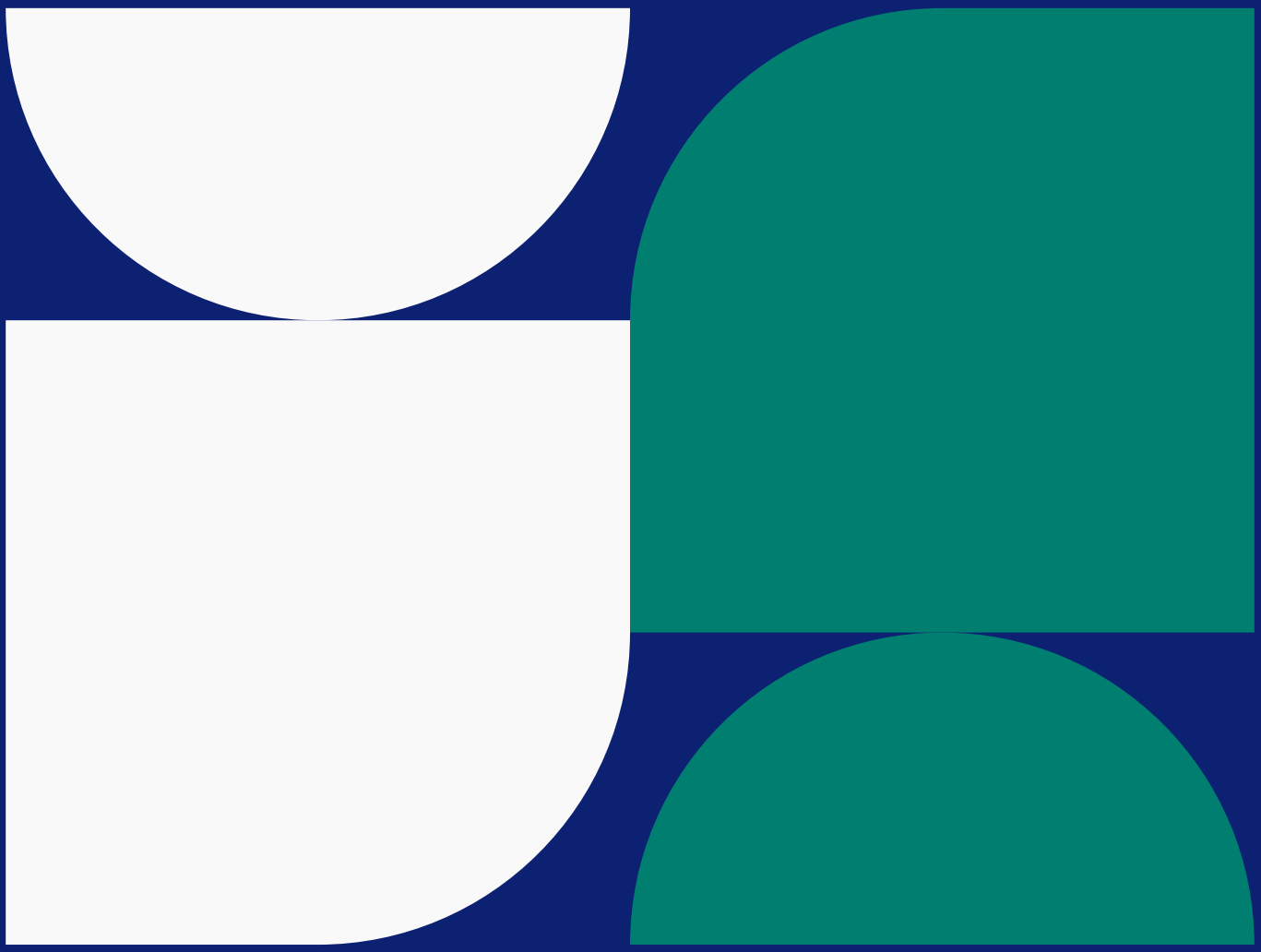
Strategic research agenda

National research programme in viruses and pandemics



Swedish Research Council

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Strategic research agenda

National research programme in viruses and pandemic

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Contents

Foreword

The Swedish Research Council has been tasked by the Government to establish a national research programme in viruses and pandemics. The programme runs over a ten-year period, and is carried out based on a research agenda describing goals and activities. The research agenda provides a summary of joint research and development needs within the area. The primary target groups for the research agenda are the Government, research funding bodies, relevant public agencies and other organisations involved in research. The agenda has been produced by a project team at the Swedish Research Council consisting of Frida Mowafi, Maria Starborg, Maria Bergström, Karin Tegerstedt, Maud Quist and Ulrica Horwath, supervised by Madeleine Durbeej-Hjalt (Secretary General for Medicine and Health), together with other public agencies that are members of a programme committee as well as expert teams from the research community. Opinions have also been obtained from the Swedish Research Council's scientific councils and committees. In total, around one hundred persons have contributed actively through workshops and reference groups. The Swedish Research Council would like to express its sincere thanks all who have contributed to producing the research agenda.

Stockholm, 26 May 2023

Madeleine Durbeej-Hjalt

Secretary General, Scientific Council for Medicine and Health, Swedish Research Council

Summary

New infectious diseases regularly arise and are transmitted to humans. These diseases are either completely new and spreading to new areas, populations and species, or they are pre-existing diseases that have changed and become more serious or contagious. A pandemic affects a large number of people worldwide, unlike an epidemic that is limited to a group or a geographic area. An example is the COVID-19 pandemic that recently swept around the world and affects individuals and societies.

Against the background of such threats to health and society, the Swedish Research Council was tasked in 2021 to establish a ten-year national research programme in viruses and pandemics. The focus of the research programme is based on a strategic research agenda. The agenda is presented in this report. The overall objective of the research programme is to contribute with knowledge that can reduce the consequences on people's lives and health resulting from viral diseases and pandemics. The operational goals are to contribute to high-quality research in viruses and pandemics. The research should strengthen Sweden's preparedness for a pandemic, but also contribute to establishing and identifying structures and organisation to quickly initiate research in the event of a pandemic. The research programme is divided into two types of activities, namely activities that must be prioritised between pandemics and activities in the event of a pandemic.

Between pandemics, the national research programme prioritises:

- strengthening the development of the research area
- initiating and financing research
- promoting international collaboration
- promoting management and storage of research data and infrastructure
- disseminating research results generated via the programme
- creating an action plan for research in the event of a pandemic.

In the event of a pandemic, the national research programme prioritises:

- the ability to make relevant calls for research funding according to the action plan for research in the event of a pandemic drawn up by the programme committee
- convening the reference group and the programme committee to discuss necessary research issues that must be addressed quickly
- having an annual budget for funding research in the event of a pandemic to address acute issues
- providing the opportunity for ongoing research to be redirected in case of emerging pandemic.

The research programme's orientation and activities will be based on this strategic research agenda. It is developed in consultation with the programme committee, which is made up of other funding bodies and organisations. As the programme spans across several research areas, the programme has been divided up into five focus groups with experts in each area. The experts have identified knowledge gaps where research is needed. The conclusions are based on data and reports and the experts' knowledge of the area. Through the identified knowledge gaps, the national research programme can in future provide increased support for research that contributes to meeting the challenges and knowledge needs.

1 Introduction

In Government Bill 2020/21:60, the Swedish Government mandated the Swedish Research Council to set up a national research programme in viruses and pandemics in order to increase preparedness for future pandemics [1].

The research programme is part of the Government's long-term strategy and action plan to counteract and reduce virus outbreaks and pandemics. The overarching goal for the programme is to contribute new knowledge about how different viruses are detected can cause infection, and also how pandemics can arise, so that society can be prepared ahead of future pandemics.

The programme shall also contribute evidence and critical reflection for weighing up different measures in the event of a pandemic. The programme shall contribute to new knowledge in a number of disciplines, such as viral diseases, transfer mechanisms for viruses between animals to humans and between humans, and the development of medicines, vaccines, diagnostics and therapies. Knowledge is also needed about the economic and social effects of pandemics. Results from the research can also be useful in other areas, such as public health work outside times of crisis, or for societal crises other than pandemics.

As the mandate spans a number of research disciplines, the agenda has been divided into five different focus areas (Chapter 3). Five focus groups with experts from the specific fields were appointed to identify knowledge gaps in each area. These knowledge gaps form the basis for the strategic research agenda, future calls and other initiatives for research in the field. A programme committee consisting of relevant public agencies, research funding bodies and organisations has been established within the programme (see Chapter 3). The programme committee will assist the Swedish Research Council with the design, implementation and regular updating of the strategic research agenda.

The national programme is a ten-year initiative to create long-term conditions for research. To date, the Government has invested 100 million SEK per year for the period 2021–2024. New funding decisions for the remaining years will have to be made.

2 Starting points

2.1 The focus of research policy

The goal of the Government's research policy is to: "Sweden shall be one of the world's foremost research and innovation countries and a leading knowledge nation, where high-quality research, higher education and innovation lead to societal development and welfare, a competitive business sector, and address the societal challenges we are facing, both in Sweden and globally."

Sweden's research policy therefore focuses on creating a prominent research nation, contributing to strengthening the business sector, and to addressing societal challenges. Having several purposes for research policy is also reflected internationally. A clear example of this is Horizon Europe, the EU's ongoing framework programme for research and innovation, which consists of three pillars: (i) scientific excellence, (ii) global challenges and European industrial competitiveness, and (iii) Innovative Europe.

Governmental research funding in Sweden can, in a similar way, be divided up into supporting scientific quality, addressing societal challenges, and promoting innovation and business sector competitiveness. The national research programmes that were first introduced in 2017 are therefore part of the research policy goal of addressing societal challenges and promoting research quality.

2.2 National research programmes

The Swedish Government has established 13 national research programmes in total. The first seven programmes were initiated in 2017, and a further six programmes were initiated in 2021. The Swedish Research Council is responsible for six of these, Formas for four, and Forte for three. Common factors for the national research programmes established by the Government are that they run for ten years, and shall contribute to addressing different societal challenges. The research programme is also subject to an assignment text that is common for all national research programmes. Based on this mandate text, the Swedish Research Council has identified the following common programme goals (in no particular order):

- ensure the research programme creates prerequisites for interdisciplinary and intersectoral collaboration
- contribute to a strong link between research and higher education
- contribute to gender equality
- ensure the research programme is well coordinated with other initiatives nationally and internationally, and that synergies are created
- ensure the research programme is adapted and designed to fit the various prerequisites of the research fields and is conducted on a flexible basis.

These goals can overall be divided up into three groups. The first group points to the need to contribute to high-quality research and contribute to evidence-based policy and administration. This therefore references the national research programmes' focus on knowledge accumulation and contributing to addressing societal challenges. The second group points to the need to develop dialogue and collaboration between different actors, and to work in an interdisciplinary and intersectoral way. This also includes a goal of creating strong links between research and higher education. The third group of goals points to coordination and ensuring the programme is adapted to the research field, and not vice-versa. Contributing to gender equality should be interpreted both as a question of allocation of research funding, and also as a question of research content.

The national research programmes will also be included in an overarching research and innovation system for increased Swedish competitiveness and for managing the major societal challenges.

2.3 Mandate to establish a national research programme in viruses and pandemics

The establishment of the national research programme in viruses and pandemics is based on and regulated by the following four documents:

- The Government bill on research and innovation
- The Government's mandate description for national programmes
- The Swedish Research Council's appropriation directive
- The Swedish Research Council's official instruction document

According to the mandate, the national research programme in viruses and pandemics shall contribute to new knowledge in a number of disciplines relating to viruses, such as viral diseases including sequelae (post-COVID syndrome, stroke, heart infarction, and others), transfer mechanisms for viruses from animals to humans, and the development of medicines, vaccines, diagnostics and therapies. More knowledge is also needed about the economic and social effects of viral diseases, sequelae and pandemics. Research into measures introduced to manage the transmission of infection is urgently needed, as is research into what makes the general public adapt to the advice and requirements of public agencies. The effects of working from home, school shut-downs, remote teaching and similar consequences of the COVID-19 pandemic are also important study subjects, based on the differing preconditions for different people, as is fit-for-purpose organisation, governance and coordination of important societal functions during a pandemic.

The design of the mandate is also based on the Swedish Research Council's official instruction document, which describes that the Council has been tasked to support strategic initiatives and to support basic research of high scientific quality.

Conclusions that emerged from the half-time evaluation of the first set of national research programmes indicated some general lessons to consider for the

programme, such as understanding the needs of society, disseminating new knowledge, and setting general goals for research in the area. According to the evaluation, a research agenda needs to be linked to overarching goals in order for the research to be better utilised. Here, it is important to evaluate in the slightly longer term to allow us to assess effects (both expected and unexpected) and to think beyond the programme period of the research programme when it comes to establishing a national research programme.

3 National research programme in viruses and pandemics

3.1 About viruses and pandemics

New infectious diseases arise and are transmitted to human beings on a regular basis. These diseases can either be entirely new and spread to new areas, populations and species, or they may be already existing diseases that have changed and become more serious or infectious. An epidemic is a breakout, usually of an infectious disease, that transmits between humans and animals, and between humans. Epizootic describes the corresponding disease transmission among animals. The COVID-19 pandemic is transmitted primarily by droplets, and is counted as an airborne infection. Different viruses have differing infection routes, however, and it is important to study these, as we do not know which type of virus will cause the next pandemic. An epidemic spreads quickly, often through transmission of an infection, and affects many individuals in a limited area or a population simultaneously.

The World Health Organization (WHO) defines a pandemic as an epidemic that affects the world across international borders, and that usually affects a large number of persons [2]. Humanity has suffered several major pandemics during the latest century, and the WHO has announced public health emergencies of international importance on seven occasions during the last fourteen years. These pandemics and emergencies have all been caused by viruses, but pandemics can also be caused by other infectious agents, such as bacteria. Collaboration with the national research programme in antibiotic resistance, which focuses on bacteria, can contribute to bridging the areas. The national research programme in viruses and pandemics focuses primarily on viruses, but must be flexible, so that it can redirect research resources in the event of an acute crisis and approaching pandemic caused by an infectious agent other than a virus.

Humans are regularly exposed to ‘zoonoses’, that is, events when viruses spread from animals to humans. How often zoonotic events occur is unknown, but during the next 50 years, humanity is expected to be exposed to 4 000 zoonotic events, that is, situations where viruses pass the species barrier from animals to humans and risk transmitting further between humans. The risk of new, virus-caused breakouts and pandemics is increasing and is due to factors such as climate change, population increase, and changing behaviours of humans, such as increased travel, but the risks can also be due to changes in animal populations and changes in the genetic composition of a virus. Even the smallest genetic change in a virus can have a great impact [3]. The WHO has highlighted more than ten different infectious diseases, all caused by zoonotic viruses, that should be prioritised in relation to research and development [4]. The diseases are highlighted as they are dangerous and infectious, and as medicines and

vaccines for treatment and prevention are either lacking or exist in insufficient quantities. It also includes ‘Disease X’, which is characterised as an unknown infectious agent that can cause breakouts and pandemics. COVID-19 is a typical example of Disease X. To achieve results in the fight against pandemics, a system perspective and an overall approach is needed, such as the ‘one health model’, where the health of humans, animals and the planet are linked together. The one health model applies an interdisciplinary approach that involves monitoring, research and close collaboration between the public health, veterinary and environmental protection sectors.

Infectious diseases can be transmitted in different ways, for example via air or droplet infection, contact, blood, foods, or via vectors such as mosquitoes and ticks. Environmental change can lead to vector-borne diseases spreading further, as areas that are favourable to vectors (organisms that carry disease) expand. Food and water-borne diseases can also cause major breakouts, but with high hygiene levels it has usually been possible to limit transmission in high-income countries. Many zoonoses have little or no transmission between humans, but on those occasions when effective transmission arises between humans, the new disease can cause breakouts or even a pandemic. Susceptibility to an infectious agent in a population can vary. The infectiousness of an infected person or an animal is determined by the amount of infectious virus in the body. Infection routes and environmental factors such as temperature and air humidity, population density and the degree of overcrowding, as well as the infection dose required to infect a new recipient are important factors for infection transmission. A further complicating factor is that many persons can function as infection carriers without displaying any disease symptoms. The infection transmission is therefore affected by the environments where we meet other people and how we behave in these.

Virus diseases and their sequelae have great impact on healthcare and society, not least during the winter months. During winter, absence due to illness and the care of sick children leads to disruption of several societal functions, as well as very large costs to society. This is a strongly contributing factor to why every year several hospitals declare a state of readiness during the winter months.

The shortage of antiviral medicines and vaccines against the majority of viruses and virus-caused infections contributes to a virus-caused disease being able to spread in society and cause a pandemic. Influenza viruses and corona viruses have been reported as having a greater potential to become pandemic compared to other viruses [5]. All seven international public health emergencies declared by the WHO have been caused by viruses.

3.2 Programme organisation

A programme committee and focus groups have been established to develop and implement the national research agenda. The aim is to receive inputs from a broad range of external actors, and to hold ongoing discussions with scientific councils and committees at the Swedish Research Council.

The programme committee consists of organisations with links to the research programme's scientific area, which assist the Swedish Research Council with the design, implementation and regular updating of the strategic research agenda. The programme committee also takes part in discussions about the activities and calls to be carried out between and in the event of a pandemic. The following public agencies and organisations are part of the programme committee: the Public Health Agency of Sweden (FHM), the Swedish Civil Contingencies Agency (MSB), the Swedish Medical Products Agency, the Swedish National Veterinary Institute (SVA), Research Institutes of Sweden (RISE), Vinnova - Sweden's Innovation Agency, Formas - the Swedish Research Council for Sustainable Development, Forte - the Swedish Research Council for Health, Working Life and Welfare, and the Swedish International Development Cooperation Agency (SIDA).

The focus groups consist of experts within the scientific field, and advise on scientific issues.

3.2.1 The research programme's focus areas

As the mandate is very broad and spans many disciplines, the programme was divided up into five different focus areas. For each focus area, focus groups were established, and a number of subject experts were appointed to these (see Appendix 1). The experts in the focus groups do not take part in the development of calls; instead, they have only worked on identifying knowledge gaps in order to avoid any conflict of interests. In Chapter 5, the focus groups discuss and identify knowledge gaps in each field, which contributes to the grounds for the agenda. Ethical and gender equality aspects are taken into account in all areas. The purpose of each focus area is described in brief below.

Viruses, virus-caused disease conditions and fundamental disease mechanisms (Focus area 1)

The area aims to increase knowledge about different viruses, virus diseases and their sequelae, as well as mechanisms relating to the infection and disease process. Increasing knowledge about fundamental mechanisms relating to viruses and the diseases that may arise due to virus infection is of great importance for global public health.

Mechanisms for the emergence and transmission of zoonoses with pandemic potential, and strategies for prevention and management of infection transmission (Focus area 2)

Focus area 2 aims to increase knowledge about the mechanisms for diseases and infections that can transmit by natural means between animals and humans, that is, zoonoses. A pandemic may arise when zoonoses are spread and established in new populations. The area also includes prevention and monitoring of infection transmission, and aims to provide knowledge of how changes to climate and environment affect the risk of new pandemics emerging.

Development of antiviral medicines, vaccines and diagnostics (Focus area 3)

Focus area 3 aims to increase knowledge about preventive and therapeutic measures to protect against and control virus-caused diseases and their sequelae in humans and animals by developing new antiviral medicines, vaccines and diagnostics, and improving existing medical measures and treatments.

Societal measures introduced as a result of a pandemic and their effects on human living conditions and health (Focus area 4)

Focus area 4 aims to investigate the effects on people's living conditions and health of the societal measures and behavioural changes that resulted from the pandemic, and to improve the prerequisites for weighing up the benefits and costs to society and health.

Organisation, governance and coordination (infrastructures) of important societal functions during a pandemic (Focus area 5)

Focus area 5 covers research into the organisation, governance and coordination of important societal functions during a pandemic. The pandemic gave rise to important questions about organisation, governance and coordination, for example the ability of different societal actors to mobilise, absorb and use new knowledge, and to act in a coordinated and situation-adapted way.

3.3 The importance of interdisciplinary science

This area is in large parts interdisciplinary, and the research programme can stimulate collaboration between different research fields and lead to interdisciplinary and intersectoral collaborations. Although the programme is divided up into five focus areas, it is important to promote research that is common for the different focus areas. Using a holistic approach, we can ensure that knowledge and practices in a certain field can help to speed up advances in another field, and vice versa.

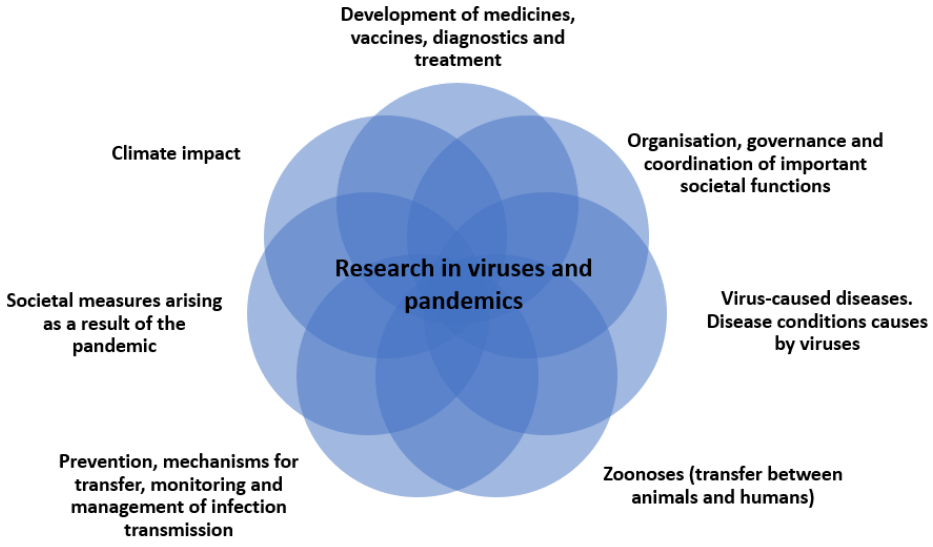
This might relate to how different viruses infect, understanding virus diseases and sequelae in general, identifying targets for new antiviral medicines and developing these new medicines, vaccines, diagnostics and therapies. Increased knowledge in these areas is important in itself, given their effects on society and healthcare, but new knowledge in these areas is probably essential to allow effective prevention and management of future virus-caused breakouts and pandemics. The programme can also relate to how equitable and gender-equal health is safeguarded during extraordinary events.

Mechanisms for transferring viruses from animals to humans need to be clarified to enable prevention of future pandemics. To understand mechanisms for transferring viruses from animals to humans we also need to know the disease dynamics in the host animals. Climate change increases the risk of outbreaks of infectious diseases. Climate change and disease transmission from animals to humans are research areas with clear interdisciplinary aspects.

To build up preparedness ahead of future pandemics, knowledge is needed about the economic and social effects of large and long-lasting societal transmission. Research into measures introduced to manage the transmission of infection is urgently needed, as is research into what makes the general public adapt to the advice and requirements of public agencies. There is therefore a need for research to understand human behaviour, and the impact of cultural, religious and traditional attributes that affect our actions. The effects of working from home, school shut-downs, remote teaching and similar consequences of the COVID-19 pandemic are also important study subjects, based on the differing preconditions for different people, as is fit-for-purpose organisation, governance and coordination of important societal functions during a pandemic.

Figure 1 illustrates how different areas interact with each other, and how interdisciplinary the area is. Research in one of the areas can contribute to increased knowledge also in other areas.

Figure 1. Interdisciplinary research in viruses and pandemics



3.4 Strategi and overall goals of the national programme

The overarching goal of the programme is to accumulate knowledge about how to the reduce the negative consequences for human life and health arising from virus diseases and pandemics by supporting high-quality research. The overarching and general goals for the national research programmes have been incorporated in the national programme in viruses and pandemics. Figure 2 illustrates the national research programme's goal, mandate and activities linked to the programme, and the effects the programme is expected to contribute. The research programme also links to several specific goals in Agenda 2030, which is an action plan with goals for transition to a sustainable society for humans, the

planet and wellbeing [6]. In summary, the fight against viral diseases is a central part of the UN's Agenda 2030.

To achieve the overarching goal, the programme includes planning and preparedness for relevant research and research implementation ahead of and during a pandemic. The research programme does not, however, include the societal measures that are necessary for implementing research in the organisations involved. Here, other societal actors involved, such as health and medical care and the business sector, must take over and investigate how research results can be implemented.

The research programme has set two operational goals for the overarching goal:

- The programme shall contribute to high-quality research between pandemics, which strengthen Sweden's preparedness.
- The programme shall ensure that there are established structures and processes to rapidly initiative research in the event of a pandemic.

The operative goals are primarily intended to strengthen Sweden's knowledge base and its ability to quickly gear up relevant research during the next pandemic. The knowledge basis includes basic research into viruses and viral diseases to knowledge about how society can best act to reduce the transmission of infection, using the right measures, so that the societal effect of the pandemic is as small as possible.

The programme is expected to fulfil the operational goals, which are as follows:

- More synergies between research funding bodies, researchers and organisations active in research in the area of viruses and pandemics
- Increased knowledge about viruses and viral diseases and about the risk of infection transmission
- Development of new therapy alternatives and vaccines
- Increased knowledge about societal effects of measures taken during a pandemic to better address a future pandemic
- Increased preparedness for relevant research and research implementation in the event of a pandemic.

During the programme period, the programme can act as a meeting point (platform) for research in viruses and pandemics, and is expected to contribute to important societal actors being as well prepared as possible and having functioning collaboration structures that allow them to quickly reset, and to important research being identified quickly and initiated via various funding calls in the event of a pandemic.

The result of the national programme refers to the result of the activities carried out within the framework of the programme, and that are expected to lead to the effects mentioned above. The primary results that the national programme intends to achieve are:

- A national meeting place for research in the field, that is, viruses and pandemics

- Research funding of relevant high-quality research to strengthen the research area according to knowledge gaps identified in the agenda
- The programme committee draws up an action plan for research in conjunction with a pandemic to enable it to initiate important research
- Increased research connection with higher education, for example by funding graduate schools
- More international research collaborations (participation in relevant international bodies, calls targeted at international research collaborations/environments)
- Interdisciplinary research and intersectoral interaction.

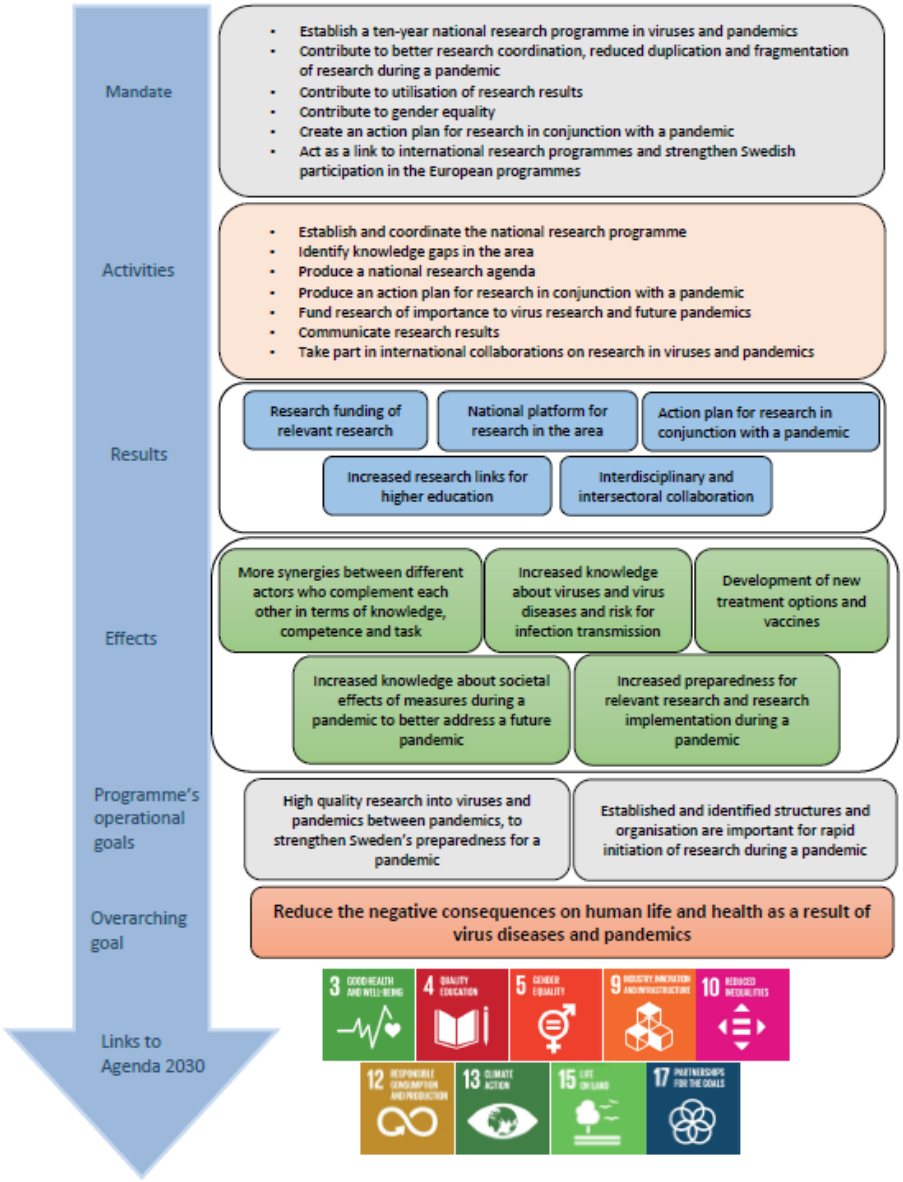
The research programme can be seen as a national meeting place, in particular when it comes to relevant research and its implementation for viruses and pandemics, with the ambition to bring together researchers, organisations, stakeholders and networks that are important for strengthening Sweden's preparedness in a pandemic. The research programme should also collaborate and maintain a dialogue with other national networks and centres, to ensure as good coordination as possible of research initiatives. The primary purpose of the research programme is to fund research that has been deemed to be relevant to cover the knowledge gaps that have been identified by the focus groups. Another important task of the programme is to develop an action plan for adaptation of research in the event of a pandemic. It is important for all national research programme to ensure that the research also leads to increased links between research and higher education, and that there are processes for ensuring that the teaching is continually updated and supported by relevant research.

It is important that the research programme leads to more international research collaborations, participation in relevant international bodies, and that it issues calls targeted at international research collaborations and environments. Finally, interdisciplinary and intersectoral research is central for the programme, and shall be based on inputs from the programme committee and the focus groups.

The results are dependent on the planned activities being implemented according to plan and, according to the goal in Figure 2, includes an initial step of establishing and coordinating a national programme in viruses and pandemics. Other activities included in the programme are, in summary, to identify knowledge gaps within the field, to develop a national research agenda and an action plan for research in conjunction with a pandemic, to fund virus research between pandemics, to communicate research results to stakeholders involved, and to take part in international collaborations on relevant research relating to viruses and pandemics.

Figure 2 illustrates the programme's goals, activities, results and effects, and how the different parts relate to each other. The primary target group for the national programme consists of researchers, research institutions and organisations that implement results from research. It is important to underline that external factors may arise that impact on the goal and implementation of the research programme. For this reason, active contemporary environment monitoring is important throughout the programme period.

Figure 2. Goals of the national programme in viruses and pandemics



3.5 Strategy of the research agenda

To implement the goal of the strategy, a number of activities are proposed. The activities are divided up into periods when there is no pandemic and during a pandemic. The work between pandemics focuses on building up a knowledge basis to create as good preparedness as possible. During a pandemic, the programme focuses more on implementing research initiatives that are necessary in the acute situation. The research agenda includes activities that are either carried out by the Swedish Research Council on its own, or jointly and in a coordinated way with other research programmes, public agencies and organisations.

3.5.1 Prioritised activities between pandemics

In order to give society and healthcare as good knowledge as possible ahead of a pandemic, we need more tools for discovering, understanding, treating and preventing virus diseases, their consequences and their transmission. The strategic research programme proposes a number of different activities to contribute to increased knowledge in this field. The activities are based on the focus groups' identified knowledge gaps and prioritisations, data from the documentation presented in the agenda, and discussions with the programme committee and the Swedish Research Council's scientific councils.

The activities can be carried out by an individual actor or in collaboration between different actors, such as research funding bodies, to contribute to the goal of the research agenda.

3.5.1.1 Strengthening the development of the research field

To carry out the necessary research initiatives, a clear structure and process is needed for the work of implementing the research agenda. A number of different activities are needed to coordinate the work on the research agenda, and a central part is to issue calls for research funding for the field. A first step is to identify knowledge gaps within the field. When research has been carried out within the programme, it is important to follow up the initiatives and update which knowledge gaps remain, and which have been filled. The programme needs to be flexible and possible to develop, based on new research being done.

- The focus groups form a reference group that discusses the current situation of the field, and can propose new, future research prioritisations within the programme. It is suggested that the group should meet once a year.
- The programme committee continues to meet regularly, around 4 meetings per year, for strategic planning, information exchange, follow-up and evaluation of the programme.
- Every two years, a joint conference with the reference group and the programme committee should be held, to discuss needs, knowledge gaps and results from the programme.
- Develop an implementation plan for activities in the agenda.
- The programme committee will produce a national action plan for research in the event of a pandemic to prioritise necessary research initiatives, allocate resources and coordinate initiatives by research funding bodies, institutes and public agencies that are important for the pandemic in question.
- The Swedish Research Council shall establish a call and review process for a new grant form, a grant to fund an urgent need, which will be possible to use quickly during a crisis.
- The Swedish Research Council shall establish a call and review process for a new grant form for research reviews. The grant form can be used to carry out literature studies aimed at identifying knowledge gaps.

3.5.1.2 Initiating and funding research

Based on the knowledge gaps identified by the focus groups and the mappings, different calls will be proposed aimed at filling the knowledge gaps. The proposals for calls will be made gradually during the program period, as all calls cannot be issued at the same time. Follow-up of grants awarded can also guide future calls. One area that is highlighted particularly as having major knowledge gaps by focus groups 1 and 3 is basic research in virology. This is a prerequisite for understanding viruses and their biology. Even though we are today seeing COVID-19 and HIV dominate the literature, these are just two out of thousands of viruses known to humans. In addition to these, there are new viruses that we do not know about today that can cause illness. As most fundamental mechanisms relating to virus infections are as yet unsolved, it is important that basic research in virology is prioritised, so that society is prepared ahead of the next pandemic.

Basic research is also important in the areas of zoonoses, prevention and monitoring of infection transmission, and how changes to climate and environment affect zoonoses, which was highlighted by focus group 2. Here, a 'one health' perspective should be applied. Research into zoonoses has had slightly less funding and a lower proportion of publications in the virus field. To reduce infection transmission in society and reduce the amount of illness at individual level, preventive measures are needed. Preventive measures include everything from cleaning, disinfection and mouth covering to travel restrictions, lock-downs, quarantine measures and other societal limitations. To reduce the risk of infection transmission to humans, we need new methods for monitoring at the interfaces between animals and humans. Then it is possible to determine which viruses will be successful in adapting to humans, and thereafter develop interventions to reduce the transfer.

Development of new antiviral medicines, vaccines, new, more and better diagnostic tools and improving existing medical interventions and treatments are also needed.

During a virus pandemic, secondary bacterial or combined viral and bacterial infections can also increase. Here, antibiotic resistance may also play a part. Joint calls with the national research programme in antibiotic resistance may be a solution for bringing the research areas together.

It is of the utmost importance to have a societal organisation that can cope with addressing a pandemic, for example in primary care, elderly care, childcare and schools. Focus groups 4 and 5 highlight the importance of evaluations of infection protection and societal measures in the long and short term. This includes economic aspects, inequality, democracy and research into leadership, decision-making and communication in the event of major uncertainties or crises. As different countries had different strategies during the COVID-19 pandemic, the effects of the strategies chosen need to be studied. This would give deeper understanding and allow lessons to be learnt about which societal

measures have the best possible effect on preventing infection transmission and disease.

The COVID-19 pandemic taught us the importance of developing diagnostics, broad-spectrum antivirals and vaccines. What is needed from Day 1 when there is a risk of an emerging pandemic is access to quality-assured diagnostics for the virus emerging, and access to broad-spectrum antivirals, as vaccine manufacture for a new virus will always take a bit longer.

In the years after the outbreak of COVID-19, the number of publications and the funding of virus and pandemic research has increased compared to previous years. Sweden is above the average in terms of highly cited articles in the virus field (see Appendix 2). The virus and pandemic field is in a dynamic phase, where knowledge gaps can be filled as new research is completed. It is therefore essential, ahead of future calls under the programme, to systematically evaluate the scientific literature. To strengthen research and clarify research needs in a specific area, calls for funding of grants to research reviews may be issued.

The following measures are proposed:

- Research funding bodies create calls based on the knowledge gaps identified by the focus groups (see Table 1 and Chapter 3), where researcher-initiated projects in viruses and pandemics can get funding. Different types of grant forms are needed to highlight one or more knowledge gaps in different calls.
- Update, evaluate and summarise mappings of relevance to the programme, for example via grants to research reviews, mappings made by public agencies, etc.
- This area is in large parts interdisciplinary, and to stimulate collaboration between different research fields, strong research environments should be created, aimed at stimulating interdisciplinary and intersectoral collaborations.
- Grants to graduate school can also contribute to interdisciplinarity and train the researchers of the future in the field.
- To stimulate national collaborations in virus and pandemic research, the opportunity to network grants should be offered, to promote research between the focus areas, where different competences and organisations can hold discussions.

Although Swedish virus research is internationally prominent, there are major knowledge gaps. A central part of the programme is to develop and deepen knowledge in the field, from basic research to implementation. During the mapping, it became clear that there are a large number of viruses and virus-caused diseases that are wholly or partly not researched in Sweden.

Table 1 summarises in greater detail different proposals for calls that may be made within the research programme. Calls may include one or several focus areas, and one or several different grant forms.

Table 1. Proposed calls. For a description of grant forms, see Appendix 5

Call for	Types of grant	Knowledge gap/Challenge
Viruses, virus-caused disease conditions and fundamental disease mechanisms (Focus area 1)	Project grant Career support	Basic research in virology, for example pathogenesis, susceptibility at population level, tropism
Mechanisms for the emergence and transmission of zoonoses with pandemic potential, and strategies for prevention and management of infection transmission (Focus area 2)	Project grant Career support	Emergence and transmission of zoonoses, virus evolution, infection transmission, prevention, climate change, ecology, monitoring
Development of antiviral medicines, vaccines and diagnostics (Focus area 3)	Project grant Career support	Identification and development of new antiviral medicines, vaccines, diagnostics, patient-proximate translational research
Societal measures arising as a result of a pandemic and its effects on human living conditions and health (Focus area 4)	Project grant Career support	Societal measures, such as infection protection, evidence supply, effects at individual level and population level, leadership and decision-making, behaviour
Organisation, governance and coordination (infrastructures) of important societal functions during a pandemic (Focus area 5)	Project grant Career support	Resource use, relationship between different actors, different countries' strategies during a pandemic
Infection field (joint call with the antibiotic resistance field)	Proof of concept grant	Virus diagnostics, antiviral medicines, patient-proximate research
Interdisciplinarity in pandemic preparedness, such as infection transmission, public health, societal effects	Network grant	National collaboration between different actors and research fields

Call for	Types of grant	Knowledge gap/Challenge
Interdisciplinary research collaborations between different scientific fields in viruses and pandemics	Research environment grant	Identified knowledge gaps that relate to several focus areas (1–5)
Virology, zoonoses, antiviral medicines, etc.	Distinguished professor grant	Long-term basic research
Virology and pandemic research	Graduate schools	Interdisciplinarity
Knowledge gaps in identified areas	Grant for research review	Update and identify knowledge gaps in specific scientific fields
Take part in calls under international research programmes		Identified knowledge gaps in the research agenda

3.5.2 Promote international collaboration

The virus and pandemic field has a clear global profile, as viruses and pandemics do not recognise any national borders. For this reason, it is of the utmost importance that the programme takes part in international collaborations and research programmes, such as Horizon Europe. International collaboration is also highlighted in the mandate. The Swedish Research Council and Vinnova take part in the European collaboration Pandemic Preparedness (BE READY). Within the framework for BE READY, the fifteen participating countries shall produce a European research and innovation agenda, which will form the basis for the planned European partnership in pandemic preparedness. Participation in BE READY provides opportunities to establish synergies between the national programme and the European arena. The experts in the different focus groups and the programme committee form an important platform, where topical issues within the area are discussed, and where experiences and guidelines can be shared. BE READY collaborates closely with the European Health Emergency Preparedness and Response Authority (HERA) which was established in 2021, and is an important partner for the national research programme at European level.

The Global Research Collaboration for Infectious Disease Preparedness (GLOPID-R) gathers together funding bodies from different countries that fund research relating to new or recurrent infectious diseases. The aim is to increase preparedness and to speed up research initiatives during breakouts with pandemic potential. The work aims to facilitate collaboration between research funding bodies globally, to improve pandemic preparedness and response. There are several international alternatives where the programme can participate to create collaborations both at policy level and research funding level, and the following are some of these:

- Continued participation in BE READY.
- Take part in the future European partnership in pandemic preparedness.
- Take part in the global collaboration GLOPID-R.
- Take part in suitable calls within Nordforsk.
- Take part in global collaborations of relevance to the area.

3.5.3 Research data and infrastructure

There is a need to also illuminate gaps in the prerequisites for carrying out high-quality research in relation to data sources and infrastructure. Management, sharing, storage and security of data are also important in this context.

- More and better high-risk laboratories with associated animal facilities for important research into societally dangerous viruses.
- Research is needed to contribute to the development of national guidelines, development and procedures for diagnostics and rapid diagnostics, for example for care homes and in primary care in conjunction with a pandemic.
- Facilitate collection of comparable clinical data between different regions for research.
- Facilitate analysis of data generated during a pandemic with societal data, environmental data, climate data, data on the geographic spread of wild animals that are important for infection transfer and infection transmission, etc.

More test and demonstration facilities may also be needed. These can promote collaboration between universities, higher education institutions and industry in the research. However, this lies outside the remit of the programme.

3.5.4 Dissemination and impact of research results

Disseminating and making research results accessible are important tasks for the programme. The following measures are proposed:

- Conference arranged by the Swedish Research Council every second year to disseminate results from initiatives carried out within the programme.
- Seminar to present research results.
- Ensure that results from the research programme are made accessible, both internationally and to civil society.
- The programme committee will develop a communication plan for the programme, to disseminate information about the programme and its results.
- Dialogue with national and international actors for knowledge exchange.

3.5.5 Prioritised activities in the event of a pandemic

To enable rapid support for research in the event of a pandemic breakout, the Swedish Research Council and other research funding bodies shall be able to issue relevant calls quickly according to the action plan developed between pandemics. One example of such an initiative is a grant to fund an urgent need by Formas. It is also important to enable changed assessments of the

coordination of Sweden's research priorities in the agenda when a pandemic breaks out. It may be necessary to take into account that the need at national level may differ from the need in other countries. If a future pandemic is caused by a non-viral pathogen, such as a prion or a parasite, a research initiative may be needed for that particular pathogen.

The following activities are proposed in the event of a pandemic:

- The established reference group with experts in the field is summoned in the event of a pandemic to discuss necessary research issues that should rapidly be addressed and funded. The reference group's proposals are thereafter discussed by the programme committee to evaluate the opportunities for implementation.
- Part of the research programme's annual budget is reserved for a funding initiative that may be used in the event of a pandemic. Between pandemics, the reserved budget is used for activities according to the research agenda.
- Research funding bodies should encourage and enable researchers with ongoing grants in relevant fields to use part of their funding during a limited time for research contributing to solutions to challenges relating to the pandemic breakout, irrespective of what project idea had been funded to begin with.

3.5.6 Follow-up and evaluation of the programme

According to the Government's mandate description, all national research programmes should be followed up and evaluated at regular intervals. The Government intends to establish that future evaluations between follow-ups shall be initiated and implemented by the Swedish Research Council. To concretise the content of the research agenda, an implementation plan will be produced, indicating when the activities in the agenda will be carried out within the framework for the programme between pandemics. Both the follow-ups and the evaluations are intended to ensure that activities and initiatives within the programme produce results that contribute to the programme goals. According to the mandate to the Swedish Research Council, a report shall also be submitted to the Government Offices no later than 1 March every year.

Follow-up shall be carried out annually for some parts, and at longer intervals for other parts, and the programme shall be evaluated on two occasions over a ten-year period. The areas to take into account in the follow-up and evaluation are:

1. What knowledge gaps are filled by the research grants funded within the programme, and what knowledge are not filled (evaluation/follow-up).
2. Analyse how interdisciplinarity has been created via the research funded under the programme (evaluation).
3. State the total allocation of research funding to the field of viruses and pandemics, divided up into focus areas, for example. This aims to trace research funding over time (follow-up).

4. International participation in framework programmes and research programmes relating to research in viruses and pandemics that can be directly attributed to the national research programme (follow-up).
5. Account for approval rates and amounts awarded divided up between women and men for funding within the programme (follow-up).
6. Analyse gender equality in the research contents of grants funded under the programme (evaluation).
7. Analyse the potential for utilisation of research results (evaluation).
8. Bibliometrics (follow-up).

The result from the follow-ups contribute to ensuring the goals are achieved and develop the programme over time. The follow-ups can be included as assessment documentation in the evaluations to be carried out on two occasions during the programme's ten-year period. A first evaluation will be carried out halfway through, and includes evaluation of the results to date. Following the end of funding, a final evaluation will be carried out, to evaluate the effects of the programme. An important part of the final evaluation is to assess which measures are important for ensuring a good level of the research between pandemics, and how to rapidly switch over the research in the event of a pandemic.

4 Mapping of research in viruses and pandemics and its funding

Research in viruses and pandemics is a wide field. To describe the field, a number of compilations have been used for the focus groups' discussions about knowledge gaps. This chapter shows an overview of the compilations produced. Four different documents were produced: research funding bodies' initiatives divided up according to the five focus areas (those that report to the Swecris database), publication of research in focus areas 1–3 (bibliometrics), and evidence maps of the research in focus areas 4 and 5. Table 2 shows an overview of the documentation produced, the type of documentation they represent, and whether they have undergone any form of quality control.

Table 2. Constituent mappings for the different focus areas.

Focus area	Source	Outcome/Type of mapping	Quality
1–5	Research funding in Sweden (Swecris 2009–2022)	Early phase – Projects funded in Sweden (n=1152)	Reviewed according to the funding bodies' peer review processes
1–3	World-wide scientific publication (Web of Science 2017–2021)	World-wide scientific publications publications (n=414 015)	Web of Science, reviewed according to the publications' peer review processes
4–5	Mapping using evidence maps relating to viruses and pandemics (Campbell Collaboration)	Late-phase guidelines and evidence syntheses	Yes, according to methods developed by Campbell Collaboration (see Appendix 3)

In the bibliometrics for focus areas 1–3, no own direct quality control has been carried out of the publications identified, as the number of publications is too

great. Ahead of an update of the agenda, prioritised areas can be selected for possible deeper analysis and quality control.

In focus areas 4 and 5, primary studies have not been analysed initially, instead evidence syntheses and recommendations (guidelines) have been identified (see Chapter 4.3). On behalf of the Swedish Research Council, Campbell Collaboration has carried out its own quality control (see Appendix 3 for method description). At a later stage, prioritised areas may be selected for a possible literature review of the area.

The mapping has also contributed to the identified prioritisations and activities for the programme described later on in the report.

4.1 Research funding in Sweden

The area is an active research field, with many initiatives resulting from the COVID-19 pandemic, both nationally and internationally.

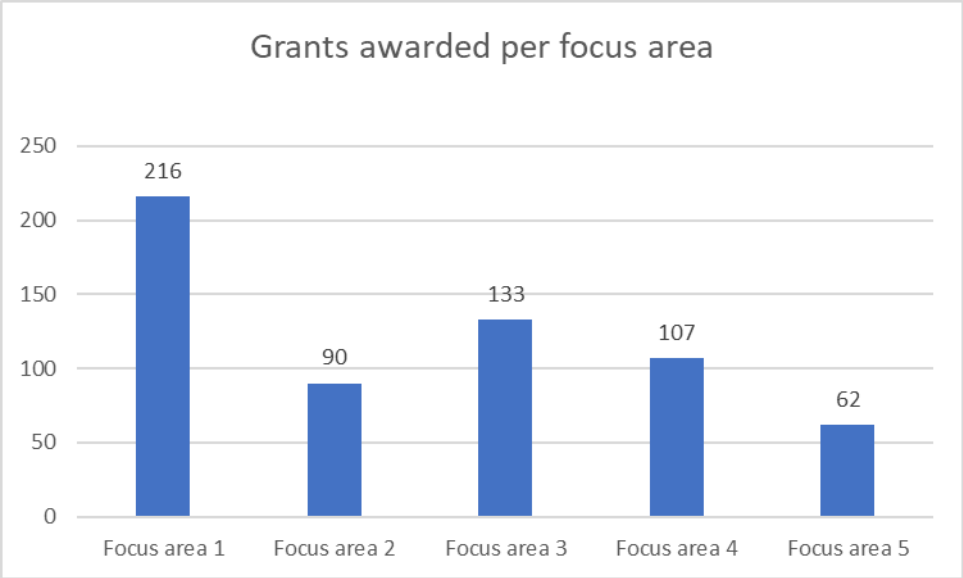
A national initiative in the area was made already in the Government's research bill from 2012 (Govt. Bill 2012/13:30), which entailed a considerable injection of funding to research in infection and antibiotics; 40 million SEK for 2013, and thereafter 75 million SEK annually since 2014. These specific funds have primarily been used for broad calls, including grants to research environments and projects in the infection field.

In conjunction with the COVID-19 pandemic, further funding was given to the area, resulting in calls relating to COVID-19 in particular, but also broader initiatives within the area. Compiled information about the Swedish Research Council's initiatives for research into COVID-19 can be found on the Council's website.

The Swedish Research Council has mapped research funding in the area through searches in the Swecris database. In Swecris, a number of different research funding bodies report funding of research projects for five different types of grants: project grants, grants for positions or scholarships or scholarships, research environment grants, research infrastructure grants and international collaboration.

The search words used were "virus" and "pandemic" during the years 2013 to 2022. In total, 608 different research grants were found. For 2022, further projects may be awarded and entered into the database, and therefore the figures for 2022 should not be seen as final. These research projects were categorised under the five different focus areas, see Figure 3 (if a project could be categorised under two focus areas, the most relevant one was selected).

Figure 3. Total number of grants awarded, all grant types, per focus area during the period 2013 to 2022

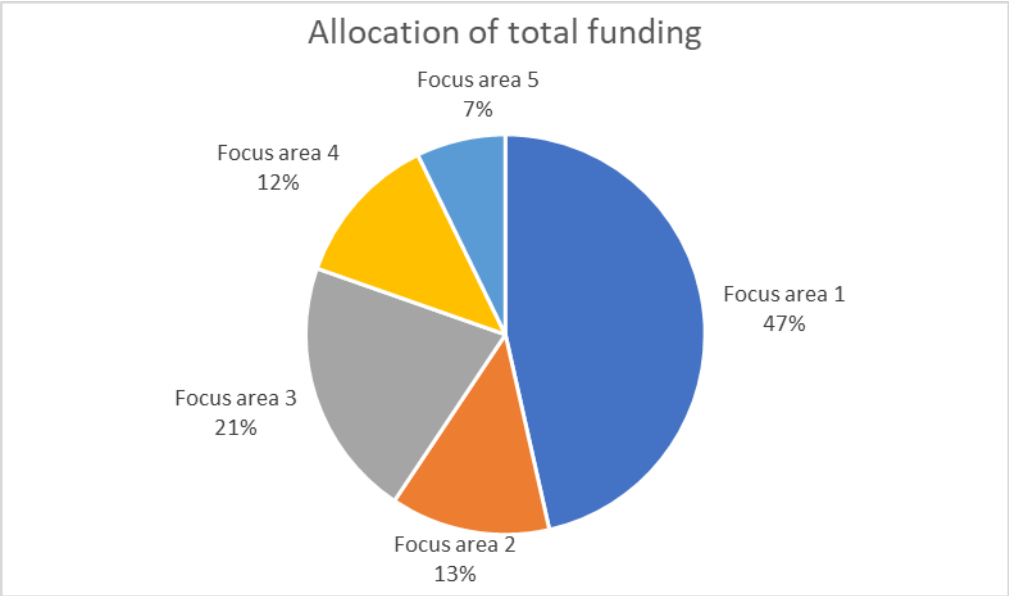


Swedish Research Council responses to COVID-19

Focus area 1 (viruses, virus-caused disease conditions and fundamental disease mechanisms) is the area with the most grants awarded 2013–2022.

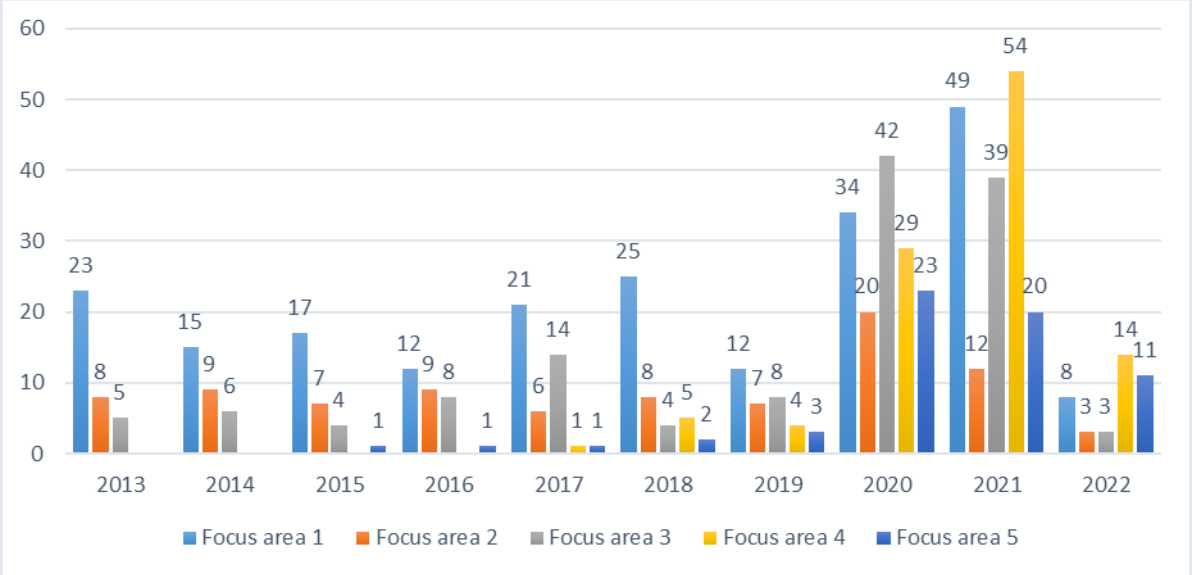
In total, around 2.3 billion SEK has been paid out to the grants awarded in all focus areas. Of this total, 47 per cent went to grants in focus area 1, followed by focus area 3 (development of antiviral medicines, vaccines and diagnostics), which was funded by 21 per cent (Figure 4).

Figure 4. Allocation of total funding per focus area (approx. 2.3 billion SEK).



Over the ten-year period, a clear increase can be seen in the number of grants funded in all focus areas for the years 2020 and 2021, a result of the initiatives made by the Government in conjunction with the COVID-19 pandemic. Grants within focus Areas 4 and 5 in particular have increased in 2021 and 2022 compared to previous years (see Figure 5). A considerable proportion of the funding (88 per cent) was awarded to universities, and a smaller proportion to businesses and institutes (6 per cent) during the period 2013–2022.

Figure 5. Allocation of number of grants funded per focus area and year.



Furthermore, of the funding granted, 2 per cent went to higher education institutions, 3 per cent to research within national government, regions and municipalities and also parishes, and 1 per cent to non-profit associations and foundations.

Results of the mapping

Funding within the field remained at an even level between 2013 and 2019, that is, the years before the pandemic. During this time, focus Areas 4 and 5 received few grants compared to the other focus areas. A rise in the number of funded grants occurred in 2020–2022 in all areas as a result of initiatives occasioned by the pandemic. It is important to create a knowledge foundation in the form of basic research to enable preparedness for various scenarios, at the same time identified knowledge gaps should be researched and filled.

The greatest proportion of the funding during 2013–2022 was in focus area 1, which includes basic virology research. Continued investment in basic virology research is crucial for gaining new knowledge about known and unknown viral diseases, but also because this is a good way to increase preparedness ahead of future pandemics, as it is difficult to predict which type of virus that will cause the next pandemic. Focus area 3 (development of antiviral medicines, vaccines

and diagnostics) needs to continue being invested in, in order to enable future threats to be addressed.

In recent years, focus areas 4 and 5 have been strengthened, even though knowledge gaps still remain in these areas. For example, organisational issues need to be highlighted in the future. The area dealing with zoonoses and prevention of infection transmission (focus area 2) has received a smaller proportion of funding, and may need a specific initiative. An interdisciplinary approach and application of the 'one health' concept is important and should be strengthened.

To date, a small proportion of the funding has gone to companies and institutes as grant recipients. The programme has issued calls for funding in the form of "proof of concept grants", which constitutes a step in this direction, but further initiatives from other research funding bodies may be needed here.

4.2 Scientific literature in the world

Within the research programme, the Swedish Research Council has classified and analysed the production of scientific articles linked to viruses and pandemics during the years 2017–2021. The publications included in the bibliometric statistics have been found through searches for key words in the title and summary of articles in the Swedish Research Council's publication database (where the contents are based on Web of Science data from Clarivate Analytics). A selection of the results of the analysis is presented below. Further information about the methods and further data can be found in Appendix 2.

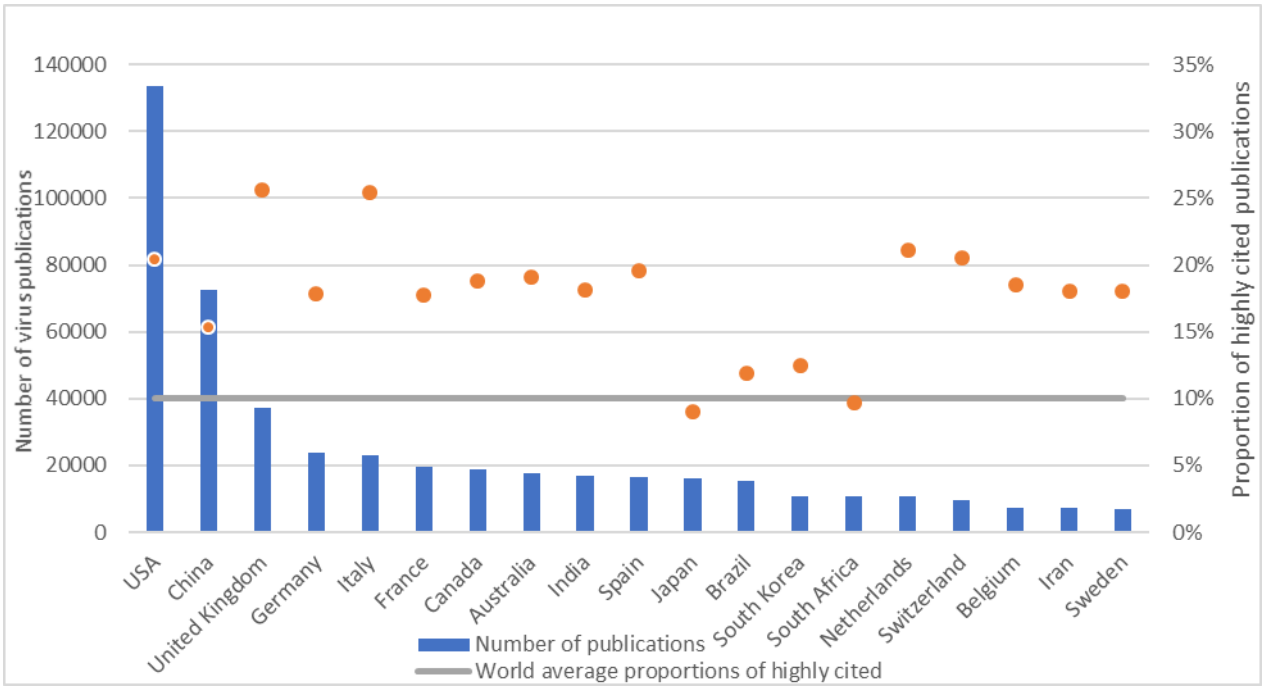
4.2.1 Number of publications in viruses and pandemics

The number of publications in viruses and pandemics around the world between 2017 and 2021 was 414 015 publications. The number of publications in the selection was fairly stable between 2017 and 2019, but increased dramatically in 2020 and 2021. This is probably an effect of increased funding for the field, and also that research was re-focused from other fields to research important issues relating to the COVID-19 pandemic.

The total number of publications within the entire field of medicine was 2 582 372, of which the proportion of virus-related publications increased from 9 per cent in 2017 to 13 per cent in 2020, indicating increased activity in virus research.

Figure 6 the countries with the most publications in the field of viruses and pandemics. The highest number of publications are from USA and China, while Sweden occupies 19th place. The figure also shows the countries' proportion of highly cited publications as dots. These designate the proportion of a country's total publications that are among the 10 per cent most highly cited in the world (world average is 10 per cent).

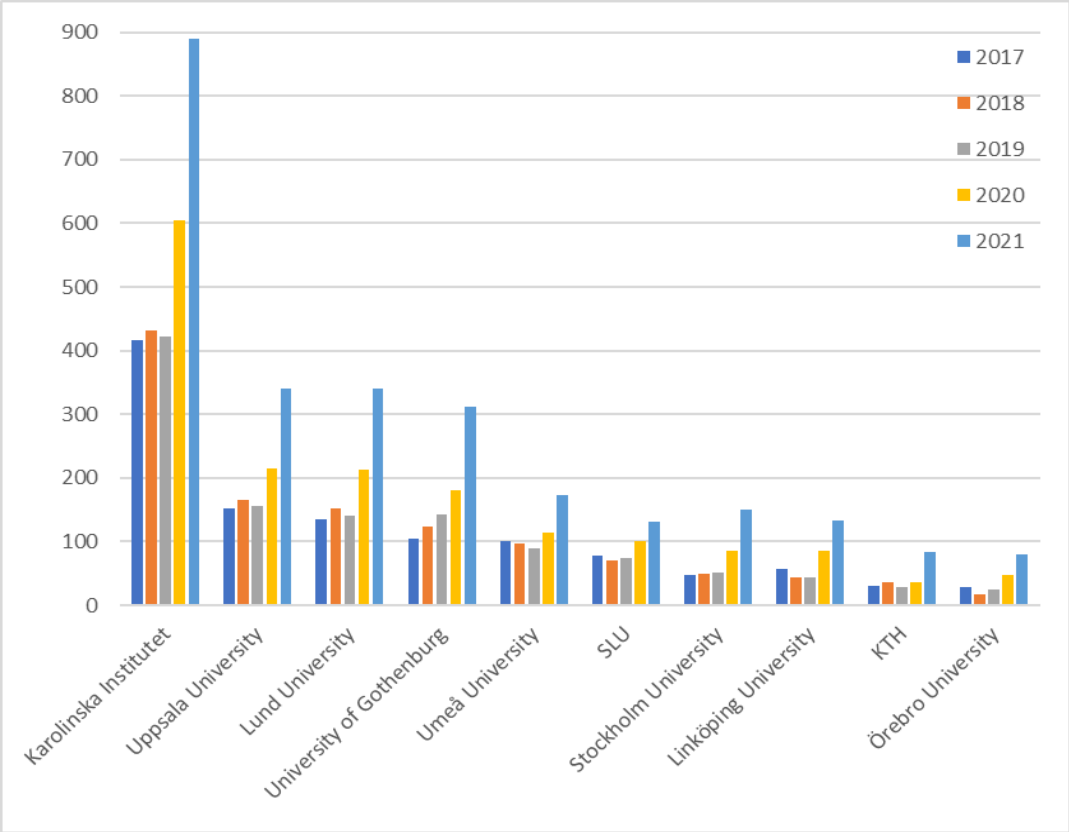
Figure 6. Number of virus-related publications from the years 2005–2017, divided by country. The countries' proportions of highly cited publications are shown as dots. Source: Clarivate Analytics.



The proportion of highly cited publications is far above the world average for nearly all countries in the figure, despite the citations being field-standardised (only compared with publications within the same field). This is clearly an effect of increased activity within the field due to the COVID-19 pandemic, as the proportion of highly cited publications increased considerably for 2020 and 2021 for all countries (see Table 2 in Appendix 2). The countries' number of publications and proportion of highly cited publications is divided up per year in this.

During the period 2017–2021, 6 724 articles within the virus field were published in Sweden. Karolinska Institutet leads the field, and doubled the number of publications between 2019 and 2021. A marked increase can be noted for all higher education institutions, and the universities of Uppsala, Lund and Gothenburg more than doubled their production, while Stockholm University tripled the number of virus-related publications.

Figure 7. Number of virus-related publications divided between Swedish higher education institutions for the years 2017–2021. The publications of the university hospitals are included with the respective university. SLU (Swedish University of Agricultural Sciences), KTH (Royal Institute of Technology). Source: Clarivate Analytics.



The table below shows the proportion of virus-related publications that include different search terms identified as being significant in the field, both for Sweden and the world. Sweden's pattern is very similar to that of the world, which shows a high proportion of research in therapy, pandemics and vaccines.

Table 3 Occurrence of a number of search terms in the selection, first as proportion of Sweden's virus-related publications and then as proportion of all virus-related publications in the world Source: Clarivate Analytics.

Search term	Proportion of Sweden's virus-related publications	Proportion of the world's virus-related publications
Treatment	20%	21%

Search term	Proportion of Sweden's virus-related publications	Proportion of the world's virus-related publications
Pandemic	18%	18%
Vaccine	14%	13%
Therapy	10%	12%
Transmission	10%	9%
Drug	9%	10%
Outbreak	8%	7%
Antiviral	6%	8%
Epidemiology	6%	6%
Zoonotic	3%	3%

A more detailed focus on research in Sweden and the world is available in Appendix 2, which shows the number of publications divided up into different viruses/diseases.

4.2.2 Results of the mapping

The last few years have seen a constant increase in publications, and the number of virus publications has doubled at most higher education institutions. One reason for this may be the increased need for knowledge about the field as a result of the pandemic. A rapid increase in publication could entail a reduction in quality, as some data were produced very quickly. One way of analysing quality is to carry out research reviews of priority areas where studies exist, as they may be areas with many studies but of less good quality. The mapping shows that Sweden is above the average in terms of highly cited articles, and is therefore an important research nation within the area in international terms.

To gain an overview of the different focuses within virus research, the publications in the selection have been categorised further. This shows that the focus on zoonoses has the smallest proportion of publications compared to the other focuses, both in Sweden and internationally. All viruses prioritised by the World Health Organization (WHO) as having pandemic potential are zoonoses, yet knowledge about these is still lacking. Treatment is the focus with the highest proportion of publications of virus-related articles. When mapping funding, it was again found that zoonoses was the area that received the smallest

proportion of funding. This is an area that could be investigated more closely, for example using research reviews.

4.3 Mapping using evidence maps relating to viruses and pandemics

To map the social sciences field in conjunction with viruses and pandemics, the Swedish Research Council commissioned the Campbell Collaboration to map focus areas 4 and 5. Campbell Collaboration is an organisation working with evidence syntheses in social sciences research.

The commission resulted in 'evidence maps' for the area. An Evidence Gap Map (EGM) is an intuitive, visual and interactive tool designed to provide an overview of identified sources in a subject, theme or domain [7–10]. Together with the focus groups and Campbell Collaboration, the Swedish Research Council has identified important overarching themes for research relating to viruses and pandemics and created an evidence map. Each thematic area has been divided up into a number of specified areas (sub-categories). Campbell has then mapped accessible sources within each thematic area relating to selected viruses and diseases. The evidence map is structured according to viruses, where identified sources of each virus have in turn been investigated and categorised according to different thematic areas. The starting point for the viruses/diseases selected was the WHO's list (4) of serious diseases with the potential to generate threats to public health, for which there are not sufficient or no preventive measures or cures, and which could cause a future epidemic or pandemic. The WHO also states that research into these is of utmost importance. In the work, the WHO's list was supplemented with further viruses/diseases by the focus groups. Below follows a summary of Campbell Collaboration's work on mapping knowledge gaps. Further information about Campbell Collaboration's work can be found in Appendix 3.

The sources included in the evidence gap maps are as follows:

1. Evidence collection: A collection of studies or other evidence resources supplied by an organisation. These are usually the organisation's own studies or resources, but not necessarily so.
2. Evidence platform: Website containing links to relevant resources, for example list of the latest publications, or publications organised according to theme. A platform can also include blogs and other materials, such as event messages.
3. Database: A database is a searchable set of studies. The database can also be categorised in different ways, for example to enable key word searches or filters to be applied.
4. Evidence map: An evidence map presenting evidence (usually, but not necessarily, studies) in a visual map online, with access to the underlying database of studies.
5. Evidence-based decision-making products (Guidance/toolkit/checklist): Evidence-based products used as documentation for policy and practice, for

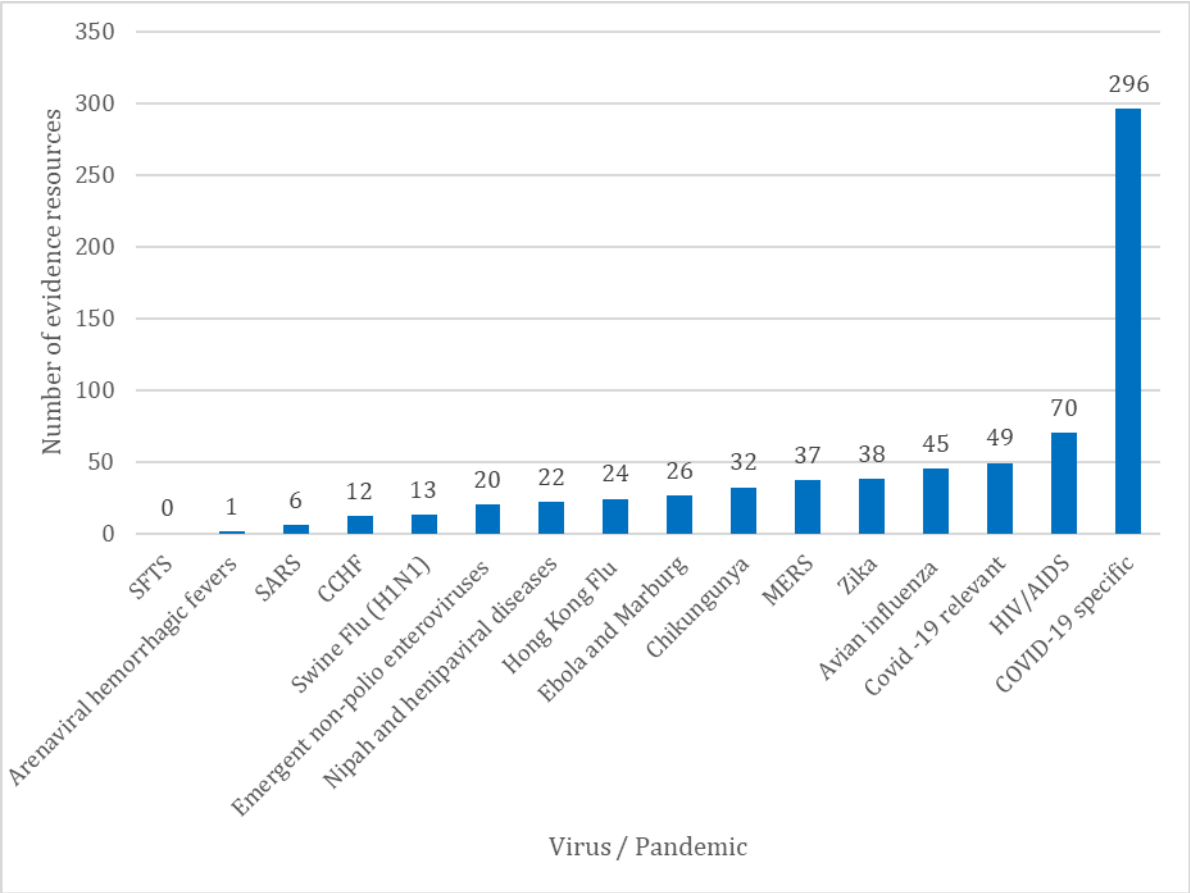
example guidelines for recommended policy and practice. Should be based on a systematic review of the evidence.

4.3.1 Results of the mapping

The search initially produced 802 sources (for detailed information, please see Appendix 3) and, following the gradual screening process where duplicates and sources irrelevant to the commission were removed, 496 sources were included in the final evidence gap map.

A large number of sources focused on COVID-19 specifically, and no sources were found for severe fever with thrombocytopenia syndrome (SFTS). Few sources relating to Severe Acute Respiratory Syndrome (SARS) and to Lassa fever (Arena viral haemorrhagic fever) were found compared to other viruses and diseases.

Figure 8. Distribution of sources across different viruses and diseases.



The majority of sources were in the form of evidence platforms that focused on transmission, prevention, management and impact of the disease burden, while a limited number of sources related to evidence, health systems and behavioural reactions, such as attitudes to vaccination and quarantines. A large number of sources in the form of policy documents specific to a particular virus were also identified.

Figure 9. Sources in the search divided into thematic areas.

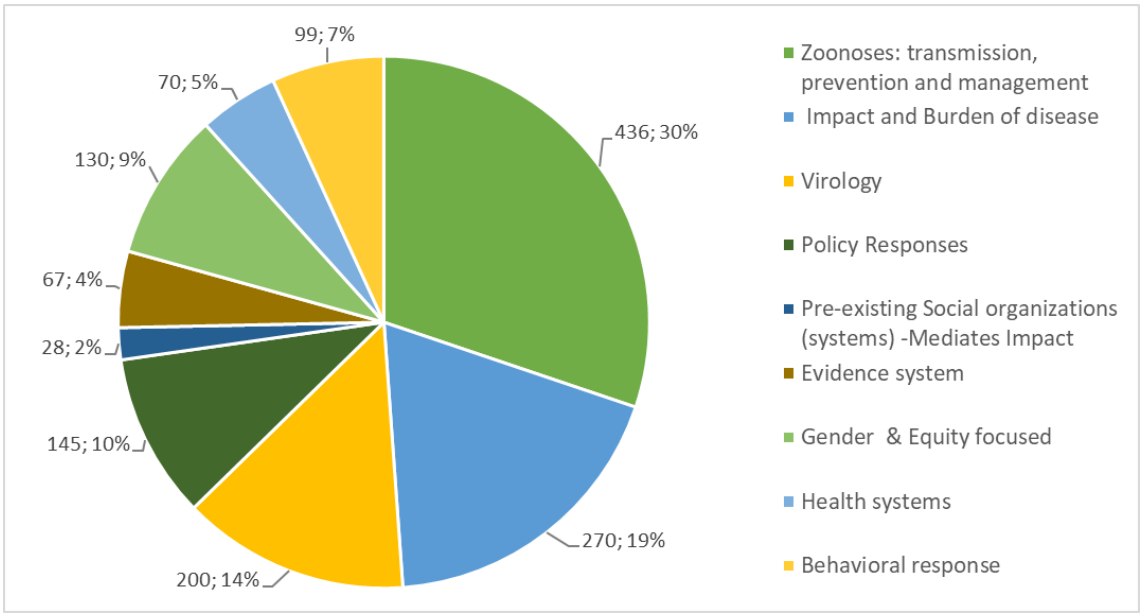
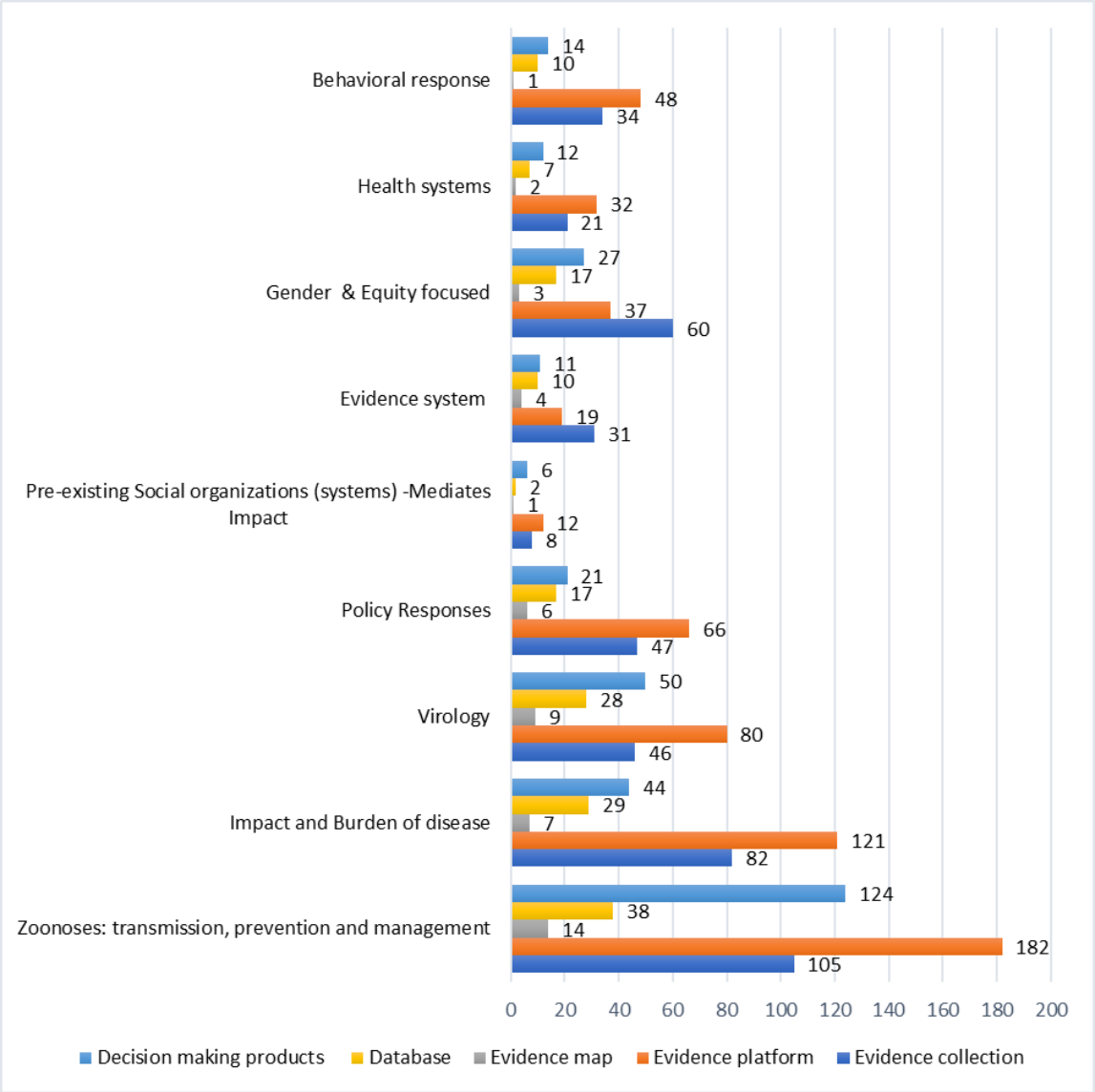


Figure 10. Type of evidence source divided into different thematic areas.



4.3.2 Results of the evidence maps

The evidence maps (EPPI-Mapper) shows that sources for COVID-19 exist in all thematic areas. Another virus that also has sources in all thematic areas is HIV, but there are fewer within the thematic area including effects in health systems, such as privatisation, collaboration, etc. This result can be compared to severe fever with thrombocytopenia syndrome (SFTS), for which no sources at all have been identified in any thematic area.

What stands out as potential knowledge gaps is the lack of sources for practically all thematic areas, except for COVID-19 and HIV, which have more sources of evidence than other viruses. Knowledge gaps are particularly frequent in the thematic area of political measures, which includes social services, education, economics, employment and law. Knowledge gaps are also found in the thematic area of social organisation systems, which includes welfare and

politics. Evidence systems specific to pandemics, which includes digitisation, is a further knowledge gap. For groups vulnerable in relation to pandemics, such as children and youths, the elderly, and socially vulnerable persons and ethical prioritisations within the thematic area of gender equality, sources are lacking for most identified viruses apart from COVID-19 and HIV.

When it comes to the thematic area of health and medical care system, potential knowledge gaps exist, in particular within the sub-categories ethical prioritisations in health and medical care systems and the design and governance of the health and medical care system.

5 Knowledge gaps and prioritisations within the focus areas

To fulfil the Government's broad mandate and to enable knowledge gaps to be identified in the different scientific areas, the programme was divided up into five different focus areas. A focus group was established for each focus area, with experts in the relevant subjects.

The following chapter describes how the focus groups worked out the priorities for the focus areas and identified knowledge gaps. The documentation produced is presented in its entirety in Appendices 2–4 in the agenda, and has been used to the extent it is relevant for the focus area. The knowledge gaps and prioritisations are largely based on the expert groups' collected experiences.

5.1 Viruses, virus-caused disease conditions and fundamental disease mechanisms (Focus area 1)

The focus group's summary of identified knowledge gaps and research priorities in Area 1.

Basic research in virology

Fundamental virological mechanisms

Interplay between virus and host

Viruses' life cycles and interactions in the cell

Pathogenesis, mechanisms for the emergence and development of viral disease

Tropism, how different viruses search out and multiply in specific tissues and organs

Pathogenetic mechanisms at individual level

Molecular mechanisms for differences in susceptibility to virus infection at population level

The area aims to increase knowledge about different viruses, virus diseases and mechanisms relating to the infection and disease process. Increasing knowledge about fundamental mechanisms relating to viruses and the diseases that may arise due to virus infection is of great importance for global public health.

Sweden has a strong tradition of translational research, with close links between basic research and clinical use. This provides unique opportunities for broad-based collaborations, which are necessary to discover new viruses and for studies of disease-causing characteristics of known viruses, as well as for application of the research results generated by basic research.

Viruses are contagious organisms that infect living cells and reproduce themselves inside a host cell, which can lead to disease that is transmitted between humans, but sometimes also from animals to humans. Contributory causes of viral transmission are, for example, urbanisation, increased trade in animals, and contacts between humans. Basic virology research that includes the interaction between cells and viruses and processes in the cells are crucial for obtaining knowledge about disease conditions caused by viruses. The susceptibility of a population to an infectious agent can depend on whether there are receptors on cell surfaces or not in the person infected, but also on other factors, such as previous immunity. It is therefore important to continue doing basic research that includes both individual cells and cell systems, and their links to the functions of the immune defence system. Furthermore, aspects relating to virus-host interactions can be emphasised, which in turn includes transmission mechanisms of different virus infections. Overall, an initiative in basic virology research is a precondition for new and successful applications relating to diagnostics, therapy and prophylaxis. With such scientific advances, we can better fight against constantly ongoing virus infections, as well as current and future pandemics.

Good examples of Swedish virological research that we wish to highlight are the opportunities for rapid applications of new in-depth sequencing methods for clinical sample materials, new molecular biology techniques for eliminating human and viral genes, advanced cell cultivation methodology including differentiation from human stem cells, access to tissue material, *in vitro* tissue models, and genetically modified animal models. In genomics, new viruses are being discovered, and transcriptome analysis contributes to new and better understanding of infection biology in a broader perspective. Furthermore, national initiatives in proteomics and glycomics have had a direct and lively application in basic virus research.

Large and active international collaborations position Swedish virus research at the international level, not least thanks to our use of impactful technological platforms and our good opportunities for combining laboratory and clinical research.

5.1.1 Identified knowledge gaps

Far more than 90 per cent of all viruses are still thought to be undiscovered. Basic research in virology should include both development of new experimental model systems to enable detailed study of virus-host interactions and their pathological processes, and also evaluation of new potential antiviral medicines and vaccine candidates. Together, this provides opportunities for new knowledge about individual viruses, and how virus interactions impact on both

individual cells and also tissues and organisms, and about infection biology mechanisms, such as virus replication and pathogenesis.

There are also knowledge gaps in relation to the interplay between virus and host and its consequences for public health as a whole, for example for cancer, and for degenerative and inflammatory diseases. Better understanding of such connections can give rise to new therapy opportunities and consequent reduced morbidity, with positive effects for both individuals and society as a result.

The documentation in Table 5, in Appendix 3, shows that Swedish research handles a broad spectrum of viruses relevant to pandemics. One reason why specific virus have not been specified in relation to knowledge gaps and prioritisation is the difficulty predicting which viruses will cause future pandemics (Pathogen X, that is, an as yet unknown virus that is included in the WHO's list of prioritised viruses). The entire research field relating to fundamental virological mechanisms and pathogenesis constitutes of a lot of knowledge gaps. The items below define these knowledge gaps more closely, from molecular virology up to host and population level. Strengthened basic research in virology raises the level of understanding of the entire research field, and therefore also the preparedness for a new pandemic. Such increased understanding also has great potential to lead to new approach directions for both vaccines and antiviral medicines.

Initiatives are also needed in the following areas:

Viruses' life cycles and ability to infect host cells

Knowledge about a virus' lifecycle and interactions in individual cells, which results in the production of new viruses, are imperfectly mapped and in many cases unknown for most of our disease-causing viruses. The area includes discover of new viruses, mapping of virus receptors, co-receptors and other cellular factors, and mechanisms for multiplication and genetic changes to viruses' genomes (for example through mutation and genetic adaptation to elude immune defence and antiviral treatment). It also includes how new virus particles are formed and leave the cell in order to infect new cells, and processes that cause a virus to re-program their host cells. There are also knowledge gaps in relation to how viruses cross mucous membranes and other barriers, how viruses establish infection and persist in a complex tissue environment, and tissue-damaging mechanisms linked to virus infection (both direct and indirect). Furthermore, the virus-infected cell's defence mechanisms and interplay with surrounding cells are completely unknown. These processes are often damaging at cell level, for its immediate surroundings (tissues) and at organ level. Studies of such disease-causing mechanisms (pathogenesis) benefit from newly developed analysis tools, and it is important to use these to fill this knowledge gap.

Models for virus infections

New data are often generated through trials in traditional cell cultures, which provides important, but limited, knowledge in more complex contexts. A great need therefore exists to study how different viruses seek out and multiply in specific tissues and organs ('tropism'). To do so requires development of models for virus infection in multi-cellular experimental and clinical systems (such as organoids, biopsies and animal models).

Pathogenetic mechanisms

Pathogenetic mechanisms are incompletely known even at individual level. The body's local and systemic immune defences usually lead to inflammation, which can cause tissue damage, disease and death. The area also includes the host's susceptibility to different virus infections and the existence of varying disease presentations, depending on age, biological gender and underlying diseases and co-infections.

Sample material from well-defined patient groups

In sample material at population level from well-defined patient groups, connections between viral disease presence and susceptibility and their underlying molecular mechanisms can be studied. This applies in particular for new disease conditions with increasing transmission, where new pandemics often can be discovered and explained at an early stage through clinical basic research.

Analysis of large data sets

Many of our newer techniques generate large amounts of data, which are independent of the researchers' assessments and need to be processed in entirely new ways, for example via machine learning and artificial intelligence (AI). This applies to data-generating activities, such as imaging, cryo-EM, experimental results from various 'omics' fields (genomics, transcriptomics, proteomics and glycomics), from single cell and organoid/organ-based analyses, and from animal experiment data, clinical data and register data.

One possibility of improving the research quality for all these areas is interdisciplinary applications in virology, with particular focus on new techniques in basic research.

5.1.2 Prioritised research areas

According to the identified knowledge gaps, the group has identified the following prioritised research areas:

- Fundamental mechanisms for virus-cell interactions in a broad sense
- Virus/host interactions in multi-cellular systems and organs
- Fundamental mechanisms for virus pathogenesis at host level

- The role of viruses in disease conditions with increasing transmission or virulence in the population
- Creation and use of innovative methods, techniques and tools for improving the four items above.

By investing in this strategy, Swedish virological basic research could become ground-breaking, which is an important precondition for creating a platform for pandemic preparedness, but also for managing our common and uncommon virus infections during periods between pandemics.

5.2 Mechanisms for the emergence and transmission of zoonoses with pandemic potential, and strategies for prevention and management of infection transmission (Focus area 2)

The focus group's summary of identified knowledge gaps and research priorities in Area 2.

Virus evolution and in-depth knowledge of the ability of different viruses to bridge species and cellular barriers

Methods and models for studying mechanisms for infection transmission

Preventive measures for pathogens with different transmission routes, focusing on air-borne transmission

How changes in climate, ecology, and demography impact on the emergence and transmission of viruses

New methods for monitoring infection transmission

Focus area 2 aims to increase knowledge about the mechanisms for diseases and infections that can transmit by natural means between animals and humans (zoonoses). A pandemic may arise when zoonoses are transmitted and established in new populations. The area also includes prevention and monitoring of infection transmission, and aims to provide knowledge of how changes to climate and environment affect the risk of new pandemics emerging.

During the COVID-19 pandemic, increased knowledge and major advances were made, but the pandemic also showed major shortcomings and knowledge gaps relating to the emergence of new zoonotic diseases, how infection transmission occurs, how it is monitored and best limited.

Infectious diseases that have managed to achieve pandemic transmission have successfully used the transmission routes that our civilisation has enabled. New diseases include diseases that are either entirely new, spread to new areas, new populations or new species, or that have changed so that they are more serious or

more infectious. New infectious diseases can be caused by different infectious agents, but viruses are the most common; in particular RNA viruses, as they have a greater tendency to mutate, which can lead to broadening of their host spectrums [11]. In addition to viruses, bacteria such as plague and cholera [12] have also caused serious pandemics throughout history, but with antibiotic therapy and better hygiene standards, viruses have gained a greater importance as the cause of new pandemics. Of the new diseases the humans suffer, zoonoses are over-represented [13, 14].

The ability to quickly be able to diagnose infected individuals is therefore of great importance for stopping infection transmission, and for zoonotic diseases in particular, we need functioning warning signals, collaboration between veterinary and human medicine agencies, and also a system where animal owners have knowledge and dare to report suspicions. Non-pharmaceutical prevention techniques, such as disinfection, breathing/mouth protection, quarantines and social distancing/isolation can also affect the risk of infection, and it is therefore crucial that we understand how the infection is transmitted.

There are many factors that interact to increase the risk of new diseases emerging, and also the opportunities for transmission. Climate change can have a direct effect on vector-borne diseases, as it impacts on temperature and precipitation, and can therefore increase the areas that are favourable to the vectors and enable the number of vectors to increase and spread to new areas. Many water-borne infectious agents can also be affected directly by climate change. There are, however, many other environmental changes that contribute to increase the risk of new diseases, as humans and animals come into contact with each other to an increased degree, for example through tree clearance and new construction. Animal husbandry and urbanisation also impact on disease risk where many humans and animals are present in limited spaces, which can simplify rapid transmission of disease between animals, between animals and humans, and between humans.

5.2.1 Identified knowledge gaps

To prevent new infections, we need to know the risk factors for emergence and transmission of emerging zoonoses, how environmental changes affect these in the future, and what preventive measures have the best effect, at the least cost to society. When a new infectious agent is introduced in society, we need preparedness to enable rapid identification of the infectious agent, its transmission routes, and also the groups that are the most susceptible. Knowledge about the movements and behaviour of humans, vectors and host animals is also important. When transmission is wide-spread, knowledge is needed about where the transmission is most highly concentrated, and under what circumstances transmission increases.

Below are identified knowledge gaps and five prioritised research areas, based on the knowledge gaps.

Virus evolution and viruses' ability to bridge species and cellular barriers

Important questions to investigate are what happens during co-infections with different infectious agents in animals and humans, what agents exist among animals that could have a zoonotic potential, and what causes an agent in animals to start infecting humans. A mapping of evolutionary intermediate variants and what importance they have for transmission between different species is needed. There is also a need to investigate what factors exist in different animal species that limit transmission and sensitivity to specific infectious agents in different species, and how viruses interact with different host animals.

Molecular aspects of virus/host interaction (for example when switching hosts), studies of the immune system of the host, and barriers and environmental factors are important. How is the binding of viruses affected, how is serious illness caused in different species, and how infectious is the virus? Another important aspect to investigate is how viruses impact on populations with reduced immune defence.

Transmission

Diseases can transmit in different ways, for example via air-borne infection, contact with body fluids, foods, or vectors such as mosquitoes and ticks. Many infectious diseases with pandemic potential are transmitted via short-term contacts between humans, such as via contact surfaces or respiratory aerosols. RNA viruses transmitted through inhalation, such as influenza viruses and corona viruses, have been reported as having a greater potential to become pandemic compared to other viruses [5]. Vector-borne diseases also have great potential for transmission, and here the spread of the vectors is also of great importance. Food and water-borne diseases can also cause major breakouts, but with high hygiene levels it has been possible to limit transmission in high-income countries. Knowledge gaps in the area include how different viruses infect, where transmission occurs and how this is affected by the environment, and what are the reservoirs and potential intermediate hosts.

We also need to investigate how demographic factors, such as increased urbanisation, socio-economic factors such as over-crowding, workplace conditions, increased mobility, trade and cultural and religious differences impact on disease transmission in society. What behaviours affect transmission, and how is this affected by attitudes and knowledge?

Impact on and changes to land use, environment and climate can lead to the natural habitats of animals and humans beginning to overlap, and therefore it is important to study these factors in order to understand disease transmission. How immunity and immunological factors impact on infection transmission needs to be further investigated, including how populations with reduced immune defence impact on infection transmission and viral evolution. Transmission patterns also need to be studied, and under what conditions viruses are transmitted, as well as knowledge about ‘super-spreaders’ (that is, persons who transmits viruses to a large number of other persons) and what makes certain individuals transmit more viruses than others.

How asymptomatic individuals are infectious, and whether individuals are infectious during the incubation period can also have a great impact on the pandemic potential. It is therefore important to obtain increased understanding of this.

Effects of different preventive measures

To limit disease transmission, it is crucial that the disease can be rapidly diagnosed, to monitor and understand how transmission occurs, and thereafter put in place effective preventive measures. Non-pharmacological measures can include everything from cleaning, disinfection and mouth covering to travel restrictions, lock-downs, quarantine measures and other societal limitations. Other possible measures include vector eradication and vaccination. Knowledge-based risk and consequence analysis is required as the basis for a good decision-making process on suitable preventive measures. Models of the disease transmission can form an important part of such analyses. This is therefore a broad area that is much dependent on our societal structure.

For this reason, it is important to carry out research in areas with major knowledge gaps, such as how different preventive measures function based on the conditions of different societies, and the effect of the preventive measures in different contexts. One challenge is to understand how to act optimally when a suspected infection emerges. The effect of vaccines on infection transmission, morbidity and mortality and how best to implement a vaccination programme also need investigation.

We need increased understanding for how contact tracing can contribute to reduced infection transmission, and how to increase bio-security awareness in society, care institutions and in animal husbandry. Attitudes, knowledge and opinions on public agencies impact on the effect of different preventive measures, and more research is needed to understand this connection in order to increase compliance with measures introduced.

Identification of risk factors for emergence and transmission in a changing world

Virological monitoring to foresee the emergence of new diseases and pandemics, and early warning systems that can stop infection transmission are important factors for preventing pandemics. More research is needed here into how these can be designed effectively and securely. The importance of evolutionary intermediate variants of infectious agents in different populations of animals and when they have been transferred to humans needs to be investigated. The effects of climate and environment changes on movements and behaviours of vectors, animals and humans and their ability to facilitate transmission is as yet relatively unresearched. There is a great need to build models for predicting this. The risk of new diseases emerging is greater in areas of poverty or high population density, and this requires research initiatives in the form of international collaboration.

New methods for monitoring

To identify new zoonotic infectious agents, we need functioning warning systems and collaborations between veterinary and human medicine agencies. Opportunities for rapid diagnostics is another important factor. Many zoonoses have little or no secondary transmission between humans, but when effective transmission occurs between humans, the new disease may develop pandemic potential. The zoonotic origin of micro-organisms often loses its epidemiological importance when effective infection transmission occurs between humans. Transmission is dependent on contact with other humans, with infection sources in our surroundings or any vectors, the number of such contacts and the duration of the infectiousness. Infection agents that have become pandemic have successfully used the transmission routes that our civilisation has enabled.

Monitoring and screening of waste water, wild and domesticated animals, vectors, or air filters are necessary for enabling new threats to be discovered, and the potential the new threats have for transmission. We can, for example, use AI, sequencing data, and mobile apps with geographic location data to better create monitoring systems and to assess whether the viruses discovered have zoonotic and/or pandemic potential. There is also a need to map existing systems for discovering new or increasing infections.

5.2.2 Prioritised research areas

According to the identified knowledge gaps, the group has identified the following five prioritised research areas:

- Virus evolution and viruses' ability to bridge species and cellular barriers
- Transmission: Mechanisms for infection transmission, development of methods and models for studying this
- Preventive measures for pathogens with different transmission routes, focusing on inhalation transmission
- Identification of risk factors for emergence and transmission in an unpredictable world with changing climate, ecology and demographics
- Development of new methods for virus monitoring and viral risk assessment with the help of new data sources, AI and sequencing data, for example.

5.3 Development of antiviral medicines, vaccines and diagnostics (Focus area 3)

Summary of identified knowledge gaps and research priorities in Area 3:

Virus diagnostics that are rapid, broad-based, validated, quality-assured and accessible

Identification of targets for antiviral medicines

Development of antiviral medicines with specific and broad function

Evaluation of already approved medicines with other indications for treatment of viral disease

Vaccine technologies that can provide long-lasting and broad immunological protection

Optimise different administration routes for vaccines and antiviral medicines

Patient-proximate and translational research into viral diseases.

Focus area 3 aims to increase knowledge about preventive and therapeutic measures to protect against and control virus-caused diseases in humans and animals by developing new antiviral medicines, vaccines and diagnostics, and improving existing medical measures and treatments.

Research in focus area 3 is important, and probably also crucial for how we can manage virus-caused outbreaks and pandemics in future, but strengthened research in the area can also contribute strongly to the development of tools that help and also relieve the pressure on healthcare's ability to look after people who suffer from common acute virus-caused diseases and their sequelae.

Infectious diseases caused by bacteria and fungi can often be treated with antibiotics, which often have a broad-spectrum effect, but the corresponding antiviral medicines for most virus-caused infectious diseases are lacking. An important difference between viruses and bacteria is that bacteria can transmit resistance to other types of bacteria. This is a major problem, and a reason for why the use of antibiotics, and in particular broad-spectrum antibiotics, is limited. Although viruses can develop resistance to antiviral medicines, they lack any known ability to transmit resistance between different virus types. This is important for the understanding that the prerequisites for using antiviral medicines with broad-spectrum effect – when these are available – are considerably better than the prerequisites for using broad-spectrum antibiotics. The need to strengthen research into the development of antiviral medicines with broad-spectrum effect was recently highlighted by the G7 countries' equivalents of the Swedish Research Council and scientific academies [6].

Vaccines are an important tool for protecting against virus-caused disease and death. Vaccines against COVID-19 were quickly developed during the pandemic, and vaccines have great potential for preventing virus-caused diseases. However, vaccines cannot be developed in advance against pandemics caused by infectious agents that are unknown to us, and vaccines cannot be developed to provide a broad-spectrum effect against differing, unrelated viruses. The COVID-19 and AIDS pandemics are two different examples of virus-caused pandemics, where vaccines produced the greatest benefit in one

case (COVID-19), and antiviral medicines produced the greatest benefit in the other case (AIDS).

It is now possible to rapidly diagnose certain virus infections in primary care, acute healthcare and elderly care, for example, but implementation of these important tools is slow. Rapid, reliable and specific diagnostics are essential for enabling treatment with antiviral and other medicines, and for limiting transmission. Development of new antiviral medicines and vaccines also requires clinical studies, which must be adequate for proving both safety and effect, and be based on analysis of relevant bio-markers, diagnostics and well thought-through regulatory, measurable parameters in clinical studies.

5.3.1 Identified knowledge gaps

A significant cause of shortages of medicines and vaccines against virus-caused diseases is that we have very large gaps in our knowledge of viruses' life cycles and disease-causing mechanisms.

The ongoing COVID-19 pandemic can be described as a global, long drawn-out natural disaster. However, the consequences would probably have been significantly worse if we had not managed to set up diagnostics and develop antiviral medicines and vaccines in record time. On the other hand, if strategic initiatives had been taken before the pandemic, aimed at filling knowledge gaps, then we would have had greater opportunities to have antiviral medicines with broad-spectrum effect in place right from Day 1 of the pandemic. We would then probably have managed the pandemic considerably better than we now did, and probably also have contributed - at global level - to increased access to healthcare and less inequality in low-income countries.

Focus group 3 analysed the available documentation, including Government Bill 2020/21:60. The group identified a number of knowledge gaps that are assessed as being essential for the national research programme in viruses and pandemics:

Molecular and cellular mechanisms and medicines

The research field has insufficient knowledge of molecular and cellular mechanisms that viruses use to infect cells and cause disease. This lack makes identification of "goals" for antiviral medicines and vaccines more difficult. Knowledge gaps in this field are clearly reflected in the lack of antiviral medicines and vaccines against an estimated 95 per cent of all viruses that cause disease in humans. We also need more knowledge about and better platforms for implementing clinical trials and evaluations of the benefit of antiviral medicine candidates.

Virus diseases and their sequelae

There are many research results that indicate that virus infections cause or increase the risk of diseases such as cancer, cardio-vascular diseases, auto-immune diseases and asthma, but we still have limited knowledge of which viruses, and how virus infections cause such diseases. Post-COVID syndrome

has affected tens of thousands of Swedes, and is a good example of the type of sequelae that arise following a virus infection. ME/CSF are probably also sequelae of virus infections. We have extremely limited knowledge of the origin of these and other sequelae, and of how they can be discovered, treated and prevented.

There are a number of virus families and a large number of individual viruses that cause disease in humans, and which are very little or not at all researched in Sweden (0-10 publications in total over the period 2017–2021), but also in the rest of the world. Several of these viruses and virus families cause diseases that are indicated by the WHO as threats to human public health.

Targeted diagnostics and testing

Sweden, but also large parts of the rest of the world, have knowledge of and methods for targeted diagnostics and testing of a relatively limited number of individual viruses or smaller groups of closely related viruses. This means that many tests often show negative results for the individual virus we are looking for. We therefore lack knowledge and tools for point-of-care diagnostics (for example at medical centres) that can enable rapid analysis of patient samples to diagnose a large number of viruses. Access to such knowledge and quality-assured tools in combination with access to antiviral medicines has the potential to revolutionise our ability to discover, understand, treat and prevent virus-caused diseases and their sequelae. In this way, we would significantly ease the burden on healthcare, which is heavily burdened by virus-caused diseases also during non-pandemic periods.

Development of vaccines

Although vaccines were developed in record time during the COVID-19 pandemic, it has become clear that the vaccines used do not always provide long-term protection, and not always sufficiently broad protection against new variants that emerge. The same applies for influenza, where genetic changes have led to a new vaccine being developed and offered each year. The vaccines developed against COVID-19 usually provide good protection against serious illness, but do not provide sterilising immunity that prevents infection and transmission. We therefore need knowledge that enables vaccines to be developed that provide broader, more long-lasting, and sterilising protection against viral diseases. It is also important to emphasise that coronavirus is one of the slowest-mutating RNA viruses that we know. The next pandemic might be caused by a considerably faster-mutating virus. We can therefore not rely on the vaccine technique (mRNA-based) that served us so well during the current pandemic to be sufficient for the challenges and needs caused by a faster-mutating virus. We therefore need more and better knowledge about additional vaccine techniques for developing and manufacturing vaccines, but also knowledge and platforms for analysing the effects of vaccines.

We have insufficient knowledge about the types of vaccine platforms, antigen types and administration routes that provide long-term immunological protection and memory in mucous membranes.

5.3.2 Prioritised research areas

In order to provide healthcare and society with better knowledge and new, more and better tools in the form of antiviral medicines, vaccines and diagnostics, we need to strongly prioritise research relating to these fields. Based on the knowledge gaps, threats and challenges identified above, focus group 3 provided the following prioritisations:

1. Reinforce research and development aimed at developing virus diagnostics that are validated, quality-assured, rapid, broad and accessible. It became clear during the COVID-19 pandemic that rapid diagnostics are needed to isolate and trace persons who might have been exposed to infection as quickly as possible. Broad-based diagnostics are needed for the infectious agent behind "Disease X" to be identified early on.
2. Increased research aimed at identifying targets for antivirals, in particular broad-spectrum antivirals, is an important method for fighting virus-caused diseases and their sequelae, and for strengthening preparedness ahead of future pandemics. Access to these, in combination with rapid diagnostics, can be used early on during an outbreak of a pandemic to limit transmission. Development of antivirals targeting the host's own molecules does theoretically have a low risk of resistance development. Strengthened research into "re-purposing drugs" is also important.
3. Strengthened research and development of vaccine techniques that can provide long-term immunological protection and memory in mucous membranes. In addition, research and design relating to which parts of viruses that should be included in vaccines ("antigen design") and research investigating different ways of administrating vaccines, such as via injection, or via mouth or nose.
4. Facilitate patient-proximate studies and translational research to study virus diseases, sequelae, vaccines, and antivirals, and develop diagnostics.

5.4 Societal measures arising as a result of a pandemic and its effects on human living conditions and health (Focus area 4)

Summary of identified knowledge gaps and research priorities in Area 4:

Evaluations of infection protection and societal measures in the long and short term, including processes, outcomes, economics, inequality, democracy and effects in different groups

Consequences of measures arising due to a pandemic for individuals, groups, geographic areas and activities of particular interest

Leadership, decision-making and communication in the event of major uncertainties or crises

Understanding of behaviours, relationships, norms and values and their importance in a crisis

Learning systems with structures for ensuring evidence is both created and accessible to decision-makers.

Focus area 4 aims to investigate the effects on people's living conditions and health of the societal measures and behavioural changes that followed from the pandemic, and to improve the prerequisites for weighing up the benefits and costs to society and health.

The COVID-19 pandemic has had far-reaching consequences for society. Many became ill, and many died as a result of the virus. Effects arising from behavioural changes to avoid infection and measures for reducing transmission have also impacted on individuals and society. Measures were taken to limit negative economic consequences for individuals and businesses. Reductions in social contacts, travel and economic activity produced rapid negative consequences for the national economy. Groups that were already vulnerable were often more affected.

When the pandemic started, we lacked knowledge and evidence about both intended and unintended effects of non-pharmacological transmission limitation measures. The difficulties and uncertainties of forward-looking assessment of societal benefits and costs may have contributed to pandemic measures differing in design in different countries. Even now, several years after the pandemic began, knowledge and evidence continue to be sparse.

Research within the area can touch upon both effects of infection transmission, disease and death and other consequences of non-pharmacological measures, but also, for example, consequences of the importance of healthcare organisation and accessibility, or measures aimed at promoting high and equal vaccination cover, and consequences that can contribute to reduced differences in mortality and care between social groups. It can also illuminate how effects of pandemic-related behavioural change and societal measures affected different persons depending on their gender, age, functional variation, socio-economic position, origin and geographic location. International and historical comparisons that highlight differences in context, measures, health and economics are important.

The consequences of measures and behavioural changes that followed from the pandemic have arisen broadly, and should therefore be studied broadly. Consequences for individuals can be direct, as disease, but also indirect, as mental and somatic ill health, social vulnerability or effects on behaviour and outcomes in terms of education, family formation and labour market. Consequences for society can relate to the labour market, schools, social insurance, social services or civil society. Links to social factors, such as

exclusion, poverty and inequality, and how inequalities in disease-preventing work can be counteracted may be of interest, as can the impact on children's and young people's living conditions and life chances.

The focus area spans medicine and social sciences, but also provides openings for humanities and historical perspectives, including effects on ideals, norms and culture, which are important for studying the consequences of the pandemic and provides knowledge of how to make society better equipped to manage future crises. It is important to monitor the need for qualitative and comparative studies, and ensure humanities, ethics and legal research are included as part of the programme.

Sweden has a tradition of drawing up registers, in the form of population data and healthcare data, which is a strength in a research context. As Sweden's management of measures during the pandemic differed from that of many other countries, comparative studies between countries are interesting.

5.4.1 Identified knowledge gaps

The overall assessment is that there are relatively large knowledge gaps about societal measures and their effects on people's living conditions and health.

This is due both to the fact that studies are lacking, and that the study quality is often low, or not reviewed. Processes for publication and quality assurance of scientific literature may have been speeded up too much during the pandemic, as rapid results were needed. This could have contributed to lowering the scientific quality of existing studies. Another challenge is that the area is broad in terms of disciplines. Before a call is issued, it is crucial that the review of existing research is systematically updated, including making a quality assessment of the overall studies. The group would like to emphasise that, besides identifying knowledge gaps, it is important to take into account where Swedish research has the opportunity to move the research frontier forwards.

The following knowledge gaps should be specially mentioned:

- What societal measures are needed during a pandemic? How should the measures be designed and implemented, and how should they be phased out in different social areas?
- Evidence provision for measures in all parts of society
- Positive and negative consequences of digitisation in conjunction with a pandemic
- Quantitatively measured outcomes when positive and negative effects of measures are weighed up (such as Disability Adjusted Life Years (DALY), Quality Adjusted Life Years (QALY))
- Study the side effects of societal measures introduced, such as traffic measures, consequences for public health, etc.
- The consequences of both the pandemic and society's measures for fighting it have differed for different groups in society, but we are lacking a lot of knowledge about the allocation and degree of inequality
- Consequences for vulnerable groups

- Cost effectiveness of the societal measures introduced
- Outcome of the societal measures introduced. For example, school closures may reduce transmission in the short term, but in the long term entirely different consequences arise (and the effect on transmission may also change over time)
- Behaviour and changes in behaviour as a result of a pandemic, for example risk communication, trust, norms, values
- Ethics (equal value of all humans, ageism vs the ethical platform in healthcare and its implementation during a pandemic [15])
- System for monitoring (infected but not tested persons)
- Ethnicity: Data has shown that both the pandemic and societal measures have had differing consequences for groups of differing ethnicities. It is important to obtain knowledge of the pattern, and in particular what causes it
- Learning system: System where new knowledge is captured as an integral by-product of health and medical care production. Data from healthcare meetings are aggregated and analysed continuously, and the knowledge generated is used to improve healthcare in future
- Methods for achieving a high and equal level of vaccination
- Economic evaluation: Many societal measures have considerable costs that should be offset against their benefits to ensure limited resources are used as effectively as possible
- Comparative studies of societal measures.

5.4.2 Prioritised research areas

All the prioritised areas below refer to research that is either based on empirical facts from pandemics, or research in other areas of clear relevance to pandemics. There is value in relevance and generalisability to other areas, but the starting point is lessons for or from pandemics.

- Evaluations of infection protection and societal measures in the long and short term, including processes, outcomes, economics, inequality, democracy and effects in different groups
- Learning systems and structures for evidence supply, including ethical and legal aspects
- Consequences for individuals, groups, geographic areas and activities of particular interest
- Understanding of behaviours, relationships, norms and values
- Leadership, decision-making and communication in the event of major uncertainties or crises.

5.5 Organisation, governance and coordination (infrastructures) of important societal functions during a pandemic (Focus area 5)

Summary of identified knowledge gaps and research priorities in Area 5:

Mobilisation and flexible resource use, for example when allocating personnel, and creating prerequisites for data accessibility.

Relationship between local and central actors. Ability to formulate and receive control signals. More knowledge is needed about the role of municipal self-governance, actors' ability to communicate and the municipal actors' capacity to make decisions.

Coordination between different actors. More studies are needed to illuminate different possible solutions and good examples that can be realised systematically in a crisis. Increased knowledge for effective allocation and coordination of responsibility.

Differences in strategies between Sweden and other countries and societies. International exchanges and comparisons should be central to continued knowledge accumulation and preparedness.

Focus area 5 covers research into the organisation, governance and coordination of important societal functions during a pandemic. The pandemic brought issues relating to organisation, governance and coordination to a head. For example, the ability of different societal actors to mobilise, absorb and use new knowledge, and to act in a coordinated and situation-adapted way was revealed.

To address a crisis such as a pandemic, it is important to have a societal organisation that manages to fulfil the organisational, governance and coordination needs that arise. Important fundamental values are democracy, the rule of law and effectiveness, but also more specific pandemic and crisis-related values, such as resilience, ability to prioritise, flexibility, security and preparedness. Research into how health and medical care can prepare for pandemics (increased resilience) and how experiences from the COVID-19 pandemic can be used to strengthen preparedness are important issues. Additional challenges are how the system can be prepared to both look after pandemic cases and also maintain regular healthcare and research. The healthcare ”debt” is a consequence of poor resilience, and this is now a major problem in healthcare in Sweden and many other countries.

The focus is, in a broad sense, relationships in vertical and horizontal directions that shape the ground for more specific challenges to research.

The allocation of responsibility in the health and medical care organisation has clarified challenges to roles and responsibilities at national, regional and healthcare institution level. There is limited understanding of how the healthcare system can be strengthened ahead of future pandemics and healthcare crises.

When the pandemic occurred, the ability to coordinate and act quickly was tested, for example by the vaccination campaign. Crisis preparedness issues were realised in terms of preparation and exercises. At the same time, it became

clear that needs, roles and inputs changed over the period, which turned out to be longer than most had been able to imagine beforehand.

A number of different areas can be pointed out as being crucial to address in social sciences research, based on different theories, disciplines and methods. One area that is particularly urgent to research relates to the health and medical care system's governance, organisation and interaction with other sectors. The healthcare system is complex and can be described as disintegrated, both horizontally and vertically. Vertically, there is a division between national government, regions and municipalities, which are all autonomous in relation to each other, while still being assumed to interact and coordinate all their activities. This multi-level system has been characterised as politically difficult to govern, and the pandemic has made plain problems with coordination of this fragmented system. In vertical direction, there is also what can be described as a horizontal division, reflected by several public agencies with overlapping responsibilities, for example. At regional level, there is a division of the public activities into primary and hospital care, and to this must be added private, profit-making actors, non-profit organisations and civil society. The system also includes actors who have great influence but a less clear formal role, such as the Swedish Association of Local Authorities and Regions (SALAR) and professions as systems, which add a further dimension to the societal organisation. Various reforms of the public sectors, including introducing competition, privatisation and marketisation, also contribute to the system's complexity.

More knowledge is needed about the actual design of the relationships and their strengths and weaknesses, the role of ideals and possible ways of acting. The relationship between politicians and officials/administration turned out to be crucial. During the pandemic, the actors could, however, not always fall back onto established roles and knowledge [16,17].

Overall, there is a need for research using differing approaches to focus on the interplay between different actors and levels.

5.5.1 Identified knowledge gaps

The pandemic brought issues relating to organisation, governance and coordination to a head. For example, the ability of different societal actors to mobilise, absorb and use new knowledge, and to act in a coordinated and situation-adapted way was revealed. Crisis preparedness issues were realised in terms of preparation and exercises. At the same time, it became clear that needs, roles and inputs changed over the period, which turned out to be longer than most had been able to imagine beforehand. More research based on different disciplines is needed to fill the knowledge gaps identified in relation to governance, organisation and coordination.

One area that is particularly urgent to research relates to the health and medical care system's ability to re-focus, and its governance, organisation and interaction with other sectors. The healthcare system is complex and can be described as

disintegrated, both horizontally and vertically. Vertically, there is a division between national government, regions and municipalities, which are all autonomous in relation to each other, while still being assumed to interact and coordinate all their activities. This multi-level system has been characterised as politically difficult to govern, and the pandemic has made plain problems with coordination of this fragmented system. In vertical direction, there is also what can be described as a horizontal division, reflected by several public agencies with overlapping responsibilities, for example. The system's vulnerability to health threats, such as the COVID-19 pandemic, was obvious, and the ability to maintain regular healthcare appeared to be limited. What is focused on is the importance of the healthcare system's resilience. What this means is how the system can stand up to external shocks, such as COVID-19, and handle the extra ordinary disease burden that is created, at the same time as maintaining ordinary healthcare and avoid indirect health effects.

To this complex picture can be added international coordination. During the pandemic, the EU adopted an ever more active role, both in the crisis management and also generally in the area. One sign of a new role for the EU is the creation of a European health union, which among other things means that a European agency for crisis preparedness in the field of health (Health Emergency Preparedness and Response, HERA) has been established. There is also very high political activity at national level in this field. A large number of public sector reports have recently been working on various issues relating to the pandemic.

Research focusing on organisation, governance and coordination is central for highlighting how different groups were affected by the pandemic and its management. Elderly and fragile persons living at home or in care homes, children and young persons in schools, socially vulnerable persons and various categories of workers are examples of groups that turned out to be particularly vulnerable and needed special initiatives during the pandemic. Various fairness, equality and power aspects become noticeable during the pandemic. Managing these groups based on partly changed legal prerequisites during the pandemic required well-developed organisation. From this, it also emerges that issues relating to health and medical care became central for actors in a number of sectors, both private and public, but also how vulnerability to the pandemic was clearly linked to the socio-economic prerequisites of different groups in society. A number of specific issues were raised, linked to law, competence and education, the dissemination of knowledge, leadership, working conditions and politics. Value conflicts often arose. For example, the public interest conflicted with the integrity of individuals, the need for aggregated statistics with confidentiality, and short-term measures with long-term sustainability.

During the pandemic, data and data accessibility was a problem for both research and effective crisis management. Central issues relate to effective data sharing/accessibility, identification of risks and solutions for secure data sharing, and development of tools/solutions/platforms for effective and secure data sharing. Existing systems for ethical review were entirely unprepared for rapid administration of clinical studies, and important opportunities for rapid testing of

medicines and new therapies were lost due to delays. A central dimension relates to communications and digitisation. The unwieldy multi-level system contributes further to difficulties with knowledge and information sharing between different organisations and geographic regions, which contributes to challenges in relation to coordination, and prevents coordinated, organised and effective crisis management during a pandemic.

Within the framework for organisation, governance and coordination, it is important that the focus on society's actors should both be directed towards the pandemic in itself, and also include research based on specific issues relating to health and medical care that were discovered during the pandemic, and that a broad social sciences perspective should be used for both. The latter can be the foundation for knowledge accumulation that equips society's organisation for any future pandemics and crises. The broad-based nature of the issues means that it is not only contributions from different disciplines that are important, but also that different methods and approaches are used.

5.5.2 Prioritised research areas

The expert group in focus area 5 has discussed five different areas that are important to prioritise in the continued work ahead of future pandemics, as follows below.

Mobilisation and flexibility

Mobilisation and flexible resource use became topical during the pandemic, but are also relevant for other potential crises. The ability to allocate personnel, apply standards, and data accessibility, to maintain stores of medicines and equipment, as well as re-allocate capacity turned out to be important. This has to happen while continuing to provide regular healthcare. More knowledge about the prerequisites for flexible societal organisation is therefore central for good pandemic preparedness.

Relationship between national government and municipalities

The relationship between local and central actors was problematised regularly during the pandemic. The ability to formulate and receive control signals was tested. More knowledge is needed about the role of municipal self-governance, actors' ability to communicate and the municipal actors' capacity to make decisions.

Fragmentation and collaboration

Coordination between different principals turned out to be a challenge during the pandemic, at the same time as new solutions emerged. Well-functioning established collaboration forms between private, public, associations and non-profit organisations were lacking. More studies are needed to illuminate different possible solutions and good examples that can be realised systematically in a crisis.

Coordination and allocation of responsibility

Horizontal coordination between different public agencies, but also between different regions and municipalities was the subject of much discussion during and after the pandemic. For example, a common understanding of prioritisation and management of key resources was lacking, both resulting in a lack of equivalence. The discussion lays bare the need for increased knowledge for effective allocation and coordination.

Sweden in the world

The pandemic led to comparisons between Sweden and other countries and societies, not least due to differences in strategy. Despite the existence of early lessons from the situation in Italy where healthcare was overstretched, this information was not taken seriously. International relations are central to the planning, management and follow-up of the pandemic. International exchanges and comparisons should therefore be central to continued knowledge accumulation and preparedness.

6 References

[1] Regeringskansliet, Prop. 2020/21:60; Forskning, frihet, framtid – kunskap och innovation för Sverige, 2020-12-17.

[2] W.H.O. (WHO), World Health organization pandemic definition, 2022.

[3] C.J. Carlson, G.F. Albery, C. Merow, C.H. Trisos, C.M. Zipfel, E.A. Eskew, K.J. Olival, N. Ross, S. Bansal, Climate change increases cross-species viral transmission risk, Nature, 607 (2022) 555-562.

[4] W.H.O. (WHO), Prioritizing diseases for research and development in emergency contexts, 2022-10-14.

[5] N.H.L. Leung, Transmissibility and transmission of respiratory viruses, Nature reviews. Microbiology, 19 (2021) 528-545.

[6] U. Nations, United Nations - The Sustainable Development Agenda, 2022-09-29.

[7] W.E.a.G.M.f.t.U.D.o.H. Ageing, WHO Evidence and Gap Maps for the Decade, (2023).

[8] U.-O.o. Research-Innocenti, Evidence Gap Maps, 2022.

[9] B. Snilstveit, M. Vojtkova, A. Bhavsar, J. Stevenson, M. Gaarder, Evidence & Gap Maps: A tool for promoting evidence informed policy and strategic research agendas, Journal of clinical epidemiology, 79 (2016) 120-129.

[10] W.H. Saran A, Evidence and gap maps: a comparison of different approaches, Campbell Systematic Reviews, 14 (2018).

[11] A.S. Lauring, R. Andino, Quasispecies theory and the behavior of RNA viruses, PLoS pathogens, 6 (2010) e1001005.

[12] J. Piret, G. Boivin, Pandemics Throughout History, Frontiers in microbiology, 11 (2020) 631736.

[13] L.H. Taylor, S.M. Latham, M.E. Woolhouse, Risk factors for human disease emergence, Philosophical transactions of the Royal Society of London. Series B, Biological sciences, 356 (2001) 983-989.

[14] K.E. Jones, N.G. Patel, M.A. Levy, A. Storeygard, D. Balk, J.L. Gittleman, P. Daszak, Global trends in emerging infectious diseases, Nature, 451 (2008) 990-993.

[15] S. Läkaresällskapet, Prioriteringsplattformen, 2023.

[16] Niemann, C. (2013). Villkorat förtroende. Normer och rollförväntningar i relationen mellan politiker och tjänstemän i Regeringskansliet. Stockholms universitet: Statsvetenskapliga institutionen, akademisk avhandling.

[17] Sundström, G. (2022). Brutet förvaltningskontrakt – metastyrning av svensk biståndsförvaltning. Studentlitteratur.

7 Appendix 1: Participants in the focus groups

Focus area 1;

Viruses, virus-caused disease conditions and fundamental disease mechanisms

Anna Överby, Umeå University
Clas Ahlm, Umeå University
Joakim Esbjörnsson, Lund University
Karin Blomqvist, Karolinska Institutet
Marie Larsson, Linköping University
Tomas Bergström, University of Gothenburg

Focus area 2;

Mechanisms for the emergence and transmission of zoonoses with pandemic potential, and strategies for prevention and management of infection transmission

Anne-Lie Blomström, Swedish University of Agricultural Sciences
Björn Olsen, Uppsala University
Carl-Johan Fraenkel, Lund University
Fredrik Liljeros, Stockholm University
Gerald McInerney, Karolinska Institutet
Johanna Lindahl, Swedish National Veterinary Institute
Magnus Evander, Umeå University
Magnus Johansson, Örebro University
Malin Alsved, Lund University
Patrik Medstrand, Lund University
Tom Britton, Stockholm University

Focus area 3;

Development of antiviral medicines, vaccines and diagnostics

Ali Mirazimi, Karolinska Institutet
Anna Lena Spetz, Stockholm University
Göran Tomson, Karolinska Institutet
Valentina Screpanti-Sundquist, Valneva Sweden AB
Johan Brun, Sobrera Pharma
Jorma Hinkula, Linköping University
Marianne, Jansson, Lund University
Matti Sällberg, Karolinska Institutet

Mattias Forsell, Umeå University
Niclas Roxhed, KTH Royal Institute of Technology
Niklas Arnberg, Umeå University

Focus area 4;

Societal measures arising as a result of a pandemic and its effects on human living conditions and health

Anders Johansson, Umeå University
Anna Sjögren, Uppsala University
Anton Lager, Karolinska Institutet
Bo Burström, Karolinska Institutet
Curt Hagquist, University of Gothenburg
Finn Nilson, Karlstad University
Joacim Rocklöv, Umeå University
Joakim Ramsberg, Swedish Brain Foundation
Knut Lönnroth, Karolinska Institutet
Kristofer Hansson, Malmö University
Malin Inghammar, Lund University
Mikael Rostila, Stockholm University
Per Axelsson, Umeå University
Pär Schön, Stockholm University

Focus area 5;

Organisation, governance and coordination (infrastructures) of important societal functions during a pandemic

Arash Heydarian Pashakhanlou, Swedish Defence University
Carl Dahlström, University of Gothenburg
Gustaf Kastberg Weichselberger, University of Gothenburg
Göran Sundström, Stockholm University
Jessica Alm, Karolinska Institutet
Johan Von Schreeb, Karolinska Institutet
Mikael Granberg, Karlstad University
Martina Axmin, Lund University

8 Appendix 2: Scientific literature in the world

Methods and indicators

The Swedish Research Council has an international publication database, based on the contents of Web of Science[1].

Subject classification

A publication is subject classified according to the journal it is published in, and each journal is classified according to one or more of Web of Science's 250 subjects. Articles in broad multidisciplinary periodicals, such as Nature or Science, are classified based on the articles' reference lists. These 250 subjects have been further divided up into 16 areas.

Publication volume and fractioning

One challenge of counting the number of publications is that a publication often has authors from several countries. The sum of the number of publications from the different countries is then greater than the total number of publications. The same challenge arises in comparisons of the number of publications within different subjects, as a journal may belong to several subject classifications.

The number of publications can therefore be calculated using fractional counting. This means that if a publication has two authors, A and B, they are awarded half a publication each, and the author total ends up the same as the actual number of publications. If the publication is also given several subjects, it is fractioned further. Swedish publications are identified using the address stated in the publications.

Field standardisation

The Swedish Research Council uses field-standardised citations to adjust differences in citation traditions between subject areas. Field standardisation means that the number of citations for each publication is compared to a global field reference value, which quite simply is the average number of citations for a publication in the same subject class during the same year.

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[1] When Web of Science is mentioned in this text, it refers to the Swedish Research Council's database, which consists of the following products: Science Citation Index Expanded®, Social Science Citation Index® and Arts and Humanities Citation Index®. These products have been compiled by Clarivate Analytics®, Philadelphia, Pennsylvania, USA© Copyright Clarivate Analytics® 2022. All rights reserved.

Proportion of highly cited publications

The proportion of highly cited scientific publications means the proportion of a country's or organisation's publications that are among the 10 per cent most cited scientific publications in the world. If the proportion is above 10 per cent, then the proportion of highly cited publications is above the world average. This measure of citation impact is not affected by single extremely highly cited publications to the same extent as the average citation measure can be.

All citation statistics ae based on fractions and field standardised citations. The number of citations is counted during a three-year window, which means that the citations are counted as from the year the publication is published and for two years afterwards. Self-citations are excluded.

Publications in viruses and pandemics

Within the national research programme, the Swedish Research Council has classified and analysed the production of scientific articles linked to viruses and pandemics (designated as 'virus-related publications') during the years 2017–2021. The publications included in the bibliometric statistics have been found through searches for key words in the title and summary of articles in the Swedish Research Council's publication database. Swedish publications are defined as having at least one author address from Sweden. The key words included different viruses and other terms, and the entire list is shown in Table 8.

Number of publications in viruses and pandemics

Table 1 shows the number of virus-related publications in the world during the last five years. The selection, which is based on a key word search, for the period is 414 015 publications for the world. The number of publications in the selection was fairly stable between 2017 and 2019, but increased dramatically in 2020 and 2021. As a comparison, the number of publications in the entire field of medicine is shown as well as the proportion of virus-related articles out of all publications in medicine. The proportion of virus-related publications was 9 per cent between 2017 and 2019, and then increased to nearly one fifth in 2021.

Table 1. Number of publications in viruses and pandemics within the entire medicine field, and the proportion of virus-related publications by the medicine field. Source: Clarivate Analytics.

Year	Number of publications in viruses	Number of publications in medicine	Proportion of virus publications
2017	55 293	603 484	9%
2018	56 121	617 297	9%
2019	57 188	643 880	9%
2020	95 961	717 711	13%
2021	148 761	805 144	18%

Table 2 shows the countries with the most virus-related publications in the world. First, it shows the total number of publications per country for 2017–2021. USA produced one third of the world's publications in the field, China produced around one fifth, and the United Kingdom around one tenth. After these, production per country evens out a bit, and Sweden is in 19th place and responsible for 1.7 per cent of the publications.

Thereafter it shows the proportion of highly cited publications from the selection per country, divided up by year (2021 is not included, as these publications have not had time to be cited to the same extent as the others). It is noticeable how the proportion of highly cited articles increases for 2020, and no country on the list falls below the world average. Even countries that in previous years have had a citation impact well below the world average, such as Japan, India, Brazil, South Africa and Iran, are now above the world average. Sweden has been above the world average throughout the period.

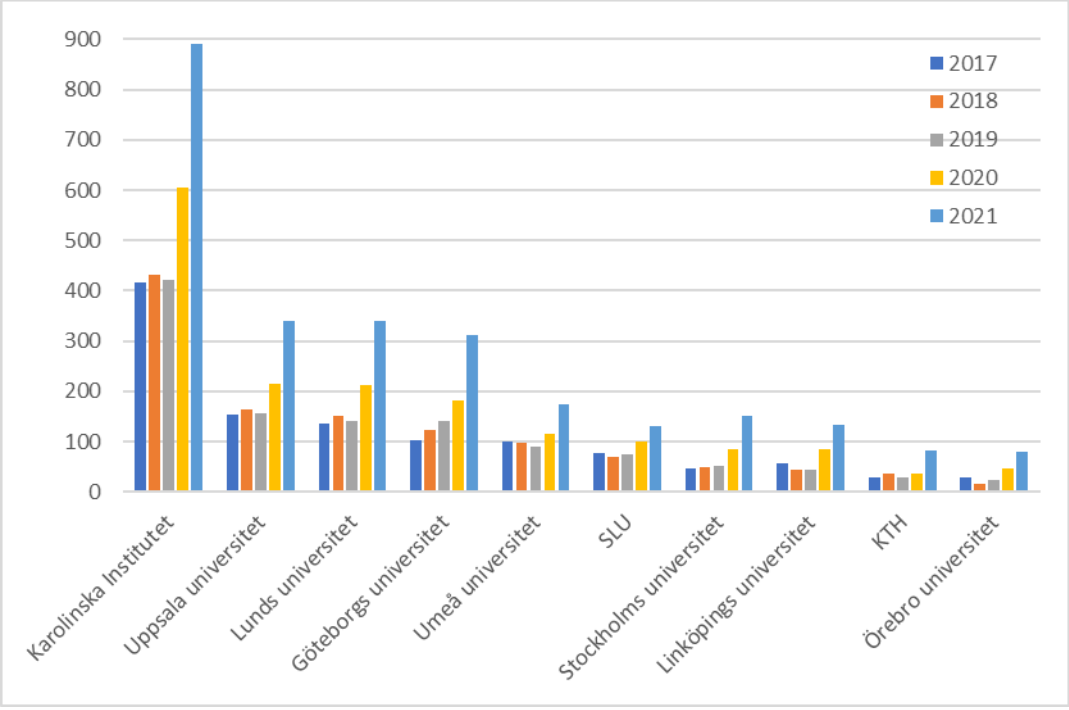
Table 2. Number of virus-related publications 2017–2021 per country and percentage of highly cited publications per country and year. Source: Clarivate Analytics.

Ranking	Country	Number of publications 2017–2022	Percentage Top 10% 2017	Percentage Top 10% 2018	Percentage Top 10% 2019	Percentage Top 10% 2020
1	USA	134 941	16%	14%	15%	26%
2	China	73 059	9%	9%	10%	22%
3	United Kingdom	37 664	17%	16%	17%	32%
4	Germany	23 913	13%	13%	11%	21%
5	Italy	23 401	10%	11%	12%	35%
6	France	19 618	12%	12%	12%	24%
7	Canada	19 172	12%	11%	12%	25%
8	Australia	17 878	13%	14%	13%	24%
9	India	17 063	7%	7%	7%	21%
10	Spain	16 589	10%	10%	10%	26%
11	Japan	16 244	5%	6%	6%	12%
12	Brazil	15 602	8%	6%	6%	15%
13	South Korea	10 904	7%	7%	9%	18%
14	South Africa	10 776	7%	9%	8%	10%
15	Netherlands	10 748	14%	15%	15%	26%
16	Switzerland	9 885	16%	16%	16%	23%
17	Belgium	7 423	12%	12%	11%	23%
18	Iran	7 245	5%	5%	8%	23%
19	Sweden	6 845	10%	11%	13%	24%

Ranking	Country	Number of publications 2017–2022	Percentage Top 10% 2017	Percentage Top 10% 2018	Percentage Top 10% 2019	Percentage Top 10% 2020
29	Denmark	4 484	10%	11%	16%	23%
36	Norway	3 028	13%	10%	13%	27%
38	Finland	2 680	9%	11%	11%	17%

Figure 1 shows the Swedish higher education institutions that publish the most within the field, and the development over the last five years. Karolinska Institutet leads the field, and doubled the number of publications between 2019 and 2021. A marked increase can be noted for all higher education institutions in the table and the universities of Uppsala, Lund and Gothenburg more than doubled their production, while Stockholm University even tripled the number of virus-related publications.

Figure 1. Number of virus-related publications from Swedish higher education institutions for the years 2017–2021. The publications of the university hospitals are included with the respective university. SLU (Swedish University of Agricultural Sciences), KTH (Royal Institute of Technology). Source: Clarivate Analytics.



Subject areas

As mentioned in the method chapter, the selection of publications in the analysis was done using key words. In Web of Science, these publications are classed as one or more out of 250 subjects. This classification is done based on the journal the publication was found in. Table 7 lists the number of publications in all subjects, both for the world and for Sweden.

Web of Science's subjects are further sub-divided into 16 subject areas. In Table 3, Swedish virus-related publications are divided up by these subject areas and years. It is interesting to note that in this table, the number of publications has increased in other areas then medicine. In 2021, there are many publications also in social sciences, engineering, psychology and economics.

Table 3. Number of Swedish virus-related publications per subject areas and year.

Research area	2017	2018	2019	2020	2021
Clinical medicine	456	456	460	677	996
Biomedicine	489	538	520	626	858
Health sciences	144	136	129	207	400
Agronomy	61	73	56	70	84
Geosciences	22	33	25	64	150
Biology	47	57	50	52	83
Social sciences	14	13	10	66	168
Chemistry	21	42	35	43	65
Engineering	11	13	17	38	86
Psychology	6	13	7	24	64
Economics	1	3	7	15	57
Materials science	7	15	13	19	23
Physics	6	12	13	14	25
Humanities	4	7		12	24

Research area	2017	2018	2019	2020	2021
ICT	5	2	4	10	22
Mathematics	3	8	7	6	15

To gain an overview of the different focuses within virus research, the publications in the selection have been categorised further. Table 4 shows publications including a certain key word, first as a proportion of the world's virus-related publications, and thereafter as a proportion of Sweden's virus-related publications. Sweden's pattern is very similar to that of the world, which shows a lot of research in therapy (treatment), pandemics and vaccines.

Table 4. Publications including a certain key word, first as a proportion of the world's virus-related publications, and thereafter as a proportion of Sweden's virus-related publications. Source: Clarivate Analytics.

Key words	Proportion of the world's virus-related publications	Proportion of Sweden's virus-related publications
Antiviral	8%	6%
Pandemic	18%	18%
Vaccine	13%	14%
Therapy	12%	10%
Drug	10%	9%
Transmission	9%	10%
Epidemiology	6%	6%
Treatment	21%	20%
Outbreak	7%	8%
Zoonotic	3%	3%

Network maps

The network maps show collaboration partners in terms of author relationships. The network analysis was carried out using VOSviewer software and represents identified organisations/countries from the publication selection. Each organisation forms a circle in the diagram, and lines between nodes represent co-publications. The larger the circle, the greater the number of publications, and the thicker the line, the greater the number of co-publications between the organisations. The different colours represent clusters, that is, the programme identifies clusters of organisations that collaborate a lot.

Figure 2 shows Swedish organisations' co-publications in the selection. Here we can see that the major higher education institutions from Figure 2 and a further 25 organisations, and the collaboration patterns between them all.

Figure 2. Network map of co-publications based on virus-related publications from Sweden 2017–2021. The publications of the university hospitals are included with the respective university. Only collaborations with at least 10 co-publications are shown. Source: Clarivate Analytics.

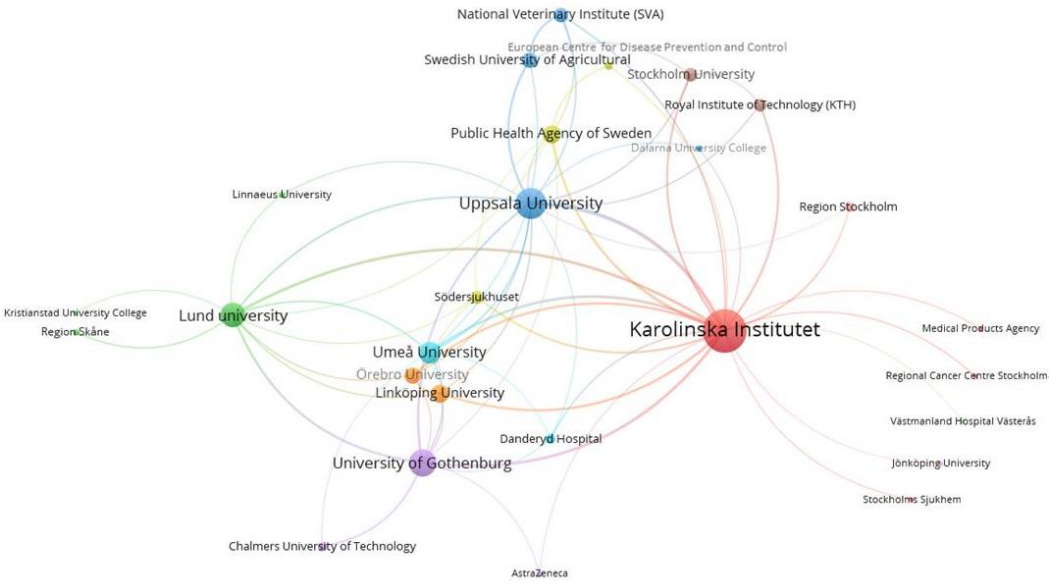


Figure 3 shows the countries that Sweden co-publishes most with, based on Swedish virus-related publications from 2017–2021. The countries that Sweden co-publishes with the most are, in order of size: United Kingdom, USA, Germany, Italy, Spain, France and Netherlands.

Figure 3. Network map of countries that Sweden co-publishes with, based on Swedish virus-related publications from 2017–2021. Only collaborations with at least 100 co-publications are shown. Source: Clarivate Analytics.

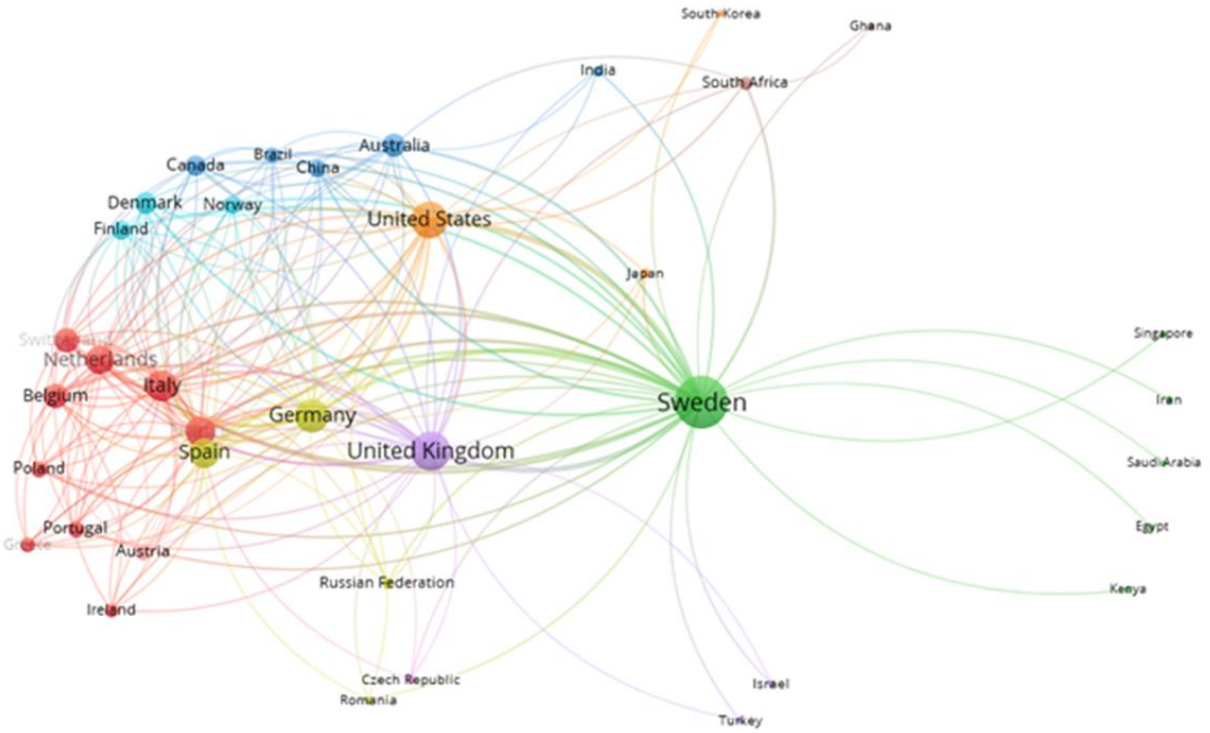


Table 5 below shows the number of publications in the world and in Sweden 2017–2021 relating to different viruses/diseases, and Sweden's percentage of world production. Both the diseases and viruses have been used as search words to enable as many relevant publications as possible to be identified. The listing below does not include any duplicates within coronavirus and COVID, for example.

Table 5. Number of virus-related publications in the world and in Sweden 2017–2021 relating to different viruses/diseases and Sweden's percentage of world production. Source: Clarivate Analytics.

Virus/Disease	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Coronavirus, COVID	125 298	1 874	1.5%
HIV	69 791	1 179	1.7%
Hepatitis A, B, C	33 467	486	1.5%
Influenza	31 766	614	1.9%
Retrovirus	25 338	440	1.7%
HPV, Papillomavirus	17 471	429	2.5%
Herpesvirus	16 874	241	1.4%
Dengue	10 648	174	1.6%
Cytomegalovirus (CMV)	10 562	225	2.1%
Adenovirus	8 399	159	1.9%
Zika	7 779	139	1.8%
Epstein-Barr	6 598	146	2.2%
H1N1, Swine flu	4 940	91	1.8%

Virus/Disease	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Ebola	4 767	112	2.3%
Respiratory syncytical virus	4 201	70	1.7%
Morbili, Measles	4 004	104	2.6%
Enterovirus	3 875	92	2.4%
Arbovirus	3 820	74	1.9%
Flavivirus	3 777	82	2.2%
Chikungunya	3 517	69	2.0%
Rotavirus	3 227	81	2.5%
Rabies	3 219	29	0.9%
MERS-CoV	2 975	26	0.9%
Polio	2 968	85	2.9%
Norovirus	2 658	79	3.0%
Viral haemorrhagic fevers	2 462	73	3.0%
Varicella	2 405	59	2.5%

Virus/Disease	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Parvovirus	1 925	25	1.3%
Rhinovirus	1 769	56	3.2%
Rubella	1 743	54	3.1%
Polyoma	1 691	28	1.7%
Yellow fever	1 612	35	2.2%
Vaccinia	1 516	35	2.3%
Japanese encephalitis	1 371	21	1.5%
HTLV	1 213	6	0.5%
Poxvirus	1 175	16	1.4%
Reovirus	1 156	12	1.0%
Circovirus	1 123	7	0.6%
Parainfluenza	1 003	14	1.4%
Picornavirus	943	26	2.8%
Bunyavirus	900	24	2.7%
Pneumovirus	898	14	1.6%

Virus/Disease	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Paramyxovirus	798	5	0.6%
Tick-borne encephalitis	794	84	10.6%
Hantavirus	774	51	6.6%
Variola	732	13	1.8%
Calicivirus	713	8	1.1%
Astrovirus	605	12	2.0%
Rhabdovirus	574	6	1.0%
Filovirus	541	11	2.0%
Rift Valley fever	520	27	5.2%
Nipah virus	478	2	0.4%
Bocavirus	404	5	1.2%
Arenavirus	367	10	2.7%
Marburg virus	341	3	0.9%
Parecho	281	16	5.7%
Lyssavirus	269	2	0.7%

Virus/Disease	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Orthopox	258	2	0.8%
Orthoreo	227	2	0.9%
Viral meningitis	221	3	1.4%
Hendra virus	191	0	0.0%
Togavirus	187	7	3.7%
Orthomyxo	182	3	1.6%
Hepadna	169	4	2.4%
Henipavirus	165	0	0.0%
Mayaro virus	157	0	0.0%
Anellovirus	156	9	5.8%
West Nile	128	7	5.5%
Hepevirus	123	1	0.8%
Nairovirus	123	10	8.1%
Oropouche	73	0	0.0%
Picobirnavirus	72	2	2.8%

Virus/Disease	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Borna disease	62	2	3.2%
Mamastro	38	2	5.3%
Banyangvirus	17	0	0.0%
Lloviu virus	10	0	0.0%
Issyk-Kul virus	5	0	0.0%

* Including Crimean Congo, Lassa and Severe fever with thrombocytopenia

The table below shows the number of publications, both in the world and in Sweden, per Web of Science research subject, instead of per area as in Table 3.

Table 6. Number of virus-related publications in the world and in Sweden and Sweden's percentage of world production 2017–2021 divided up by research subject. Source: Clarivate Analytics.

Subject	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Immunology	48508	1039	2.1%
Infectious diseases	47063	1 156	2.5%
Public, environmental & occupational health	37884	740	2.0%
Virology	36840	620	1.7%
Microbiology	31300	586	1.9%

Subject	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Biochemistry & molecular biology	25478	398	1.6%
Medicine, general & internal	24882	407	1.6%
Medicine, research & experimental	20944	289	1.4%
Pharmacology & pharmacy	18713	206	1.1%
Oncology	16962	374	2.2%
Veterinary sciences	15500	187	1.2%
Cell biology	15211	302	2.0%
Biotechnology & applied microbiology	13728	215	1.6%
Environmental sciences	12595	254	2.0%
Gastroenterology & hepatology	10011	150	1.5%
Parasitology	9948	184	1.8%
Chemistry, multidisciplinary	9763	110	1.1%
Tropical medicine	8216	137	1.7%
Paediatrics	8014	129	1.6%
Genetics & heredity	7220	127	1.8%

Subject	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Neurosciences	7072	158	2.2%
Healthcare sciences & services	6900	105	1.5%
Surgery	6177	62	1.0%
Psychiatry	6073	115	1.9%
Plant sciences	5807	45	0.8%
Clinical neurology	5630	114	2.0%
Biochemical research methods	5580	125	2.2%
Health policy & services	5317	77	1.4%
Respiratory system	5260	107	2.0%
Chemistry, medicinal	5092	40	0.8%
Social sciences, biomedical	5053	69	1.4%
Biology	5016	78	1.6%
Haematology	4801	126	2.6%
Psychology, multidisciplinary	4173	63	1.5%
Obstetrics & gynaecology	3991	66	1.7%
Cardiac & cardiovascular systems	3956	64	1.6%

Subject	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Materials science, multidisciplinary	3708	48	1.3%
Mathematical & computational biology	3635	53	1.5%
Pathology	3599	33	0.9%
Chemistry, analytical	3583	49	1.4%
Biophysics	3533	55	1.6%
Entomology	3435	45	1.3%
Endocrinology & metabolism	3297	74	2.2%
Transplantation	3211	48	1.5%
Nanoscience & nanotechnology	3154	43	1.4%
Food science & technology	2998	37	1.2%
Radiology, nuclear medicine & medical imaging	2980	15	0.5%
Chemistry, physical	2941	36	1.2%
Nursing	2861	32	1.1%
Ecology	2774	92	3.3%
Economics	2774	52	1.9%
Fisheries	2766	21	0.8%

Subject	Number of publications in the world	Number of publications in Sweden	Sweden's percentage of world production
Environmental studies	2528	59	2.3%

Table 7. Number of virus-related publications where the respective Swedish funding bodies is mentioned in acknowledgements 2017–2021. Source: Clarivate Analytics.

Funding body	**Number of publications**
Swedish Research Council	1448
Swedish Cancer Society	369
Wallenberg Foundations	342
Formas	225
Swedish Foundation for Strategic Research	183
Swedish Heart-Lung Foundation	112
Swedish Society of Medicine	72
Swedish Childhood Cancer Fund	71
Swedish Society for Medical Research	71
Swedish International Development Cooperation Agency	67
Forte	66
Vinnova	66

Table 8. Key words used when searching for virus-related publications. * indicates a "wild card" (includes one or more characters) and is used to expand the search result.

- Adenovir*
- Anellovir*
- Antiviral*
- Arbovir*
- Arbovirus*
- Arenavir*
- Astrovir*
- Banyangvir*
- Bocavir*
- Borna disease*
- Borna virus*
- Bunyavir*
- Calicivir*
- Chicken pox*
- Chikungunya*
- Circovir*
- CMV*
- Coronavir*
- Covid*
- coxsackie*
- Crimean Congo*
- Crimean-Congo*
- Cytomegalo*
- Dengue*
- Ebola*
- Enterovir*
- Epstein barr*
- Epstein-barr*
- EV71*
- EV-A71*
- Filovir*
- Flavivir*
- H1N1*
- H3N2*
- H5N1*
- hantavir*
- HBV*
- HCV*
- Hemorrhagic fever*
- Hendra vir*
- Hendravir*
- Henipavir*
- Hepadna*
- Hepatitis A *
- Hepatitis B*
- Hepatitis C*
- Hepevir*
- Herpes*
- HIV*
- HPV*
- HSV*
- HTLV*
- Influenza*
- Issyk-Kul virus*
- Japanese encephalitis*
- KSHV*
- Lassa Fever*
- Lassa virus*
- Lloviu*
- Lyssavirus*
- Mamastro*
- Marburg virus*
- Marburgvirus*
- Mayaro virus*
- Measles*
- MERS-CoV*
- Middle East respiratory syndrome*Varicella*
- Morbili*
- Nairovir*
- Nipah*
- Norovir*
- Oropouche*
- Orthomyxo*
- Orthopox*
- Orthoreo*
- Pandemi*
- Papillomavir*
- Parainfluenza*
- Paramyxovir*
- parecho*
- Parvovir*
- Picobirnavir*
- Picornavir*
- Pneumovir*
- Polio*
- Polyoma*
- Poxvir*
- Rabies*
- Reovir*
- Respiratory syncytial virus*
- Retrovir*
- Rhabdovir*
- Rhinovir*
- Rift Valley fever*
- Rotavir*
- Rubella*
- SARS-CoV*
- Severe Acute Respiratory Syndrome*
- Severe fever with thrombocytopenia*
- Shingles*
- Smallpox*
- Swine fever*
- Swine flu*
- Tick-borne encephalitis*
- Togavir*
- Vaccinia*
- Variola*
- Viral meningitis*
- viridae*
- virome*
- virus*
- West nile disease*
- West nile fever*
- Yellow fever*
- Zika*
- Zikv*
- Zoono*

9 Appendix 4. Some experiences from the COVID-19 pandemic in Sweden

All societal sectors and policy areas are affected by the COVID-19 pandemic. The Public Health Agency of Sweden, the Swedish Civil Contingencies Agency, and the National Board of Health and Welfare are public agencies with particular responsibility for the issue. But many other public agencies have received Government mandates to follow up how their sectors have been affected by the COVID-19 pandemic and by the measures taken in conjunction with the pandemic. The Swedish Research Council has received a number of Government mandates in conjunction with the COVID-19 pandemic, both for special research funding and also other types of mandates.

The Government's strategy

The Government's strategy for addressing the COVID-19 pandemic was presented in April 2020, where the overarching goal was to protect human lives, health and jobs[2]. The work and decisions of the Government then in place aimed to:

1. Limit the transmission of infection in the country
2. Safeguard resources to health and medical care
3. Limit the impact on socially important activities
4. Ameliorate the consequences for citizens and companies
5. Reduce anxiety
6. Introduce the right measures at the right time

The COVID-19 Commission

In June 2020, the Government appointed a commission, tasked with evaluating the measures by the Government, the administrative agencies, and the regions and municipalities to limit the transmission of the virus causing the disease COVID-19, and the effects of the transmission[3]. They reported their observations and conclusions in two subsidiary reports and a final report, which was published in February 2022[4].

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[2] Arbetet med coronapandemin (regeringen.se)
[3] Utvärdering av åtgärderna för att hantera utbrottet av det virus som orsakar sjukdomen covid-19, dir. 2020:74 (regeringen.se)
[4] Coronakommissionen

The commission's final assessments are summarised in a number of items in the final report:

- The focus on advice and recommendations that people expected to comply with voluntarily was fundamentally correct. This meant that citizens retained more personal freedom than in many other countries.
- This focus should, however, not have stopped Sweden from having chosen more powerful and intervening measures in February/March 2020. When a plan to protect the elderly and other risk groups was lacking, earlier and more interventions should have been made to try to reduce the general level of infection transmission. Such introductory measures would also have created more time for monitoring and analysis.
- Advice and recommendations should have been communicated as clear rules of behaviour.
- The Government should immediately have assumed leadership in the crisis. In a democracy, citizens can demand responsibility from the Government, not from a public agency. The obstacles to clear national leadership on the part of the Government – to some extent independent public agencies, self-governing regions and municipalities, and the Government Offices' normal review procedures – should have been possible to override. The Government should also have adopted clearer leadership in relation to the overall communication to the general public.
- The Government was too one-sidedly dependent on the assessments by the Public Health Agency of Sweden. Responsibility for the Health Agency's assessment rest ultimately on a single person, the head of the Health Agency. This is not a good enough system for decision-making during a serious societal crisis.

Proposal from the Commission

The commission reports a number of lessons and proposals that it believes can improve the ability to manage future pandemics, and to some extent also other crises. One of the lessons that has particular bearing on the national research programme for viruses and pandemics is that we need more interdisciplinary research into the effects of the pandemic on medical, economic and social outcomes for different groups in society, and into its long-term effects, to improve the prerequisites for future crisis management.

- The material, organisational and mental preparedness for protection against infection during a future pandemic must be significantly strengthened.
- The legal preparedness must also be stronger.
- During a crisis such as a pandemic, clear, honest and unanimous communication is needed, aimed at everybody in the population.
- The principles for crisis management – responsibility, equivalence and closeness – are not sufficient. They should at least be complemented with a precautionary or management principle.
- A body providing clear national crisis leadership should be established, reporting direct to the Government. It should be able to take in information

from all actors, analyse the situation and provide documentation for weighing up the effects of measures in different areas against each other, and as necessary also issue binding directives to public agencies to introduce measures that are considered necessary.

- A parliamentary inquiry should consider changes to both the principles for and organisation of crisis management. Its starting point should be to make the Government's responsibility clear.
- The Government must have as good documentation as possible for the deliberations and decisions that must be made during a pandemic. The Public Health Agency of Sweden can therefore not be solely responsible for providing the Government with decision support documentation on issues relating to pandemic management.
- The issue of a major administrative reform, which previous inquiries have recommended, must be the subject of new, unbiased consideration.
- The Government Offices' documentation of its crisis management must become significantly better.
- International collaboration must be strengthened.
- Easily accessible, detailed data is vital to ensure public agencies can monitor an ongoing crisis in real time, and design purposeful measures. At the moment, we are partly lacking important information about areas such as primary care, special housing for the elderly, municipal health and medical care, and short-term periods off work due to illness. These problems should be further investigated and dealt with before the next crisis hits.
- To improve the prerequisites for future crisis management, we need more interdisciplinary research into the effects of the pandemic on medical, economic and social outcomes for different groups in society and, eventually, into its long-term effects.

Royal Swedish Academy of Sciences' summary of the state of knowledge

In autumn 2020, the Royal Swedish Academy of Sciences appointed an expert group at its own initiative to inventory the state of knowledge about the SARS-CoV-2 virus, the COVID-19 disease and its transmission in society[5]. The group worked between November 2020 and November 2021. In the first instance, the group was to illuminate the state of knowledge at the end of 2021 and remaining gaps in knowledge about the virus and the disease. The group was also to investigate what lessons could be learnt in relation to infection protection, vaccination and treatment of COVID-19. A further task was to reflect on how collaboration between the scientific community, state authority, public agencies and healthcare can be developed for the future. The group published six interim reports and summarised its conclusions, lessons and recommendations ahead of future pandemics in a final report in 2021[6][7].

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[5] Expertgrupp om Covid-19 vid Kungl. Vetenskapsakademien - Kungl. Vetenskapsakademien (kva.se)

[6] covidrapportslutrapport211130MINDRE.pdf (kva.se)

[7] Sammanfattning – Vad kan vi lära av pandemin? (kva.se)

One of the group's proposals related to long-term investment in basic research and applied research within relevant parts of the fields of epidemiology, infection biology, immunology, vaccine research, psychology and social sciences, and an expanded mandate for the national research programme in viruses and pandemics. The following needs and proposals were identified by the expert group:

1. A review of the need for suitable dormant pandemic legislation/crisis legislation, which can be activated by the Riksdag at short notice.
2. Design of a new pandemic plan that can be applied to different infectious agents with pandemic potential. The plan should be preceded by analysis of the prerequisites for ensuring the responsibility principle functions in all sectors of society, illuminating possible shortcomings in this respect, and offering flexibility for alternative solutions.
3. A preparedness plan for vital medicines, protection materials, healthcare equipment, basic food and other life-sustaining goods and services.
4. It should be ensured that all actors carrying out public or private health and medical care, care homes and home helps undertake the measures that are required in a pandemic, and that there are established structures for following up these.
5. Coordination between regions in relation to epidemiology, infection protection, testing and vaccination. Establishment of a coordination and responsibility allocation plan for diagnostics between the regional laboratories, and also a framework for international collaboration and knowledge exchange that can be mobilised in a pandemic.
6. The conditions for merging and achieving fewer infection control regions stronger in terms of competence provision should be investigated.
7. Strengthened international engagement in pandemic preparedness and pandemic management, for example in the WHO and the EU's infection protection organisation ECDC, as well as increased collaboration with our Nordic neighbours within the entire infection protection area.
8. Long-term investment in basic research and applied research within relevant parts of the fields of epidemiology, infection biology, immunology, vaccine research, psychology and social sciences. Strong regrowth of junior researchers as well as expertise that is continuously developed. Strengthened links between clinical and academic research laboratories, as well as with research and development at higher education institutions and industry.
9. An ethical panel with scientific competence to support politicians and public agencies in the difficult ethical deliberations that must be made during a pandemic.
10. Increased educational inputs in epidemiology and infection protection at all levels. Specific education and further education within the field of infection protection for persons in leading positions in operations that are particularly involved in a pandemic. A specialist educational programme in infection epidemiology for persons working within regional infection protection should be considered.

11. Information programmes aimed at creating acceptance for the measures a society may need to introduce in a pandemic, and at increasing acceptance of vaccines. To do this may require expanded research initiatives into how to motivate people with differing backgrounds to accept society's assessments in relation to vaccination and infection protection measures.
12. Long-term environmental work to improve indoor air quality, for example through air cleansing and air circulation. Future pandemics will probably also be caused by infectious agents that are transmitted via aerosols in the air.
13. A national plan for recovery of healthcare and care personnel to counteract mental ill health and its effects on the Swedish healthcare system.
14. Incentives and resources during "pandemic peace-time" are needed to better address future pandemic challenges. Because it has several large regional laboratories with university links, Sweden has good opportunities to be top-class internationally in relation to pandemic infectious agents, both in method development and in identification and characterisation.
15. The expert group proposes that Sweden establishes an independent expert unit with high scientific competence in the relevant fields. This unit would provide the Government, responsible politicians and public agencies with access to updated scientific information and advice on infectious agents, infection transmission, infection protection measures, implementation and harmonisation of testing methods, vaccination strategies and communication relating to these subjects.

The expert group proposes, in relation to research of importance for pandemic preparedness, that the Swedish Research Council is given an expanded mandate within the framework for the national research programme in viruses and pandemics. The mandate shall cover coordination and targeted initiatives for both basic research and applied research. In addition, this shall include appointing positions in infection biology, immunology and vaccine research, epidemiology and psychology (both relating to people's crisis management and motivation to protect themselves and others). The mandate should include funding for universities' secure laboratories for infection research and for expensive equipment, which is needed for large-scale full genome determination of micro-organisms and their characteristics.

Public Health Agency of Sweden

The Public Health Agency of Sweden works systematically to prevent infection transmission in society and to reduce the negative consequences of pandemics for individuals and society. It follows developments closely, for example through monitoring, modelling, microbiological and epidemiological analyses, and risk assessments. Based on knowledge, it recommends measures suited to the situation.

The Public Health Agency of Sweden coordinates pandemic preparedness at national level and provides support for planning at regional and local level, where the operative work is carried out. It has coordination responsibility in the work on preventing and managing infectious diseases.

To promote coordination in the pandemic area, a special National Pandemic Group (NPG) has been formed. NPG consists of representatives from the Public Health Agency of Sweden, the National Board of Health and Welfare, the Swedish Civil Contingencies Agency, the Swedish Medical Products Agency, the Swedish Work Environment Authority, the Swedish Association of Local Authorities and Regions and the county administrative boards.

The Public Health Agency of Sweden has produced a number of documents to support the planning ahead of an influenza pandemic, but this also includes planning for pandemics caused by other viruses. The target groups are public agencies, infection protection physicians, preparedness leaders, preparedness coordinators and persons with operational and planning responsibilities within regional and municipal health and medical care.

The Public Health Agency of Sweden carries out surveys and studies about the prevalence of COVID-19 and the immune defence that the disease results in. Information and collected statistics and analyses relating to COVID-19 including vaccinations can be found here: Statistik och analyser om covid-19 inklusive vaccinationer — Folkhälsomyndigheten (folkhalsomyndigheten.se).

Swedish Civil Contingencies Agency

The Swedish Civil Contingencies Agency (MSB) has been tasked to strengthen society to prevent and manage accidents, crises and the consequences of war. It protects people's life and health, society's functionality and fundamental values, such as democracy, the rule of law, and human rights. MSB was given several Government mandates linked to the COVID-19 pandemic. During 2020–2021, MSB funded eleven research projects relating to the COVID-19 crisis. The purpose was to capture data while the pandemic was ongoing, and then to analyse these from different aspects. Several relevant publications are available on MSB's website.

National Board of Health and Welfare

The National Board of Health and Welfare supports health and medical care in the work with COVID-19. It has collected information and offers knowledge support and training to persons working in healthcare and personal care. The National Board of Health and Welfare also publishes information about other mandates that it has linked to COVID-19, such as risk groups and post-COVID syndrome. It also reports continuously on the current situation in health and medical care. Collected information about coronavirus COVID-19 – National Board of Health and Welfare

The pandemic exposed shortcomings in elderly care, and quality differences across the country. For this reason, in August 2022, the National Board of Health and Welfare started a national competence centre for elderly care as part of a Government mandate. The competence centre shall make it easier to introduce working practices that are based on the best available knowledge and good examples from different operations. The competence centre shall also

provide a national picture of the situation in Swedish elderly care, including the strengths and challenges that exist. National competence centre for elderly care opened – National Board of Health and Welfare

The Swedish Research Council's mandates in conjunction with the COVID-19 pandemic

The Swedish Research Council was given a number of Government mandates as a result of the COVID-19 pandemic, which in addition to research funding entailed:

- Communication initiatives about vaccination against the disease COVID-19
- Mandate to prepare funding of research studies into post-COVID syndrome
- Mandate to prepare funding of follow-up studies of COVID-19 vaccines
- Mandate to prepare funding of research initiatives linked to the COVID-19 pandemic (together with Vinnova)
- Mandate to temporarily reinforce the activities within Clinical Studies Sweden
- Mandate relating to Swedish coordination and Swedish participation in the European Commission's COVID-19 platform within the framework for the European Open Science Cloud (EOSC)

10 Appendix 3. Evidence resources for pandemic response: An evidence and gap map

Bhumika T.V., Kevin Ouma Ojiambo, Sujata Shirodkar, Howard White

ABSTRACT

Background: The emergence and transmission of infectious disease in the form of pandemics has occurred throughout history, significantly impacting humanity and various development sectors. The occurrence of pandemics has regularly highlighted the need to identify effective preparedness and strong health policies to combat hazardous consequences in a timely manner.

Aim: The aim of this paper was to map evidence resources for a priority set of pandemics and provide an overview of them to avoid duplication of primary research and determine priority areas for future research.

Methodology: The literature search was carried out using Google and selected agency websites such as that of WHO, the Centres for Disease Control and COVID-End; a snowballing approach was followed to obtain all relevant evidence resources. The retrieved resources were initially maintained in an Excel spreadsheet and subsequently entered into EPPI-Reviewer 4 software. Further, the resources were screened based on the inclusion and exclusion criteria, and the final screened resources were coded according to themes and subthemes that were pre-identified by the experts working in the national research programme for viruses and pandemics. The overall quality of evidence was also assessed using a critical appraisal tool developed by the team.

Results: The search yielded 802 evidence resources; after the stepwise screening process, 496 were included in the map. The majority of resources were in the form of evidence platforms, which focused on transmission prevention, management, and impacts of disease burdens. They were quite limited regarding evidence systems, health systems and behavioural response. A significant number of virology-specific and policy response-based documents were identified, and a large number of resources focused on COVID-19. No resources focused on severe fever with thrombocytopenia syndrome.

Conclusion: The map illustrates that most available evidence on pandemics focus on COVID-19, which may be the result of its recent occurrence. There must be concerted efforts to produce evidence resources, particularly maps and decision-making products, for pandemic preparedness and response.

LIST OF ACRONYMS

CDC; Centers for Disease Control and Prevention

COVID-END; The COVID-19 Evidence Network to support Decision-making

EGM; Evidence and Gap Map

MERS; Middle East Respiratory Syndrome

SARS; Severe Acute Respiratory Syndrome

1. INTRODUCTION

1.1 The problem, condition, or issue

What do we know about the impact of COVID-19, the policy and social response to it, and the effectiveness of that response? What can we learn from experiences of previous pandemics, other major viruses, and COVID-19 to improve pandemic preparedness?

Since diseases are diverse and pandemics occur on a large scale, prevention and successful treatment may be challenging. When there is a sudden outbreak of a pandemic, not only the health sector is affected (1); other sectors experience negative shocks, although there are exceptions which benefit (2). Efforts to prevent and control new diseases are likely to best entail an evidence-based, multidisciplinary approach. Effective prevention should be informed by a thorough understanding of the clinical severity, extent of transmission and infection, and efficacy of treatment options to speed the development of diagnostic and therapeutic modalities for emerging diseases that lead to pandemics (3).

However, when a pandemic first strikes there is a need for quick evidence in order to design interventions to tackle challenges in various sectors. Initially, an immediate evidence pool would be required to act at the same time, there by instigating the new research (4). When there is no understanding of what research has been conducted in the area, there is always duplication, and there could be a lack of time to conduct new research (5). In such scenarios, an existing resource pool is helpful; rather than undertaking research that may be redundant (due to the hundreds of thousands of research papers on this issue, with many more conference presentations), it is important to assess what is already available.

This project aims to help address such issues and avoid duplication of the research (particularly primary research), and to help identify important potential areas for research in different sectors related to pandemics. This can assist policymakers, researchers, and funders to develop policy guidelines and design interventions. The aim of the proposed research is to conduct a scoping exercise and map available evidence related to COVID-19 and similar pandemics in order

to identify relevant reviews on a sectoral basis, from which user-friendly evidence products can be produced.

1.2 Aims and objectives

The main objective of this project is to help address the issues stated above by avoiding duplication of research (particularly primary research), identifying important potential areas for research in different sectors related to pandemics – thereby assisting policymakers, researchers, and funders in developing policy guidelines and designing interventions.

1.2.1 Specific objectives

1. Develop a framework for the mapping of pandemic evidence resources, including assessment of confidence in each resource.
2. Identify and map evidence resources for a priority set of pandemics and viruses, including COVID-19.
3. Provide a summary overview of the evidence resources in the map.
4. Identify priority areas for future research.

Follow-up work is expected to include the commissioning of new systematic reviews, and the development of new evidence products in the priority areas identified by the Swedish Research Council.

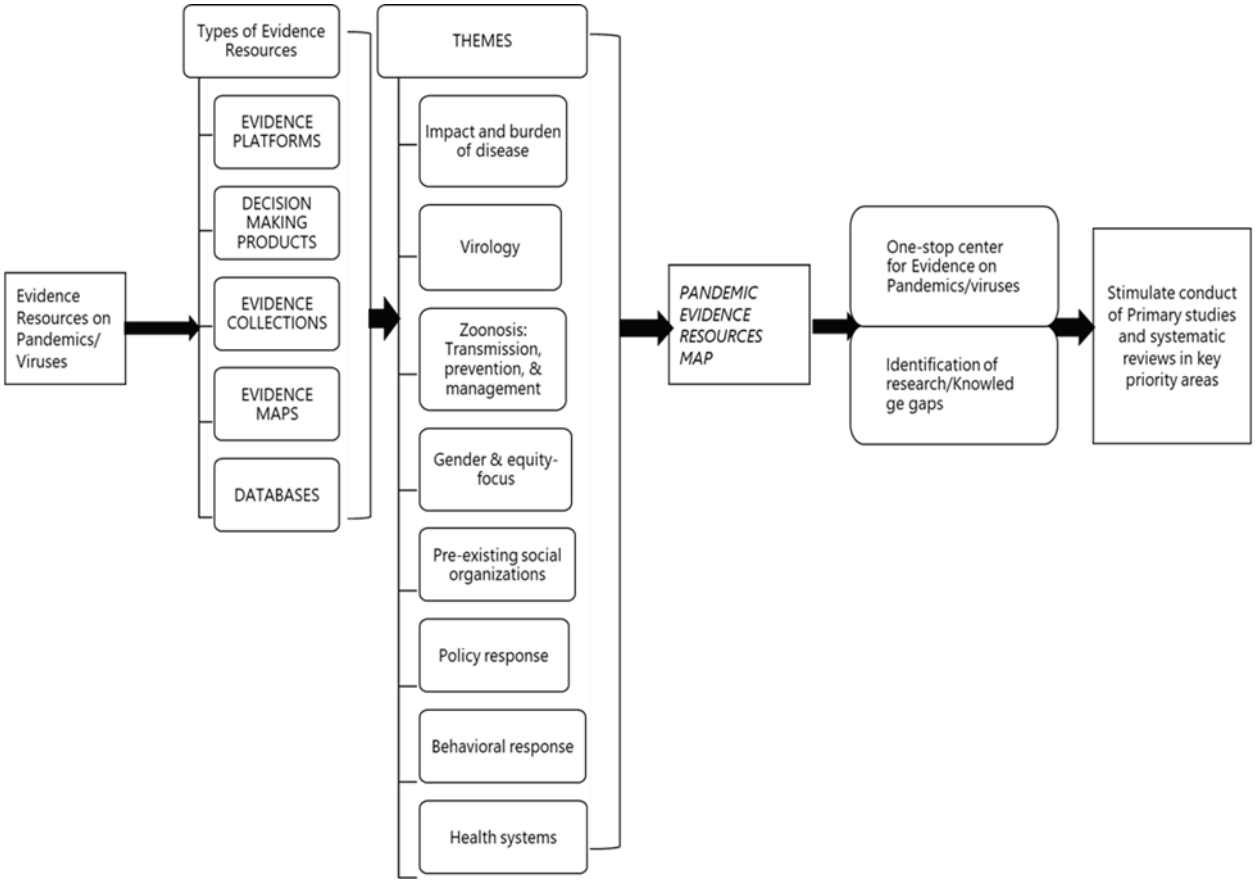
1.3 Conceptual framework of the evidence and gap map (EGM)

The framework depicts the various dimensions that comprise the pandemic evidence resources map. The primary dimensions are those which are used as the row and column headings in the main presentation of the map:

- Five types of evidence resources (collections, platforms, databases, maps and decision-making tools such as guidance/toolkits)
- Key themes identified in collaboration with the Swedish Research Council and their expert groups. These themes are discussed further below.

The conceptual framework also shows the map as a one-stop centre for pandemic-related evidence, and allows for the easy identification of research and knowledge gaps. These can stimulate further research and evidence synthesis in key priority areas to meet the demand for pandemic control and prevention in the future. Use of the map would reduce duplication by encouraging use of existing resources, and identifying existing reviews which can be used for further decision-making products.

Figure 1. Conceptual framework depicting the proposed plan for the evidence map. The themes are further divided into subthemes presented in Appendix 3



1.4 Why is it important to develop this EGM?

Pandemics can significantly increase mortality and morbidity, as well cause as short- and long-term economic effects that lead to social and economic disruption. They also cause behavioural changes and increase political stress and tension in affected regions or countries. This evidence map can assist us in identifying potential research gaps and in tracking pandemic preparedness and response efforts, as well as economic impacts. It may also lead to common prerequisites for future effective preparedness and response.

This EGM can contribute to the strengthening of the core public health infrastructure and the formation of a coordinated response centred on situational awareness, public health messaging, transmission reduction, and care and treatment of the sick. It will also aid in the development of policy guidelines, pandemic interventions, and the development of an evidence-based pandemic response.

1.5 How to use this EGM

The COVID-19 pandemic resulted in an expansion in the literature. To avoid duplication of resources among various organisations, we have produced a map

of available evidence. Those interested in developing evidence resources may: (1) find an existing resource which meets their needs; (2) review existing resources to determine what type of resource they require; or (3) mine existing documents for content to supplement their own resource.

The primary intended use of this map is to determine what resources are available that may be synthesised. For example, pandemic preparedness guidelines could be prepared by synthesising existing guidelines, or information from the map may be used for pandemic preparedness or to tackle various challenges in future pandemics.

This map may also be used to track research conducted on various pandemics. It can be accessed to learn about pandemic preparation and response efforts, as well as economic consequences of pandemics. The map also identifies research gaps that may be the most important requirements of future effective preparedness and response, such as benchmarks of existing evidence on prevention, control, and management in the event of a recurrence of any mapped pandemic.

The information from the map may help to strengthen core public health infrastructure and create a coordinated response focused on situational awareness, public health messaging, transmission reduction, and management. It may also serve as a clearinghouse for evidence on pandemics for the development and updating of policy and guidelines, as well as interventions in coordinated efforts to combat future pandemics.

1.6 Existing EGMs and/or relevant systematic reviews

Some evidence maps on pandemics are as follows:

UNICEF. (2020). Evidence gap map: Pandemics, epidemics and outcomes on child protection and violence.

Elmore, R., Schmidt, L., Lam, J., Howard, B. E., Tandon, A., Norman, C, Shah, R. R. (2020). Risk and protective factors in the COVID-19 pandemic: a rapid evidence map. Frontiers in Public Health, 8, 582205.

Norwegian Institute of Public Health (NIPH). (n.d.) NIPH systematic and living map on COVID-19 evidence.

Liu, N., Chee, M. L., Niu, C., Pek, P. P., Siddiqui, F. J., Ansah, J. P., Ong, M. E. H. (2020). Coronavirus disease 2019 (COVID-19): an evidence map of medical literature. BMC Medical Research Methodology, 20(1), 1–11.

The above-mentioned maps focus on narrower, specific topics. The nearest to our purpose is the COVID-19 Evidence Network to support Decision-making (COVID-END), which aims to be a comprehensive evidence platform for COVID-19 evidence resources; however, it does not have a map and is restricted to COVID-19. Our proposed map will capture a wide range of evidence

resources and help us navigate towards more specific resources for a range of pandemics and viruses.

2. METHODS

Our approach to the EGM was informed by the Campbell Collaboration approach (6). An EGM highlights where evidence is available, and where more evidence is required. This map consolidates what is known and what is not known by mapping out existing evidence resources on pandemics and providing a graphical representation of areas with strong, weak, or no resources, based on pre-identified themes as depicted in the conceptual framework.

A pilot exercise was carried out to collect evidence based on pre- specified eligibility criteria and to answer the research question. The procedure for gathering evidence resources included four basic steps: (1) obtaining resources curated by COVID-END and conducting our own search (a specific topic-related search using Google and the websites of selected agencies such as WHO and the CDC); (2) applying the inclusion and exclusion criteria described below; (3) coding data based on the basic set of themes we identified (which was adapted in an iterative manner as the pilot proceeded); and (4) critically appraising the evidence resources using the criteria specified in the critical appraisal tool.

We used the EPPI mapper adds-on for EPPI-Reviewer v4.13.0.0 software to conduct systematic reviews, producing an EGM visual presentation of the evidence resource matrix. The pandemics or viruses lie on the y-axis, while thematic domains lie on the x-axis. Additional dimensions of the evidence resource characteristics, such as type of evidence resource, gender, equity, language, presence of systematic reviews, and quality of the evidence resource were applied as filters.

2.1 Eligibility criteria

2.1.1 Inclusion criteria

We included evidence resources, which are defined as online resources that present or provide links to primary studies, reviews of those studies, guidance documents, and other user-friendly knowledge products based on such studies. This definition is restricted to open-access online resources, as we are interested in resources which are readily accessible.

2.1.2 Exclusion criteria

We excluded evidence resources with inadequate evidence dedicated to a specific pandemic/virus, or if there was a page with limited information about pandemics and viruses.

We also excluded resources that included blogs, news, webinars, or articles lacking scientific foundation, or resources that were not about one of the specified pandemics or viruses.

2.2 Information sources and search strategy

We started with COVID-END, as they had undertaken a significant amount of work curating evidence resources for COVID-19. Many COVID-19 evidence resources were accessed via links provided by COVID-END. We applied a snowballing technique to identify additional resources from collated evidence resources on COVID-END website.

Given that the evidence resources we are mapping are mostly found on organisational websites, Google was initially our primary information source. We created keywords with the name of the pandemics and the word evidence resource, and then with different types of evidence resources, such as HIV/AIDS evidence resource, COVID-19 map, avian influenza database, and Ebola tool kit. We performed this process for all pandemics/viruses listed, and searched Google for any relevant resources on the first ten pages.

Furthermore, we looked for links on any relevant evidence resources that could lead us to other resources in a snowball manner. Similar searches were carried out for all pandemics and important themes. Manual searches were conducted – using websites of organisations championing pandemic management in the fields of research, academia, and service provision, as well as websites of worldwide ministries of health – to find evidence such as decision-making products, evidence maps, databases, and collections on a specific virus or pandemic.

The above exercise was repeated for all pandemics/viruses listed – namely, avian influenza (A/H5N1), arenaviral haemorrhagic fever, Chikungunya, COVID-19, Crimean-Congo haemorrhagic fever, Ebola and Marburg, emergent non-polio enteroviruses (including EV71D688), HIV/AIDS, Hong Kong flu (influenza A/H3N2), Middle East respiratory syndrome (MERS), Nipa and henipaviral diseases, severe acute respiratory syndrome (SARS), severe fever with thrombocytopenia syndrome, swine flu (H1N1) and Zika.

2.3 Data management, screening, and coding

2.3.1 Data management

A record of the retrieved evidence resources and their website links was maintained in an Excel spreadsheet by three independent reviewers. Initially, the retrieved resources were manually entered using EPPI-Reviewer v4.13.0.0 online software. Some were converted to RIS files using Python 3 software, and then exported to EPPI-Reviewer to manage duplicates, create a citation database, and clean the metadata to ensure the clarity and completeness of each item's description.

2.3.2 Screening/selection of evidence resources

This set of evidence resources was then screened in accordance with the inclusion and exclusion criteria by four independent reviewers. Resources that did not match the eligibility criteria, and duplicates, were excluded.

2.3.3 Data extraction

The coding tool was developed and piloted to ensure it captures all data items required for this EGM using EPPI-Reviewer v4.13.0.0 online software, from which abstraction was performed. The final set of included resources after screening were then allocated to four reviewers for data extraction. The coding process was carried out independently; any discrepancies were reconciled through discussion, and an independent senior reviewer later resolved any disagreements.

2.3.4 Data items

Administrative data and other items were organised to include the name of the virus/pandemic, type of resource, themes such as zoonosis, impact and burden of disease, virology, pre-existing social organisations working in pandemic control, policy response, evidence systems, gender, equity, health systems and behavioural responses. Based on discussions with an expert team and the team's senior expert, the following themes, focus areas, and subcategories were developed (Appendix 3).

2.4 Critical appraisal

The overall quality of evidence resources was assessed using a domain-based critical appraisal tool developed by the team and piloted by 10% of the resources. We assigned quality ratings of high, medium, and low under the domains – namely, ease of use, clarity of purpose, achievement of purpose, regular update of resources, and sources of available content. The overall quality rating was based on the lowest rating in any of the first four critical domains. A pair of team members performed the critical appraisal process in duplicate, and the results were reconciled to resolve disagreements. The critical appraisal tool was validated and will be published as one of the project outputs (Appendix 2).

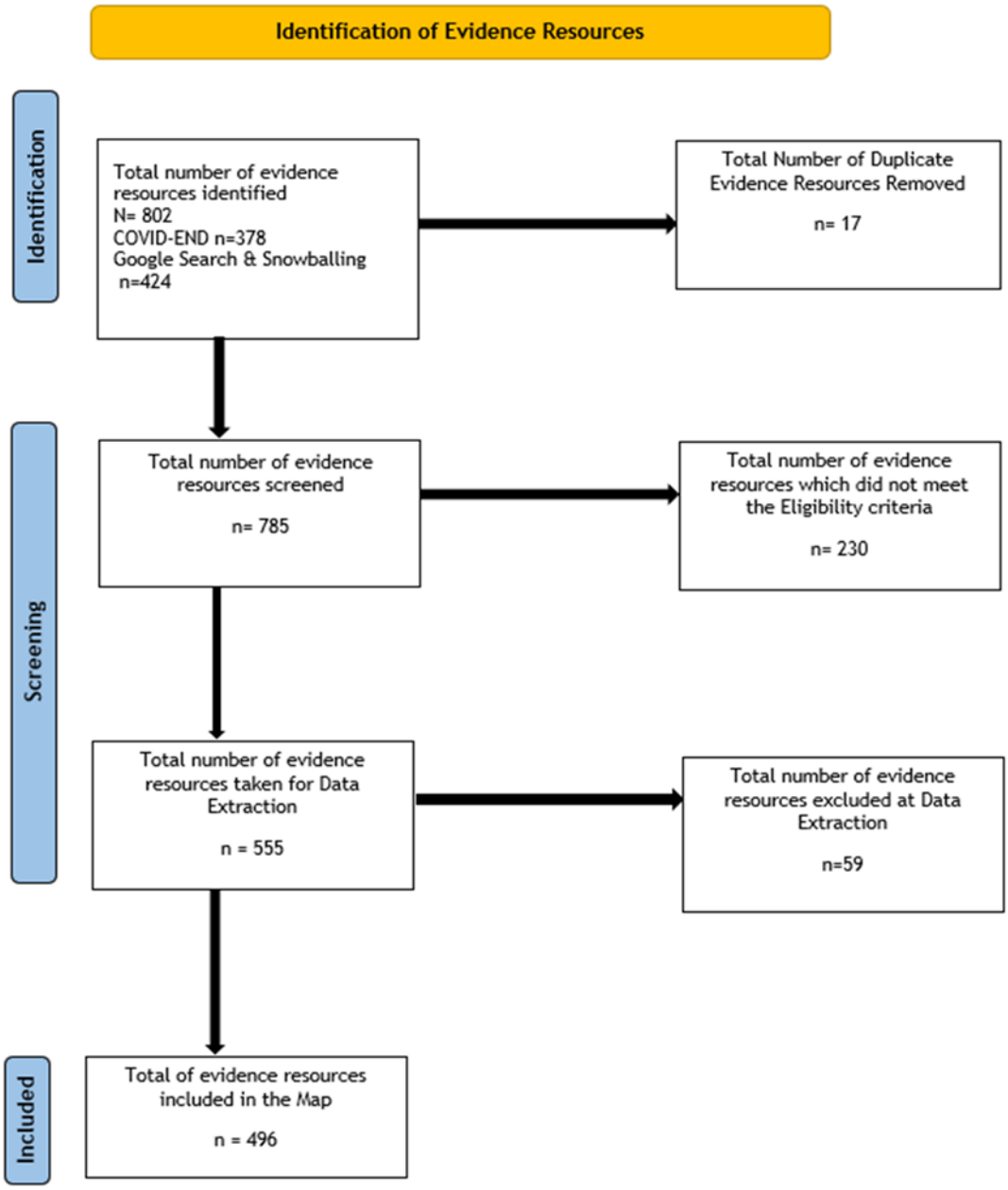
3. RESULTS

EPPI-Reviewer software was used to manage the data. The results section summarises the findings on type of pandemic, type of evidence resources, the resources under the themes.

3.1 Identification of evidence resources

The search yielded 802 evidence resources, 17 of which were duplicates. We screened 785 evidence resources and excluded 230 that did not meet the inclusion criteria. The remaining 555 were taken for data abstraction; upon critical review, 59 were excluded and we mapped 496 evidence resources that satisfied the eligibility criteria (Figure 2).

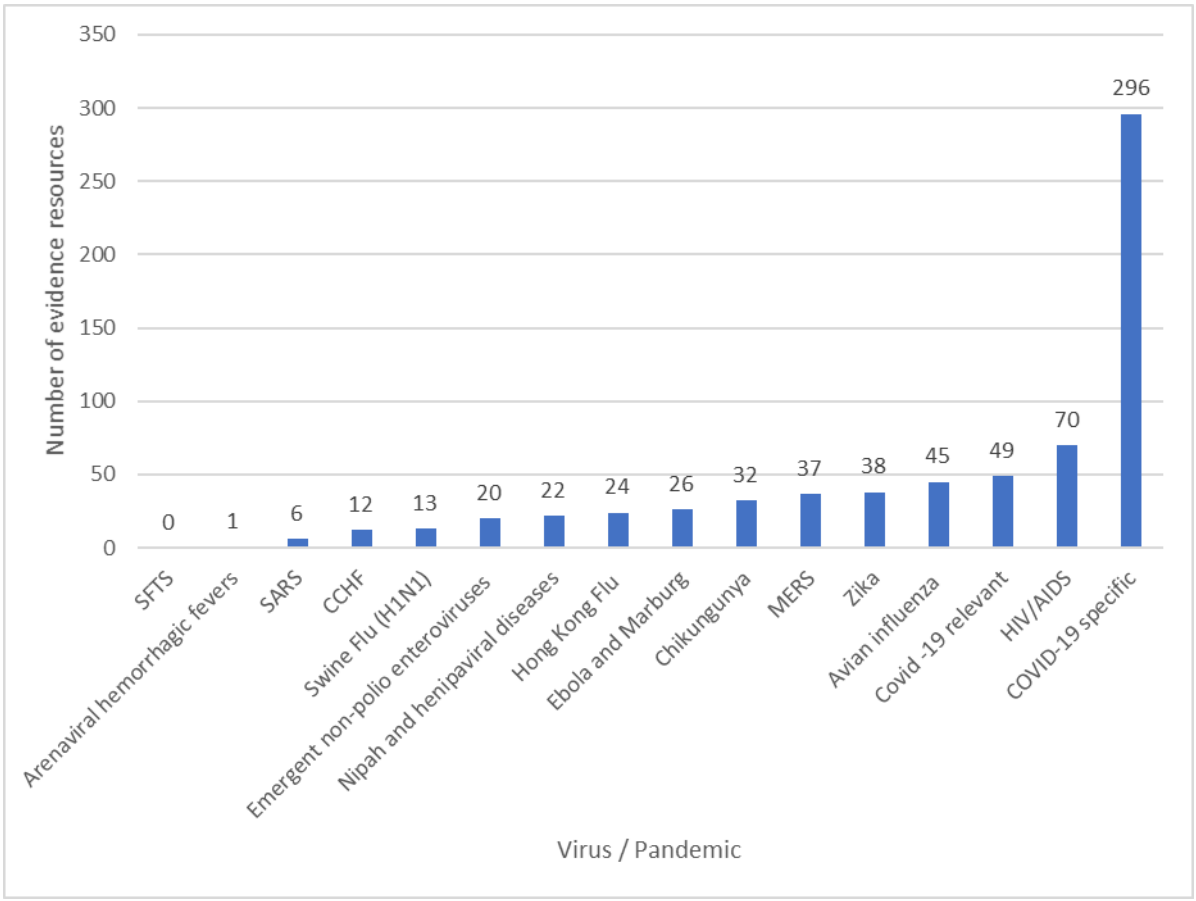
Figure 2: Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow chart showing evidence resources



3.2 Pandemic evidence resources

The results suggest that most evidence resources specifically focused on COVID-19, followed by HIV/AIDS. The average number of resources (out of total of 300) examined other pandemics, such as influenza, Chikungunya, MERS, Hong Kong flu, Zika and Ebola. A limited number of resources were found on swine flu, MERS, Crimean-Congo haemorrhagic fever and SARS. Figure 3 presents a summary of various types of pandemics, alongside the number of resources for each.

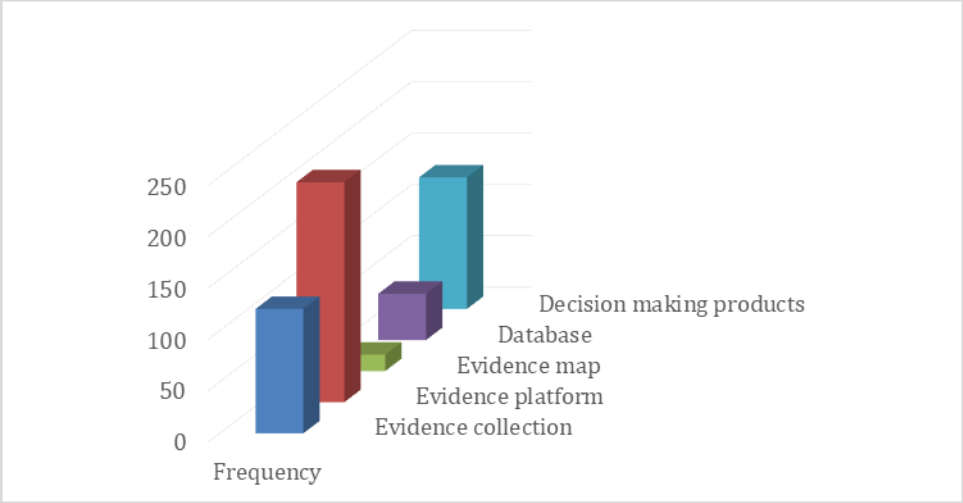
Figure 3: Distribution of pandemic evidence resources



3.3 Types of evidence resources

The majority of resources were in the form of evidence platforms (as defined in the above section), followed by evidence collection and decision-making products. We have identified very few resources in specific databases, and 16 evidence maps related to pandemics (Figure 4).

Figure 4: Types of evidence resources



3.4 Themes

The majority of resources focused on transmission, prevention and management, followed by impact on burden of disease. It is important to note that there many resources specifically on virology research. A significant number of resources were also found on policy responses, and an average number had a filter for gender and equity (Figure 5).

Figure 5: Distribution of evidence resources across different themes

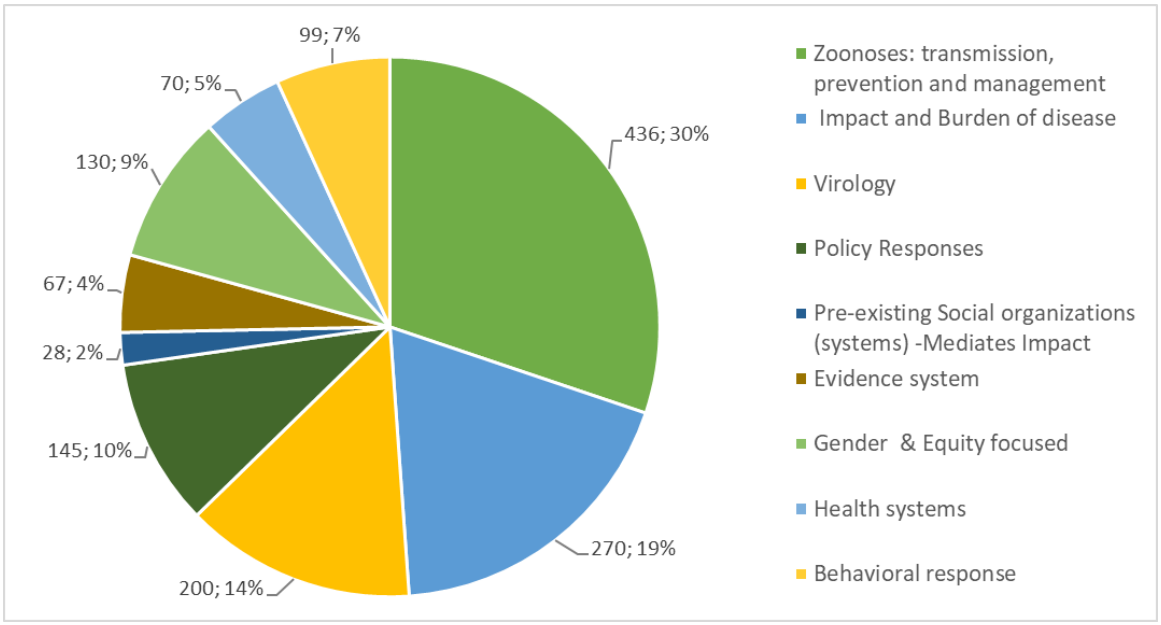
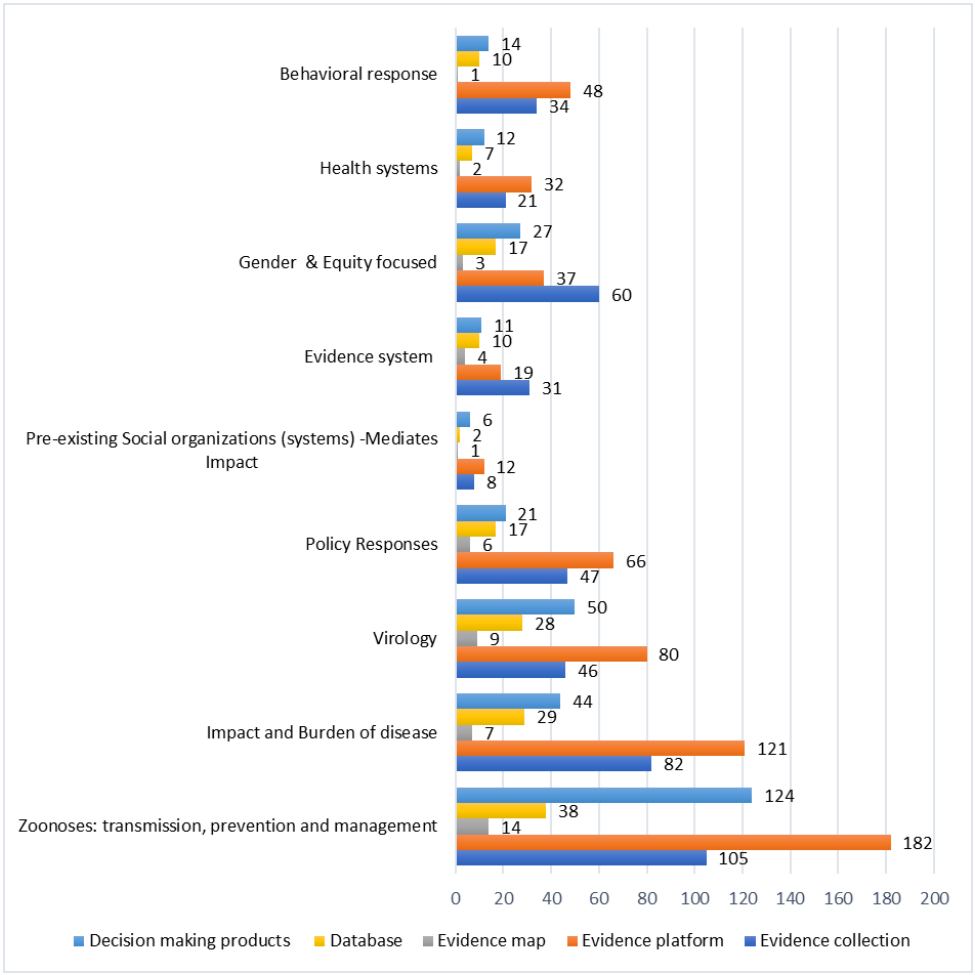


Figure 6: Distribution of evidence resources across different themes



3.5 Summarising the evidence map

The below cross-tabulation and map suggests that the majority of evidence resources focus on COVID-19, and we did not come across any evidence on severe fever with thrombocytopenia syndrome. The resources are limited on evidence systems, health systems and behavioural response. There is a relatively a smaller number of systematic reviews; only 84 evidence resources reported systematic reviews conducted on various pandemics. The decision-making products are relatively very few for pandemics other than COVID-19.

3.6 Quality assessment

3.6.1 Overall quality rating of evidence resources

The critical appraisal for the study was conducted based on the tool developed and pretested by the team. It had a final pooled Cohen's kappa of 0.71 ($P < 0.001$), corresponding to 85.9 per cent agreement in terms of inter-reviewer reliability. The tool had five primary categories: ease of use, clarity of purpose, achievement of purpose, updating with new information, sources of available content, and overall rating of the evidence resources.

The summary suggests that most of the evidence resources were of medium quality, with very few of high or medium quality. This can be attributed to inconsistences observed across all evidence resources, as there is no standard reporting format for the majority of resources, apart from evidence maps.

Figure 7: Overall quality of included evidence resources

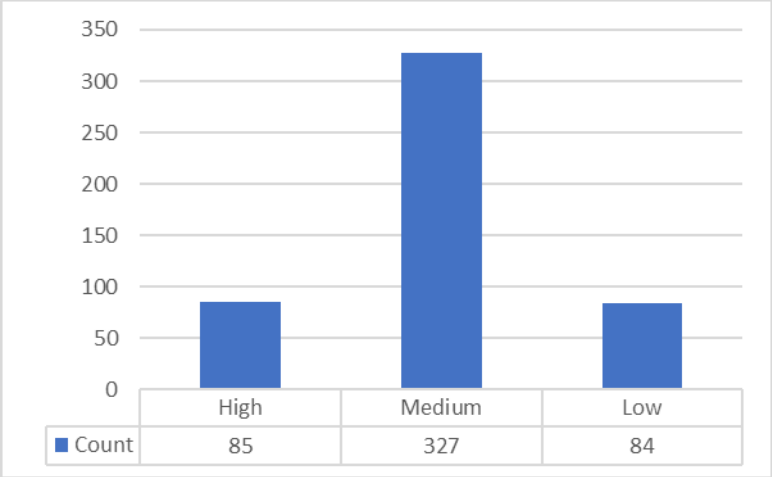
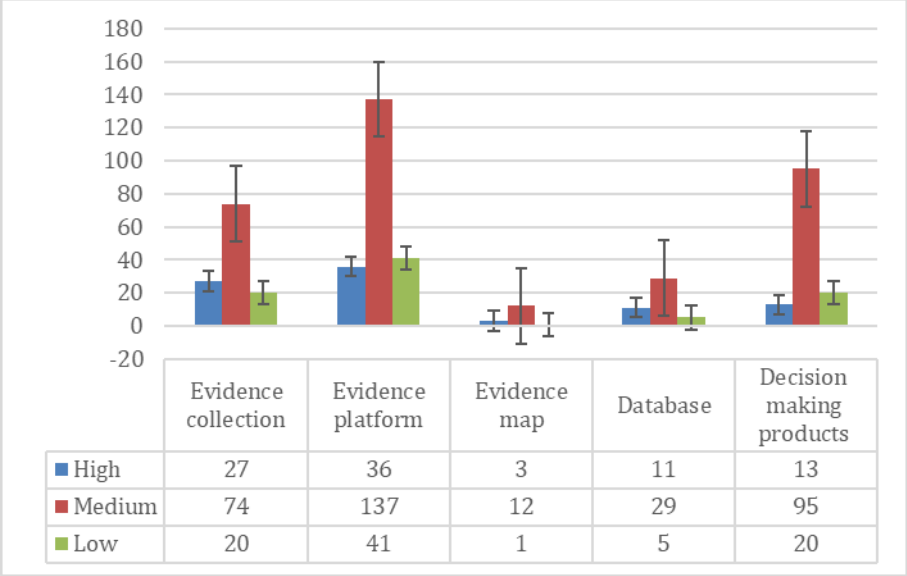


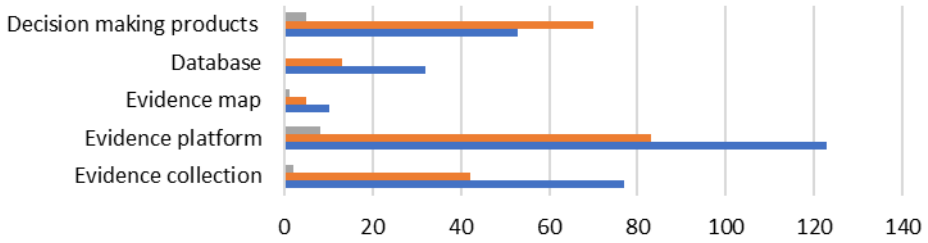
Figure 8: Overall quality, by type of evidence resource



3.6.2 Clarity of purpose rating

More than half of the evidence resources (59.5%) had a well-described statement of purpose and clearly stated goals, and thus were rated as "high" in this domain; 42.9 per cent were rated as medium and the rest were low. The majority of databases (high = 32/45) had well-defined mission statements, followed by evidence collection (high = 77/121) and evidence maps (high = 10/16) (Figure 9).

Figure 9: Clarity of purpose, by type of evidence resource



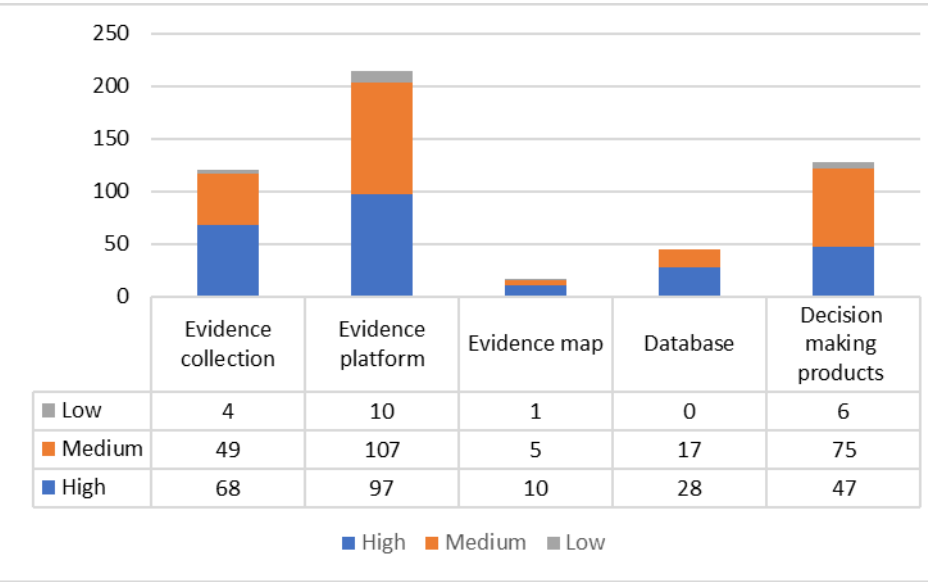
	Evidence collection	Evidence platform	Evidence map	Database	Decision making products
Low	2	8	1	0	5
Medium	42	83	5	13	70
High	77	123	10	32	53

Low Medium High

3.6.3 Achievement of purpose rating

Slightly more than half of the evidence resources (51%, n = 253) did not achieve exactly what they set out to do in their statements of purpose; less than half (48.6%, n = 241) achieved their set goals, and the rest either deviated from the set goal or did not have one at all. The majority of evidence maps met or exceeded their objectives (Figure 10).

Figure 10: Achievement of purpose, by type of evidence resource



	Evidence collection	Evidence platform	Evidence map	Database	Decision making products
Low	4	10	1	0	6
Medium	49	107	5	17	75
High	68	97	10	28	47

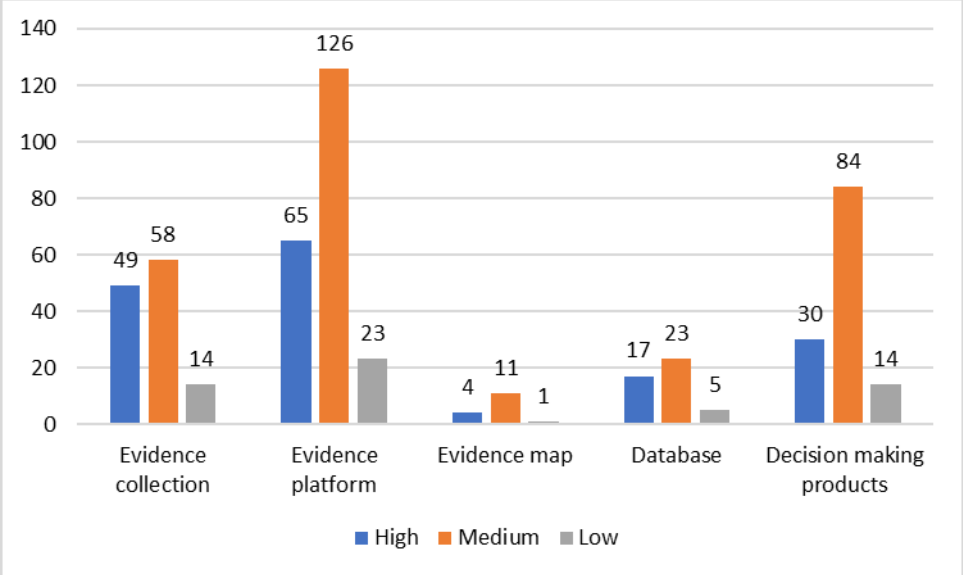
High Medium Low

3.6.4 Ease-of-use rating

Fewer than half of the evidence resources were very easy to use (33.3%); the majority were slightly easy to use (60.9%), and the rest were not user friendly.

Across all types of evidence resources, those that were simple to use were in the majority (Figure 11).

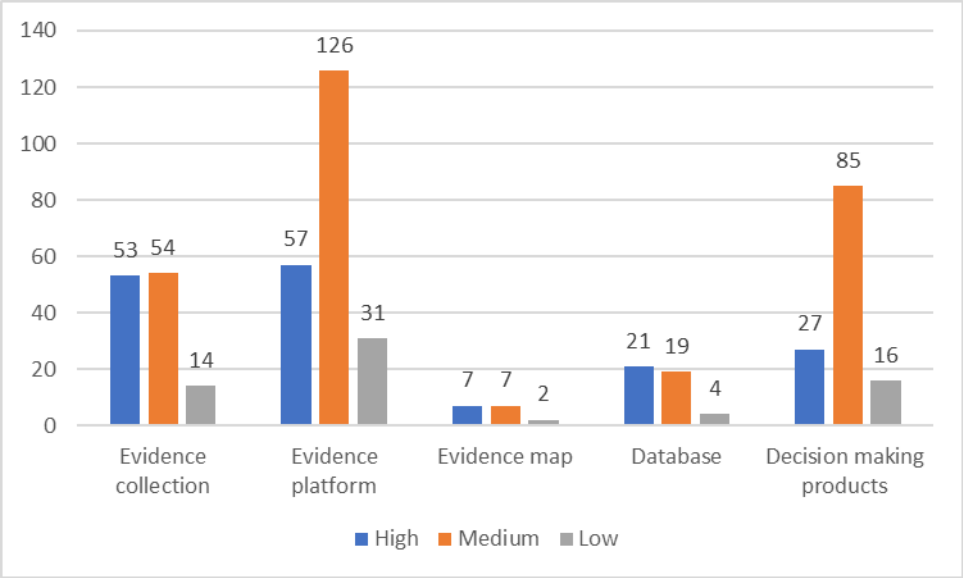
Figure 11: Ease of use, by type of evidence resource



3.6.5 Updating with new information rating

Less than half of the evidence resources (33.3%) kept their information up-to-date on a regular basis. A total of 59.1 per cent updated their information frequently but irregularly, while the rest did not update with new information. The information was generally updated with new information across all types of evidence resources (Figure 12).

Figure 12: Updating with new information rating, by type of evidence resource



4. DISCUSSION

The present map provides a unique overview for researchers and policymakers on the available evidence and research gaps concerning various pandemics worldwide. It acts as a central repository of resources that can be used as a clearinghouse for evidence on pandemics listed for academic, research, and policy formulation purposes.

The map shows an inadequacy in evidence resources on the following pandemics: Nipa and henipaviral diseases, SARS, swine flu (H1N1), Zika, arenaviral haemorrhagic fevers, Chikungunya, Crimean-Congo haemorrhagic fever, Ebola and Marburg, emergent non-polio enteroviruses (including EV71, D668), Hong Kong flu (influenza A/H3N2), and MERS. These areas comprised fewer than 50 evidence resources each (Figure 3); this highlights a lack of adequate evidence, indicating a need for consolidated efforts in terms of research and policy in preparation for recurrence of these pandemics.

Most of the evidence resources are based on the following themes: transmission, prevention and management, disease burden, and virology – with significant gaps regarding social economic impact, behavioural response, gender and equity, health system organisation, and evidence systems. These topics require greater research and policy attention, as lapses in these areas can undermine gains in therapeutic and preventive measures during pandemics.

Finally, the map depicts the strengths and weaknesses of the available evidence system on various pandemics, and it would be useful in shaping policy in areas that require attention to prepare for the listed pandemics.

The summary of the map suggests a need for research in evidence systems, health systems and behavioural responses with respect to all the pandemics. There is a need for a significant number of systematic reviews in order to create a preparedness plan to inform policy guidelines on various pandemic treatments and management.

The databases, evidence maps, and collections within this map contain a large number of studies conducted in various settings and on numerous subjects related to the listed pandemics, which can inform researchers about areas that lack information and/or are under-researched. This can in turn facilitate priority-based research that avoids duplication and subsequent resource waste. It can also inform funding organisations' resource allocation policies regarding directing grants to under-researched areas and ensuring that limited resources are used efficiently and effectively. The decision-making products are largely only available only for COVID-19, revealing a need for similar resources or information from the above products in order to contextualize other pandemics.

This EGM includes decision-making products such as guidance documents and tool kits that can be accessed centrally by policymakers to help shape policies on the prevention, control, treatment, and management of the various pandemics listed. Other than primary research, policymakers typically rely on finished products. Decision-making products derived from systematic reviews and meta-analyses of primary studies provide well-synthesised information to inform and shape policy related to various pandemics.

4.1 Application of the pandemic resources EGM

This EGM can help to track pandemic preparation and response efforts, as well as the economic consequences of pandemics.

It may also help researchers and implementers to identify and better understand common requirements for future effective preparedness and response, providing a benchmark of what evidence exists on prevention, control, and management in the event of a recurrence of any mapped pandemic.

It can help to strengthen core public health infrastructure and create a coordinated response focused on tackling emergencies, creating situational awareness, public health messaging, transmission reduction, and management.

It will also serve as a clearinghouse for evidence on pandemics for the development and updating of policy and guidelines, as well as interventions, in coordinated efforts to combat future pandemics.

5. CONCLUSION

This map highlights that most pandemic-related evidence resources focus on COVID-19. This may be a result of its recent occurrence. However, most pandemics have devasting effects on myriad aspects of human life; therefore, better preparation for them requires scientific evidence on medical, social, economic, and other relevant aspects of life. There must be concerted efforts to

produce evidence resources particularly maps and decision-making products for pandemic preparedness and response.

6. IMPLICATIONS FOR RESEARCH, PRACTICE AND/OR POLICY

This is a central repository of evidence resources that can be used as a clearinghouse for evidence on pandemics listed for academic, research, and policy formulation purposes.

The resources in this map contain a large number of studies covering various settings and subjects related to the listed pandemics. They can inform researchers as to which areas require further research, thereby encouraging priority-based research and avoiding duplication. They can also inform resource allocation policies for funding organisations to direct grants to under-researched areas and to use limited resources more efficiently and effectively.

This EGM includes decision-making products, such as guidance documents and tool kits, which can be accessed centrally by policymakers to help shape policies on the prevention, control, treatment, and management of pandemics. Other than primary research, policymakers typically rely on finished products. Decision-making products derived from systematic reviews and meta-analyses of primary studies provide well-synthesised information to inform and shape policy related to pandemics.

The map illustrates inadequate evidence resources on the following pandemics: Nipah and henipaviral diseases, SARS, swine flu (H1N1), Zika, arenaviral haemorrhagic fevers, Chikungunya, Crimean-Congo haemorrhagic fever, Ebola and Marburg, emergent non-polio enteroviruses (including EV71, D668), Hong Kong flu (influenza A/H3N2), and MERS. These pandemics had fewer than 100 evidence resources altogether; this highlights a lack of adequate evidence, indicating a need for consolidated efforts in research and policy in preparation for recurrence of these pandemics.

Most of the evidence resources are based on the following themes: transmission, prevention and management, disease burden, and virology, with a significant gap in social economic impact, behavioural response, gender and equity, health system organisation, and evidence systems. These topics require more attention in terms of research and policy, as lapses in these areas can undermine gains in therapeutic and preventive measures during pandemics.

Finally, the map depicts the strengths and weaknesses of the available evidence system on various pandemics, and it would be useful in shaping policy in areas that require attention to prepare for the listed pandemics.

REFERENCES

Arora, A. (2020, May 13). How COVID-19 is changing the world: A statistical perspective, Volume I. UNICEF DATA.

Banks, J., Karjalainen, H., & Propper, C. (2020). Recessions and health: The long-term health consequences of responses to the Coronavirus. Fiscal Studies, 41(2), 337–344.

Bell, C., & Lewis, M. (2005). Economic implications of epidemics old and new. SSRN.

Else, H. (2020). How a torrent of COVID science changed research publishing—In seven charts. Nature, 588(7839), 553–553.

EPPI. (2022). EPPI-Reviewer: Systematic Review Software.

Forum, M. H. (2022). COVID-END. McMaster Health Forum.

Gai, N., Aoyama, K., Faraoni, D., Goldenberg, N. M., Levin, D. N., Maynes, J. T., McVey, M. J., Munshey, F., Siddiqui, A., Switzer, T., & Steinberg, B. E. (2021). General medical publications during COVID-19 show increased dissemination despite lower validation. PLOS ONE, 16(2), e0246427.

Hynes, W., Trump, B., Love, P., & Linkov, I. (2020). Bouncing forward: A resilience approach to dealing with COVID-19 and future systemic shocks. Environment Systems and Decisions, 40(2), 174–184.

Lee, C. K., Merriam, L. T., Pearson, J. C., Lipnick, M. S., McKleroy, W., & Kim, E. Y. (2022). Treating COVID-19: Evolving approaches to evidence in a pandemic. Cell Reports Medicine, 3(3), 100533.

Morgan, C., & Rose, N. (2020). Multidisciplinary research priorities for the COVID-19 pandemic. The Lancet Psychiatry, 7(7), e33.

Morganstein, J., Ursano, R., Fullerton, C., & Holloway, H. (2017). Pandemics: Health care emergencies. In R. J. Ursano, C. S. Fullerton, L. Weisaeth , & B. Raphael (Eds.), Textbook of Disaster Psychiatry, Volume 2 (pp. 270–283). Cambridge University Press.

New England Journal of Medicine. (n.d.). Coronavirus (Covid-19).

OECD. (2021). Building a resilient recovery: How we can emerge stronger from the COVID-19 pandemic.

Palinkas, L. A., Springgate, B. F., Sugarman, O. K., Hancock, J., Wennerstrom, A., Haywood, C., Meyers, D., Johnson, A., Polk, M., Pesson, C. L., Seay, J. E., Stallard, C. N., & Wells, K. B. (2021). A rapid assessment of disaster preparedness needs and resources during the COVID-19 pandemic. International Journal of Environmental Research and Public Health, 18(2), Art. 2.

Saran, A., & White, H. (2018). Evidence and gap maps: a comparison of different approaches. Campbell Systematic Reviews, 14(1), 1–38.

Smith, E. M., Rakestraw, C., & Farroni, J. S. (2022). Research integrity during the COVID-19 pandemic: Perspectives of health science researchers at an Academic Health Science Center. Accountability in Research, 1–22.

Tisdell, C. A. (2020). Economic, social and political issues raised by the COVID-19 pandemic. Economic Analysis and Policy, 68, 17–28.

WHO. Coronavirus disease (COVID-19). (n.d.).

APPENDICES

Appendix 1: Screening tool

1. Include: We included evidence resources defined as online resources that presented, or provided links to, primary studies, reviews of those studies, guidance documents and other user-friendly knowledge products based on such studies. The definition was restricted to open-access online resources, as we were interested in resources that were readily accessible.
2. Exclude: We excluded evidence resources with inadequate evidence dedicated to a specific pandemic/virus, or with limited information about pandemics and viruses. Resources including blogs, news, webinars, or articles lacking a scientific foundation, or resources that were not about one of the specified pandemics or viruses was excluded.

Duplicates: If we screened the same evidence resource on the same pandemic/virus, we marked it as a duplicate. We took care with this process, as the same evidence resource could provide information on different pandemics/viruses, and should not be excluded as a duplicate.

Appendix 2: A critical appraisal tool to assess the quality of evidence resources

Domain	**Rating**
A. Ease of use (yes or no)	
A.1 For collections/databases/ maps and platforms	
Do evidence resources have filters for easy navigation?	
Free access to resources and information	

Domain	Rating
Systematic representation of the themes and links and the navigation keys of the database	
Judgment	
Meets all the three criteria	High
Meets at least one or two of the above criteria	Medium
Meets none of the above criteria	Low
A.2 For toolkits and guidance documents	
Free access to resources and information	
Systematic representation of the themes and links	
Judgment	
Meets all the above criteria	High
Meets at least one of the above criteria	Medium
Meets none of the above criteria	Low
B. Clarity of purpose	
Does the evidence resource have a clear description of the purpose?	
Judgment	
A clear description of the purpose of the evidence resource	High

Domain	Rating
There is no clarity in the description of the evidence resource	Medium
No description of the purpose of the evidence resource	Low
C. Achievement of purpose	
Are available resources clearly and specifically aligned with the purpose provided in the description?	
Judgment	
Available resources are clearly and specifically aligned with the purpose	High
Available resources are not very clearly and specifically aligned with the purpose	Medium
Major deviations from the intended purpose, no information or minimal information	Low
D. Updating with new information	
Are the evidence resources frequently and regularly being updated?	
Judgment	
Regularly and frequently updated	High
Irregularly and not frequently updated	Medium
Not updated at all	Low

Domain	Rating
E. Sources of the available content	
Is there a description of how the content available in the evidence resource was identified/obtained?	
Judgment	
A clear description of how the content available on the evidence resource was identified and how it can be accessed	High
Unclear description of how the content available on the evidence resource was identified and how it can be accessed	Medium
No description of the sources of the available content	Low
F. Overall rating	
Based on the lowest rating on any of the critical domains, A, B, C and D assign the rating	
	High
	Medium
	Low

Appendix 3: Themes and sub-themes

Themes	Sub-themes	Examples
Zoonosis: Transmission, prevention and management	Prevention, management, and treatment	Vaccines
	Non-pharmacological interventions	Handwashing, masks, quarantine
	Transmission channels	
Virology	Information on variants	
	Virulence	
	Pathogenesis	
Impact and burden of disease	Prevalence/incidence	
	Mental health	Anxiety, stress, depression
	Post COVID-19 effects on humans	Long-term effects
	Socio economic impact	Unemployment, poverty
Behavioural response	Health behaviour	Adherence to quarantine rules, uptake of vaccination
	Social behaviour	Stigma and discrimination
Policy response	Social services	Public transportation
	Education	School and childcare closures and social consequences
	Economy and employment	Firm-level effects
	Justice system, law, and politics	Violence/injuries/suicide

Themes	Sub-themes	Examples
Pre-existing social organisations	Socioeconomic and political organisations	
	Social welfare and security	
Health systems	Resilience of health system	
	Ethical priorities in healthcare system	
	Organisation of healthcare system	
	Direct and indirect effects on healthcare system	
Evidence system	Evidence system on pandemics	
	Digitalisation, information, and data	
Gender and equity-focused	Vulnerable groups	Pregnant women, LGBTQ groups
	Children and younger people	
	Elderly people	Management of elderly care
	Low socioeconomic setting and conflict areas	

LIST OF INCLUDED EVIDENCE RESOURCES

1. China National Knowledge Infrastructure
2. UCSF HIV InSite
3. USAID
4. US MHRP –Military HIV Research Program (2020)
5. Academia
6. ACET EVP (2023)
7. American College of Physicians
8. ADA- Dental experience and research exchange
9. American Dental Association
10. ADVEHEALTH (2023)
11. African Evidence Network
12. Africa CDC
13. The African Federation for Emergency Medicine
14. The African Federation for Emergency Medicine
15. Africa CDC (2023)
16. Africa CDC (2023)
17. Africa CDC - Chikungunya (2023)
18. Africarxiv
19. Australian government
20. Australian Government Department of Health
21. American Hospital Association
22. Association for Health Care Resource & Materials Management (AHRMM)
23. The Agency for Healthcare Research and Quality (AHRQ) COVID-19 Resources
24. AIDSINFO
25. American Lung Association
26. American Medical Association
27. American Medical Association (AMA) (2023). Avian Flu.
28. American Medical Association (AMA) (2023)
29. Australian Medical Association – Practical Guidance and Fact Files
30. American Lung Association (2023)
31. American Society of Hematology (2023)
32. American Planning Association (2023)
33. American Chemistry Society
34. American College of Cardiology
35. American Red Cross
36. African Medical Research Foundation (AMREF)
37. American Society of Microbiology
38. ANA Enterprise (2023)
39. Annals of Internal Medicine
40. American Psychology Association (APA)
41. American Psychology Association (APA) (2023)
42. Association for Professionals in Infection Control and Epidemiology (APIC)

43. Association for Professionals in Infection Control and Epidemiology APIC (2023) ABSA International (ABSA). Avian Flu
44. Artist Relief
45. ASCP (2023)
46. American Sexual Health Education (ASHA) (2022)
47. The American Society for Health Care Engineering (ASHE) (2023)
48. American Society of Health System Pharmacists
49. Asian Development Bank (ADB)
50. Antimicrobial Stewardship Program
51. Association of Schools of Public Health in the European Region (ASPHER)
52. Association for Health Care Environment
53. African Union
54. Australian Government Deptartment of Health and Aged Care (2023)
55. The AIDS Vaccine Advocacy Coalition (AVAC) (2022)
56. ECDC Toolkit for investigation of cases of avian influenza in humans
57. The Association of Zoos and Aquariums (AZA) (2023)
58. British Association of Oral Surgeons
59. Baylor College of Medicine – Departments of Molecular Virology and Microbiology (2023)
60. Baylor College of Medicine Departments of Molecular Virology and Microbiology (2023)
61. Baylor College of Medicine Departments of Molecular Virology and Microbiology (2023)
62. Brennan Center for Justice
63. Benefits.gov (2023)
64. Bill & Melinda Gates Foundation
65. BioExcel-CV19
66. Baylor College of Medicine
67. BMJ – Coronavirus (COVID-19) Hub
68. BMJ – Best practice
69. Britannica (2023)
70. Boston University Research Support (2023)
71. Communication for Development Network
72. Cambridge University – Coronavirus free access collection
73. Campbell UK and Ireland
74. Canadian Centre on Substance Use and Addiction
75. The Center to Advance Palliative Care (CAPC) (2023)
76. California All (2023)
77. Canadian Centre for Occupational Health and Safety (CCOHS) (2023)
78. Centers for Disease Control and Prevention – Zika Virus Guidance
79. Centers for Disease Control and Prevention
80. Centers for Disease Control and Prevention
81. Centers for Disease Control and Prevention
82. CDC – Guidance for COVID-19
83. CDC – Avian Flu (2023)
84. CDC – Avian influenza (bird flu) (2023)
85. CDC – Information on Bird Flu (2023)

86. CDC – Arenaviridae (2023)
87. CDC Foundation (2023)
88. CDC Database of COVID-19
89. CDC-Chikungunya Virus (2023)
90. Centers for Disease Control and Prevention – Nipah Virus (NiV)
91. The COVID-19 Disorder Tracker (CDT)
92. The Centre for Evidence-Based Medicine – Evidence Service to support the COVID-19 response
93. Cell Press Coronavirus Resource Hub
94. CDC – Avian Flu (2023)
95. CDC – Crimean-Congo haemorrhagic fever (CCHF) (2023)
96. CDC – COVID-19 (2023)
97. CDC – COVID-19 (2023)
98. Center for reproductive rights
99. CDC (2023)
100. CDC – Non-Polio Enterovirus. Arenavirus (2023)
101. Centre for Health Protection (2023)
102. Centre for Health Protection, Department of Health for disease, control and Hong Kong
103. Centre for Effective Practice
104. Centre for Science in the Public Interest
105. CGD – COVID education policy tracking
106. CGIAR
107. Community Health and Information Network
108. World Health Organization (WHO) – Guidelines on Clinical Management of Chikungunya Fever
109. OPS – Chikungunya: Guidelines
110. Public Health Division – Chikungunya Investigative Guidelines
111. Burson-Marsteller Brussels – Chikungunya Fever
112. Chinese Center for Disease Control and Prevention
113. Centre for Infectious Disease Research and Policy
114. CIDRAP – COVID-19 (2023)
115. Citizen Science: COVID-19 resources
116. Centers for Medicare & Medicaid Services
117. Cochrane Clinical Answers
118. Cochrane COVID Reviews
119. Cochrane Covid-19 Study Register
120. Cochrane ENT, Hearing & Balance
121. Cochrane Gynaecology and Fertility – COVID-19 Pregnancy and Fertility
122. Cochrane Library
123. Cochrane Oral Health
124. Collabovid
125. The Communication Initiative Network
126. Community Resource Hub-COVID19 Policing
127. Conflict and Covid-19 Resource Hub
128. Covid-19 Open Research Dataset
129. CORE Group
130. Cornell Chronicle – COVID-19 (2023)

131. CoronaNet Research Project
132. UNICEF – Coronavirus in West and Central Africa (COVID-19)
133. Coronavirus Research Repository
134. Coronavirus Tech Handbook
135. CoVariants.org
136. COVAX: CEPI's response to COVID-19
137. COVID -19 Africa Data Research
138. COVID 19 and Policing
139. COVID-19 Behaviour Tracker Data
140. COVID- Clinical Repository
141. World Health Organization (WHO) – COVID-19: WHO Guidance
142. Love Platform – COVID-19
143. Lancet – COVID-19 Resource Centre
144. JAMA – COVID-19: JAMA Network Evidence Collection
145. ESP – COVID-19 Evidence Reviews
146. COVID-19 Africa Watch
147. COVID-19 Communication Network
148. COVID-19 Data Portal
149. COVID-19 Digital Classroom
150. Epistemonikos – COVID-19 News
151. COVID-19 Research Explorer
152. COVID-19 Research Project tracker by UKCDR & GloPID-R
153. COVID-19 South African Resource Portal
154. COVID-19 TrialsTracker
155. COVID-19 Living-NMA Initiative
156. COVID19 Disease Map
157. COVID19 Recommendations
158. CovidBaseAU
159. COVIDScholar
160. Croatian Institute of Public Health
161. Database Commons – COVID-19 (2023)
162. DC.gov (2023)
163. Development Initiatives (2023)
164. Dimension of COVID-19
165. DisGeNET
166. Division of High-Consequence Pathogens and Pathology (2023)
167. Doctors of the world
168. DynaMed
169. Dynamed – Avian Flu (2023)
170. US Department of Education – Guidance for Schools and Districts About Ebola
171. NCDHHS – Ebola Information
172. Social Science for Emergency Response-Ebola Response Anthropology Platform
173. EBSCO Medical
174. European Centre for Disease Prevention and Control
175. European Centre for Disease Prevention and Control
176. ECRI Guidelines Trust COVID-19 Resource Center

177. Elizabeth Glazer Paediatric AIDS Foundation (EGPAF)
178. ELIXIR – Recommended Interoperability Resources (RIRs)
179. Elsevier Connect – Avian Flu (2023)
180. Elsevier Coronavirus Research Hub
181. emedicinehealth (2023)
182. Emerge – Gender, Health and the COVID-19 -Pandemic Measures to Build the Evidence of Need and Response for Women and Girls
183. Elsevier Novel Coronavirus Information Center
184. ENVIS
185. EPA (2023)
186. EPI – WHO Information for Network for Epidemics (WIN)
187. Epicenter Health Research
188. EPPI Centre – COVID-19: a living systematic map of the evidence
189. EPPI – Mega Evidence Map
190. European Respiratory Society
191. ETH Zurich – COVID-19 Pandemic
192. EUI – Covid Knowledge Hub
193. European Center for Disease Prevention and Control – COVID-19 (2023)
194. European Center for Disease Prevention and Control – COVID-19 (2023)
195. European Centre for Disease Prevention and Control (2023)
196. European Centre for Disease Prevention and Control (2023)
197. European Centre for Disease Prevention and Control (2023)
198. Eurosurveillance
199. Evidence Aid – Covid Evidence Collection
200. UNICEF-Innocenti – Evidence Gap Map: Pandemics, epidemics and outcomes on child protection and violence
201. Fairsharing.org – standard, databases and policies
202. Food and Agriculture Organisation (FAO)
203. US Food and Drug Administration (FDA) – Zika Virus Response Updates from FDA
204. FIGO (2023)
205. Fit for Travel (2023)
206. Florida Health (2023)
207. FluNet (2023)
208. French National Authority for Health
209. FRLA – Avian Flu (2023)
210. Frontiers Coronavirus Knowledge Hub
211. Frontline AIDS
212. GBV Guidelines (2023)
213. GDA – Guidelines on Consultation and Supervision During the SARS-CoV-2 Epidemic
214. Global Education Coalition
215. Gender & COVID-19
216. Genetic Literacy Project – COVID-19 (2023)
217. Genomic epidemiology of SARS-CoV-2
218. Global Health Uganda (GHU)
219. Ginkgo Bioworks
220. GiveDirectly

221. Global Influenza Programme (2023)
222. Global Influenza Surveillance and Response System (GISRS)
223. Global Health Network – Covid-19 Research Implementation Hub
224. Global Influenza Programme (GIP)
225. Gov.uk
226. Gov.uk – Nipah virus (2023)
227. Government of South Australia – Crimean-Congo haemorrhagic fever (2023)
228. Government of Canada (2023)
229. Government of Canada – COVID-19 (2023)
230. Government of South Australia – COVID-19 (2023)
231. Global Virus Network
232. National Centre for Disease Control – Technical Guidelines for H1N1
233. World Health Organization (WHO) – Clinical Management of Human Infection with Pandemic (H1N1) 2009: Revised Guidance
234. CDC – Influenza A (H3N2) Variant Virus
235. Harvard AIDS Institute
236. Harvard Dataverse- COVID-19 Research & Evaluations
237. Health direct
238. Health direct (2023)
239. Health Cluster (2023)
240. Health Care Ready (2023)
241. Health Leads (2023)
242. Health Equity in Healthy People 2030
243. Health Leads USA
244. HHS.gov (2023)
245. Health Information and Quality Authority – Health Technology Assessments
246. Frontline AIDS Evidence map of community action on HIV, health and rights
247. Youth Power – Toolkit on Adolescents Living with HIV
248. HIV.gov
249. Rural Health Information Hub – Rural HIV/AIDS Prevention and Treatment Toolkit
250. What Works for Women – Evidence for HIV/AIDS Interventions
251. National Health Library & Knowledge Service
252. HOPE worldwide Kenya
253. HVTN – The HIV Vaccine Trials Network (2022)
254. International AIDS Society (2022)
255. International AIDS Vaccine Initiative (IAVI) (2022)
256. ICAO
257. icddr,b
258. Infectious Disease Institute
259. Infectious Disease Management Programme at UCSF
260. INFECTIOUS DISEASE RESEARCH COLLABORATION (IDRC)
261. International Fund for Agricultural Development (IFAD)
262. International Food Policy and Research Institute (IFPRI)
263. IFPRI (2023)

264. The International Federation of Red Cross and Red Crescent Societies (IFRC)
265. IFRC (2023)
266. Illinois Department of Agriculture – Avian Influenza (2023)
267. International Labour Organization (ILO)
268. International Monetary Fund (IMF) Policy Response to COVID-19
269. Indiana Department of Natural Resources (2023)
270. Infectious Disease Advisor (2023)
271. Infectious Diseases Institute
272. Influenza research database (2023)
273. IRU
274. Biokeanos
275. Journal of the American College of Cardiology
276. JAMA Network
277. J Craig Venter Institute
278. JCVI-Influenza Research Database (IRD) (2023)
279. Johns Hopkins
280. Johns Hopkins COVID-19 (2023)
281. Johns Hopkins CCP (2023)
282. Johns Hopkins Bloomberg School of Public Health
283. Johns Hopkins Medicine Coronavirus (COVID-19) Information and Updates
284. Johns Hopkins Medicine POC IT Guide
285. John Snow, Inc.
286. Kansas Department of Health and Environment (2023)
287. KEMRI
288. Kaiser Family Foundation
289. Lancet COVID-19 Resource Centre
290. Lit COVID
291. Louisiana Center – Avian Flu (2023)
292. MAGIC Evidence Ecosystem Foundation
293. Make 12.4% Work (2023)
294. Makerere University- COVID-19 Resource Center (2023)
295. MAYO Clinic (2023)
296. McKinsey & Company
297. McMaster COVID-19 Evidence
298. COVID-19 Evidence Alerts from McMaster PLUS
299. Mcmaster University – National Collaborating Centre for Methods and Tools: Canada
300. MedicineNet – Arenavirus (2023)
301. medRxiv
302. Medscape – Avian Flu (2023)
303. MEDScape (2023)
304. ECDC – Risk assessment guidelines for infectious diseases transmitted on aircraft (RAGIDA) – Middle East Respiratory Syndrome Coronavirus (MERS-CoV)
305. Manatu Hauora
306. Microbes info (2023)

307. Minnesota Department of Health: Highly Pathogenic Avian Influenza (2023)
308. Minnesota Department of Health (2023)
309. Medical News Today
310. MOH_Jamaica (2023)
311. MOH_Jamaica (2023)
312. Médecins Sans Frontières (MSF)
313. Microbe Wiki
314. Naccho – Avian Flu (2023)
315. NACHW (2023)
316. Nucleic Acids Research
317. NASP (2023)
318. National Institute of Allergy and Infectious Diseases (2023)
319. National Health Portal-India (2023)
320. National Academies (2023)
321. National Medical Association (2023)
322. National Academy of Medicine (2023)
323. National AIDS Trust
324. National COVID-19 Living Evidence Task Force
325. National Institute for Communicable Diseases
326. National institute of Health Treatment Guidelines
327. National Institute of Health: Covid-19 Research
328. National Center for Biotechnology Information
329. NCCN (2023)
330. NCD ALLIANCE (2023)
331. NEJM (2023) Avian Flu
332. NETEC (2023)
333. New York State Department of Health (2023) COVID-19
334. Nextstrain
335. National Health Council
336. National Health Portal
337. NIAID (2022) National Institute of Allergy and Infectious Diseases of The National Institutes of Health
338. NICD (2023) The National Institute for Communicable Diseases
339. National Institute of Health - COVID-19 Treatment Guidelines
340. NIOSH Website: Avian Influenza- Information for Workers (2023)
341. Norwegian Institute of Public Health
342. National Library of Medicine
343. NSW HEALTH (2023)
344. OXFAM America
345. Organisation for Economic Co-operation and Development
346. Organisation for Economic Co-operation and Development Knowledge Hub
347. Ohio Department of Health (2023)
348. Oklahoma State Department of Health (2023) – COVID-19
349. Oklahoma state Department of health (2023)
350. Ontario (2023)
351. ORA Oxford University Research Archive (2023) – Chikungunya Virus

352. Our World in Data Coronavirus Disease (COVID-19)
353. Pan America Health Organisation
354. PAHO (2023)
355. PAHO (2023)
356. PAHO (2023)
357. Palliative Care Association Of Uganda (2023)
358. PATHFINDER International
359. The US President's Emergency Plan for AIDS Relief (PEPFAR)
360. Public Health England
361. Public Health Ontario
362. ProQuest (2023)
363. Respiratory Diseases Department and National Infections Service Middle East Respiratory Syndrome (MERS-CoV) Infection Prevention and Control Guidance
364. UK Health Security Agency and Office for Health Improvement and Disparities
365. Queensland Government (2023)
366. REACTOME Pathway
367. Rakai Health Sciences Program
368. Rapid Research Information Forum
369. SA Health (2023)
370. SAGE
371. Society of Critical Care Medicine
372. SCRIBD (2023) – COVID-19
373. ADB – COVID-19 Policy and Database
374. CIDRAP
375. Wisconsin Department of Health Sciences
376. State of Hawaii, Department of Health, Disease Outbreak Control Division
377. European Center for Disease Prevention and Control
378. Government of South Australia
379. Department of Health (Hongkong special administrative region)
380. Database Commons
381. Australian Government
382. Microbes.info
383. Shared Health (2023)
384. SinoBiological (2023) Crimean-Congo haemorrhagic fever (CCHF)
385. SKOLL foundation (2023)
386. Strategic Marketplace Initiative – COVID-19 Resource Centre
387. Springer Nature
388. SPOR Evidence Alliance
389. Swedish Research Council (SSRC) (2023)
390. State of Rhode Island Department of Health (2023) Arenavirus
391. Cochrane Effective Practise and Organisation of Care: Task Shifting
392. National COVID-19 Clinical Evidence Taskforce
393. The Centre for Evidence-Based Medicine
394. Tennessee Department of Health (2023)
395. Texas Department of State Health Services (2023)
396. Taylor & Francis – Coronavirus (COVID-19) Reading List

397. The Lancet – Zika Virus Resource Centre (2023) Avian Flu
398. The Pirbright Institute (2023)
399. The Jenner Institute (2023)
400. The International Association of National Public Health Institutes (2023)
401. The Australian Commission (2023)
402. The Arc (2023)
403. The National Institute for Communicable Diseases (NICD (2023)
404. The Pirbright Institute (2023)
405. The Jenner Institute (2023)
406. The COVID Prison Project
407. The Global Fund
408. The IMF and COVID-19 (CORONAVIRUS)
409. TRIP
410. Turning research into practice (TRIP)
411. Tufts Now (2023)
412. THE Well Project
413. UCSF (2023) University of California San Francisco
414. UMASH (2023)
415. UMASH (2023)
416. UNITED NATIONS
417. UN Foundation (2023)
418. UNAIDS (2022)
419. United Nations COVID-19 Response United Nations Conference on Trade and Development
420. UNDP – Covid 19 Dashboard
421. UNECA – ECA COVID-19 RESPONSE
422. University Health Network (UNH) (2023)
423. UNHCR (2023)
424. UNICEF Data Hub – Education and COVID-19
425. UNICEF (2023)
426. UNICEF Innocenti's curated library of COVID-19 + Children research
427. UNICEF USA
428. United States Department of Labor (occupational safety and health administration)
429. Universiti Teknologi Mara (2023) – COVID-19
430. US Embassy Uganda (2023)
431. US Embassy Uganda (2023)
432. US Department of Veteran Affairs (2022)
433. USAID'S COVID-19 Response
434. USDA – Avian Influenza (2023)
435. United States Department of Labor (occupational safety and health administration)
436. USFDA (2023)
437. US Veterans Affairs Evidence Synthesis Programme
438. UVRI
439. UVRI-IAVI HIV Vaccine Program
440. University of the Witwatersrand hub
441. Virginia Department of Health

442. Virology Down Under
443. Very Well Health (2023) – Arenavirus
444. The Virginia Hospital & Healthcare Association (2023)
445. Virginia Department of Health (2023) COVID-19
446. Virginia Department of Health (2023) COVID-19
447. Virology Down Under (2023) COVID-19
448. Virus Variation (2023) COVID-19
449. VisualDX (2023)
450. Health and Care Research Wales
451. World Bank
452. World Bank Data
453. World Bank Group
454. Wiley Covid 19
455. World Customs Organization COVID-19
456. Wisconsin Department of Health Services
457. WEBMD (2005)
458. World Economic Forum
459. West Virginia Office of Epidemiology and Prevention Services (2023)
460. World Food Programme (WFP)
461. World Health Organization (WHO) MERS Outbreak Toolbox
462. World Health Organization (WHO) (2022)
463. WHO
464. WHO
465. WHO
466. WHO (2023) COVID-19
467. WHO (2023) COVID-19
468. WHO (2023)
469. WHO (2023)
470. WHO – EMRO (2023)
471. WHO (2023)
472. WHO (2023)
473. WHO Regional Office for Europe
474. WHO Technical Guidelines
475. WHO Technical Guidelines
476. WHO global research on coronavirus disease
477. WikiPathways COVID-19 Pathways Portal
478. Worldmeters
479. Wiley Novel Coronavirus
480. World Organisation for Animal Health (WOAH)
481. World Organisation for Animal Health (WOAH)
482. World Organisation for Animal Health (WOAH) (2023)
483. World Organization for Animal Health – COVID-19
484. World Infectious Disease Monitoring Organisation
485. Wolters Kluwer (2023)
486. World Organisation for Animal Health (2023) COVID-19
487. WSDA (2023)
488. World Trade Organisation
489. World Tourism Organization COVID-19

490. Youth Lead
491. BMJ resources – Zikah virus (2023)
492. FDA – Zika Virus Response Updates (2023) Avian Flu
493. Zika Virus Resources for Healthcare Providers - Emergency Preparedness (2023)
494. WHO ZIKA (2023)
495. PAHO Guidelines for Surveillance of Zika Virus Disease and its complications

11 Appendix 5 Swedish Research Council's grant forms

The Swedish Research Council's support and grant forms

Support form	Purpose of support form	Grant form and purpose
Project support	Support to one or several researchers to carry out a specified research project in line with the intentions described in the application.	**Project grant:** The purpose is to give researchers the freedom to formulate their own research concepts, methods and implementation, and to solve a defined research task within a limited period of time. Reward research of the highest scientific quality in national competition. Funds all types of cost related to the project. Led by a researcher, who acts as project leader. **Proof-of-Concept:** The purpose is to give (former) holders of research grants from the Swedish Research Council the opportunity to refine their research results and carry out activities to prepare for innovation or commercialisation.
Career support	Support to individual researchers for the purpose of improving their academic career opportunities. Grants within career support focus on researchers as individuals at various phases of their careers.	**International postdoc:** The purpose is to give researchers with recently awarded doctorates (0–2 years after award) the opportunity to expand their networks and their competences by working abroad under secure employment conditions. Minimum 2/3 of the time shall be spent abroad. **Starting grant:** The aim is to give junior researchers (2–7 years after doctorate award) the opportunity to establish themselves as independent researchers. **Consolidation grant:** The purpose is to give the most prominent junior researchers (7–

Support form	Purpose of support form	Grant form and purpose
		12 years after doctorate award) the opportunity to consolidate their research initiatives and broaden and deepen their activities. **Grant for research time:** The purpose is to give persons within a specific professional group the opportunity to conduct relevant research and to establish themselves as independent researchers in parallel with developing their professional competence. **Grant for employment as a half-time researcher in a clinical environment:** The purpose is to give clinically active persons the opportunity to conduct research on a half-time basis in parallel with developing their clinical competence.

Source: Swedish Research Council

The Swedish Research Council's grant forms – grants to research environments and collaborations

Support form	Purpose of support form	Grant form and purpose
Research environment and research collaboration support	Research environment and research collaboration support aims to support a research goal or research area over a long term. Support is also given to activities within excellent research environments, networks and graduate schools, or to build up these operations.	**Research environment grant:** The purpose is to create added value through collaboration in larger groupings than in a normal project, and the grant applicants shall be a cluster of several researchers working towards a joint long-term research goal. Collaboration may be justified by research linked to a national or international infrastructure, a collaboration between researchers at different universities, or a research task with a multi-disciplinary focus.

Support form	Purpose of support form	Grant form and purpose
		The grant is generally larger than those awarded to individual projects. **Graduate school grant:** Graduate schools aim to build up a new area, strengthen competence within a specific area or increase collaboration nationally and internationally by contributing to research education activities. The costs that can be covered by the grant form are costs related to the graduate school, such as new courses, coordination, etc. Salaries for doctoral students are not normally covered. Graduate schools can, for example, be linked to a research environment grant. **Distinguished professor grant:** The purpose is to build up a larger environment, with coherent funding, around a leading researcher. **Visiting researcher grant:** The visiting researcher grant aims to give universities the opportunity to develop a subject area by recruiting an internationally prominent researcher during a short period. **Network grant:** Network grants aim to give researchers the opportunity to create or develop networks around a research area during a limited period. **Conference grant:** The purpose of the grant is to promote research collaboration and exchange of experience. Calls for conference grants normally focus on internationalisation, and are then a way of giving

Support form	Purpose of support form	Grant form and purpose
		researchers active in Sweden the opportunity to arrange a conference with internationally recognised speakers. **Exploratory workshop grant:** The purpose of the grant is to support the development of new research areas, research programmes or collaborations. The grant may be used to investigate the opportunities of creating new research areas, or to investigate common areas in conjunction with bilateral agreements.

Source: Swedish Research Council

The Swedish Research Council's grant forms – support for the prerequisites of research

Support form	Purpose of support form	Grant form and purpose
Research infrastructure funding	The purpose of infrastructure support is to support coordination, development, construction and operation of research infrastructures of national interest, including Swedish collaboration in international infrastructures of national interest. Support to national and international research infrastructure. May relate to build-up, operation and close-down of infrastructure.	**Research infrastructure grant:** The purpose is to support coordination, development, construction and operation of research infrastructures of national interest, including Swedish collaboration in international infrastructures of national interest.
Operational support	The purpose of operational support is	**Operational grant to research coordination and**

Support form	Purpose of support form	Grant form and purpose
	to contribute to the other necessary support structures and mechanisms for research at national or international level.	**institutes:** The purpose is to enable national coordination within a certain area or to contribute to a (internationally leading) research environment focusing on programme activities. **Publication grant:** The purpose is to support the development of high-quality open access journals based in Sweden.
Research communication support		**Research communication grant:** The purpose of the grant is to enable holders of earlier and/or ongoing research grants from the Swedish Research Council to plan, implement and evaluate communication activities that entail dialogue or co-creation with identified groups outside academia.

Source: Swedish Research Council