the energy supply and demand or optimise the grid management. Machine-learning algorithms with big data and quantum mechanical models could create better (and even previously unknown) material systems or synthesis paths for energy devices. At some point, we may envision Artificial Intelligence to help us in aiding policies to bridge multiple issues from energy, environment, economy to social factors [10].
In material science, catalysis based on nanomaterials could open up new avenues in fuel production. For example, band gap-engineered black TiO_2-nanotubes as photocatalysts can be used for water splitting. Maybe in far future such black solar panels could produce hydrogen aside traditional blue photovoltaic modules producing electricity. Scientific discovery on nanostructured photocatalysts could offer even more radical ways to produce fuels, chemicals, and fertilizers from just water and air (O_2, CO_2, N_2) with the help of sunlight in a fully sustainable way shown in Figure 2 [11]. Much of the above-mentioned technologies work already in laboratory-scale, but the main challenge remaining is their scaling economically up into the industrial level to reach a global impact.

CONCLUSIONS

Deep decarbonisation is already underway through the present technology base offering workable and scalable clean energy solutions. The energy transi-

tion to carbon neutrality is complex involving new elements both on the supply and demand side. Complexity often equals to flexibility in the energy system context, which will be increasingly necessary in the future decarbonised energy systems. Advanced system solutions to these quests are already emerging. The technological progress and the new scientific discoveries underway provide new hope to combat the climate change.

As stated earlier, new technologies are an important part of the energy transition to carbon neutrality. "But the energy transformation is not merely a technical and economic issue. It is about people, about societies, values and behaviors. Technology is an integral part of the society and an expression of collective intentionality through aggregation of sundry individual choices." [12].

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THE FINNISH PRICE OF ELECTRICITY-TRANSFER DILEMMA – HIGH RETURNS DRIVEN BY THE REGULATION?

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Electricity-transfer is infrastructure-based service-business that operates under a natural monopoly. The risk-level that faces the business is low and the industry is regulated. The circumstance would under typical expectations point to return-levels that lie under the return-levels of companies that operate with a similar risk-level on competitive markets. Interestingly and importantly, this is not the status quo in Finland, where the observed returns of Finnish distribution system operators are comparatively high. The main reason for this apparent returns-related dilemma seems to be the regulation allows the relatively high returns. The regulation model is based on using a specific and separate balance sheet as the basis for the calculation of the accepted reasonable return. The regulation-balance sheet is based on usage value and not on the accounting value of the networks in place. Furthermore, the accepted costs of borrowed capital, interests, are not considered according to the actual paid interest costs, but according to a constructed value. In addition to resulting in very high relative returns on the capital actually employed, the regulation model and especially the treatment of costs of capital is problematic from the EU regulation requirement of cost reflective pricing. This research discusses the role of the Finnish regulation model on the costs to customers.

INTRODUCTION

The times are those of transition to a more electrified society, and the importance of electricity transfer networks is growing. In Finland the transfer networks have been mainly built in 1950–1970 and they are now facing the end of their economic life. In addition to the age of the networks, the reliability requirements of the networks, that is, weatherproofing, causes heavy investment needs in the coming years. The electricity distribution system operators (DSO) are local monopolies that operate relatively low-risk businesses with customer lock-in. The DSOs are regulated by the Finnish Energy Authority (FEA) that among other things is responsible for the rate of return regulation and sets a reasonable rate of return for both equity and for interest bearing debt capital [1] and inspects the network investment plans submitted by the DSOs to the regulator yearly. The regulator is responsible for oversight of the companies regulated and as the DSOs are monopolies the duty of "protecting" the consumers also falls under the mandate [2]. The work of the regulator is that of balancing the well-being of the DSO and the customers, and making sure that the infrastructure is developed in a way that corresponds to the long-term goals of society and provides security of service as decreed by the legislation.

On this background the observation that the profitability of the Finnish DSOs is very high, return on equity of over 20% for all years 2016–2019 as industry [3] with the observation that the DSOs are using expensive strategies to rebuild and weatherproof the electricity network [4] have sparked a lot of discussion about the reasons that underlie these observations. Over-investment and the role of the used regulation model have been mentioned as "suspects" and criticism has been launched against allowing extraordinary profit levels as a way to incentivise investments [5].

INVESTMENTS TO THE NETWORK AND CALCULATION OF REASONABLE RETURN IN THE REGULATION MODEL

The DSOs in Finland are in a rather independent position with regards to their network investments as it is for them to plan and decide what investments they make. It is no novelty that in regulation regimes the profits to capital ratio determine the absolute returns of companies that companies have an incentive to over-invest [6]. Investment plans are submitted to the FEA for inspection, and they reveal that DSOs have heterogenous plans in terms of the strategy that they utilise in making their investments [4]. Some DSOs (self-reported in 2018 that they) categorically use ground cabling as their modus of choice for investments, while others use cheaper aerial cabling coupled with ground cabling for main lines. The difference between the costs of different strategies is considerable and is ultimately reflected in the cost of electricity transfer. Furthermore, the investment strategies of the Finnish DSOs differed in the way they utilise the by-the-law allowed exceptions to weatherproofing investments for specific locations (such as islands) – the locations that allow for an exception are typically locations that would carry high investment costs for a weatherproof cabling, such as the construction of underwater cables [4]. In summary, the consideration for the cost level incurred in making network investments and ultimately paid by the consumer, differs considerably among the Finnish DSOs. There is reason to believe that savings that would affect end-user costs could be made, while maintaining the required level of security of supply, if the DSOs were to less categorically use the most expensive investment strategies and more widely utilise allowed exceptions to weatherproofing investments.

The rate of return regulation model used by the FEA [1] is based on the notion that the absolute return a DSO may at maximum collect for the service provided, from its customers in the form of electricity transfer costs, is determined by multiplying a reasonable rate of return with the capital invested in the business in the regulation balance sheet. The reasonable rate of return is determined as a weighted average cost of capital (WACC), where the weights of debt and equity are determined as 40% (debt) and 60% (equity) for all DSOs. The reasonable return for debt and equity are separately determined, and are also the same for all DSOs. The real industry capital ratio if the interest-bearing debt and equity are considered was different, ca. 45% equity and 55% debt, for years 2016–2019 [7]. The effect of this difference between reality and model is relatively small, as the model changes the beta used based on the capital ratio used. The parameter values used in the WACC calculation have been previously criticised, especially in connection with the changes put into effect between the years 2015 and 2016 [5].

From the year-end figures of the DSOs we know that

Table 1. Indicative figures for the 4th regulatory period 2016–2019, calculated from FEA reported data for DSOs

In M€	2016	2017	2018	2019
A. Reasonable return	675.58	686.92	685.05	674.40
B. Reasonable return % *	7.42%	7.05%	6.62%	6.20%
C. Regulatory capital (equity + int. bearing debt)	9110.38	9747.01	10345.05	10885.54
F. Equity + Int. bearing debt (year-end book value)	3619.79	3952.17	4276.09	4392.82
E. A/F*100%	18.66 %	17.38 %	16.02 %	15.35 %

* From FEA documents (FEA WWW-site).

Table 1 shows the difference between the yearly level of the regulatory capital used to calculate the reasonable return and the year-end book figures for the DSOs. The reasonable return on the regulatory capital creates very high returns on the year end-book capital.

the accounting balance sheet and regulation balance sheet numbers differ remarkably. The difference causes the regulation-based determination for reasonable costs of capital, the return extractable from the service users, to differ remarkably and to be higher than the actual costs of capital incurred. This translates to very high returns on the actual capital employed, e.g., the costs of interest-bearing debt for the DSOs collectively were under 140M€ for all years 2016–2019, while 40% of the reasonable return attributable to debt according to the regulation model, corresponded to over 330M€ for all these years [7].

WHAT CAN WE LEARN?

When regulation models are based on using separate regulatory balance sheets, the numbers used may be very different from what can be considered to be the real-world numbers. Such a discrepancy can in turn cause outcomes, such as the very high relative return levels observed for Finnish DSOs that can be considered an anomaly from the point of view of regulatory success. In such cases the actual costs of capital may differ greatly from the by the regulator accepted level, thus causing a "regulatory windfall" profit to the DSOs, based on the regulatory model used. Such profits are a case example of non-cost reflective regulatory practices.

Furthermore, when companies operate in environments, where their capital employed determines their return-levels they have a tendency to over invest – the regulator must act decisively to prevent over investment and extraordinary costs to end-users. Any extraordinary profits reaped by DSOs are money away from other consumption, including the investments important to energy transition of society. A regulatory system built on non-cost reflective practices carries a policy risk that may be realised if the EU commission finds the system to be in violation of EU regulations that require the pricing of electricity transfer and distribution to be cost reflective, causing a possibly abrupt change in the system.

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SHINING FUTURE OF ORGANIC LIGHT EMITTING DIODES

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During the past two decades, the technology of organic light emitting diodes (OLEDs) has seen a widespread practical adoption which has resulted in a large variety of innovative products. Most significant application direction of OLEDs is related to their use in the production of smart device displays. In comparison to previous generations of screens (e.g., liquid crystal displays, LCDs) OLED counterparts provide multiple benefits. Since the light in OLED is directly generated by small pixels, composed of around 100 nm thick organic material layers, no background lighting or light filters are needed to realise full colour image generation. Not only this allows production of very thin and lightweight displays, suitable for mobile devices, but also results in a supreme contrast ratio. Because individual OLED screen pixels can be selectively turned off, the "dark" regions of the produced image are purely black. In comparison, in LCDs some of the background lighting leaks through the liquid crystal filters limiting contrast ratio to 1:5000, whereas for OLEDs this parameter can exceed 1:1,000,000 value. Besides providing superior image quality, continuous development of OLED display technology has resulted in several innovative solutions. One of such examples is a recent emergence of foldable screens. Due to compatibility between organic materials and polymeric additives, flexible displays are attainable with OLED technology, while no other technological solution can provide similar products. Other OLED application direction includes OLED TVs. In these devices the full-colour image is usually not generated by individual pixels, but by white OLED background and colour filter overlay, in order to simplify the production procedure. The current global OLED technology market is estimated at several tens of billions of euros, a large share of which is attributed to Korean technological giants Samsung and LG, who dominate mobile display and TV sectors.

Lighting devices are another application direction of OLED technology. In terms of power efficiency parameters well-optimised OLEDs can compete with state-of-art technological alternatives. Because OLEDs allow production of thin emissive surfaces, lighting objects with practically unrestricted geometrical shapes and sizes can be produced providing means for almost unlimited design possibilities. A combination of these factors has encouraged several manufacturers to explore this direction. Unfortunately, the current efforts have been unsuccessful due to large production cost of such devices. This is largely related to the fact that the generation of white light is often achieved by complex device architectures since all visible spectrum needs to be covered simultaneously. Outside of luxury lighting object market and automotive industry OLED lighting devices cannot compete with conventional alternatives. New technological solutions are needed to overcome this drawback.

Light-emitting molecules or in short emitters are the key components of any OLED. The recent advances in development of such materials have largely contributed towards the practical adoption of the technology. In simple terms every OLED consists of sandwiched organic material layers in the middle of which resides the light emitting layer incorporating light emitting molecules. When each side of the sandwich is connected to a power source (e.g., a battery) positive and negative charge carriers move from each side of the sandwich, until they meet in the middle. If both positive and negative charges are captured by a single emitting molecule then it assumes an excited state. When positive and

negative charges trapped by emitter recombine to return it to its initial state the energy excess is given back in a form of a light photon. This is the main working principle of any OLED, which allows transformation of electrical charge to visible light. The discovery of underlaying physical mechanisms behind the aforementioned process has allowed identifying specific subset of organic molecules which are suitable as emitters. Current selection of commercialised light-emitting molecules are dominated by phosphorescent organometallic complexes incorporating heavy transition metals, such as iridium of platinum. This poses a long-term problem for this industrial sector, as the mentioned metals are among the most expensive and rarest elements found in the Earth's crust. Because of this, in the recent decade, the focus of the scientific community involved in OLED development field has been largely focused on finding new light emitting molecules that would avoid the use of rare metals. One of such directions involves substation of expensive metals with cheaper and more abundant alternatives, such as copper. Through a carefully crafted molecular design alternative physical mechanism of light emission is enabled in these compounds switching form phosphorescence to thermally activated delayed fluorescence. In this process no loss of performance is observed in comparison to the aforementioned iridium and platinum complexes [1].

In a recent study our research group developed new structural derivatives of these copper based organometallic complexes, often called carbene-metal-amides (CMAs). We particularly focused on the carbene part of the compounds and introduced previously unexplored thiazoline heterocycle as the novel complexed organic ligand [2]. When incorporated into OLEDs, these compounds exhibited unusual behaviour, as the devices emitted white light instead of expected bluish-green colour. As the data showed, the origin of the white light was the emission from two different sources, one with bluish-green, other with orange colour. Since both these emission bands evenly cover almost whole visible spectrum, human eye perceives the resulting colour as white, making the devices suitable for lighting applications (Fig. 1). In addition, the constructed OLEDs exhibited excellent performance

Fig. 1
Photograph of an operational OLED device incorporating our developed emitters

characteristics with 16 % external quantum efficiency (a ratio between consumed electrons and emitted photons) and 40,000 cd m-2 maximum luminance.

Our following investigations unambiguously revealed the origin of this phenomena [3]. Due to the specific chemical structure of the thiazoline carbene fragment two separate molecules of the synthesised emitter can be located close to each other, to a point where electronic systems of individual molecules start to interact with each other and form a new light emitting species called a dimer. If we compare the emitted light of an isolated complex (monomer) and dimer, the first one covers spectral region in blue to green region, while the second gives light in yellow to red region. If the intensities of both species are equal, we get white overall emission. If the concentration of molecules in the emissive layer is large, more dimers form and emission turns orange-red. In the opposite case monomers dominate and bluish-green light is obtained.

From the point of a practical application potential this discovery provides means for much cheaper production of white OLEDs and as a result this could make OLED lighting devices more accessible to the general public. First, the corresponding thiazoline complexes are much less costly to synthesise as they contain copper as the complexing metal avoiding the use of more expensive transition metals. Second, the white emission in the devices is produced in a single layer by a spontaneous formation of monomer and dimer mixture. This allows

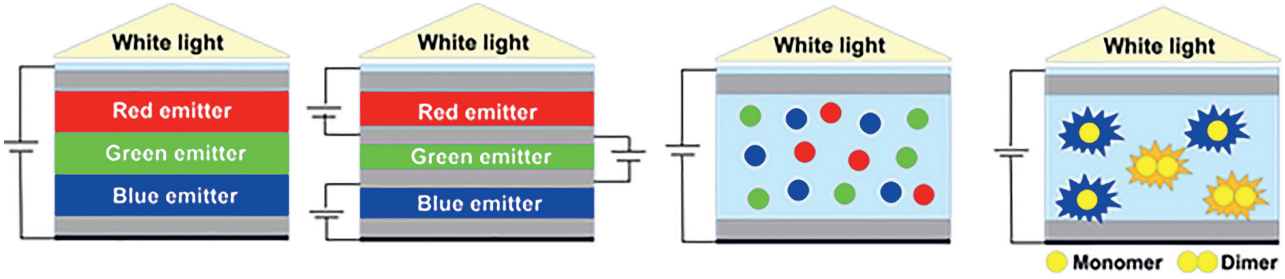

Fig. 2
Approaches towards construction of white OLEDs

construction of a simple one-layer emissive device, in contrast to much more complex designs that are currently used for manufacturing of OLED lighting devices. The current approaches to white emissive devices are outlined in Fig. 2. Most widespread is the multi stack design, where blue red and green (or blue and orange) emitting layers are placed on top of each other. The combined light from these layers creates a white emission. The drawback of this design is the highly complex production process. Most of the OLEDs are produced by vacuum deposition technique, where organic material is placed in a high-vacuum chamber then heated and sublimed on the substrate surface. This is time and energy consuming process and each additional layer adds complexity to an overall production cycle. If even one of the layers are defective, the whole device must be discarded, adding to manufacturing cost. In addition, the engineering of stack device is difficult as photophysical characteristics of each layer should be carefully tuned to achieve acceptable performance level. Alternative approach is based on a use of a single emissive layer that contains multiple emitting molecules each giving different colour. While theoretically simple, such approach has several drawbacks. To achieve white light, the layer should have highly precise individual emitter concentrations. Since the layers are created by vacuum deposition technique, concentration control is highly difficult. The molecules may also be distributed unevenly, negatively affecting the performance. In light of this, our presented approach overcomes all these drawbacks. White OLED can be prepared using only one emissive layer and multiple emission bands originate from a single compound, eliminating issues related to deposition process.

Lastly, the widespread adoption of OLED based lighting devices due to reduced production cost could revolutionise the related industrial sector by providing multiple innovative solutions. This could include production of lighting objects with very complex geometry and design, including large area light emitting wallpapers. In contrast to conventional lighting sources with fixed spectrum of emitted light, the colour of OLEDs can be changed. Such lighting sources could have potential therapeutic use as they can mimic natural cycle of Sun's daily spectral change, reducing the body stress caused by often blue colour rich conventional lightbulbs [4]. Such functionality was observed in our prepared OLEDs, where depending on applied voltage, the emitted spectrum of the devices could be changed from reddish to bluish-white.

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THE STRENGTH OF LATVIA FOR THE LONG-TERM DEVELOPMENT: THE CROSS-BORDER CONTEXT

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The collective scientific monograph, edited by a full member of the LAS, Baiba Rivža, *The Strength of Latvia for the Long-term Development* (2022, 480 pp., the scientific institutions represented: Latvian Academy of Sciences (LAS), University of Latvia (UL), Latvia University of Life Sciences and Technologies (LULST), Riga Stradiņš University (RSU) etc.) has been published based on the research results achieved within the project "Challenges for the Latvian State and Society and the Solutions in International Context (Interframe-LV)". Link to the monograph:
https://www.lza.lv/images/INTERFRAME-LV/The%20Strength%20of%20Latvia%20for%20the%20Long-term%20Development_170x240.pdf

TRENDS AND MAIN CHALLENGES IN THE CONTEXT OF EU SUSTAINABILITY GOALS

First of all, it should be highlighted that the project Interframe-LV and the monograph *The Strength of Latvia for the Long-term Development* produced within this project represent a success in maintaining the continuity of scientific research under insufficient funding conditions in Latvia, as scientific research is funded based on the research programme and project principle, and often any research that has started stops once the funding has ended. In the preface of the monograph, academician Ivars Kalviņš, president of the LAS, states that thanks to the project Interframe-LV and the monograph, it has been possible to successively continue interdisciplinary economic and social research projects implemented under the national research programme Ekosoc-LV (2014–2018) and administered by the LAS, yet with a new focus – sustainability in the international context. The sustainability of Latvia, i.e. the strength to exist and develop as an independent country for a long time, could be created together with other members of the European Union (EU).

The ability of scientists to flexibly reorient research activity under changing circumstances should also be emphasised as a success because when the project Interframe-LV began in 2019, there was neither a pandemic nor an anti-democratic full-scale invasion of Ukraine by the aggressor state Russia. Along with these events, however, new focuses entered research, incl. also the need to analyse the role of the Covid-19 pandemic as a driver of development and use of social and technological innovations (LBTU), as well as the successes and failures (RSU) of government support to businesses and residents at this stage. In Chapter I, its author, Eižens Eteris, examines sustainability policies implemented in the world and in Europe in the context of EU recovery and resilience measures in the Member States due to Covid-19 and in synergy with the sustainability goals, giving insight into also the financial resources available to the Member States for making changes. A research study and a paper produced based on it by Inna Šteinbuka and her co-authors (UL) on populism during the pandemic, which assessed the negative impact on the economy and fiscal policies and referred to Hungary as one of the examples, where populism continued at the level of state leadership at the expense of disregarding the basic principles and values of the EU.

Among the results of a review of scientific findings on economic and social developments, incl. the formation of a knowledge society, achieved at the previous stage (Ekosoc-LV), there is also a finding, which is prospective for rural areas in Latvia: the proportion of high-tech goods and knowledge-intensive services has increased faster in the rural areas than in the cities, yet the overall level was still low. The project Interframe-LV performed an in-depth examination of structural changes in the knowledge economy, aspects necessary for improvement, incl. digitalisation, especially in small and medium enterprises, public administration and the education system, as well as the creation of an innovation ecosystem (European Innovation Scoreboard 2021 rated Latvia only as a future innovator). Overall, the project Interframe-LV and the papers included in the monograph closely related to the EU sustainability policy, as well as the necessary improvements in the implementation of it in Latvia. The main topics are as follows: technological and social innovations, company digitalisation and digital competences of the public; the bioeconomy and the circular economy (the driver is progress in digitalisation) as part of green policies; population aging and stratification with the necessary improvement in the pension system, regional stratification prevention, the contribution of professional education to the reduction of inequality; risk management in business in the context of values and social security. According to research data, Latvia had a relatively large proportion of the population exposed to poverty (Fig. 1), a high tax burden on low-wage earners and income inequality, a pronounced lack of quality housing, many people had poor health, which together determined the low level of satisfaction of the population in comparison with that in other EU Member States.

REGIONAL FORUMS FOR PUBLIC AWARENESS AND FEEDBACK

For the dissemination of research findings and having public feedback, a cycle of five regional forums held during the project, which is presented in the monograph, was started by Ekosoc-LV and continued by Interframe-LV as one of the tested forms of best practice. In the forums held in four large regions of Latvia – Zemgale, Vidzeme, Latgale and Kurzeme – as well as in Pierīga, by the LAS in cooperation with regional universities, the central topic was digitalisation for supporting businesses, yet at the same time other issues relevant to each region were discussed. The first forums took place in person, whereas the last ones were held only remotely both because of the pandemic and because the newly gained experience in online digital communication was sufficient.

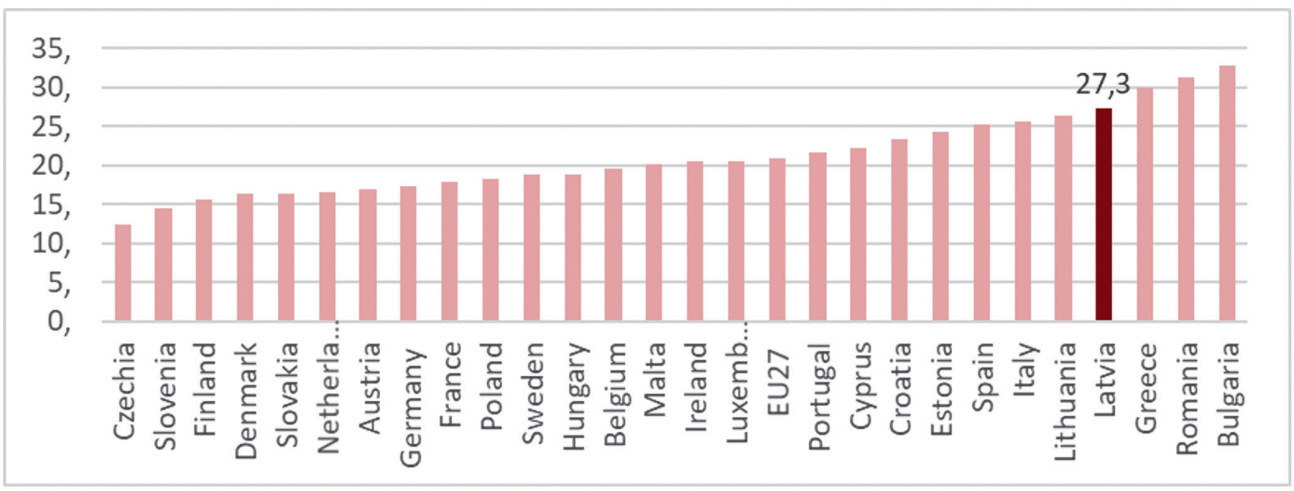

Fig. 1
Proportion of persons at risk of poverty and social exclusion, EU-27, 2019, %
Source: author's construction based on Eurostat (online data code: ILC_PEPS01)

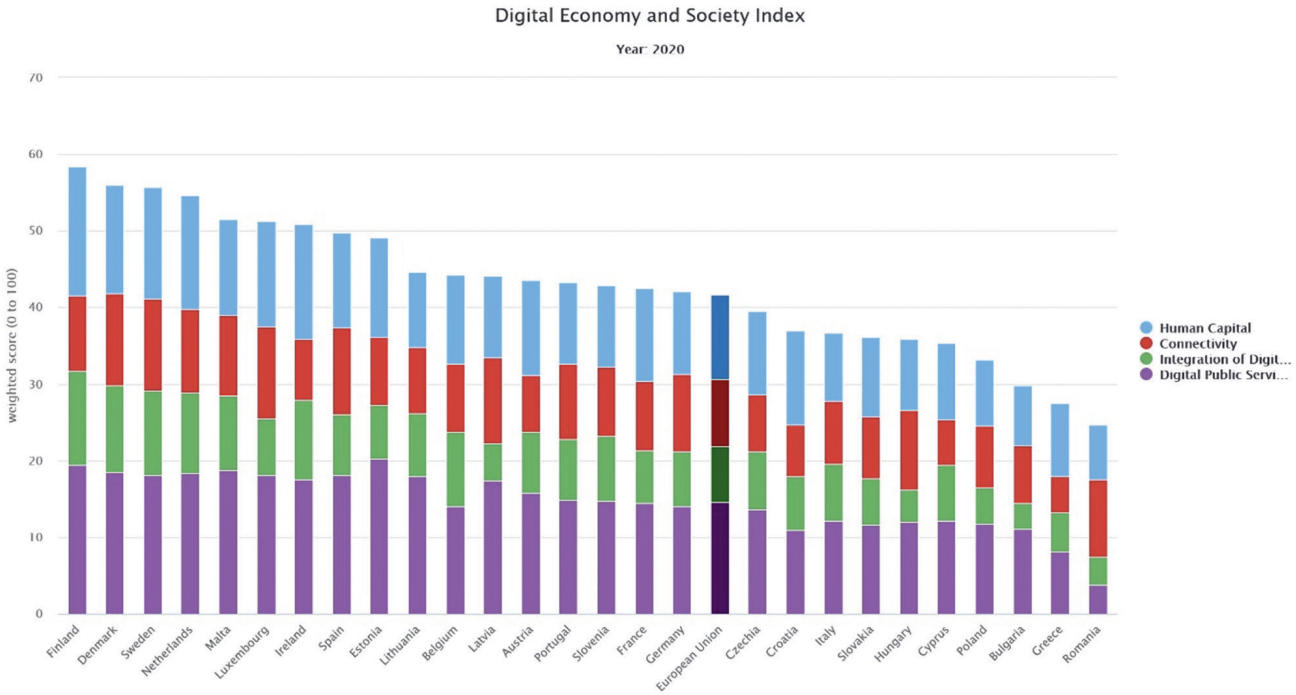

Fig. 2
Digital economy and society index scores for European countries in 2020
Source: European Commission, Digital Scoreboard data

Since LBTU researchers worked on the topic of digitalisation within the project Interframe-LV, each forum began with a presentation of the professor of this university, Baiba Rivža, about the digital environment, its characteristics and opportunities for business, incl. a comparison of Latvia's performance with that of the EU and the Baltic states based on the Digital Economy and Society Index (DESI) (Figure 2); and with an insight given by Professor Pēteris Rivža into trends in artificial intelligence (AI) and its integration in business. The great interest of the forum audience in these topics has allowed us to conclude that it is necessary to educate the population more broadly and intensively about technology issues, the objective needs of the 4th industrial revolution or Industry 4.0 (according to a definition by Klaus Martin Schwab) in the fields of education, the labour market, skills and competences, as also about the principles of the Green Deal and the circular economy.

Latvia is still at the 1st stage of the 4th industrial revolution, which features sensors, drones, big data, robots, the Internet of Things etc. The country has a well-developed technological infrastructure, yet it lags behind in the use of digital technologies by companies, i.e. business digitalisation, incl. Internet use for e-commerce (below the European average); human capital should be developed (lack of IT specialists) and the overall digital competence of the public should be improved, digital skills also include digital intelligence and digital discipline.

Among the conclusions and recommendations on the development of digitalisation and AI in Latvia are the following: innovative digital solutions should be created and adapted to specific needs by using the service design method; electronic service systems develop digital thinking; a digital platform is also inevitable for small businesses in order not to lag behind or stay in business; AI plays a big role in making human life easier; security risks should be reduced, incl. by users themselves by not being naive, not spreading redundant information and checking the information received; distance learning methods and approaches applied during the pandemic should be enhanced, combined methods should be used more; the development and use of digital solutions in the regions requires extensive further cooperation between regional businesses, municipal employees, scientists and academics.

At the regional forums, the unbalanced development of the regions, which created regional differences and all the consequences, was a hot topic; for example, residents left the region due to lower earnings. In the monograph, Gundars Bērziņš and Māris Pūķis and others (UL) analysed regional stratification at different scales; in the opinion of public administration in Latvia, both belongingness to regions of several sizes and division into regions of several sizes, from the EU to Latvian municipalities of different levels, are essential. In such a context, Latvia, as one of the 27 EU Member States, belongs both to the third largest economy (behind China and the USA) and to peripheral EU Member States, which are characterised by lower levels of health, education, prosperity etc. The EU Cohesion Policy has made a contribution, yet the indicators have not yet reached the average EU level, although there has been progress. Problems also arise for Latvia as an EU border country because the politicians of Latvia's neighbouring countries – Russia and Belarus – violate human rights, basic municipal rights and international agreements. Consequently, the citizens and businesses of Latvian municipalities have to pay for the EU policy of defending democracy – the makers of global politics do not come to the rescue. Likewise, an increase in centralisation in the EU regarding various fields leads to the fact that national parliaments and governments increasingly intervene in issues that are naturally resolved by local governments.

The significant regional stratification within the country is therefore also influenced by external factors. The authors have concluded, based on several indicators, that Latvia is the most monocentric EU Member State, as huge differences have emerged between the Riga metropolitan region and the rest of the country. The data for Riga and nearby Pierīga indicate that one-third of the country's population lives in this area, contributing to two-thirds of the products produced and resources, which leads to significant differences in the available human capital, financial capital and social capital, while the opportunities of natural capital are not fully used. The regional stratification emerges on a complex and large scale and could be solved in this way.

ACHIEVING HUMAN RESOURCES DEVELOPMENT GOALS WITHIN THE PROJECT – EIGHT NEW DOCTORS OF SCIENCE

Interframe-LV as a multi-year project has given doctoral students an opportunity to produce and defend their doctoral theses: eight doctoral theses have been produced for obtaining a doctoral degree (PhD). At the same time, young scientists deal with topics important for the development of the economy and society. Below is an overview of the topics of the doctoral theses and the scientific and economic significance thereof.

Ina Gudele. *Analysis of Electronic Commerce Use Factors in the Sector of Regional Small and Medium Sized Enterprises in Latvia* – the author analysed factors in e-commerce development and the impact on business, the legal framework for the use of e-commerce in business, factors in the development of e-commerce in regional SMEs in Latvia, designed scenarios, developed recommendations for the national and local governments and non-governmental organisations for the promotion of e-commerce and therefore economic development of the regional SME sector.

Zaiga Oborenko. *Analysis of Factors Influencing the Employment of People with Disabilities in Latvia* – the author examined factors in the employment of people with disabilities in Latvia, calculated annual GDP unproduced in 2010–2020 due to the unemployment of such people, developed a formula for calculating the GDP unproduced by unemployed working-age persons with disabilities and calculated the lost GDP of Latvia per year in 2017–2019, assessed disability management factors in a company, designed cooperation scenarios for the stakeholders interested and involved in the employment of people with disabilities in order to promote the employment and inclusion of people with disabilities in the labour market in Latvia.

Ligita Āzena. *Territorial Competitiveness For Smart Business Development In Pieriga Region* – the author summarised the main criteria for a territory's competitiveness and the connection with the development of smart businesses, performed an analysis of the smart economy and smart business indicators for Pierīga region, identified the most appropriate

criteria for assessing the development of smart businesses and the competitiveness of Pierīga region, as well as developed a competitiveness assessment matrix and recommendations for the development of smart businesses in Pierīga region.

Dace Štefenberga. *Innovative Entrepreneurship in the Economic of Region* – the author justified the role of innovation as a driver of change in the economy of a region, developed a system approach model for cooperation in the implementation of innovations at the individual–institutional level at various scales, tested the model in the regional context in Kurzeme region, identified factors in regional business: geographical proximity between companies and cooperation between the components of the regional innovation system.

Ilze Priževoite. *Remuneration and Performance of Teachers of General Education Institutions in the Regions of Latvia* – the author examined labour supply and demand problems at the macro, micro, and regional levels, factors in the performance of teachers in the regions of Latvia, the procedure of funding teacher salaries in Latvia, incl. in the regions, identified a relationship between remuneration and performance, proving that teacher remuneration is a motivating or demotivating factor in their performance.

Eduards Lielpēters. *Opportunities and Limitations of Digital Democracy in Latvia* – the author analysed opportunities for and limitations on improving the business environment along with the advantages of digital democracy for residents to participate individually in the decision-making process, as well as proved that national administrative institutions should change the current downward and informative form of communication to a more open and two-way communication, so that the improvement in the business environment could be achieved with the participation of residents.

Aija Pilvere. *Stock Market Improvement Opportunities for the Development of the Baltic States* – the author performed an analysis of and developed recommendations on how to enhance scientific research on the financial performance and capital structure of companies included in the stock exchange lists; theories on capital structure, except for an attempt to identify an optimal capital structure or factors therein, provide no detailed analysis of such a large number of companies, which links the factors in capital structure to all the three parts of financial statements of companies: a) balance sheet, b) profit or loss statement, c) cash flow statement.

Natālija Kostrikova. *Opportunities for Blockchain Technology Adoption in the Economy of Latvia in the Context of Baltic States Region* – it is the first doctoral-level research study on the topic of blockchain technology in Latvia; the international research base was also supplemented with a unique research study on factors in the implementation of blockchain technology for economic development, as well as potential blockchain innovations and their implementation in the national economy.

SCULPTURAL ENSEMBLE "GATES OF LIGHT" – DEDICATED TO ACADEMICIAN JĀNIS STRADIŅŠ, IN HONOUR OF GOTTHARD FRIEDRICH STENDER AND ENLIGHTENMMENT

A SYMBOL OF LATVIAN STATEHOOD, SCIENCE, EDUCATION, CULTURE AND THE FUTURE OF THE SĒLIJA REGION IN LATVIA

PĒTERIS STRADIŅŠ
PhD, Stender Society; Riga Stradiņš University; Pauls Stradiņš Clinical University Hospital; University of Latvia

The assembled works of art have been inspired by reference to Light of the Spirit, which has been stored up for future generations from the time of Pastor Gotthard Friedrich Stender (1714–1796) and which academician Jānis Stradiņš (1933–2019) has richly augmented during his lifetime for the benefit of his contemporaries.

After the passing away of academician Stradiņš (in 2019), the idea was advanced to add a spatial display of artwork in Sunākste parsonage park, which sculptures would encourage visitors to appreciate the importance of education, science, and culture in the collective intellectual development of our nation and also for individual personal advancement.

Although the parsonage itself has not survived, nevertheless, the site enjoys symbolic importance in the cultural history of the Sēlija region and Latvia at large. During the period of the Enlightenment, the theologian Gotthard Friedrich Stender, or Old Stender (1714–1796), lived and worked in Sunākste for a part of his life; today he is seen as an outstanding personality with broad interests in philology, natural sciences, and the philosophy of religion. G. F. Stender played an important role in the history of Latvian literature, starting with the publication of the first illustrated ABC's to the beginnings of linguistics and Latvian secular literature. His efforts to educate Latvian serfs by writing a popular science encyclopaedia in the Latvian language, *The Book of High Wisdom from the World and Nature* are highly appreciated.

Jānis Stradiņš and Gotthard Friedrich Stender shared curiosity, versatility, and an ability to inspire followers – qualities that characterise the values of the Enlightenment. The Stender and Stradiņš families also have shared a history through the ages. The Stender family served in the parish of Sunākste, in which parish wherein Pauls Stradiņš, father of Jānis Stradiņš also served, evidently at a much later time. At the beginning of the Third Awakening in Latvia, Jānis Stradiņš became actively involved in public life and contributed to the restoration of Latvian independence, given the strength of his spirit; he became the initiator and promoter of the idea of revival of Sēlija region. Jānis Stradiņš was a chemist by profession and headed the Physical and Organic Chemistry Laboratory at the Institute of Organic Synthesis in Riga. Nevertheless, the history of science and culture became for him a personal passion, which gave rise to many articles and books, including one on the merits of the work of Old Stender.

The sculptural ensemble "Gates of Light" by sculptor Ojārs Arvīds Feldbergs has a multidimensional character and its composition can be read as a universal sign. The horizontal circular structure of this sign is formed by the four-part plan, in the centre of which there sits a polished granite column symbolising light. Beams of light from this column, in

the form of granite plates, reach out to four sides. The force of light transfixes a huge boulder splitting it into four parts, creating four pylons, whose symbolic meaning can be interpreted in different ways. They encode the four cornerstones of national identity – education, science, culture, and statehood – and at the same time the four primordial elements of nature, the four sides of the sky, the four seasons, or the four stages of human life, offering the visitors the opportunity to create their own stories based on personal experience. At the same time, the composition of the ensemble also features the cross, which can be found in the symbolism of the Christian Church and in ornaments adopted by many nations world wide. The exterior of the stone pylon is rough, but the inner planes are polished with light, both literally and abstractly, creating an open space where everyone is invited to enter and feel the power of light of the spirit that has been gathered since the time of Old Stender, and that Jānis Stradiņš so generously shared during his lifetime.

Everyone can be the bearer of light of the spirit. The wider the gates of light are open, the further the beam of light is able to shine. Similarly, the ideas of enlightenment have come to Latvia from Europe via Sēlija, through the life and work of Old Stender and that of Jānis Stradiņš to the present day. One beginning was the parsonage in Sunākste, where, encouraged by Old Stender, Latvian peasants learned to understand the world so that future generations would grow in strength of spirit, and later be able to establish their own country. We must take care to increase this light of wisdom so that Latvia in the future can boast of brilliant minds and scientific achievements.

We believe that the "Gates of Light" will not be unchanging, but rather a forum able to accumulate the power of light of the spirit and also provide energy for the future, encouraging everyone to think about individual development and participation in development of our land and country.

The sculptural ensemble "Gates of Light" by sculptor Ojārs Arvīds Feldbergs was inaugurated on 9 September 2023.

ABOUT THE SCULPTOR OJĀRS ARVĪDS FELDBERGS

The method of this artist may be characterised by reference to the thoroughness of the Latvian school of sculpture as well as glorification of stone – an essential feature of Latvia's landscape. His sculptures activate emotions and allow the viewer to become more aware of himself as a part of both nature overall and his own land.

Translated by **Eduards Bruno Deksnis**

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