European Research Studies Journal
Volume XXIV, Special Issue 1, 2021

pp. 1049-1073

Development of Innovation Cooperation in the Time of COVID-19 Pandemic

Submitted 28/12/20, 1st revision 25/01/21, 2nd revision 01/03/21, accepted 20/03/21

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Abstract:

Purpose: *The aim of the article is to present the development of new partnerships and R&D alliances in the time of COVID-19 pandemic.*
Design/Methodology/Approach: *The main method applied in this research was the scientific study. Descriptive, comparative, documentation and desk research methods were used. Additionally, the authors used the methods of deductive and inductive forecasting.*
Findings: *The authors present new partnerships undertaken by biopharma (biotech and pharma) companies (in and outside the industry) in order to face pandemic and to discover and deliver a new vaccine for SARS-CoV-2 to the market. In addition, the research projects in the European Union focused on the development of diagnostics, treatments, vaccines, epidemiology, preparedness and response to outbreaks, socioeconomics, production and digital technologies as well infrastructures and data resources that make it possible this research will be presented.*
Practical Implications: *It should be taken into consideration that due to the current situation caused by pandemic the cooperation of companies and all entities in the whole biopharmaceutical R&D innovation ecosystem is even more challenging than before COVID-19. Biopharma–university alliances can significantly increase the likelihood of creating better medical therapy for patients.*
Originality/value: *Results of this cooperation enable a number of innovative projects given the significant pressure on innovativeness and challenges caused by the pandemic.*

Keywords: *COVID-19 pandemic, innovation cooperation, open innovation, open innovation alliances, R&D alliances, business-academia alliances, biopharmaceutical industry, patient care, ECMO.*

JEL codes : *031, 032, 033.*
Paper Type: *Research article.*

Acknowledgement: *This paper includes findings from the research project financed by the research grant of the National Science Centre (Poland) awarded based on the decision no. DEC-2015/19/D/HS4/00414 and project awarded funding from a POWER competitive national grant no. POWR.05.04.00-IP.05-00-006/18 by the Polish Ministry of Health.*

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1. Introduction

Analysing the development of cooperation of biopharmaceutical (biotech and pharma) companies with universities we can observe these relations for many years, starting with individual, single projects, from small research projects to large clinical trials. Later the companies developed alliances with individual academic institutions, including a wider range of cooperation, through research programs, clinical trials, and translational research. Companies also increasingly began to apply different models of R&D alliances, from individual links in research projects to multilateral agreements involving multiple research projects, including various models for open innovation (Chesbrough, 2003). According to the latest definition by Chesbrough open innovation is "*a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with each organization's business model*" (Chesbrough, Bogers, 2014, p. 17). This concept can be realized in bilateral and multilateral alliances. Open innovation model in comparison to traditional alliances is more dynamic because partners in alliance are not identified in the conventional, purposeful way.

Cooperation is focused more on the exchange of knowledge and ideas during the period preceding the creation of the alliance. Open innovation alliances are aimed at supporting the free flow of knowledge and ideas leading to the creation of partnerships focused not only on joint innovation, but also at risk and profit sharing (Wilks and Prothmann, 2012). The results of research on open innovation have shown how firms are managing both the inflows and outflows of knowledge and how they are searching for partners and the innovations they provide (Culpan, 2014; West, 2014; Chesbrough, 2019). We can also observe how companies in specific industries (like biopharma) use the model of open innovation to establish open innovation alliances not only with firms from the same or other industry but also with universities, individuals, communities, or other organizations (Wilks and Prothmann, 2012; Deloitte, 2017).

It should be considered that the organizational fluidity of open innovation initiatives as well as multiparty relations increase the complexity in the alliance management but at the same time increase the innovation potential. The use of open innovation model can significantly speed up the production process of new drugs and vaccines, which are in demand on the market because of COVID-19 pandemic (Chesbrough, 2020a). More interdisciplinary academic teams can also accelerate and support this process (Wilks and Prothmann, 2012). Open innovation was implemented by companies in several ways, including innovations for users, crowdsourcing, creation of joint development alliances or through building innovative ecosystems (Wilks and Prothmann, 2012; Deloitte, 2017; Hanson, 2015; Puślecki, 2015; 2016; Puślecki and Staszków, 2015).

The main aim of the article is to present the development of new partnerships and R&D alliances in the time of COVID-19 pandemic. The authors will present new

partnerships undertaken by biopharma companies (in and outside the industry) to face pandemic and to discover and deliver a new vaccine for SARS-CoV-2 to the market. In addition, the research projects in the European Union focused on the development of diagnostics, treatments, vaccines, epidemiology, preparedness and response to outbreaks, socioeconomics, production, and digital technologies as well infrastructures and data resources that make it possible this research will be presented.

It should be taken into consideration that due to the current situation caused by pandemic the co-operation of companies and all entities in the whole biopharmaceutical R&D innovation ecosystem is even more challenging than before COVID-19. Biopharma–university alliances can significantly increase the likelihood of creating better medical therapy for patients. In addition to partnerships within the industry, biopharma companies develop alliances with universities or research institutes as well as more often cross-industry alliances and public-private partnerships.

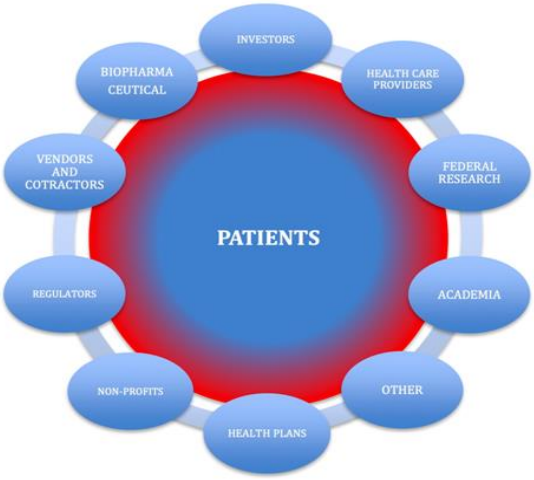
Results of this cooperation enables several innovative projects and allows significant synergy effects given the significant pressures on innovativeness and challenges caused by pandemic of coronavirus SARS-CoV-2. The main method applied in this research was a method of scientific study. Descriptive, comparative, documentation and desk research methods were used. Additionally, the authors also used the methods of deductive and inductive forecasting.

2. Boosting Innovation in the Biopharmaceutical R&D Innovation Ecosystem

Innovation cooperation developed in biopharmaceutical R&D ecosystem enables important scientific breakthroughs in novel diagnostic technology and the definition of molecular targets for the development of personalized medicines. These advances have an impact on the current development of new drugs in the time of COVID-19 and improvement of medical care. Biopharmaceutical companies involved in cooperation can develop targeted therapies and drugs needed to treat serious diseases and unmet medical needs (Deloitte, 2017; Gomes-Casseres, 2014; Chesbrough, 2020b) and have better innovation cooperation performance (Trąpczyński, Puślecki, and Staszków, 2018). The biopharmaceutical R&D ecosystem is composed of a varied group of stakeholders (Figure 1) and makes it possible for them to achieve together that which would be difficult acting as an individual entity.

In the R&D ecosystem biopharma companies are responsible for two functions – they are contributors as well as integrators of the ecosystem. They gather diverse stakeholders offering distinct characteristics and contributions with a common goal of improving patient health outcomes. Patients are positioned as hub at the ecosystem as both key participants in driving patient-centered innovation and as the recipients of the value created as a result of cooperation in ecosystem (Deloitte, 2017).

Figure 1. *Illustrative biopharmaceutical R&D innovation ecosystem*



Source: *Own elaboration based on (Deloitte, 2017, p. 11).*

3. Growing Diversity of Partners in R&D Cooperation – COVID-19 Vaccines Projects

Analyzing examples of partnerships in biopharmaceutical industry we can observe different modes of cooperation, R&D alliances, open innovation alliances, public-private partnerships, consortia, pharma-university alliances, cross-industry alliances (especially with IT industry) as well as different entities involved in cooperation including governments, universities and research institutes, foundations, funds, banks, and organizations. As multiparty alliances these partnerships require even greater competencies and skills of alliance managers and appropriate alliance management tools.

Thanks to significant synergy effects participation in R&D Innovation Ecosystem enables the partners accessing the huge innovative potential and more market opportunities, which helps them to innovate, accelerate growth and expand into new promising markets (Fraser, 2014; Burke, 2020; De Man, 2018; De Man, Koene, and Ars, 2019; De Man, 2020; De Man and Luvinson, 2019).

Taking into consideration current challenges impacting the biopharmaceutical R&D environment - COVID-19 pandemic, development of collaborative relationships can help partners in obtaining scientific and technological advances and offer new innovations like new vaccines and drug to patients faster (Table 1). Potential vaccines, like drugs must pass through clinical trial stages. It is important when it comes to safety, even during COVID-19 pandemic. Currently scientists are testing 50 candidate vaccines in clinical trials in people. Additionally, 150 candidate vaccines are in preclinical development, including animal and laboratory testing. In China and Russia

six vaccines have been given limited or early approval (before the completion of phase 3 clinical trials), which has raised some concerns about safety (Healthline, 2020).

Table 1. *Ongoing Covid-19 Vaccine Projects*

Name/Partners	Description	Results
Moderna/ National Insitutes of Health	The company began testing its two-dose messenger RNA (mRNA) vaccine in March 2020 in a phase 1 clinical trial, with promising results. In late July 2020, Moderna began phase 3 clinical trials of the vaccine.	In mid-November 2020, Moderna officials reported that their vaccine had achieved an effective rate of **94 percent** in initial phase 3 trial results. Experts said more testing and more information is needed.
Pfizer / BioNTech / Fosun Pharma	Drugmaker Pfizer teamed up German biotech company BioNTech and Chinese drugmaker Fosun Pharma to develop a two-dose mRNA vaccine.	On November 9, 2020, the company announced that its vaccine had been more than **90 percent** effective in clinical trial participants. A few days later, company officials announced they were applying for an emergency use authorization from the FDA for their vaccine. It was the first regulatory approval in the United States for a COVID-19 vaccine. The officials said the vaccine could be available to high-risk groups as early as mid-December 2020.
Johnson & Johnson	Drugmaker Johnson & Johnson announced in late July 2020 that it had begun a phase 1/2 trial in people after their adenovirus vaccine had shown promising results when used in monkeys.	In mid-November, Johnson & Johnson officials say they expected their vaccine to be ready for FDA approval by February 2021.
AstraZeneca/ University of Oxford	A phase 1 clinical trial at the University of Oxford began in late April. The vaccine is based on a chimpanzee adenovirus, which shuttles coronavirus proteins into cells.	In August 2020, AstraZeneca began phase 3 trials in Brazil, South Africa, and the United States. These trials were halted in September when a study volunteer developed a rare spinal inflammatory disorder called transverse myelitis. The trials were restarted a week later in Brazil and the United Kingdom. In late October, the FDA authorized the U.S. trial to resume. In mid-November 2020, company officials said their vaccine had produced a strong immune response in a clinical trial that involved people over the age of 70.
INOVIO	When COVID-19 appeared in December 2019, drugmaker Inovio had already been working on a DNA vaccine for MERS,	Company officials announced at the end of April 2020 that it had enrolled 40 healthy volunteers in its phase 1 trial. In late September 2020, the company

	which is caused by another coronavirus. This allowed the company to quickly develop a potential COVID-19 vaccine.	announced that its phase 2/3 trial is on hold as the it responds to the FDA's questions about the study.
Sanofi / Translate Bio.	Drugmaker Sanofi announced in February that it would work with Translate Bio to develop an mRNA vaccine. Preclinical testing showed that the vaccine could elicit a strong immune response in mice and monkeys.	The company expects results from its phase 2 trial in early December 2020. After that, they will start a phase 3 study.
Sanofi / GSK / TranslateBio	Drugmaker Sanofi is pursuing two vaccines. The company is working with drugmaker GSK on a vaccine based on proteins from the coronavirus. When combined with another compound, called an adjuvant, the proteins elicit an immune response.	They expect results from a phase 2 trial in early December 2020, after which they will begin a phase 3 study. Sanofi is also working with biotech company Translate Bio to develop an mRNA vaccine. They expect to start clinical trials in December 2020.
CanSino Biologics	Scientists at this Chinese company are also working on a potential vaccine that uses an adenovirus known as Ad5 to carry coronavirus proteins into cells.	The Chinese military approved the vaccine in June 2020, allowing the vaccine to be given to its armed forces. In August 2020, the company began phase 3 trials in Pakistan, Saudi Arabia, and Russia.
Gamaleya Research Institute	This Russian institute developed a vaccine that includes two adenoviruses, Ad5 and Ad26.	In August 2020, President Vladimir Putin announced that the country's regulatory agency had approved the vaccine, even before phase 3 trials had started. Russian officials later said the vaccine had received a "conditional registration certificate." Results of a phase 1/2 trial found that the vaccine elicited an immune response with mild side effects. Phase 3 trials are currently under way in Russia, Belarus, United Arab Emirates, and India.
Novavax	This company received up to $388 million in funding this spring from the Coalition for Epidemic Preparedness Innovations (CEPI), a group that has funded COVID-19 vaccine development. The vaccine is made by attaching virus proteins to microscopic particles.	In August 2020, Novavax launched a phase 2 trial in South Africa. A month later, the company began a phase 3 trial in the United Kingdom. It plans to start another phase 3 trial in the United States by the end of November 2020.
University of Queensland in Australia / CSL	Researchers at the university developed a vaccine by growing viral proteins in cell cultures. They began preclinical testing stages in early April 2020.	The phase 1 trial in people began in early July 2020. A phase 2/3 trial is expected to start late in 2020.

Wuhan Institute of Biological Products / Sinopharm	Chinese company Sinopharm is testing an inactivated virus vaccine developed by the Wuhan Institute of Biological Products.	After a successful phase 1trial, researchers launched phase 3 trials in the UAE in July 2020 and a month later in Peru and Morocco.
Beijing Institute of Biological Products / Sinopharm.	Sinopharm is testing a second inactivated virus vaccine developed by Beijing Institute of Biological Products.	Phase 3 trials began in June 2020 in the UAE and in September 2020 in Argentina. In September 2020, the UAE approved the vaccine for use on healthcare workers even before the results of the phase 3 trials.
Sinovac Biotech	This Chinese company launched phase 3 trials of its inactivated virus vaccine in Brazil in July, Indonesia in August, and Turkey in September 2020.	In August 2020, the Chinese government issued emergency approval for the vaccine for use on high-risk groups.
Bharat Biotech / Indian Council of Medical Research / Indian National Institute of Virology	The Hyderabad-based company has been developing the vaccine, Covaxin, in collaboration with the Indian Council of Medical Research (ICMR) – India's premier medical research body.	Indian company Bharat announced in late October 2020 that it was beginning a phase 3 trial of its inactivated virus vaccine.

Source: *Own elaboration (state as of 8th December 2020).*

4. Growing Diversification of Partners - COVID-19 Research Projects in the European Union

Due to the challenges caused by COVID-19 pandemic we can also observe the development of new research Horizon 2020 projects **(**the EU's research and innovation programme)in the European Union on coronavirus diagnostics and treatments taking into account following categories: clinical management and treatment, vaccines, preparedness and crisis management, health system resillence, basic science, including biology of SARS-Cov-2 virus, diagnosis, as well as public health measures (161 projects) (Table 2) and other non-specific COVID-19 Horizon 2020 projects reoriented to fight the COVID-19 emergency (842 projects) (Table 3).

Table 2. *Covid-19 Horizon 2020 projects according to major needs by EU financial contribution.*

Category	Number of projects	Funding (million euro)
Clinical management and treatment	45	EUR 118.9
Vaccines	4	EUR 108.2
Preparedness and crisis management	25	EUR 78.2
Health system resilience	27	EUR 48.5
Basic science, including biology of SARS-Cov-2 virus	24	EUR 38.2
Diagnosis	25	EUR 36.3
Public health measures	11	EUR 12.3

Source: *Own elaboration.*

Table 3. *Distribution of other non-specific COVID-19 Horizon 2020 projects reoriented to fight the COVID-19 emergency according to major needs (number of projects per category).*

Category	Number of projects
Preparedness and crisis management	234
Clinical management and treatment	231
Basic science, including biology of SARS-Cov-2 virus	225
Health system resilience	47
Public health measures	42
Diagnosis	36
Vaccines	27

Source: *Own elaboration.*

Dedicated calls for proposals for COVID-19 funding in 2020 have so far attracted nearly 700 partners in EU-funded projects from the Member States and beyond. Most of the participants are in Germany, Italy, France, Spain, Great Britain, the Netherlands and Belgium (433 participants). Scientists from the countries associated with the Horizon 2020 program are located in Albania, Bosnia and Herzegovina, Israel, Norway, Serbia, Switzerland and Turkey. In terms of cooperation partners, higher or secondary education (mainly universities) together with research organizations (Table 4) accounted for the majority of the participations of EU-funded COVID-19 projects, followed by private entities, 67% of which were SMEs (Table 5) (European Commission, 2020a).

Table 4. *Top 10 participants in COVID-19 Horizon 2020 Projects – by EU financial contribution (million euro).*

Participants in COVID-19 Horizon 2020 Projects		EU financial contribution
1	Insem	EUR 22.9
2	UNINOVA – Instituto de Desenvolvimento de Novas Technologicas-Associacao	EUR 5.0
3	Universidad Politechnica de Madrid	EUR 4.9
4	Academisch Ziekenhuis Leiden	EUR 4.6
5	Karolinska Institutet	EUR 4.4
6	Centre hospitalier universitaire vaudois	EUR 3.8
7	AVA AG	EUR 3.8
8	Universiteit Utrecht	EUR 3.6
9	Laboratorio Iberico Internacional de Nanotecnologia	EUR 3.5
10	Goethe-Universitat Frankfurt am Main	EUR 3.3

Source: *Own elaboration.*

Table 5. *Top 10 SMEs in COVID-19 Horizon 2020 Projects*

SMEs in COVID-19 Horizon 2020 Projects		EU financial contribution
1	AVA AG (Switzerland)	EUR 3.8
2	Remedy Biologics Limited (Ireland)	EUR 2.5
3	Onera BV (Netherlands)	EUR 2.5
4	SwissDeCode SA (Switzerland)	EUR 2.5
5	Resistell AG (Switzerland)	EUR 2.5
6	NanoScent Ltd (Israel)	EUR 2.5

7	Ventinova Medical BV (Netherlands)	EUR 2.5
8	Osivax SAS (France)	EUR 2.5
9	COVID-19 TELEMEDICINE ApS (Denmark)	EUR 2.4
10	Kahun Medical Ltd (Israel)	EUR 2.4

Source: *Own elaboration.*

Below you can find description of 8 research projects financed by the Innovative Medicines Initiative (IMI) (EU's partnership with the pharma industry) with the total amount of EUR 72 million (IMI, 2020)selected for funding from its fast-track call for proposals on coronavirus and diagnostics treatments in May 2020 (Table 6) as well as 41 projects financed by the European Commission (European Commission, 2020b, 2020c) in Horizon 2020 in March 2020 (Table 7) and August 2020 (Table 8). Up till September 2020, the EU has already invested EUR 458.9 million from in 103 Horizon 2020 research projects specifically targeting the COVID-19 pandemic (not including loans from the Horizon 2020 InnovFin Infectious Diseases Finance Facility or the EUR 5.9 million top-up to projects funded from non-COVID-19 calls). These research projects are focused on the development of diagnostics, treatments, vaccines, epidemiology, preparedness and response to outbreaks, socioeconomics, production and digital technologies as well as the infrastructures and data resources that enable this research (IMI, 2020; European Commission, 2020a; 2020b; 2020c).

Table 6. *Innovative Medicines Initiative Projects (8 projects selected for funding from its fast-track call for proposals on coronavirus diagnostics and treatments).*

Acronym/ Title	Description	Project coordinator	Partners
Total IMI funding: € 72 million			
DIAGNOSTICS			
COVID-RED - COVID-19 infections - remote early detection	Could digital technologies help to detect COVID-19 cases? The COVID-RED project thinks so – it will combine expertise in clinical epidemiology with digital devices (such as wearables and mobile apps) to rapidly and reliably detect cases so that they can be prioritised for testing.	Universitair Medisch Centrum Utrecht, the Netherlands	9 partners from Denmark, Lithuania, the Netherlands, Switzerland, United Kingdom
DECISION - A minituarized disposable molecular diagnostics platform for combatting coronavirus infections	The DECISION project hopes you won't have to wait more than 15 minutes. They're working on a low-cost, miniaturised, disposable molecular diagnostic system that will make it possible to test patients with laboratory quality performance pretty much anywhere and give them their results in a matter of minutes.	4 partners from Germany, Italy, Spain	4 partners from Germany, Italy, Spain
DRAGON - Rapid and secure AI imaging-based diagnosis,	If you've been tested for COVID-19, you want to get your results fast The DRAGON project will apply artificial intelligence and machine learning to deliver a decision	Oncoradiomics, Belgium	21 partners from Belgium, China, Italy, the Netherlands,

stratification, follow-up, and preparedness for coronavirus pandemics	support system for improved and more rapid diagnosis and prognosis. Citizens and patients will be involved in the development of the system.		Switzerland, United Kingdom
KRONO - Evaluation of a production ready portable, point-of-need platform (instrument and reagents), direct from nasal swab test for the molecular diagnostic detection of COVID-19 infection.	The KRONO project aims to change that by delivering a simple test that can be used at a doctor's office or a patient's home (for example) and would deliver results in just 40 minutes. While the focus of the project is on the SARS-CoV-2 virus, the team also plans to demonstrate a pipeline for rapidly deploying new tests in response to future outbreaks.	BG Research Ltd, United Kingdom	5 partners from France, Italy, United Kingdom
RAPID-COVID - Robust automation and point of care identification of COVID-19	While the world focuses on COVID-19, other infectious diseases with similar symptoms continue to circulate. The RAPID-COVID project aims to develop a diagnostic test that can simultaneously detect SARS-CoV-2 as well as 30 other common respiratory bacteria and viruses. This will ensure COVID-19 patients are quickly isolated and all patients receive the right treatment. It will also avoid the unnecessary use of antibiotics.	GeneFirst Limited, United Kingdom	5 partners from France, Slovenia, Spain, United Kingdom
TREATMENT			
CARE – Corona accelerated R&D in Europe	The goal of the CARE project is to deliver treatments for the current COVID outbreak as well as future coronavirus outbreaks. To do this, they will identify candidates among existing drugs that could be effective as treatments for the COVID-19 pandemic (drug repurposing), and develop new drugs specially designed to tackle the SARS-CoV-2 virus. After extensive testing in the laboratory, the project will advance the most promising drug candidates to clinical trials in humans.	Institut National de la Santé et de la Recherche Médicale (INSERM), France	36 partners from Belgium, China, Denmark, France, Germany, the Netherlands, Poland, Spain, Switzerland, United Kingdom, United States
Impentri – Development of Impentri, an intravenous imatinib	Many people with severe COVID-19 infection experience a build-up of fluid in the lungs, making it hard to breathe and, in the worst cases, contributing to the death of the	Exvastat (Ireland) Limited, Ireland	5 partners from Canada, France, Ireland, the Netherlands

formulation for COVID-19 acute respiratory distress syndrome (ARDS)	patient. The body's own immune response is partly responsible for this build-up of fluid. There are signs that the generic drug imatinib could address the problem, and now the Impentri project plans to run a randomised, double-blind clinical trial to properly test the efficacy and safety of the drug as a treatment for COVID-19 patients with lung inflammation.		
MAD-CoV 2 - Modern approaches for developing antivirals against SARS-CoV 2	The aim of the MAD-CoV 2 project is to dive into the molecular details of the SARS-CoV-2 virus and use this knowledge to develop new COVID-19 treatments. Achieving this will entail engineering human tissue to test new treatments in the lab; studying how to exploit the role of the ACE2 receptor (which the virus latches onto to break into cells), and mapping factors that are critical for virus replication.	Statens Veterinaermedicinska Anstalt, Sweden	9 partners from Austria, France, Germany, Spain, Sweden, United Kingdom

Source: *Own elaboration based on (IMI, 2020).*

Table 7. *18 Horizon 2020 research projects on coronavirus short-listed for funding in March 2020.*

Acronym/ Title	Description	Project coordinator	Partners
PREPAREDNESS AND RESPONSE – Total **EU funding**: € 19.1 million			
I-MOVE-COVID-19 Multidisciplinary European network for research, prevention and control of the COVID-19 Pandemic	To obtain epidemiological, clinical and virological information on coronavirus and infected patients through the I-MOVE surveillance network spanning 11 countries.	Epiconcept (France)	25 partners: Albania, Germany, Spain (5), France (5), Ireland, Lithuania, the Netherlands (2), Portugal (2), Romania, Sweden, United Kingdom (5)
RECOVER Rapid European COVID-19 Emergency research Response	To gather comprehensive data from clinical and epidemiological studies to strengthen Europe's clinical research preparedness for future emerging infectious diseases.	Universiteit Antwerpen (Belgium)	11 partners: Belgium (2), China, Denmark, France (2), Italy, the Netherlands (3), United Kingdom

HERoS Health Emergency Response in Interconnected Systems	To improve the effectiveness and efficiency of the response to coronavirus outbreak by providing guidelines for improved crisis governance.	Svenska handelshögskolan (Finland)	11 partners: France, Finland (2), Italy, the Netherlands (2), Poland(3), United Kingdom, United States
EpiPose Epidemic intelligence to minimize 2019-nCoV's public health, economic and social impact in Europe	To understand epidemiological characteristics COVID-19, social dynamics of the outbreak, public health preparedness and response, and assess economic impact.	Universiteit Hasselt (Belgium)	6 partners: Belgium (2), Switzerland, Italy, the Netherlands, United Kingdom
CORESMA COVID-19-Outbreak Response combining E-health, Serolomics, Modelling, Artificial Intelligence and Implementation Research	To help devise evidence-based response strategies by combining clinical, epidemiologic and immunological data from field studies and implementation research.	Helmholtz Zentrum für Infektionsforschung (Germany)	7 partners: Switzerland, Ivory Coast, China, Germany (2), Nepal, the Netherlands,
EXSCALATE4CoV EXaSCale smart platform against pathogens for Corona Virus	To exploit powerful computing resources to identify molecules capable of targeting coronavirus and develop an effective tool to counter future pandemics.	Dompé farmaceutici (Italy)	18 partners: Belgium, Switzerland (2), Germany (2), Spain, Italy (10), Poland, Sweden
DIAGNOSTICS – Total **EU funding**: € 6.4 million			
CoNVat Combating 2019-nCoV: Advanced Nanobiosensing platforms for POC global diagnostics and surveillance	To develop a point-of-care device using optical biosensor technology for rapid diagnosis and monitoring, and also monitor the evolution of viruses in animals and help prevent future outbreaks.	Fundacio Institut Catala de Nanociencia i Nanotecnologia (Spain)	5 partners: Spain (3), France, Italy
CoronaDX Three Rapid Diagnostic tests (Point-of-Care) for COVID-19 Coronavirus, improving epidemic preparedness, public health and socioeconomic benefits	To deliver three complementary diagnostic tools, including one point-of-care diagnostic that can be used with minimal training.	Danmarks Tekniske Universitet (Denmark)	8 partners: Austria, China (2), Denmark (2), Italy (2), Sweden

HG nCoV19test Development and validation of rapid molecular diagnostic test for nCoV19	To develop and validate a novel rapid molecular diagnostic test for coronavirus.	Hibergene Diagnostics (Ireland)	4 partners: China, Ireland, Italy, United Kingdom
TREATMENT – Total **EU funding**: € 17.0 million			
Fight-nCoV Fighting-off Coronavirus with broad-spectrum antivirals: establishing animal challenge mode	To prepare the way towards broadspectrum antiviral treatments that can be taken intranasally.	Stockholms Universitet (Sweden)	6 partners: Germany (2), Denmark, France, Sweden (2)
SCORE Swift COronavirus therapeutics Response	To develop a combination of anti-viral treatments for patients infected with the coronavirus.	Academisch Ziekenhuis Leiden (the Netherlands)	10 partners: Belgium (3), Switzerland, Germany (2), France (2), the Netherlands (2)
Solnatide Exploration of safety, tolerability and clinical efficacy of Solnatide IMP in patients infected with the 2019 new coronavirus	To test peptide-based treatments targeting life-threatening pulmonary diseases in COVID-19 patients.	RTDS Association (Austria)	6 partners: Austria, Germany (2), Spain, Italy, the Netherlands
ATAC Antibody therapy against coronavirus (COVID-2019)	To optimise, produce and test antibody therapies against coronavirus based on donated blood samples from recovered COVID-19 patients.	Karolinska Institutet (Sweden)	5 partners: Belgium, Switzerland, Germany, Italy, Sweden
MANCO Monoclonal Antibodies against 2019- New Coronavirus	To develop and evaluate monoclonal antibodies as treatments against coronavirus.	Erasmus Universitair Medisch Centrum Rotterdam (the Netherlands)	8 partners: Germany, Spain, France (2), the Netherlands (4)
CoroNAb Nanobodies and antibodies against 2019-nCoV	To rapidly identify, validate and produce antibodies that block the ability of the virus to infect cells, which could be used for treatment and prevention in humans.	Karolinska Institutet (Sweden)	4 partners: Switzerland, Denmark, Sweden, United Kingdom
RiPCoN Rapid interaction profiling of 2019-nCoV for network-based deep drug-repurpose learning (DDRL)	To identify approved drugs that can be repurposed to treat coronavirus by profiling how they interact with viral components using artificial intelligence.	Helmholtz Zentrum München (Germany)	3 partners: Germany, Spain, France
VACCINES – Total **EU funding**: € 5.7 million			

OPENCORONA Rapid therapy development through Open Coronavirus Vaccine Platform	To develop a vaccine that can also be used as a therapy against the coronavirus using a DNA vaccine platform.	Karolinska Institutet (Sweden)	7 partners: Germany, Italy, Sweden (5)
Prevent-nCoV Prevention of 2019 nCoV infection through development and clinical testing of a novel Virus Like Particle (VLP) vaccine	To develop and evaluate a potential vaccine that uses virus-like particles to expose coronavirus proteins to the immune system.	Københavns Universitet (Denmark)	6 partners: Germany, Denmark (3), the Netherlands (2)

Source: *Own elaboration based on (European Commission, 2020b).*

Table 8. *23 Horizon 2020 research projects on coronavirus short-listed for funding in August 2020.*

Acronym/ Title	Description	Project coordinator	Partners
RAPID REPURPOSING OF MANUFACTURING FOR VITAL MEDICAL SUPPLIES AND EQUIPMENT – Total **EU funding**: € 22.1 million			
imPure	Injection Moulding Repurposing for Medical Supplies enabled by Additive Manufacturing (PPE, ventilator accessories, etc.)	National Technical University of Athens (Greece)	19 partners: Belgium, Greece (4), Spain (2), France, Italy (6), Norway, Slovenia, United Kingdom (3)
CO-VERSATILE	Adaptive and resilent production and supply chain methods and solutions for urgens need of vital medical suppliers and equipment	SZTAKI – Institute for Computer Science and Control (Hungary)	21 partners: Austria, Switzerland, Germany (4), Spain (3), Hungary (2), Israel, Italy (5), the Netherlands, United Kingdom (3)
RESERVIST	Reporpousing manufacturing lines for providing medical and other products and services in case of spiking dem and times	Centre Scientifique & Technique de l'Industrie Textile Belge (Belgium)	17 partners: Belgium (5), Greece, Spain (4), Finland (3), France, Italy (2), the Netherlands
Eur3ka	EUropean Vital Medical Supplies and Equipment Resilient and Reliable Repurposing Manufacturing as a Service NetworK for Fast PAndemic Reaction	Engineering Ingeneria Informatica Spa (Italy)	24 partners: Swizerland, Denmark (2), Germany (4), Spain (3), Finland, Israel, Italy (6), Luxembourg, the Netherlands, Norway, Portugal, Romania

MEDICAL TECHNOLOGIES, DIGITAL TOOLS AND ARTIFICIAL INTELLIGENCE ANALYTICS TO IMPROVE SURVEILLANCE AND CARE AT HIGH TECHNOLOGY READINESS LEVELS – Total **EU funding**: € 55.2 million			
ESSENCE	Empathic platform to personalny monitor, Stimulate, enrich, and aSsist Elders And Children in their Environment	Politecnico di Milano (Italy)	9 partners: Cyprus, Spain, France, Israel, Italy (4), Slovenia
PyXy.AI	Telehealth-ready AI-powered multi-parametric system for surveillance of COVID-19 and cardio-pulmonary chronic patients	Bat-Call Ltd (Israel)	7 partners: Germany (3), Israel (2), Norway (2)
Icovid	AI-based chest CT analysis enabling rapid COVID diagnosis and prognosis	Incometrix NV (Belgium)	9 partners: Belgium (5), Germany, the Netherlands, United Kingdom (2)
VASCOVID	Portable platform for the assessment of microvasular health in COVID-19 patients at the intensive care	Fundacio Institut de Cienes Fotoniques (Spain)	7 partners: Spain (4), Ireland, Italy, the Netherlands
PORSAV	Controlling Vidal aerosols in COVID-19 and Beyond	Pintail Ltd (Ireland)	5 partners: France, Ireland (3), Poland
CleanAir	Lab to Fab development of air decontamination system for protecting health practitoners against COVID-19	Villinger GmbH (Austria)	7 partners: Austria (4), Germany, Ireland, Italy
ICU4Covid	Cyber-Physical Intensive Care Medical System for Covid-19	UNINOVA – Instituto de Desenvolvimento de Novas Tecnologias (Portugal)	19 partners: Austria (3), Germany (7), Greece (2), Luxembourg, the Netherlands, Portugal (5)
ENVISON	Intelligent plug-and-play digital tool for real-time surveillance of COVID-19 patients and smart decision making in Intensive Care Units	Johann Wolfgang Goethe Universitaet Frankfurt am Main (Germany)	19 partners: Belgium, Germany (4), Switzerland, Spain, Finland, Hungary (2), Italy (2), Lithuania, the Netherlands, Portugal, Romania, Slovenia (2), UK

COVID-X	COVID eXponential Programme	F6S Network Ltd (Ireland)	10 partners: Cyprus, Spain (4), Ireland, Italy, Luxembourg, Lithuania, Sweden
INNO4COV-19	Boosting Innovation for COVID-19 Diagnostic, Prevention and Surveillance	Laboratorio Iberico Internacional de Nanotecnologia (Portugal)	11 partners: Austria, Belgium (2), Germany, Ireland, Spain (3), Italy, Portugal (2)
IRIS-COV	Market Release of a Portable Device for COVID-19 at the Point-of-Care; a Global Diagnostics Approach	Idryma Technologias Kai Erevnas (Greece)	8 partners: Belgium, Swizerland, Greece (3), France, United Kingdom, South Africa
COVIRNA	A diagnostics test to improve surveillance and care of COVID-19 patients	Luxembourg Institute of Health (Luxembourg)	15 partners: Belgium, Germany (2), Spain, France, Hungary, Italy, Luxembourg (2), the Netherlands, Portugal, Slovenia, Bosnia and Herzegovina, United Kingdom (2)
CorDial-S	Portable and fast surface plasmon resonance point-of-care test for COVID-19	Universite de Lille (France)	7 partners: Belgium, France (4), Ireland, Israel
BEHAVIOURAL, SOCIAL AND ECONOMIC IMPACTS OF THE OUTBREAK RESPONSES – Total **EU funding**: € 28 million			
COVINFORM	COronavirus Vulnerabilities and INFOrmation dynamics Research and Modelling	Synyo GmbH (Austria)	16 partners: Austria (2), Belgium, Germany, Greece, Spain (2), Israel, Italy (2), Portugal, Romania, Sweden, United Kingdom (3)
PERISCOPE	Pan-European Response to the ImpactS of COVID-19 and future Pandemics and Epidemics	Universita di Pavia (Italy)	32 partners: Austria, Belgium (7), Switzerland, Czechia, Germany (2), Spain (2), France (3), Italy (7), the Netherlands, Poland, Portugal, Romania, Serbia, Sweden (2), United Kingdom
SHARE-COVID	Non-intended health, economicc and social effects of the COVID-19 epidemic control decisions: Lessons from SHARE	Max-Planck-Gesellschaft zur Foerderung der Wissenschaften (Germany)	15 partners: Czechia, Germany (3), Denmark, Greece, Spain, France, HR, Israel, Italy (2), the Netherlands, Poland, Sweden
RESPOND	Improving the Preparedness of Health Systems to Reduce Mental Health and Psychosocial Concerns resulting from the COVID-19 pandemic	Stichting VU (the Netherlands)	14 partners: Australia, Belgium, Germany (2), Spain (2), France, Italy (3), the Netherlands (2), Sweden, United Kingdom
PAN-EUROPEAN COVID-19 COHORTS – Total **EU funding**: € 19.9 million			

ORCHESTRA	Connecting European Cohorts to Increase Common and Effective Response to SARS-CoV-2 Pandemic	Universita di Verona (Italy)	26 partners: Argentina, Belgium, Congo, Germany (6), Spain (3). France (3), Gabon, Italy (6), Luxembourg, the Netherlands, Romania, Slovakia
COLLABORATION OF EXISTING EU AND INTERNATIONAL COHORTS OF RELEVANCE TO COVID-19 - – Total **EU funding**: € 19.1 million			
unCoVer	Unravelling Data for Rapid Evidence-Based Response to Covid-19	Institute of Tropical Medicine – ITM (Belgium)	29 partners: Bosnia and Herzegovina, Belgium (2), Brazil, Congo, Israel, Spain (5), Croatia (2), Ireland (2), Italy (2), South Korea, Luxembourg, Norway, Portugal (3), Romania (2), Slovakia, Turkey, United Kingdom, United States

Source: *Own elaboration based on (European Commission, 2020c).*

By the end of 2020, the EU will invest EUR 1 billion into research and innovation to face COVID-19 and its consequences. In addition, 547 projects (funded by Horizon 2020 and its predecessor, the Seventh Framework Programme) could contribute scientific knowledge or technologies including new disinfectant coatings for protective clothing, safe transport of patients, waste water treatment or digital applications. The European Commission, EU Member States, industry, healthcare and research organisations, non-profit organisations and global partners rapidly prepared a coordinated research response to this public health crisis. In April 2020 Commission services and national administrations developed the first ERAvsCorona action plan, taking into account 10 priority short-term actions in research and innovation to deal with coronavirus.

Over the coming months and years, the Commission will deliver on its commitment to invest even more in coronavirus-related research and innovation, notably in the new research and innovation program, Horizon Europe, to be launched in 2021. Strong involvement of regulatory, financial authorities institutions, civil society and industry will ensure the rapid availability of research results - from new vaccines and tests to health and social care. The enormous funds for clinical management and treatment, vaccine development and diagnostics reflect the European Union's strong global commitment to fighting the pandemic. The engineering and re-purpose of production systems for emergency medical services and new digital telemedicine are expected to strengthen the resilience of the healthcare system. Evidence-based public health measures will focus in particular on vulnerable populations. They will provide solutions or inform decision makers to manage crisis and be better prepared for future pandemics. This is backed by fundamental research to improve our understanding of the SARS-CoV-2 virus, funding for data science, and flexible, adaptable clinical infrastructures. The budget of the *Access to Risk Finance for InnovFin Infectious Diseases Finance Facility,* funded under Horizon 2020 and implemented by the European Investment Bank (EIB) received an additional EUR 400 million to invest in key innovative players developing promising vaccines candidates, drugs, medical and

diagnostic devices or cutting-edge critical research and innovation infrastructures (including manufacturing facilities) (European Commission, 2020a).

5. Global Cooperation Initiatives in Research and Innovation Projects

The European Union has taken a leading role as a global actor and major contributor of international aid (including a commitment of more than EUR 1 billion for research and innovation). Funding from Horizon 2020 has leveraged the work of existing multilateral research platforms (European Commission, 2020a):

- The *Coalition for Epidemic Preparedness Innovations (CEPI)* is to receive EUR 100 million from Horizon 2020, in addition to funding from EU member states.
- The *Global Research Collaboration for Infectious Disease Preparedness (GLOPID-R)* has received €2.9 million.
- *Access to COVID-19 Tools (ACT) Accelerator* (the EU is a founding member) which aims to accelerate the development, production and fair access to COVID-19 testing, treatments and vaccines. To speed up and scale-up the development and production of the global supply of vaccines for citizens around the world, in poor and rich countries, the Commission will provide EUR 400 million in guarantees to support *COVAX* (co-led of GAVI (The Global Alliance for Vaccines), CEPI and WHO) in Coronavirus Global Response context.

EU funding is accelerating efforts to develop effective treatments, vaccines, therapies and diagnostics, and to ensure universal availability at an affordable price. Horizon 2020 projects attracted research teams from 14 countries that are not EU members or associated with the programme: Argentina, Australia, Brazil, Canada, China, Colombia, Congo, Cote d'Ivoire, Gabon, India, Korea, Nepal, South Africa and the United States . Moreover, Horizon 2020 co-funds the *European & Developing Countries Clinical Trials Partnership (EDCTP),*which is focused on infectious diseases research in sub-Saharan Africa. This public-public partnership funded 24 projects for a total of EUR 11.45 million aimed at preventing or managing the spread of the epidemic. In addition, EDCTP and its partners are investing EUR 23 million in building research capacity, strengthening regional research networks and establishing an African epidemiologist and biostatist cohort through training in institutions in Europe and Sub-Saharan Africa (European Commission, 2020a).

6. Promising First Results of Horizon 2020 Projects Focused on COVID-19 Pandemic

Taking into account the urgency of this health threat, considerable effort has gone into developing new vaccines, drugs, medical devices, and other technologies and tools that will help people return to their daily activities safely. The promising first results of the Horizon 2020 projects are presented in Table 9.

Table 9. *Promising first results of Horizon 2020 projects*

Area of innovation cooperation	**Project title**	**Promising first results**
DIAGNOSIS		
	HG nCoV19 test project	Researchers involved in the EU-funded project developed a new portable diagnostic system to detect viral infection that gives accurate and reliable results in 30 minutes.
	RealNano	It is an example of a project that successfully reoriented its activities to focus on the manufacturing of low cost and printable biosensors to detect the coronavirus.
VACCINE		
	Prevent-nCoV	Researchers from the University of Copenhagen working on the EU-funded project have announced that their vaccine candidate shows results that will enable them to progress into testing on humans already this year.
	OSIRIX project	A French SME behind the OSIRIX project funded under the European Innovation Council, is using its unique technology platform to develop a universal vaccine against all existing and emerging coronavirus infections.
	BioNTech	On 11 June 2020, the EIB concluded a EUR 100 million debt financing agreement with BioNTech to support the development of BNT162, the company's COVID-19 vaccine programme. BioNTech became the first EU company to begin clinical testing. On November 9, 2020 the company announced that its vaccine had been more than 90 percent effective in clinical trial participants. A few days later, company officials announced they were applying for an emergency use authorization from the FDA (the United States Food and Drug Administration) for their vaccine. It was the first regulatory approval in the United States for a COVID-19 vaccine. The Pfizer & BioNtech & Fosun Pharma vaccine is available to high-risk groups in the United Kingdom (accepted by MHRA – the Medicines and Healthcare products Regulatory Agency) on 2.12.2020, first vaccination in the world was done 8.12.2020) and in the United States (accepted by FDA on 13.12.2020, first vaccination was done on 14.12.2020). It is also availabe in the European Union after EMA (European Medicines Agency) approval on 21.12.2020.
	CureVac	On 23 April 2020, the EIB Board approved a EUR 75 million debt financing agreement with CureVac, a highly innovative European vaccine developer, to scale up development and production of a vaccine against the coronavirus, which should be available in 2021.
TREATMENT		

	Exscalate4CoV	The project announced on 18 June 2020, that an already registered generic drug used to treat osteoporosis, Raloxifene, could be an effective treatment for COVID-19 positive patients with mild or asymptomatic infection. The project is funded under Horizon 2020 and uses an EU-backed supercomputing platform, one of the world's most powerful, to check the potential impact of known molecules against the genomic structure of coronavirus
	ATAC	Researchers in the ATAC project have already shared highly appreciated new scientific knowledge about antibody therapy against COVID-19 in three articles published in peer reviewed journals.
ENABLING NEW DIAGNOSTICS, THERAPEUTICS AND VACCINES		
	RECOVER, EU-RESPONSE and SUPPORT-E	The cluster of 3 Horizon 2020 projects will contribute to the clinical studies of different therapeutic approaches for COVID-19, and contribute to the coordination of European clinical development efforts.
	The European Health Data & Evidence Network (EHDEN)	The Network run under the Innovative Medicines Initiative (IMI) (EU's partnership with the pharma industry), aims to make large-scale analysis of health data in Europe a reality. It is now working with 28 data partners (such as hospitals, primary care providers or databases) in 11 countries to harmonise clinical data across therapeutic areas including COVID-19 – including 150 million anonymised patient records.
PUBLIC HEALTH MEASURES		
	EpiShuttle	Developed by Norwegian company EpiGuard, is a reusable, single-patient isolation and transport system designed to provide maximum patient safety and comfort while allowing critical care and treatment to be performed. It is currently in daily and successful use in many European countries, including Norway, Denmark, and Germany.
PREPAREDNESS		
	Go Green Routes	The project will evaluate the impact of reduced air pollution during the lockdown and its aftermath, as well as the impact on the mental health of urban citizens and their views on re-greening their cities.
BASIC SCIENCE		
	European Open Science Cloud (EOSC)	The COVID-19 Data Platform, run under the European Open Science Cloud (EOSC), is a free-to-use, open digital space for researchers to share and upload data sets. Since its launch on 20 April 2020, it has seen more than 78 000 users and 2.7 million requests from over 170 countries. The platform already offers access to a comprehensive set of preprints and publications (>100 000), viral sequences (>17 000), sequences from patients, and other microbiological data (>400 protein structures).

Source: *Own elaboration based on (European Commission, 2020a).*

The involvement of many different international partners in innovation cooperation (in different projects funded by IMI, Horizon 2020 or vaccine projects) including biopharmaceutical companies, universities and research organizations, SMEs can

contribute to faster overcoming challenges related to the COVID-19 pandemic and better preparation for future pandemics (Healthline, 2020; IMI, 2020; European Commission, 2020a; 2020b; 2020c).

7. Findings

Stopping growing pandemic COVID-19 requires speed, agility and cooperation. Opening up mobilizes knowledge from many different places, making science progress and accelerating our progress in the fight against the disease. Openness unleashes a volunteer army of scientists working in their own facilities, in different time zones and in different countries. Openness uses human capital available in the world to fight disease, as well as access to already existing physical capital (such as factory and equipment) to begin rapid testing of possible solutions. Open innovation can speed up action. More than 50 vaccine candidates under consideration are already approved drugs for other medical uses (being repurposed). This means that baseline safe dosage levels for any candidate in humans have already been established. This allows testing to begin in the middle of the normal drug development process, with Phase 1 of clinical trials safety protocols already completed. Making all relevant medical research available at the same time in a machine-readable form allows for rapid learning by anyone who wants to look at it, end enabling scientists around the world to contribute to the fight against pandemic (Chesbrough, 2020a; 2020b).

Biopharmaceutical companies involved in innovation cooperation in R&D Innovation with academic institutions, especially in the model of open innovation alliances, can significantly reduce the risk and cost of research, use the resources, competencies, technology, and knowledge from partners, and thus easier respond to changes in the dynamic environment and most of all, quickly launch new biotechnology or pharmaceutical products (new vaccines and drugs) as well as offer better diagnostics and treatment of patients which are now desired because of COVID-19 pandemic. Development of different research projects funded by IMI, Horizon 2020 or vaccine projects can contribute to defeat the COVID-19 pandemic and prepare us better for potential pandemics in the future.In addition we need to focus on projects related to diagnostics, treatments, vaccines, epidemiology, preparedness and response to outbreaks, socioeconomics, production and digital technologies as well as the infrastructures and data resources that enable this research, including variety of stakeholders (public/non-profit and private) on different levels (local, regional, national) from different industries (cross-industry alliances) and countries (multinational alliances). But finding a vaccine is not enough – we need to think about logistic issues regarding transport of vaccines (mRNA vaccine) in a proper temperature as well as about distribution and delivery of vaccines to millions of people.

Mass vaccination is a giant logistic operation. Some airlines (Air France-KLM) prepared COVID-19 vaccines airlift, in order to deliver the vaccines in the right way, using dry ice. Openness could help here as well – we can learn from each other and

use good practices, which could be further applied by other airlines in the vaccines delivery and improve the mass vaccination in different part of the world. Mass vaccination of the population will be one of the biggest challenges in 2021 for many countries in addition to the already existing problems related to the fight against the coronavirus pandemic.

In these difficult times companies need to be more open to cooperation (Chesbrough, 2020a; 2020b), change their business models (Chesbrough, 2020b; Puślecki, 2020), and use local potential and local partners to develop better therapies for patients. An example of such cooperation was proposed in "ECMO for Greater Poland" program with main purpouse of wide use of extracorporeal support in critical patient states. The lack of effective antiviral treatment and vaccine concepts development induced that only prevention and supportive therapies are available. Invasive mechanical ventilation is necessary for a significant number of COVID 19-cases, in both hospitalized and critically ill (2.3-33.1% and 29.1-89.9%, respectively) (Puslecki *et al.*, 2020). About 3-5% of all cases progress into critical states. The World Health Organization (WHO) recommends extracorporeal support - ECMO in cases with refractory hypoxemia unresponsive to lung-protective ventilation emphasizing *access to expertise in extracorporeal membrane oxygenation* (WHO, 2020). The number of application of ECMO to support patients with COVID-19 growth substantially in last months (Czekajlo *et al.*, 2020; Smereka *et al.*, 2020).

It is worth considering whether the pandemic brings a decrease or an increase in cooperation between companies. The answer is not clear cut. It seems that in the long run, the consequence of the pandemic on the part of companies will be the increased interest in the development of cooperative behavior. The challenges of COVID-19 pandemic may become a development opportunity and have a positive impact on R&D and pro-innovation activities. The crisis caused by pandemic shows that companies have real opportunities to contribute to social welfare, and by acting so, they can obtain the economic benefits of doing so (Gorynia and Jankowska, 2020).

Openness to cooperation will allow companies to develop new business strategies faster during and after the COVID-19 pandemic. Taking into account Horizon 2020 projects we can also observe the development of new partnerships between universities and research organizations as well as business-academia alliances which results will be helpful both for the world of science (new publications, scientific projects, scientific discoveries) and for the main beneficiaries - patients (new therapies, procedures in patient care, new drugs, vaccines, the use of existing drugs for new therapeutic purposes, faster products and drugs delivery to market – thanks to IP release). For now, one of the biggest limitations in this article is that we are still in the fight against the coronavirus, and we do not have all the results of ongoing research projects (only promising first results of some research projects and those devoted to vaccines). We will have to wait for some of them until 2021 or even later (another 2-3 years). The effects of a pandemic will be visible for many years after the pandemic. Only then, having the results, it will be possible to carry out a broader analysis of the

effects of the measures taken during COVID-19 pandemic, to develop conclusions and recommendations in the event of the future pandemics.

Certainly, the COVID-19 pandemic contributed to the development of new strategic partnerships in the biopharmaceutical industry, also in the open model (open innovation alliances). Additionally, we can observe the involvement of many companies from Biopharma in cooperation with IT companies in order to develop diagnostic tools using the latest technologies - IOT, AI, VR, Machine Learning, Blockchain along with the progressive digitalization of health care (telemedicine, medHealth, digitalHealth). Since the end of the 1980s, the world has seen more and more non-equity R&D alliances in the biopharmaceutical industry (Puślecki, 2012), which provide greater flexibility in the selection and possible change of partners and enable a faster change of technology than traditional equity alliances.

This trend can also be seen in the region of the Central and Eastern Europe (CEE). The results of one of the first in the world quantitative research focused on innovation cooperation in the biopharmaceutical industry in the CEE, conducted within research grant entitled "Analysis of Open Innovation Alliances and Strategic Partnerships in the Biopharmaceutical Industry in Poland and CEE countries" showed that over 80% of companies from the biopharmaceutical industry from 18 CEE countries carried out mainly R&D non-equity alliances in the development of innovation cooperation in years 2015-2017. The most important objectives in the formation of these R&D alliances given by the CEE companies were access to knowledge and experience of partners. Thanks to more flexible and open cooperation it will be possible to defeat the coronavirus pandemic faster as well as current and future virus mutations.

We should know that the world after the COVID-19 pandemic will be different, we will be different, richer in knowledge and experience from the current coronavirus, which will allow us to prepare for further epidemics (better care for our health, faster diagnosis, and better treatment) and pandemics in the future. Having vaccines for current coronavirus (for now 2 mRNA vaccines available from Pfizer and Moderna) will make it easier to work on possible new drugs and vaccines in the event of future pandemics as part of expanded R&D innovation ecosystems and involvement of many partners in the cooperation.

Using the latest IT technologies will make it be possible to even better monitor, diagnose (digital Health) and take care of the patients with focus on Patient-Center Approach. *"Good ideas can come from anywhere, making openness is an imperative in these times of crisis. Global public health simply works better – and faster – when we open up"* (Chesbrough, 2020a, p. 413). Through our involvement in cooperation, knowledge and experience sharing through different innovation cooperation platforms, the evolution of our pandemic-induced behavior, with the *patient center care and innovation approach* we can further contribute to the building of the common good and improvement of the global public health.

References:

Burke, M.J. 2020. Ecosystems in Motion. Strategic Alliance Quarterly, Q1, 10-19.

Chesbrough, H. 2003. Open Innovation: The New Imperative for Creating and Profiting from Technology. Harvard Business School Press.

Chesbrough, H. 2019. Open innovation results: Going beyond the hype and getting down to business. Oxford University Press, UK.

Chesbrough, H. 2020a. To recover faster from Covid-19, open up: Managerial implications from an open innovation perspective. Industrial Marketing Management, 88, 410-413.

Chesbrough, H. 2020b. Open Innovation in Pandemic, Garwood Center for Corporate Innovation. Haas School of Business, University of California, Berkeley.

Chesbrough, H.W., Bogers, M. 2014. Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. In New Frontiers in Open Innovation, Chesbrough, H.W., Vanhaverbeke, W., West, J., Eds. Oxford University Press, Oxford, UK, 3-28.

Culpan, R. (Eds.). 2014. Open Innovation Through Strategic Alliance. New York: Palgrave MacMillan.

Czekajlo, M., Dabrowski, M., Puslecki, M., Drozd, A., Szarpak, L. 2020. Using ECMO VV in the COVID-19 pandemic. Disaster and Emergency Medicine Journal, Vol 5, No 2, 114-115.

De Man, A.P. 2018. What does an ecosystem manager do? Strategic Alliance Quarterly, Q4, 35-40.

De Man, A.P., Koene, P., Ars, M. 2019. How to survive the organizational revolution: A guide to agile contemporary operating models, platforms and ecosystems. BIS Publishers.

De Man, A.P. 2020. To Be Effective in an Increasingly Ecosystems World, It's Vital to Understand the Different Types of Ecosystems and How They're Governed and Managed. Strategic Alliance Quarterly, Q3, 38-41.

De Man, A.P., Luvinson, D. 2019. Collaborative business models: Aligning and operationalizing alliances. Business Horizons, 62, 473-482.

Deloitte. 2017. Partnering for progress. How collaborations are fuelling biomedical advances, 2017, 1-36.

European Commission. 2020a. https://ec.europa.eu/info/research-and-innovation/research-area/health-research-and-innovation/coronavirus-research-and-innovation_en.

European Commission. 2020b. https://ec.europa.eu/info/research-and-innovation/research-area/health-research-and-innovation/coronavirus-research-and-innovation_en.

European Commission. 2020c. https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1460.

Fraser, R.L. 2014. Altruistic Alliances: Business Thrives when Biopharma Companies Partner with Non-profits. Strategic Alliance Magazine, Association of Strategic Alliance Professionals, Q3, 22-28.

Gomes-Casseres, B. 2014. Creating Joint Value. In: Biopharma and Many Other Industries Not Invented Here is So Last Century. Strategic Alliance Magazine, Association of Strategic Alliance Professionals, Q3, 36-41.

Gorynia, M., Jankowska, B. 2020. Co lepsze: konkurencja czy kooperacja? Rzeczpospolita.

Hanson, C. 2015. Orchestrating Partnering – Across Enterprise and Ecosystems. How Alliance Management Can Adapt and Lead as High Tech (and other Industries) Dive

into the Life Sciences and Healthcare Ecosystem. Strategic Alliance Magazine, Association of Strategic Alliance Professionals, Q3, 14-20.

Healthline, 2020. Here's Exactly Where We Are with Vaccines and Treatments for COVID-19. Available online: https://www.healthline.com/health-news/heres-exactly-where-were-at-with-vaccines-and-treatments-for-covid-19#COVID-19-vaccines.

IMI. 2020. https://www.imi.europa.eu/news-events/press-releases/imi-announces-covid-projects-boosts-funding-pot-eur-72-million.

Puslecki, M., Dabrowski, M., Baumgart, K., et al. 2020. Managing Patients on Extracorporeal Membrane Oxygenation Support During The COVID-19 Pandemic – A Proposal for a Nursing Standard Operating Procedure. Research Square. DOI: 10.21203/rs.3.rs-89378/v1.

Puślecki, Ł. 2012. Sectoral Analysis of Strategic Technology Alliances in years 1980-2006. Intercathedra, No. 28/4, 79-83.

Puślecki, Ł. 2015. The development and management of alliance networks in the biopharmaceutical industry. In Management of Network Organizations : Theoretical Problems and the Dilemmas in Practice by Sroka, W., Hittmár, Š. Eds. Springer International Publishing Switzerland, 199-213.

Puślecki, Ł. 2016. Diversity of relationships and alliances in biopharmaceutical industry. In New Trends in Management and Production Engineering. Regional, Cross-boarder and Global Perspectives by Sroka, W., Hittmar, S., Kurowska-Pysz, J. Eds. Shaker Varlag, Aachen, Germany, 127-137.

Puślecki, Ł., Staszków, M. 2015. New Cooperation Modes: An Opportunity for Polish Biotechnological Clusters: Managing Global Transitions. International Research Journal, 13(2), 171-188.

Puślecki, Z.W. 2020, World Economy Against New Challenges in the Time of COVID-19. Dom Wydawniczy ELIPSA. Warsaw, Poland.

Smereka, J., Puslecki, M., Ruetzler, K., Filipiak, KJ., Jaguszewski, M., Ladny, J.R., Szarpak, L. 2020. Extracorporeal membrane oxygenation in COVID-19. Cardiology Journal, 27(2), 216-217.

Trąpczyński, P., Puślecki, Ł., Staszków, M. 2018. Determinants of Innovation Cooperation Performance: What Do We Know and What Should We Know? Sustainability, 10(12), 1-32.

West, J. 2014. Open Innovation: Learning from Alliance Research. In Open Innovation Through Strategic Alliances, Culpan, R., Eds. New York: Palgrave MacMillan, 1-16.

Wilks, Ch., Prothmann, Ch. 2012. Open Innovation Alliances, Novel Alliance Models Accelerate the Identification and Advancement of Breakthrough Therapies. Strategic Alliance Magazine, Association of Strategic Alliance Professionals, Q4, 42-45.

World Health Organization. 2020. Clinical management of COVID-19: interim guidance. 27 May 2020 (No. WHO/2019-nCoV/clinical/2020.5). World Health Organization Global, from https://www.who.int/publications-detail-redirect/clinical-management-of-covid-19.