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ZOONOTIC DISEASES

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IAEA

The International Atomic Energy Agency's mission is to prevent the spread of nuclear weapons and to help all countries — especially in the developing world — benefit from the peaceful, safe and secure use of nuclear science and technology.

Established as an autonomous organization under the United Nations in 1957, the IAEA is the only organization within the UN system with expertise in nuclear technologies. The IAEA's unique specialist laboratories help transfer knowledge and expertise to IAEA Member States in areas such as human health, food, water, industry and the environment.

The IAEA also serves as the global platform for strengthening nuclear security. The IAEA has established the Nuclear Security Series of international consensus guidance publications on nuclear security. The IAEA's work also focuses on helping to minimize the risk of nuclear and other radioactive material falling into the hands of terrorists and criminals, or of nuclear facilities being subjected to malicious acts.

The IAEA safety standards provide a system of fundamental safety principles and reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from the harmful effects of ionizing radiation. The IAEA safety standards have been developed for all types of nuclear facilities and activities that serve peaceful purposes, as well as for protective actions to reduce existing radiation risks.

The IAEA also verifies through its inspection system that Member States comply with their commitments under the Nuclear Non-Proliferation Treaty and other non-proliferation agreements to use nuclear material and facilities only for peaceful purposes.

The IAEA's work is multi-faceted and engages a wide variety of partners at the national, regional and international levels. IAEA programmes and budgets are set through decisions of its policymaking bodies — the 35-member Board of Governors and the General Conference of all Member States.

The IAEA is headquartered at the Vienna International Centre. Field and liaison offices are located in Geneva, New York, Tokyo and Toronto. The IAEA operates scientific laboratories in Monaco, Seibersdorf and Vienna. In addition, the IAEA supports and provides funding to the Abdus Salam International Centre for Theoretical Physics, in Trieste, Italy.

Committed to stopping pandemics

By Rafael Mariano Grossi, Director General, IAEA

The lockdowns, the testing, the vaccinations, the loss of life and the threat to livelihoods — COVID-19 has changed the world as we know it. The pandemic has fundamentally altered our understanding of diseases and impressed upon the population at large the importance of integrating environmental, animal and human health for public health responses. Avoiding future pandemics begins with the timely detection and the monitoring of the emergence of disease outbreaks, which often originate in animals. The IAEA will step up its efforts to provide support to governments worldwide in using nuclear and related techniques to enhance global response preparedness.

For over 60 years the IAEA, in cooperation with the Food and Agriculture Organization of the United Nations (FAO), has worked to better understand and tackle transboundary animal diseases — including zoonotic diseases which could jump from animals to humans. The Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, the principal vehicle of this collaboration, not only enhances global food security through its animal health and production programme, but also, in turn, significantly contributes to saving people's lives.

In this edition of the *IAEA Bulletin*, we show how the zoonotic disease work undertaken by our laboratories in Seibersdorf, Austria, is making an impact around the world. From our role in addressing the Ebola outbreak in 2014, to the invaluable support provided to address the COVID-19 pandemic, the IAEA and the FAO have played an important technical role in tackling the biggest zoonotic outbreaks worldwide.

The IAEA's support to countries in addressing COVID-19 has been particularly significant. Through the largest technical cooperation project in the IAEA's history, our support to almost 300 laboratories and health institutions around the world has improved COVID-19 testing capacity and capabilities for those most in need. We explain why nuclear and related techniques, such as real-time reverse transcription–polymerase chain reaction (RT–PCR), have played such an important role in testing for the COVID-19 virus. We explore the different services and tools that the IAEA and the FAO offer countries to identify and trace zoonotic and animal diseases.

This edition also reveals the direction we are taking to help address future outbreaks of diseases of zoonotic origin. The IAEA's global Zoonotic Disease Integrated Action project, or ZODIAC, will support laboratories with technology, equipment and training to assist them in the timely detection of zoonotic pathogens of emerging or re-emerging zoonotic diseases. The COVID-19 pandemic has clearly shown that acting early and fast is an effective way to deal with zoonotic diseases.

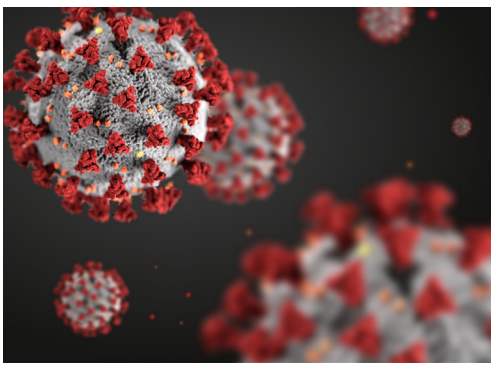
We hear from a researcher in Vienna who is using artificial intelligence to better understand emerging zoonotic diseases, and from the Director General of the World Organisation for Animal Health, who, like us, advocates for a holistic approach to human, animal and environmental health. In a world divided in our approaches to address global challenges, tackling a zoonotic pandemic has in many ways brought us all together.

"The IAEA's global Zoonotic Disease Integrated Action project, or ZODIAC, will support laboratories with technology, equipment and training to assist them in the timely detection of zoonotic pathogens of emerging or re-emerging zoonotic diseases."

— Rafael Mariano Grossi, Director General, IAEA

(Photo: Ministry of Health, Panama)

(Photo: IAEA)



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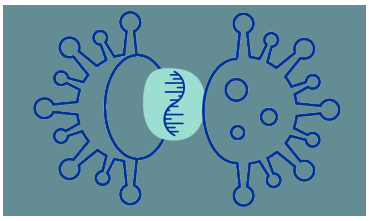
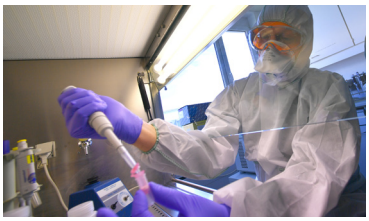




World View

IAEA Updates

Always on alert

The IAEA's record in tackling zoonoses globally

By Michael Amdi Madsen

In a course offered by the FAO and the IAEA, veterinary scientists in Sierra Leone are learning how to catch, sample and diagnose potentially virus-transmitting bats, using nuclear-derived techniques.
(Photo: Laura Gil /IAEA)

In 2005, following a spate of African swine fever outbreaks in the Democratic Republic of the Congo, Gerrit Viljoen, working for the Food and Agriculture Organization of the United Nations (FAO) and the IAEA, visited a piggery outside Kinshasa. Viljoen was there to train local scientists in disease sampling techniques and prepare them for potential outbreaks. What he witnessed still preys on his mind.

Over a dramatic three days, the highly contagious swine pathogen causing the disease swept through the farm, killing all of its 5000 pigs. As tragic as that outbreak and the devastation it wrought on livelihoods were, African swine fever fortunately stops at pigs and does not infect people. But that's not true for all animal diseases. Many of today's most contagious and deadly infectious diseases — seven out of every ten — originate from animals. We call them zoonotic diseases or zoonoses.

By providing training, equipment, chemical reagents and technical expertise, the IAEA, in partnership with the FAO, has contributed to bringing some of the world's most dangerous and damaging diseases, including COVID-19, under control. The IAEA's response to the ongoing pandemic is the latest in a string of efforts to combat zoonoses, including Zika, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), Rift Valley fever, avian influenza, brucellosis and Ebola.

Nuclear science saving lives

In late 2013, one of the worst and most widespread outbreaks of Ebola ever experienced began. Spread through contact with the blood or bodily fluids of those infected with the disease, Ebola cases rapidly proliferated in Guinea, Liberia and Sierra Leone. In August 2014, the World Health Organization (WHO) declared the region's Ebola epidemic an international public health emergency. Over two and a half years, the virus killed more than 11 000 people — 40 per cent of those infected. Authorities managed to control the outbreak, saving tens of thousands of lives.

Always on alert for potential outbreaks, already in 2012, the IAEA was informed of Ebola incidents in Central and Eastern Africa and began providing support. By the time of the large outbreaks in West Africa, the IAEA had in place primers and protocols to help identify strains of Ebola — the first step towards controlling the disease. Along with

the United States of America's Centers for Disease Control and Prevention (CDC) and National Institutes of Health (NIH), countries like South Africa and international partners like the WHO, the IAEA and the FAO helped in validating polymerase chain reaction (PCR) test results (see our infographic on page 8), provided equipment and trained experts.

"Our training went beyond how to get accurate PCR test results; we also gave training on personal protective equipment (PPE) to all medical and veterinary staff to try and ensure that all doctors and scientists involved took the precautions needed when dealing with the Ebola virus itself," said Viljoen, now Head of the Animal Health and Production Section at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. While the Ebola outbreak that brought West Africa to a standstill has ended, the IAEA is still on the trail of Ebola, now in the Democratic Republic of the Congo.

"The threat of Ebola has not gone away, but we can monitor it and act before future outbreaks occur by surveying Ebola's viral reservoirs and virus hosts, such as certain bat species," said Viljoen. Identifying new strains of the disease and analysing the mortality rate, transmissibility and infectivity will play a key role in addressing the disease and stopping future outbreaks.

Staying ahead of outbreaks

Similarly, the avian influenza virus strain H5N1 and other related strains such as H5N8 and H5N6 are an ever-present threat for poultry and people around the world. Originating in Asia but carried by migratory birds, this sometimes deadly to humans zoonotic disease has the potential to appear in other regions, including Europe and Africa. In 2017, it hit Uganda.

Unexplained bird mortalities began to appear in Uganda's western region, and, at the country's request, an IAEA emergency response team was dispatched to investigate. "We were already tracking the spread of H5 viruses across Asia, Europe and Africa, and we suspected that it might soon appear in this area. When these birds started dying, we knew we had to act quickly," said Giovanni Cattoli, Head of the Animal Production and Health Laboratory of the Joint FAO/IAEA Centre, and an international expert on avian influenza research.

In 2016, veterinary scientists in Cameroon used nuclear-derived techniques to discover an outbreak of H5N1 avian influenza. After imposing sanitary measures, killing infected animals, disinfecting farms and halting chicken trade, the outbreak ended.
(Photo: Laura Gil /IAEA)

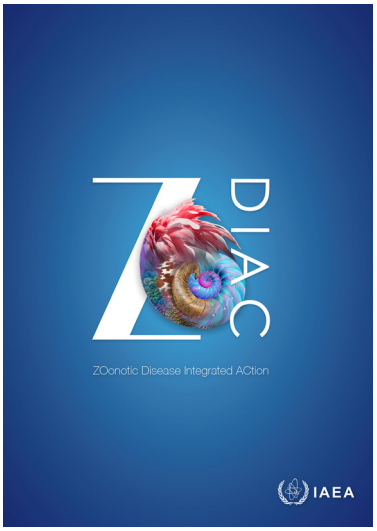
The IAEA uses stable isotopes naturally present in bird feathers and droppings to identify which areas waterfowl have visited during their migrations. Correlated with data of confirmed H5 cases, this information was used by the IAEA to trace infections moving with birds from China to the Russian Federation, across Europe and into Africa. Test results confirmed that the bird deaths were caused by the H5N8 strain. With IAEA support, Ugandan authorities were able to act quickly, retrieve bird corpses and implement measures to reduce human and livestock exposure to the disease.

"The faster you are at detecting avian influenza, the faster you can make efforts to limit the exposure of domestic birds and people," said Cattoli. The disease was later detected in the eastern part of the Democratic Republic of the Congo, and, at the start of 2021, an avian influenza outbreak was confirmed and brought under control in Senegal with IAEA support.

Early detection of zoonotic disease outbreaks is an increasingly important aspect of the IAEA's work. Last year, the IAEA launched the Zoonotic Disease Integrated Action (ZODIAC) project. Through a systematic and integrated approach, ZODIAC strengthens countries' preparedness and capabilities for detecting and responding to zoonotic disease outbreaks (read more about it on page 6).

ZODIAC, the global initiative to fight future pandemics

By Fiorda Llukmani



For the past year and a half, our world has been absorbed by the emergence and rapid spread of COVID-19. Every country has been affected, and over four million people have died. How can we control future outbreaks from emerging and causing chaos in the world?

More than 70 per cent of infectious diseases affecting humans originate from animals. Having possibly jumped from animals to humans, COVID-19 is a zoonotic disease, and the IAEA has offered 128 countries and territories support to detect the presence of its virus. The fastest and most accurate detection method for the virus, real-time reverse transcription–polymerase chain reaction (RT–PCR), is a nuclear-derived technique (see more about this on page 8), and the IAEA, in partnership with the Food and Agriculture Organization of the United Nations (FAO), has helped countries to use it.

Building on decades of experience in supporting the detection, identification and management of zoonoses, such as avian influenza, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS) and Ebola, in June 2020 the IAEA launched the Zoonotic Disease Integrated Action project, or ZODIAC, to help countries prepare for future pandemics. ZODIAC is a global initiative that supports laboratories in identifying zoonotic pathogens before they infect people. The project aims to help build and increase the capacity of veterinary and public health officials to respond to outbreaks in time.

"With COVID-19, the world was caught vastly unprepared," said IAEA Director General Rafael Mariano Grossi. "Through ZODIAC, we aim to establish a network of labs around the world that can support national authorities with reliable data, thus allowing them to act faster and more decisively." ZODIAC will help equip laboratories and train experts in countries where zoonotic diseases may emerge. By supporting countries' efforts to detect potential virus pathogens, with training in the latest nuclear and related techniques,

ReNuAL 2 is the name of the final phase of the modernization of the IAEA's nuclear sciences and applications laboratories in Seibersdorf, Austria. The centrepiece of this phase is the construction of a new, modern building to house the Plant Breeding and Genetics Laboratory, the Terrestrial Environment Laboratory and the Nuclear Sciences and Instrumentation Laboratory. ReNuAL 2 will also include new and improved greenhouses and a refurbishment of the current Dosimetry Laboratory facilities. The IAEA is seeking an additional €7.9 million in extrabudgetary contributions to reach full funding for construction of the new laboratory building.

The Animal Production and Health Laboratory, one of the laboratories that was upgraded through the Renovation of the Nuclear Applications Laboratories (ReNuAL) project, is the main laboratory that will support ZODIAC. The IAEA is cooperating with Austrian Agency for Health and Food Safety (AGES) to ensure other laboratories can benefit from its research. They will gain from research conducted because of the technology and support the IAEA can transfer to countries.

The IAEA's laboratories are a unique feature in the United Nations system. The nuclear applications laboratories in Seibersdorf focus on issues such as food and agriculture, human health, and environmental monitoring and assessment, as well as the use of nuclear analytical instrumentation.

(Photo: IAEA)

laboratories can identify potential animal viruses, with a view to act before they cause human diseases.

"Today the world faces the consequences of two major crises — the pandemic and climate change — whose effects wreak havoc on the economy and the health of populations," said Juan Francisco Facetti, Paraguay's Ambassador to Austria and Resident Representative to the IAEA. "The ZODIAC project not only foresees continuing with the strategy of enhancing the analytical capacities of our health systems to face COVID-19, but will also allow us to take a giant leap forward in strengthening the understanding of zoonotic diseases and their sequelae."

Applying decades of experience

Through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture, the IAEA advances and supports the safe and appropriate use of nuclear and related technologies to detect and control transboundary animal and zoonotic diseases.

"Through ZODIAC, we aim at making nuclear and related techniques widely available to national laboratories and providing them with a platform through which laboratories can analyse and visualize their data," said Jean-Pierre Cayol, Programme Coordinator at the IAEA Department of Nuclear Applications. "ZODIAC gathers all of our technical expertise, knowledge, experience and support to ensure that laboratories have the capacity to support countries' zoonotic response." To date, countries have nominated 144 ZODIAC National Coordinators, who will act as focal points for ZODIAC matters, and a total of 112 National Laboratories to join the project.

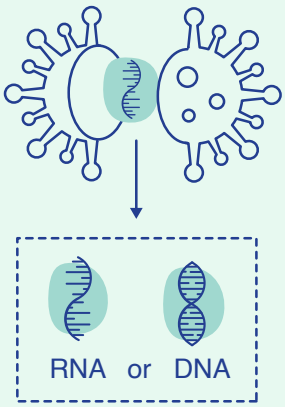
ZODIAC builds on IAEA assistance provided to countries in response to the COVID-19 pandemic. Since early 2020, the IAEA has shipped equipment packages, including RT–PCR machines and diagnostic kits, around the world, organised webinars on detecting the COVID-19 virus and produced multilingual educational videos on RT–PCR (see the photo essay on page 18 to learn more about the IAEA's response to COVID-19).

"ZODIAC is the way the IAEA is streamlining its support to countries to fight COVID-19 and be better prepared for the next pandemic through technology transfer and capacity building," said Grossi.

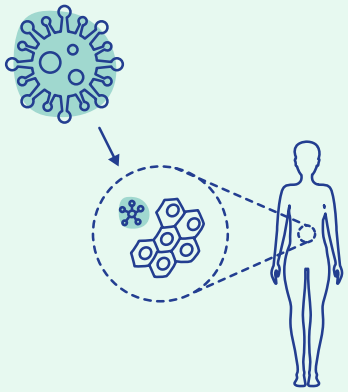
COVID-19: real-time RT–PCR explained

Since the emergence of COVID-19 in late 2019, the gold standard in testing for the disease has been a nuclear-derived technique: real-time reverse transcription–polymerase chain reaction, or real-time RT–PCR. Fast and accurate, real-time RT–PCR has been critical in detecting, tracking and studying COVID-19. But what is it and how does it work? Let us explain. But first...

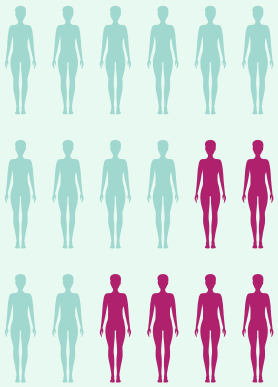
WHAT IS A VIRUS?



A microscopic package of genetic material (RNA or DNA) surrounded by a protective envelope.



Viruses take over host cells in humans or animals in order to replicate.



This can cause human and animal diseases.

Viruses are difficult to spot because of their small size, but there are some modern nuclear-derived techniques, such as real-time RT–PCR, that allow us to identify them.

WHAT IS REAL-TIME RT–PCR?

PCR
was developed in

PCR

PCR is a nuclear-derived method for detecting the presence of specific genetic material of any pathogen, including viruses.

RT–PCR

When a virus has RNA, rather than DNA genetic material, as in the case of COVID-19, an enzyme called reverse transcriptase is needed to convert the RNA into cDNA (complementary DNA). This is called reverse transcription.

Real-time RT–PCR

Real-time reverse transcription–polymerase chain reaction

HOW DOES COVID-19 REAL-TIME RT–PCR TESTING WORK?

1 Sample

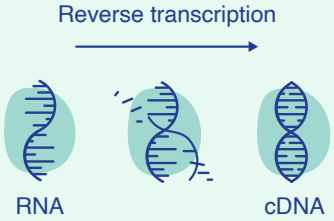
A person's blood, saliva or mucus is sampled.

Chemical solutions are added to remove substances such as proteins and fats.

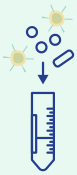
The sample contains a mix of a person's genetic material and the virus's RNA (if present).

2 From RNA to DNA

In order for PCR to work, the RNA needs to be converted into cDNA.

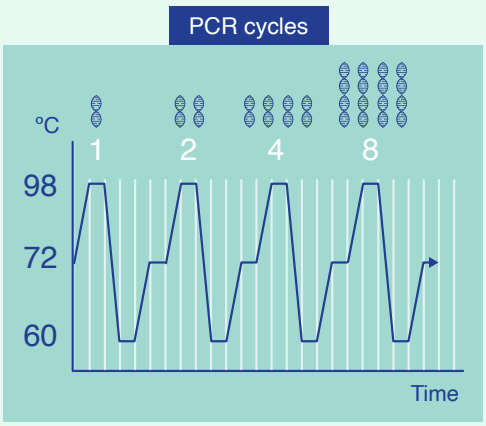


3 Copying and dyeing the DNA

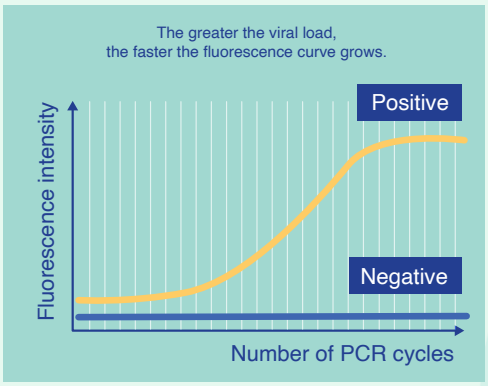


Chemical reagents, including probes with fluorescent dyes that will mark any viral cDNA found, are added in order to build copies of the genetic material.

The samples are then placed in a PCR thermocycler machine.



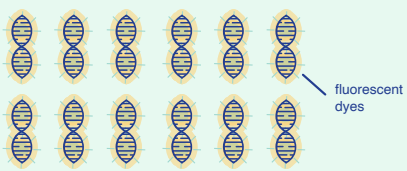
Different temperature cycles trigger chemical reactions that replicate the original genetic material.



If the virus is present, the copies will generate fluorescence. The more fluorescence, the more viral material.

In about one hour, billions of copies of the original genetic material are made, revealing if the virus is present or not.

1 hour



Croatian studies clarify the role of animals in the spread of COVID-19

By Monica Exner

The virus that causes COVID-19 can be transmitted from humans to dogs but not various species of other wild and captive animals, Croatian researchers have found. In two separate studies, results indicated that dogs are not a source of human infections, and that the COVID-19 virus has not been transmitted from infected people or the environment to a limited selection of wild and zoo animals. The study was the first time that circulation of the virus was studied between people and wild animals.

With support from the IAEA in cooperation with the Food and Agriculture Organization of the United Nations (FAO), researchers used real-time reverse transcription polymerase chain reaction (rRT-PCR) to test clinical samples. rRT-PCR, the most reliable method to detect specific genetic material from pathogens, including viruses, is a nuclear-derived technique (see article on page 8). Nearly 300 laboratories worldwide, including the Croatian Veterinary Institute and the Faculty of Veterinary Medicine at the University of Zagreb, received equipment packages from the IAEA to support the detection and characterization of virus strains and to help local authorities combat the virus. The equipment was used to evaluate test samples from people as part of the country's drive to lower infections, but when there were no human samples to test, scientists used the equipment to conduct the experiments for the animal study.

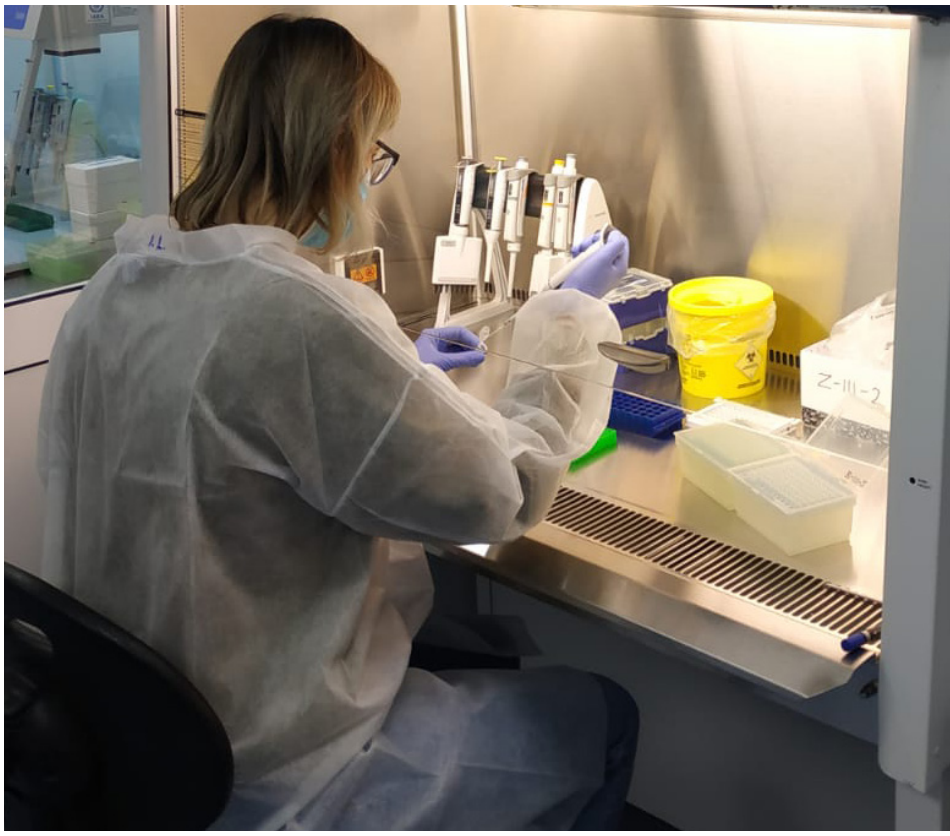
An IAEA-backed Croatian study confirmed that, for now, COVID-19 can be transmitted from humans to dogs but not from dogs to humans.
(Photo: Freepik.com)

Global support, local testing

In response to the COVID-19 pandemic, the IAEA – through an interregional technical cooperation project – has provided equipment and materials to laboratories in 128 countries to help combat the virus (see photo essay, page 18). The project was established in 2020 to respond to countries' needs in the event of disease outbreaks, emergencies and disasters. As a result of the IAEA's assistance, countries have built their capacity to prepare for and respond to threats and outbreaks of zoonotic diseases. Furthermore, in Croatia, the FAO/IAEA's technical support led to greater understanding of the transmission of the coronavirus.

"Besides supporting public health authorities, we have contributed to clarifying the role of animals in the epidemiology of this new disease on a global level and study the impact of infections on animal health and welfare," said Ljubo Barbic, Head of the Virology Laboratory at the Faculty of Veterinary Medicine in Zagreb.

The results of the research are significant, given concerns of possible infection via animals. Because the virus could behave differently in otherwise similar animal species, testing for each specie is required to rule out – or confirm – possible transmission of the virus to humans, said Ivancho Naletoski, Animal Health Technical Officer at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture.



"The support provided by the IAEA was crucial for building and upgrading laboratory capacities for early and accurate detection of the virus in humans but also in animals, as potential reservoirs of the infection but also for emergency preparedness when faced with COVID-19 or similar infections in the future," said Lorena Jemersic, Head of the Virology Department at the Croatian Veterinary Institute.

An expert from the Croatian Veterinary Institute prepares samples for COVID-19 detection by RT-PCR in a molecular laboratory of the Virology Department at the Croatian Veterinary Institute in Zagreb.

(Photo: L. Jemersic/Croatian Veterinary Institute)

The content of the IAEA COVID-19 testing packages

1. Core equipment and accessories (including PCR thermocyclers) required to run the tests, as well as biosafety cabinets level 2 and 3 required to ensure the safety of laboratory staff and prevent spillover of the infection from the routine samples;

2. Personal protective equipment (PPE), including overalls, boots, masks, gloves and goggles to protect personnel from contracting the virus, as well as preventing the release of the virus into the environment;

3. A set of diagnostics kits required to detect the presence of the COVID-19 virus using the rRT-PCR.

COVID-19's hidden costs

How the pandemic is disrupting radiation medicine and medical imaging

By Puja Daya

The world has seen many epidemics, from various flus to Typhus, but none have been as disruptive on a global scale in modern times as the COVID-19 pandemic. It has altered our daily lives, from lockdowns to quarantines and continuous testing. Millions have died, and many have recovered with long-lasting symptoms. The pandemic's indirect health effects have also been severe — limiting access to diagnostic tools and treatment facilities as a result of lockdowns and the diversion of health care resources to fight COVID-19. Experts at the IAEA have provided support to many countries in order to minimize the effects of COVID-19 on the diagnosis and management of non-communicable diseases and access to radiation medicine.

Assessing the effects of the pandemic on access to radiation medicine

"The IAEA has a unique role, as an international technical agency with convening power. It could react quickly and has the ability to determine how the routine processes and procedures that provide diagnosis and treatment of patients have been affected," said May Abdel-Wahab, Director of the IAEA's Division of Human Health. "In addition, it can provide guidance on how the medical community can resume routine procedures by recommending good practices and protocols to support practitioners. Crucially, the recommendations and guidance prepared during the pandemic, based on consensus among various professional organizations, will have lasting benefits beyond the COVID-19 pandemic."

Medical imaging includes various processes and techniques to create images of the human body in order to accurately diagnose and treat diseases. Some of these technologies include X-rays, computed tomography and ultrasound imaging, which have been used extensively to better understand how COVID-19 affects the inside of the human body.

However, surveys conducted by the IAEA following the onset of the pandemic showed

The use of radiation medicine techniques, such as radiology, nuclear medicine and radiotherapy, are important in the diagnosis, treatment and management of patients with various health conditions, as well as in saving cancer patients' lives. However, as seen with COVID-19, a pandemic can interrupt their use in medical facilities around the world.

(Photo: J. Cerci/Quanta Diagnosis and Therapy, Curitiba, Brazil)

that 70 per cent of nuclear imaging procedures were disrupted. These procedures are also crucial in the diagnosis and management of cancer and cardiovascular diseases.

The disruption has allowed non-communicable and other diseases to develop and progress undetected, potentially reversing decades of medical advances and disproportionally affecting the world's low-income regions, where resources are already scarce.

Providing advice and support

Based on the data collected through nuclear medicine surveys, the IAEA has developed guidance through publications and webinars — in cooperation with professional organizations from around the world. The COVID-19 related webinars, with over 6000 attendees, provided a platform for international discussion. This resulted in a shared knowledge of best practices and improved practices in nuclear medicine and radiation oncology departments, as well as in techniques for the diagnosis of COVID-19.

"At the beginning, we were struggling, trying to make appropriate decisions, uncertain of the impact on patient and staff safety. The little information we had was scarce and frequently originated from non-scientific sources," said Francisco Osvaldo Garcia-Perez, Head of the Nuclear Medicine and Molecular Imaging Department at the National Cancer Institute in Mexico. "Once we learned how to prioritize the accurate and beneficial information, we were able to take better decisions on how to adjust the standard operating procedures related to patient care and staff responsibilities."

The institute now has procedures in place to balance the usual treatment of patients while fighting the pandemic, he added, and these new protocols will enable his department to overcome significant pitfalls when future pandemics arise.

IT-enabled health care

In addition to webinars and publications, the frequently updated Human Health Campus, an educational and resource website maintained by the IAEA, has helped health professionals in nuclear medicine and radiotherapy to access the latest and most accurate information needed to deal with the changes they have faced in light of the pandemic.

The IAEA, like many others around the world, also had to transition its conferences online, resulting in a wider reach and therefore a bigger impact. The International Conference on Molecular Imaging and Clinical PET–CT in the Era of Theranostics (IPET-2020), held in November 2020, and the International Conference on Advances in Radiation Oncology (ICARO-3), held in February 2021, each attracted over 3000 attendees.

"New trends are emerging due to COVID-19, with new communication technologies necessary to run a more virtual environment. Nuclear medicine will have to adapt, learn from the crisis and prepare for the future while still offering essential services," said Diana Paez, Head of the Nuclear Medicine and Diagnostic Imaging Section at the IAEA.

The IAEA has redoubled its efforts to enhance virtual learning and support through a collaborative initiative with medical experts to facilitate and streamline access to educational resources created by various organizations. The Comprehensive e-Learning Platform (CeLP) is an integrated set of disease-specific interactive e-learning tools and modules.

In addition, existing professional networks such as the Asia-Pacific Radiation Oncology Network (ASPRONET) and the Africa Radiation Oncology Network (AFRONET), which use online platforms for information sharing and connect nuclear medicine and radiation oncology departments, have been strengthened.

Travel interruptions have also meant putting together more virtual teams, including in the Eastern Caribbean, where the region's Virtual Tumor Boards were launched in July 2021. These support the establishment of a regional pool of expertise and facilitate cost-effective regional referral among centres of excellence and hospitals within the Organisation of Eastern Caribbean States.

The IAEA will continue to support practitioners worldwide in adapting to the new circumstances and challenges affecting radiation medicine.

Study proves effectiveness of alternative test kits for COVID-19

By Joanne Liou

The primordial days of the COVID-19 outbreak led to a rapid surge in demand — and subsequent shortage — of many consumables, from household goods and protective equipment to the ingredients and substances needed to test for the virus. As the world grappled with the newfound need to mass-test for COVID-19, laboratories turned to real-time reverse transcription–polymerase chain reaction (real-time RT–PCR). Real-time RT–PCR is the most accurate laboratory method to detect, track and study COVID-19 (see page 8 to learn more), however, its widespread use strained resources and led some laboratories to seek more readily available and cheaper alternatives.

A study to test the performance and quality of some of these alternative resources was recently conducted by the IAEA and the Food and Agriculture Organization of the United Nations (FAO), in collaboration with the Austrian Agency for Health and Food Safety (AGES). Its results have implications for the ongoing fight against COVID-19 in developing countries and beyond.

Reagents for reaction

Reagents are the substances, compounds, primers, probes, enzymes and buffers needed in laboratory tests. Like the essential ingredients of a recipe, they are key to facilitating a chemical reaction and ensuring the proper final result — the salt and butter, so to speak.

"In a situation of increased demand such as during the COVID-19 crisis, many laboratories might quickly find themselves in a situation where they can no longer obtain reagents from their usual sources and are forced to switch to other providers of reagents or other ad hoc molecular diagnostic kits than the ones they are used to," said Adi Steinrigl, Deputy Head of the Molecular Biology Department at AGES. "Labs doing real-time RT–PCR tests rely on trusted sources of reagents, usually in the form of a master mix or ready-to-go diagnostic kit solutions, called ad hoc molecular diagnostic kits."

A master mix is a premixed solution that has all of the components for a real-time RT–PCR reaction and is not sample-specific, meaning the same reagents used to detect COVID-19 can also be used to detect other viruses. Ad hoc kits are for specific diseases and pathogens.

In April 2020, in collaboration with AGES, the Joint FAO/IAEA Centre of Nuclear Techniques for Food and Agriculture launched a study to assess and compare eight master mixes and three ad hoc kits developed by companies based in Austria, Germany, Japan, the Republic of Korea, the United Kingdom and the United States of America.

The study included the most common types of master mixes used and available on the international market among the many molecular assays, or tests, that are commercialized for the diagnosis of COVID-19. As of July 2021, 388 were listed by the Foundation for Innovative New Diagnostics.

Promising results

At the FAO–IAEA laboratories in Seibersdorf, Austria, IAEA experts tested 178 clinical samples provided by AGES, using each of the 11 commercial kits and master mixes. The results of the study established that all the tested master mixes and ad hoc kits can be used for the routine detection of the COVID-19 virus.

"The bottom line is that the tested products provided results that are similar to what can be obtained if using the reagents recommended by the World Health Organization (WHO)," said Giovanni Cattoli, Head of the Animal Production and Health Laboratory at the Joint FAO/IAEA Centre. "In a country where reagents for the recommended protocols are not available or are extremely expensive, laboratories can replace them with some of the other reagents included in the study and achieve similarly accurate results. With this study, we validated alternatives so that laboratories around the

world can utilize available reagents to mass-test populations for COVID-19, therefore making the tests more accessible."

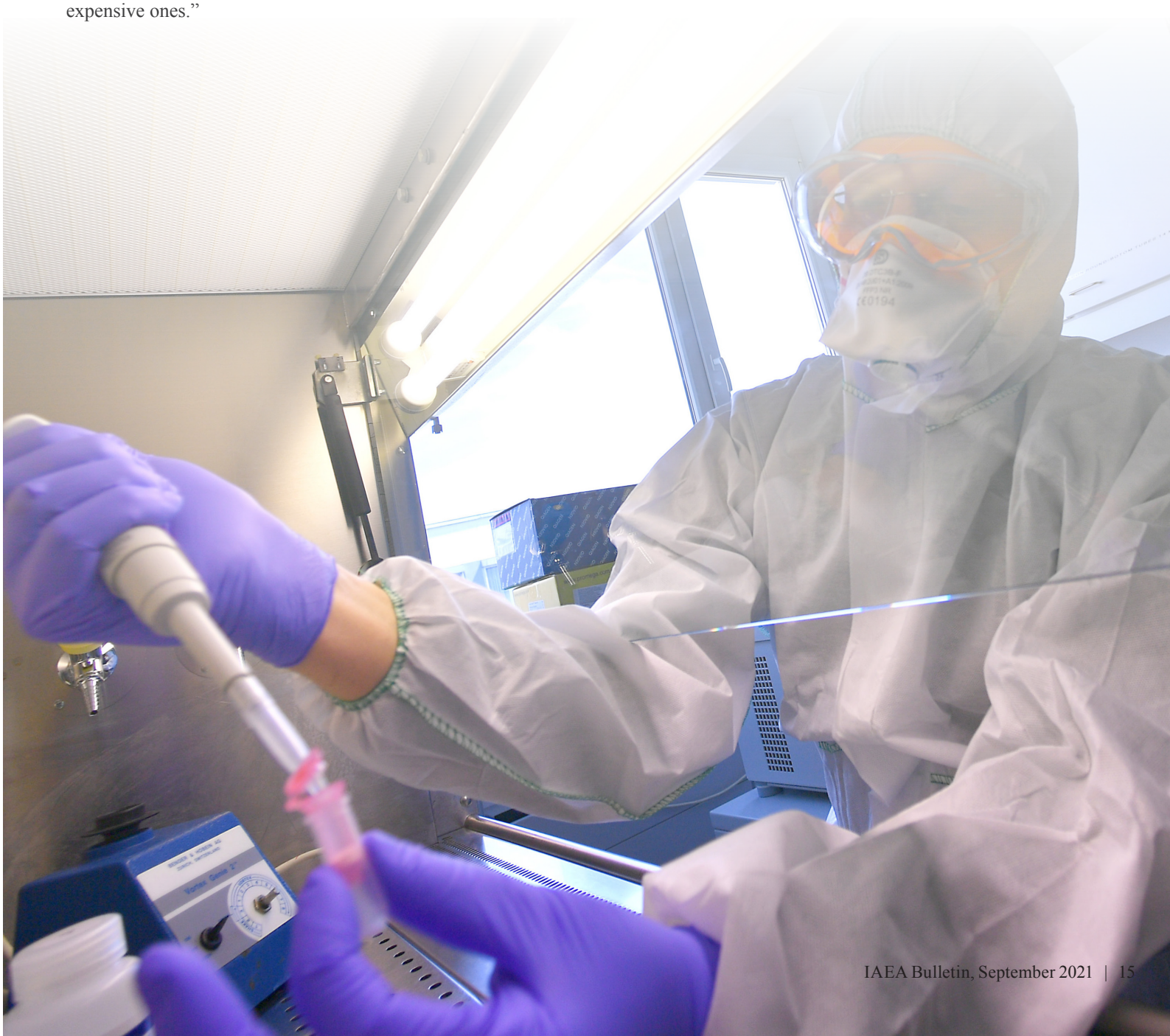
The time needed for and costs of carrying out a real-time RT–PCR test vary, especially among different countries. A real-time RT–PCR test typically takes a couple of hours to complete, from receiving samples to issuing results, and the costs of reagents depend on the company and reagent type. Overall, excluding human resource costs, tests can cost from around €7 to €20, Cattoli added.

Steinrigl agreed that reagents and ad hoc molecular diagnostic kits might differ considerably in their costs: "Comparing the performance of reagents can actually save money. We can see cheaper solutions are not necessarily any less accurate than the more expensive ones."

The procedures and results of the study have been shared with the IAEA Veterinary Diagnostic Laboratory (VETLAB) Network, in which some labs have been requested by national authorities to provide testing for COVID. The VETLAB network includes 46 countries in Africa and 19 in Asia. The study was also published online by the Journal of Virological Methods in June 2021.

"These types of studies are needed for other transboundary animal and zoonotic diseases," Cattoli said. The IAEA is conducting a similar study for African swine fever. "It is important to have an idea of what type of reagents can be used to run real-time RT–PCR testing for these diseases and ensure that the results are equal to the those produced by the recommended protocols."

A recent study tested the performance and quality of alternative test kits used for the routine detection of the COVID-19 virus.
(Photo: D. Calma/IAEA)



Sequencing pathogens to support animal disease control

By Michael Amdi Madsen

In 2019, an outbreak of foot-and-mouth disease (FMD) and an ineffective vaccine put an untold number of cattle, sheep, pigs, goats and other cloven-hoofed livestock in Morocco at risk. A highly contagious viral disease, FMD causes fever and vesicles in the mouth and on the feet of infected animals. This can lead to lameness and other symptoms, making the animals unfit for consumption, causing losses for farmers. The end of the outbreak began with a genetic comparative analysis that resulted in the selection of a different vaccine — a solution made possible thanks to IAEA support to local authorities, in partnership with the Food and Agriculture Organization of the United to Nations (FAO), in building capacity in advanced molecular techniques.

Viruses, like the one that causes FMD, are constantly evolving into new varieties and strains. Vaccines are an effective option to control virus outbreaks, but specific vaccines only work on specific virus strains. Understanding a virus's genome is essential to identifying the best vaccine.

Work to protect Morocco's cloven-hoofed animals began two years before the outbreak, when staff from the National Office for Food Safety of Casablanca were trained through the IAEA technical cooperation programme to identify and characterize disease pathogens and guide control and response measures. This is just one of many training initiatives conducted since the IAEA–FAO's genetic sequencing service was established in 2017. Today, support provided by the service stretches across Africa, Asia and Latin America and helps experts there use and understand the latest analytical techniques for pathogen characterization.

"Pathogen characterization and understanding the origins of animal and zoonotic diseases is essential for designing effective responses to such diseases," said Ivancho Naletoski, a technical officer for animal health at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. Naletoski has been spearheading the sequencing service and supporting activities in training scientists globally in developing phylogenetic trees for animal and zoonotic diseases.

A branching diagram representing the evolutionary course of an organism, a phylogenetic tree helps scientists understand the relationship between different outbreaks of a virus and determine their source or origin. Naletoski says phylogenetic trees and in-depth genetic analyses support authorities in making the right choices to bring pathogens under control. "For decision makers, it's very important to have an accurate genetic profile of the viruses they're trying to address. These data can help save countries time and money when selecting vaccines. As a result, there's a growing demand for our service."

A network of support

To date, the IAEA–FAO's sequencing service has received over 4200 samples and sequences for 54 different animal diseases (such as FMD and African swine fever) and zoonotic diseases (such as rabies, brucellosis and Rift Valley fever). The scientists that contribute to the sequencing service network's database come from 25 laboratories around the world and rely on the service to perform genetic sequencing.

"Genetic sequencing machines can be very expensive to buy and maintain. Purchasing a machine makes sense for laboratories that have very large loads to process, but it is uneconomical for most country laboratories," said Naletoski. "We're helping small laboratories in poorer countries avoid the capital costs by offering the resources to work with established sequencing companies and obtain the same information as if they had the sequencing hardware locally."

The sequencing service provides scientists in the network with reagents and training on how to take high-quality samples and prepare them for sequencing, as well as on how to perform raw data processing and phylogenetic analysis. The service also helps coordinate and pay for these samples to be sequenced by a specialized, commercial

sequencing laboratory. Therefore, the service is free-of-charge for the participating animal production and health labs.

"Because the actual sequencing is performed by a third-party, our focus is on helping labs properly prepare samples and interpret results. To do this, we've developed step-by-step, comprehensive guidelines and, before the pandemic, organized training events around the world," Naletoski explained, highlighting that the training relies on users who have mastered the service and the sample preparation process to train new participants.

Windhoek catches wind of new viruses

A prolific user and champion of the IAEA–FAO's sequencing service is Umberto Molini, a senior lecturer at the University of Namibia. Molini and the Central Veterinary Laboratory of Windhoek were among the first users of the sequencing service, back in 2016. Molini says that over the past five years, the sequencing service has not only helped Namibian authorities better understand the origins and different strains of known viruses circulating in Namibian livestock and game, but also discover viruses that were not known to be present in the country.

"We've found porcine circovirus type 2 in domestic pigs and warthogs, and influenza D virus in bovine and wildebeest. Surprisingly, we even found avian influenza in penguins," said Molini. In 2019, a big outbreak of avian influenza struck Namibia's endangered African penguin (*Spheniscus demersus*) population for the first time. With the help of the service, Molini was able to isolate and characterize the outbreak as the H5N8 strain.

"The outbreak killed around 500 penguins but having identified the virus and its strain, we were able to confirm that the efforts needed to stop the virus spreading to domestic birds were appropriate and necessary," Molini said.

While H5N8 likely came to Namibia from a migrating bird, outbreaks don't always come from the wild. In 2018, an outbreak of infectious laryngotracheitis affected chickens in Namibian poultry farms. Through the sequencing service, Molini discovered that the outbreak was linked to the improper use of a vaccine, so measures to stop the spread of the virus could easily be taken. "Genetic sequencing is a powerful and insightful tool in fighting diseases. If more countries can gain access to and learn how to use sequencing, society will be in a better position to stop future disease outbreaks," he said.

In 2019, a big outbreak of avian influenza struck Namibia's endangered African penguin (*Spheniscus demersus*) population. The IAEA-FAO's sequencing service was able to help characterize the outbreak as the H5N8 strain.
(Photo: Freepik.com)

Responding to a pandemic

IAEA helps 128 countries to stem the spread of COVID-19 in largest ever assistance project

By Omar Yusuf

Since early 2020, COVID-19 has placed an incredible burden on public health systems around the world. Policymakers, laboratory technicians and healthcare professionals have all been called upon to meet the growing demand for detection equipment and capacities, to slow down and control the number of new infections. Following requests from countries around the world, the IAEA immediately began channelling assistance.

(Photo: D. Calma/IAEA)

(Photo: D. Calma/IAEA)

In partnership with the Food and Agriculture Organization of the United Nations (FAO), and delivered through its technical cooperation programme, the IAEA organized hundreds of shipments to diagnostic laboratories around the globe. These shipments included laboratory hardware, like real-time RT–PCR kits; diagnostic reagents and laboratory consumables; biosafety supplies such as personal protective equipment (PPE); and laboratory cabinets for the safe handling and analysis of samples.

Here, a researcher from the Joint FAO/IAEA Centre prepares to conduct a real-time RT–PCR test.

Real-time RT–PCR is a nuclear-derived technique for detecting pathogen-specific genetic material and is widely used for detecting the COVID-19 virus (see infographic on page 8). While laboratories in many countries have used real-time RT–PCR for diagnosing diseases, such as the Ebola and Zika viruses, some of them needed support in adapting this method for SARS-CoV-2, the COVID-19 virus, as well as in increasing their national testing capacities.

(Photo: H. Cossa/ Mozambique)

To date, 296 laboratories in 128 countries and territories have received IAEA/FAO assistance in the rapid detection of COVID-19.

Here, biosafety cabinets are prepared for shipment from Vienna to laboratories around the world.

(Photo: IAEA)


(Photo: University of Ljubljana, Slovenia)

"Our initial work with the IAEA and FAO on foot-and-mouth disease prepared our reference lab to properly test and compare the results of a huge number of samples," explained Ana Maria Nicola, Director of Laboratories and Analytical Control at Argentina's National Food Safety and Quality Service (SENASA). "We now use this experience to quickly adapt, use our resources and build a network to obtain the same quality of results for different situations, such as COVID-19."

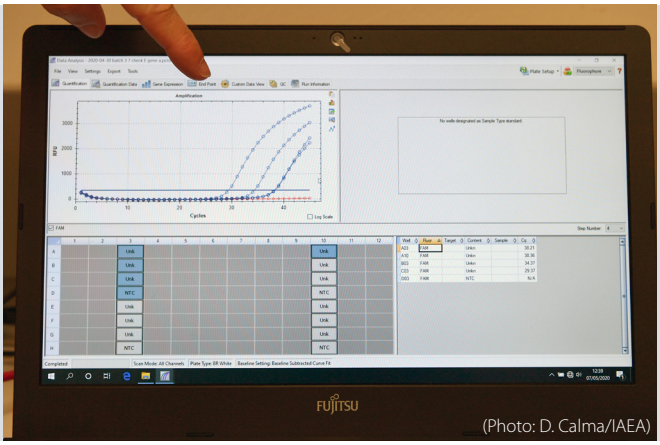
Here an expert from the Institute of Microbiology and Immunology at the University of Ljubljana, Slovenia, prepares samples for virus detection using an IAEA donated real-time RT–PCR machine.

"The consignment we received from the IAEA comprises PPE for our frontline workers," said Charles Keter, Cabinet Secretary of Kenya's Ministry of Energy. "The kits we received for the detection of COVID-19 have greatly boosted the country's capacity in diagnosing and managing the disease. The support package is a testament to the effective use of nuclear techniques in healthcare provision."

Experts at the Kenyatta National Hospital in Nairobi, Kenya prepare samples for processing by an RT–PCR machine.


(Photo: C. Madara, Nuclear Power and Energy Agency, Kenya)

In addition to the provision of equipment, 11 webinars on standard operating procedures were held for healthcare providers, with over 6000 live participants, and a further 16 RT–PCR webinars were held with just over 2000 live participants. All told, close to 300 laboratories and health institutions have received direct support, including 44 in Africa, 28 in Asia and the Pacific, 24 in Europe, and 32 in Latin America and the Caribbean.



(Photo: D. Calma/IAEA)


(Photo: D. Calma/IAEA)

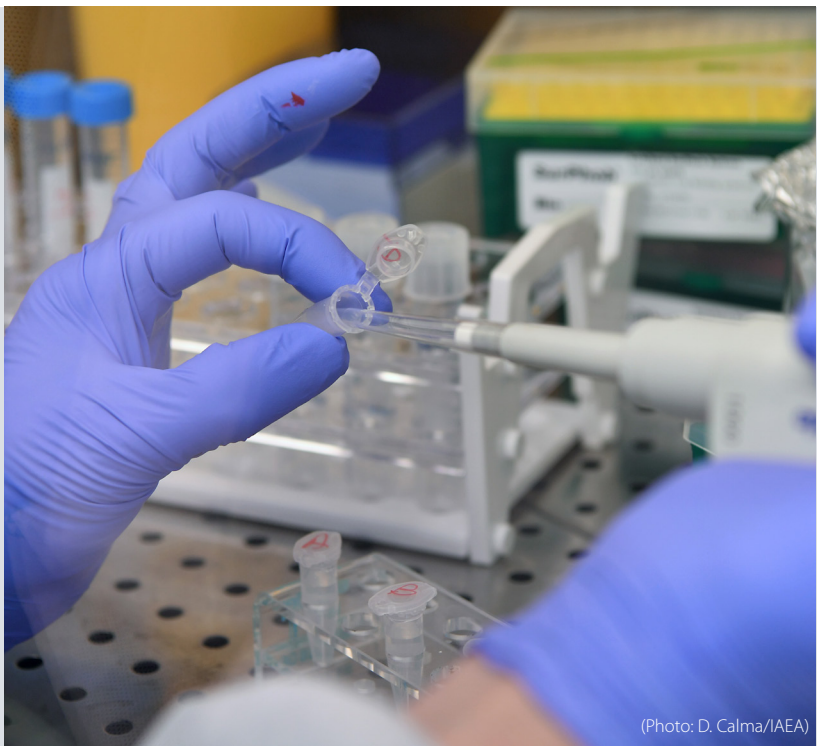
Benefitting from more than €27.7 million in extrabudgetary contributions, it is the largest technical cooperation project — both in terms of amount of funding and number of beneficiary countries — in the Agency's history.

The IAEA's experience with COVID-19 and in addressing zoonotic and animal disease outbreaks has provided the foundation for a new project, the Zoonotic Disease Integrated Action, or ZODIAC (read more about ZODIAC on page 6).

In addition, the Joint FAO/IAEA Centre is assisting countries in the early detection and surveillance of SARS-CoV-2, through research to develop and improve diagnostic tests.

For example, in collaboration with the Austrian Agency for Health and Food Safety, a comparison of 11 RT–PCR reagents for swabs and clinical material helped increase access to PCR reagents for mass testing (see article on page 14).

The evaluation of a diagnostic platform for the detection of SARS-CoV-2 antibodies in mink and other animal species will also provide an additional and very useful tool for the surveillance and monitoring of the virus.


(Photo: D. Calma/IAEA)

Strengthening disease detection across countries with iVetNet

iVetNet is an information platform run and maintained by the IAEA, in full cooperation with the Food and Agriculture Organization of the United Nations (FAO), for compiling, disseminating and harmonizing techniques for the detection and characterization of transboundary animal and zoonotic pathogens. Through the sharing of disease detection procedures, results where applicable and other technical data, the platform aims to support responses by the FAO and the World Organisation for Animal Health to animal and zoonotic disease outbreaks. Launching in 2021, iVetNet will bring together over 1000 laboratories across the globe and offer its users access to information and validated and verified procedures for the detection and characterization of animal and zoonotic pathogens, such as foot-and-mouth disease, African swine fever, lumpy skin disease, Ebola, Zika, COVID-19 and others.The platform:

Brings together laboratories with advanced technologies to serve as knowledge and expertise hubs.

Offers expert services and guidance to laboratories that need to be upgraded on how to improve their services and processes.

Helps laboratories to better collaborate on priority and emerging animal diseases.

Assists in the implementation and maintenance of international standards in laboratory testing and calibration.

Defending against zoonoses through food safety

By Joanne Liou

Food provides our bodies with essential nutrients to sustain life, but when contaminated with pathogens — including those of zoonotic origin — it can debilitate or even kill us. According to the World Health Organization (WHO), more than 200 diseases are caused by eating food contaminated with bacteria, viruses, parasites or chemical substances.

Since consumers cannot always see, taste or smell the threat of contaminated food, food safety laboratories around the world serve as a line of defence to prevent and halt the spread of harmful agents of diseases. The IAEA, in partnership with the Food and Agriculture Organization of the United Nations (FAO), has been supporting laboratories worldwide to help detect, monitor and track contaminants and agrochemical residues in foods.

To date, IAEA support for food safety testing has focused on the detection and control of chemical residues such as veterinary drugs, pesticides and contaminants. Many projects have included microbiological testing and pathogen detection, components that are expected to be expanded in the future.

"Through routine testing, surveillance and involvement in epidemiological investigations, food safety laboratories can detect pathogens' deviation from normal situations and identify emerging pathogens," said A.S.M Saifullah, Chief Scientific Officer at the Institute of Food and Radiation Biology (IFRB) of the Bangladesh Atomic Energy Commission. "Food safety laboratories can help in preparation of and response to zoonotic diseases, including in emergencies."

Food-borne diseases and zoonoses

Some food-borne diseases such as salmonellosis, caused by the salmonella bacteria, are considered zoonoses — infectious diseases that are transmissible between animals and people. Unsafe practices on farms, improper food handling and contamination during manufacturing or distribution are some of the paths for

The Bangladesh Atomic Energy Commission's Veterinary Drug Residue Analysis Laboratory (VDRAL) utilizes isotopic and nuclear-based analytical tools to screen and verify residues and contaminants in food.
(Photo: VDRAL)

salmonella, along with other pathogens, to reach the food we eat. "For many zoonotic diseases, the medium critical for transmission is food," said James Sasanya, a Food Safety Specialist at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture.

The United Nations Environment Programme (UNEP) agrees. In July 2020, it published *Preventing the next pandemic – Zoonotic diseases and how to break the chain of transmission*, a report reflecting on the causes of COVID-19 and other zoonoses. The report found that of all new and emerging human infectious diseases, some 75 per cent are transmitted from other animals to people, and that most zoonoses happen indirectly, for example, via the food system.

Animals can appear healthy despite having a disease, but once the disease is transmitted to humans, it can manifest and have significant health consequences. "It is important for countries to be prepared and conduct regular food safety testing for zoonoses and other microbial hazards," Sasanya said. "Who knows what, where or when the next pandemic will be. When looking at potential pandemics and endemics, it's critical to cover food safety appropriately."

Strengthening laboratories

The Joint FAO/IAEA Centre has been key to supporting many countries in establishing, maintaining and enhancing their food safety laboratories. In Bangladesh, for example, the FAO and the IAEA supported the development of the Veterinary Drug Residue Analysis Laboratory (VDRAL) at the IFRB. Through IAEA technical cooperation projects, FAO–IAEA experts have trained VDRAL scientists on how to test for a range of food hazards and to screen and verify residues and contaminants in food.

FAO–IAEA experts have provided VDRAL with technical guidance for the development, validation and implementation of analytical methods. "VDRAL now uses different isotopic and nuclear-based analytical tools and techniques for the determination of antimicrobial residues and mycotoxins in foods of animal and plant origin," Saifullah said, explaining that efforts are also under way to build capacity for food microbiological testing, including aspects of food-borne zoonoses.

In the past, Bangladesh outsourced food tests to other countries. Today, analysts at VDRAL can use screening tools like rapid radio receptor assays and isotopic verification methods to determine veterinary antimicrobial residues and mycotoxins in foods. More than 3000 food samples, including eggs, milk, chicken and shrimp, are analysed annually to generate residue data. This data enables regulatory institutions, such as the Bangladesh Food Safety Authority, to act to protect public health and improve the country's food safety control system.

"It is pleasing to see a laboratory starting with limited capacity to being able to provide food safety analytical support for the country, as well as to attract significant government support to ensure its sustainability," said Gerald Cirilo Reyes, an IAEA Programme Management Officer for Bangladesh.

Food safety networks

Bangladesh's IFRB collaborates with other food safety laboratories in Asia and the Pacific through the IAEA-coordinated Food Safety Asia Network. Food safety laboratories prevent food-borne incidences by controlling hazards through routine testing, monitoring and surveillance. But food safety systems aren't flawless. "Incidences do occur, and it is important that institutions and countries are prepared, taking no hazard — whether it is chemical, physical or microbiological, like zoonoses — for granted," Sasanya said.

Laboratories in the Food Safety Asia Network share information and analytical methods, as well as participating in proficiency testing schemes. This is critical to address regional food safety concerns and could be developed into an avenue for responding to food safety emergencies.

The Joint FAO/IAEA Centre has also supported the establishment and strengthening of food safety networks in other regions, such as Latin America and Africa. An IAEA project on food safety emergency response is developing isotopic and complementary rapid analytical methods at the Joint FAO/IAEA Centre's laboratories in Seibersdorf, Austria, and training network members to implement them in the field. "Such lab networks could in the future help countries respond to food safety emergencies, including food-borne zoonoses," said Sasanya.

Avian influenza vaccine research to tackle evolving virus

By Wolfgang Picot

In the majority of cases, avian influenza affects birds the same way the flu affects people — some feel nothing, others develop mild symptoms, and, in some rarer cases, the infected die. Like the human flu virus, the avian influenza virus is constantly mutating and has evolved into many different strains. Some of these virus strains can be more infectious or deadly — causing what is known as highly pathogenic avian influenza — and some have the potential to be transmitted to humans. Monitoring a virus's development and finding solutions to keep it under control is therefore a matter of public health.

In 1996, an aggressive — highly pathogenic — variant of avian influenza virus known as H5N1 first appeared in China. By 2003, it had developed into a global problem, and outbreaks around the world killed millions of chickens and led to billions of euros in damage, according to the Food and Agriculture Organization of the United Nations (FAO). Poultry industries worldwide suffered losses, and authorities everywhere hurried to impose control measures to limit the disease's impact. Small-scale farmers and producers in East and South East Asia were especially hard hit.

H5N1 avian influenza is a zoonotic disease, meaning it can be transmitted to people in close contact with infected birds and make them sick. While the total number of transmissions has been relatively low, and sustained human-to-human transmission has not occurred, the consequences for most

The IAEA's help in equipping laboratories and training scientists in the use of nuclear-derived techniques for quick diagnosis is critical.
(Photo: Laura Gil Martinez / IAEA)

infected individuals have been severe. The World Health Organization (WHO) has reported that, across 17 countries, there were just 862 human infections of H5N1 avian influenza between 2003 and 2020, but that more than half of these cases were fatal.

Today, H5N1 is still active in many regions and stringent controls are in place around the globe to prevent it from spreading. But new aggressive variants could appear at any time and severely impact international trade, public health, international tourism and travel, as well as the livelihoods of poultry farmers. Scientists are on the hunt for new solutions to keep the virus in check.

Vaccination as part of the solution

Besides monitoring livestock for illness, the consequent implementation of sanitary protocols and other measures, such as vaccinations, play an essential part in containing avian influenza. However, most vaccine development methods are complex and time-consuming. A nuclear technique currently being developed at the laboratories of the IAEA and FAO in Seibersdorf, Austria, could help to develop vaccines faster and tackle new strains more effectively.

"The IAEA has cutting edge nuclear know-how. At the same time, we also have extensive animal health immunology experience," said Giovanni Cattoli, Head of the Animal Production and Health Laboratory of the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. "This combination makes our laboratories well placed for research and development of novel and innovative animal vaccines."

The method currently being explored follows the principle of producing vaccines by inactivating viruses, that is, making them unable to infect cells and replicate. When these harmless viruses are introduced into livestock, the animals' immune system learns about their properties and can prepare a specific defence against a real infection.

Faster and more effective

When inactivating viruses, it is crucial to keep their physical structure as intact as possible. This way, the immune system recognizes them as viruses and can effectively respond to future viral infections. Scientists call this property 'antigenicity', and they try to preserve the inactivated viruses' antigenicity to make effective vaccines. This is done by irradiating them.

Mainstream vaccine production strategies include the use of chemical or thermal inactivation methods. These can damage viruses and destroy their antigenicity. Exposing the viruses to pre-determined doses of radiation could work better, as this method better preserves their structures.

"We preserve the viral protein structure by using exact amounts of radiation. As a result, the immune system will better recognize and more effectively fight an infection," said Viskam Wijewardana, the IAEA's lead scientist in vaccine development and immunology.

"With this irradiation method, we can potentially tackle constantly evolving, new strains of viruses faster and more effectively than with methods used in the industry at present. This could ultimately help save more birds and, potentially, human lives," Wijewardana said. The IAEA is now conducting experiments to find out how much irradiation is needed to produce an effective vaccine.

After irradiation, IAEA scientists use electron microscopy to screen the virus's structural integrity. Over time, the data gathered during these experiments will provide knowledge on the amount of radiation to use for optimal results. Further tests will establish whether the immune response provoked by this vaccine prototype can still recognize and neutralize the infective virus, thus protecting the animals from the disease.

The IAEA and the FAO will publish the research results with open access for the scientific community, who will be able to draw on these data to develop and manufacture vaccines. If successful, the proposed strategy could help produce vaccines to fight new virus variants relatively quickly and cost-effectively. It could also contribute to addressing future avian influenza outbreaks and other transboundary animal and zoonotic diseases.

Nuclear-derived techniques help farmers combat lumpy skin disease outbreaks in Asia

By Michael Amdi Madsen

Over the past four years, a disease once limited to the hot and humid climates of Africa has appeared for the first time in various parts of Asia and Europe. Afflicting cattle with a debilitating and sometimes deadly condition, the rapid spread of lumpy skin disease is as mysterious as it is alarming.

Laboratories of the IAEA and the Food and Agriculture Organization of the United Nations (FAO) are supporting Asian countries in diagnosing lumpy skin disease and identifying different genetic strains of the disease. This is a prerequisite to launching an effective response to this animal disease pandemic.

According to the FAO, the disease causes significant economic losses for farmers, while creating costs to authorities for preventive and control measures. The FAO estimates that the lumpy skin disease outbreak in the Balkans in 2016–2017 directly cost affected countries more than €20 million in vaccinations, compensation for culled and dead animals, and aerial fumigation. The economic impact of this much wider Asian outbreak is yet to be quantified.

Tracking the spread

Named after the characteristic lesions that form on the skin of infected cattle, how lumpy skin disease is spread is only partially understood. Previous outbreaks in Africa and the Middle East have identified different species of flies as vectors, but the movement of infected animals and contaminated animal products, such as semen or milk, are also transmission suspects.

"We need to carefully re-look at what the vectors are for this disease. We have some understanding of how it has spread in Africa. We have a weak idea of what the vectors are in Europe, but we are at a total loss as to what vectors are causing its spread in Asia," said Giovanni Cattoli, Head of the Animal Production and Health Laboratory of the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. The laboratory team is in direct contact with laboratories, researchers and veterinary authorities in Bangladesh, Bhutan, Cambodia, Indonesia, Nepal, Mongolia, Myanmar, Sri Lanka, Thailand and Viet Nam, trying to help them understand the origins and spread of the virus causing lumpy skin disease using the nuclear-derived polymerase chain reaction technique — the same method that is used worldwide to identify and analyse COVID-19 (see our infographic on page 8).

Based on the list of countries most affected, the virus may have travelled from North Africa into the Middle East and Europe, including the Russian Federation. It then unexpectedly emerged in China and South Asia. Overall, the virus has spread across numerous climates and it is unclear how such a spread could happen over such a short period.

"The virus is spreading very fast — much faster than expected. It emerged in China for the first time in 2019, and, after just a year, we already have more than one strain of the virus in Asia," explained Cattoli.

Global travel restrictions imposed under the pandemic, however, have obliged the IAEA to adapt its support in response to the outbreak. When lumpy skin disease first appeared in Bulgaria in 2016, experts were able to travel there to conduct outbreak investigations. This time, Cattoli and his team collaborate online with counterparts in affected Asian countries to give emergency support in the form of equipment, reagents and consumables, and to investigate the outbreaks and analyse the samples submitted to the FAO–IAEA laboratory in Austria. Through the Veterinary Diagnostic Laboratory (VETLAB) Network, laboratories in Asia can share data and results in near real time, and the FAO–IAEA laboratory team can provide comments and suggestions immediately on how countries can improve their procedures.

The right response

A quick response to the virus, which includes culling, vaccination and movement restriction, is critical to getting the spread of the virus under control. When the virus broke out in Europe, culling was initially used, but this was not popular with farmers. Vaccination and movement restrictions ultimately managed to eliminate the virus in the region, but it remains to be confirmed how effective existing vaccines would be against the emerging Asian strains.

"Making sure you have the appropriate vaccine is very important for saving money and being effective — using an inappropriate vaccine for the virus variant could exacerbate the problem," said Cattoli, explaining that a less than optimal vaccine could lead to new strains evolving and furthering the duration and spread of the disease. The IAEA is working with the FAO's regional office in Thailand to support Asian countries with quality assurance and ensure vaccines are effective against the virus strains present there.

Inaction could lead to dire economic consequences. Lumpy skin disease is a listed disease with the World Organisation for Animal Health (OIE), so if there is an outbreak in one country, then export of cattle could stop. Furthermore, it is a disease that compromises rural societies and villages the most. "They have few animals and can be especially dependent economically and for nutrition on animal products like milk. In these already difficult times, this additional virus is a heavy burden to bear," said Cattoli.

Once limited to Africa, lumpy skin disease has over the past four years appeared for the first time in various parts of Asia and Europe. Its vectors in Asia are not yet fully understood.
(Photo: Miklos Gaspar/IAEA)

Stopping Pig Black Death – African Swine Fever

Protection through detection

By Puja Daya

For many, looking back at 2018 might bring back memories of South Korea's Winter Olympic Games or the British royal wedding of Prince Harry and Meghan Markle, but for pig farmers in China, the year was marked by a single event: the arrival of African swine fever (ASF). That year, the disease — once endemic to only sub-Saharan Africa — broke out among Chinese piggeries, resulting in the death or culling of over a quarter of the world's domestic pig population. A year after its appearance, ASF was estimated to have directly cost China over a trillion yuan (US $141 billion) according to the dean of the College of Animal Science and Technology at China Agricultural University in Beijing, and caused the country's pork prices to spike by 85 per cent.

While China, the world's second largest economy, has been able to weather the ongoing ASF outbreak, not all countries are able to do so. The IAEA, in collaboration with the Food and Agriculture Organization of the United Nations (FAO), is working closely with China, as well as with Cambodia, Indonesia, Malaysia, Mongolia, Myanmar, Thailand and Viet Nam in Asia, and Burkina Faso, Mali, Namibia, Nigeria and Senegal in Africa, in using nuclear techniques to create early detection mechanisms for ASF and to control its spread — saving pigs and farmers' livelihoods.

"If we can limit the spread of this disease, we can limit the culling of disease-ridden pigs, which has a huge negative economic impact on countries that rely heavily on livestock production and trade," said Charles Euloge Lamien, Technical Animal Health Officer at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. For the past 15 years, he's been training experts to sample and accurately detect ASF in their countries.

In China, pork is a primary ingredient for traditional cuisine, and the rise in pork prices has led some consumers to seek cheaper alternatives in wild animals. In wet markets where these are sold, unknown animal diseases could jump from animals to humans.

African swine fever, a transboundary animal disease, is the cause of death for millions of domestic and wild pigs around the world.
(Photo: L. Martinez/IAEA)

"Bringing ASF under control would also reduce the number of consumers resorting to eating wild animals, which are a haven for zoonotic diseases," Lamien said.

ASF, a disease caused by the ASF virus (ASFV), originated in wild pigs but has since been transmitted to domestic ones. Secondary sources of transmission include ticks, contaminated meat products and slaughtered products. Although ASF is not a zoonotic disease, around 70 per cent of infectious diseases are, making stopping the spread of potential zoonoses an even higher priority (learn more about the One Health approach on page 30).

Early detection leads to less destruction

With no vaccination or treatment available for ASF, early detection is essential in controlling it. "Enabling laboratories to detect ASF as soon as possible is the most efficient way to take appropriate measures in containing the virus before it spreads further within a country or even to new countries," Lamien said. Nuclear techniques allow scientists to detect and trace where the virus originates and determine how it's transmitted.

Since 2012, the FAO/IAEA Animal Production and Health Laboratory has been working on ASF, developing what's called syndromic surveillance tools — the collection, analysis and interpretation of data to provide an early warning system for the disease — as well as characterizing the virus from different countries. There are currently 24 known variants of the ASFV. Understanding their different characteristics allows experts to determine how outbreaks of ASF are linked, if they have previously been detected in a country, and where they may have originated.

In 2019, the IAEA in partnership with the FAO helped survey at-risk Asian countries such as Cambodia, Laos, Mongolia, Thailand and Viet Nam to detect the virus early enough to reduce the chances of new strains developing and to protect these countries' pork industries. Lamien hopes to help other countries in the same way and is supporting their efforts to characterize ASFV from recent outbreaks.

The FAO/IAEA Veterinary Diagnostic Laboratory (VETLAB) Network, which includes laboratories from countries in Africa and Asia, supports this work by sharing experiences and methodologies in using nuclear derived techniques to track and trace ASFV. Techniques such as enzyme-linked immunosorbent assay, polymerase chain reaction (PCR), real-time PCR (see the infographic on page 8) and molecular sequencing are used.

African swine fever is a highly contagious disease that can cause a devastating impact on small-scale pig farmers.
(Photo: L. Martinez/IAEA

By detecting ASF-infected pigs early, scientists can separate them from the non-infected pigs and stop the disease from being transported over borders. This was the case in Indonesia in 2020.

"Following disease investigation and confirmation, local governments were able to ban the movement of affected pigs, pig products and contaminated material," said Ni Luh Putu Indi Dharmayanti, Director of the Indonesian Research Center for Veterinary Science.

When a new type of virus is discovered, experts can analyse its genome to estimate the severity of the disease. For example, in 1961, ASF genotype I was discovered in Portugal and spread around Europe. 2007 saw a re-emergence of ASF in Europe with genotype II. Experience has shown that disease-endemic areas can be re-infected with new virus strains. With genotypes I and II being the most common variants detected outside of Africa, nuclear techniques allow for their quick detection and help stop both transmission of the disease and new variants from developing.

One Health: for people and the environment

The converging global challenges of the COVID-19 pandemic and climate change have brought to the forefront the need to look at human and environmental health as one. To better understand what other organizations are doing to make that happen, we interviewed Monique Eloit, Director General of the World Organisation for Animal Health (OIE) and advocate for the One Health approach to public health.

Q: What is One Health and how is it different from what has been practised over the past 50 years?

A: The importance of collaboration across human, animal and environmental sectors has been recognized and practised for centuries. About 20 years ago, One Health was coined and called for as a holistic and multisector approach in the design and implementation of human health programmes and those that affect the health of animals and the environment. After the influenza crisis in the 2000s, and the antimicrobial resistance (AMR)-related issues more recently, the COVID-19 crisis created an opportunity for a renewed commitment to this approach.

One Health relies on the understanding that humans, animals and the environment are inherently interconnected and co-dependent. It is estimated that 60 per cent of existing human infectious diseases are zoonotic, and at least 75 per cent of emerging infectious diseases originate from animals. Healthy ecosystems are essential for the survival of humans and animals. We can no longer think of one group's health without considering the health status of others. This realization is a turning point from the past 50 years, where only human health had been the primary focus.

Since 2010, the OIE has committed to furthering the One Health approach within the Tripartite Alliance with the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO). We share common objectives and activities in the prevention and control of health risks, while also distributing and promoting scientific information on One Health topics, such as AMR, rabies and avian influenza. The Tripartite Alliance recently expanded to include the United Nations Environment Programme and set up a One Health High Level Expert Panel. The panel will advise on a long term global plan of action to avert outbreaks of zoonotic diseases.

One Health relies on the understanding that humans, animals and the environment are inherently interconnected and co-dependent.

— Monique Eloit, Director General, World Organisation for Animal Health

Q: Climate change is an issue overshadowing many decisions. How does the climate crisis affect One Health and efforts to control zoonotic disease outbreaks?

A: Climate change increases the frequency of the emergence of diseases, which impacts health systems. Climate change also increases the frequency of extreme weather events, which directly impacts animal health. Increased temperatures, for instance, have impacted the geographical and temporal distribution of disease vectors, such as mosquitoes and ticks, which are responsible for the transmission of vector-borne diseases.

Habitat loss due to climate change, as well as anthropic activities like mining, farming and deforestation, can push wildlife to new areas. Increased exposure of wildlife to human settlements or livestock can result in the transmission of pathogens. Countries need to build disease surveillance capacities for both human and animals and commit to better

wildlife health management to ensure the safety of wildlife and their ecosystems.

Q: The COVID-19 pandemic highlighted weaknesses in countries' abilities to detect and control zoonotic outbreaks. How can countries better prepare for a future outbreak?

A: Human and animal health education should include both theoretical and practical study of One Health. Beyond university, health professionals and leaders should participate in training and initiatives that encourage multisectoral collaboration on disease surveillance and detection.

The OIE's Wildlife Health Framework helps countries reduce the impact of diseases on public health, livestock health and wildlife populations, while preserving the ecosystem services provided by wildlife. Through this framework, decision makers are called upon to foster collaboration between human and animal health services, as well as wildlife authorities, to strengthen wildlife disease surveillance and prevent zoonotic outbreaks. A key step is for countries to establish legislative or regulatory frameworks for health monitoring of wildlife trade.

Countries should also increase their investment in national veterinary services, which are often at the forefront of zoonotic disease management. They are key to early detection at the human–animal–environment interface, yet they need funding, capacity building training and regulatory models that facilitate One Health collaboration.

Veterinary services also need investments in their infrastructure to improve the sustainability of veterinary laboratories, especially those involved in surveillance. The OIE's Sustainable Laboratories Initiative, supported by Global Affairs Canada, works with its members to understand their needs in building and maintaining strict laboratory biosafety and biosecurity measures. The OIE's Performance of Veterinary Services animal health infrastructure assessments have consistently identified the need to support animal health laboratory equipment upgrades, technology transfer and capacity building. The IAEA has been active in helping address this critical global need.

In addition, the FAO/IAEA Animal Production and Health Laboratory is an OIE Collaborating Centre for ELISA* and Molecular Techniques in Animal Disease Diagnosis. Laboratory capacity building and technology transfer are essential components of the response to an international health crisis. Past experiences from the response to global health crises, consultations with experts, surveys and assessments in Member States have all identified a need to carefully consider the sustainability of laboratories when supporting laboratory capacity building.

Decision makers should prioritize the development of emergency management plans. While most OIE members have some national contingency plan, most members lack resources to implement a response to a future emergency. Leaders must not only commit to developing emergency plans but also commit to funding their implementation.

Q: How can people get involved in the One Health approach?

A: Citizens can apply One Health to their lives by educating themselves on the interconnectedness and interdependence of animals, humans and the environment, and understanding how human actions and policies could affect animal and environmental health. When citizens demand good, multisectoral health governance, policymakers will need to make One Health a legislative priority.

Besides growing our own awareness, each one of us can take specific actions for One Health. If you witness unusual animal events in a forested area, for example, inform authorities because it could indicate an animal disease outbreak. In relation to antimicrobial resistance, individuals should follow antibiotic treatments prescribed by health professionals, whether it be medication for themselves, pets or farm animals. This helps prevent the spread of drug-resistant bacteria. Dog owners for example can commit to responsible dog ownership practices, build awareness of risk behaviours for dog-mediated rabies and ensure their pets are vaccinated.

As people and goods travel more, individuals can better understand their carbon footprint and how their actions affect the environment, animals and people around them. Each individual step brings the planet closer to a healthier future.

** Enzyme-linked immunosorbent assay*

The role of artificial intelligence and medical imaging in addressing zoonotic diseases

By Georg Langs

Georg Langs is the Head of the Computational Imaging Research Lab at the Department of Biomedical Imaging and Image-guided Therapy, Medical University of Vienna. A professor and researcher in artificial intelligence and its application in medicine, Langs is also affiliated with the Medical Vision Group at the Massachusetts Institute of Technology (MIT) Computer Science and Artificial Intelligence Laboratory.

Machine learning (ML), a growing part of artificial intelligence (AI), uses computers to solve complex tasks — not through programed solutions, but by creating models that can learn from examples. This approach has made great strides in recent years. ML models can now recognize people and objects in images; understand, translate and generate spoken language; and identify subtle relationships in biological data. As these models have grown more robust, they have become a part of our daily lives.

In health care, ML models play an increasingly important role in precision medicine, where they inform treatment decisions based on medical imaging data (e.g. computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and X-rays), genomics and other clinical variables. By recognizing subtle patterns, disease progression signatures and treatment responses, the models can predict the risks and future course of a disease in individual patients. In medicine, ML models enable new measurements, quantitative observations and the discovery of novel knowledge about disease.

In lung diseases, ML models have identified new dynamic disease patterns linked to progression and response. With ML, subtle changes in the lung tissue and its imaging characteristics are measurable and turned into a new vocabulary of disease signatures. These signatures link a set of different observable image patterns reoccurring across the patient population. Their gradual change informs our understanding of the disease and allows us to predict individual risk with higher accuracy. Furthermore, ML integrates additional imaging information, capturing co-morbidities to improve prediction for individual patients.

ML is becoming a tool of research and discovery in medicine, as it makes distributed patterns tangible. Yet, while we understand prediction, we are still in the infancy of translating models into mechanistic representations of the biological processes underlying disease and treatment response. Here, intense progress can be expected in the coming years.

The role of medical imaging and machine learning

Medical imaging used together with ML offers a fine-grained view of the phenotypical variability of individual patients and their disease trajectory. It complements other observations, such as the characterization of viruses, genomic and epigenomic profiles, proteomics or laboratory findings, capturing systemic processes. Medical imaging data is acquired in tremendous quantities, as part of routine examinations. As our vocabulary for using this information grows, computational models afford us detailed insights into the variability of disease, new clinically relevant phenotypes and the relationship between individual patient, disease and treatment.

During the COVID-19 pandemic, only a few weeks after the causative pathogen was described, findings in chest radiographs and CT images were published and recognized as rather characteristic for COVID-19, in contrast to the relatively unspecific respiratory clinical symptoms. They carried unseen configurations, and, in the early phase of the pandemic, CT emerged as a diagnostic tool. As testing became available, its role changed from supporting diagnosis to informing treatment and management of individual patients.

This spells out the possible role of AI in the management of future zoonotic diseases transitioning into pandemics: the early detection of a novel disease phenotype in the clinical population and the early and effective guidance of patient treatment.

Potential and objectives of artificial intelligence: What if there are no examples?

The challenge of a zoonotic disease turning into a pandemic is that, on first sight, the paradigm of learning from examples seems to fall apart. We don't have years of observations to teach a machine, and we don't know what to look for when trying to detect a new disease or variant outbreak. This places the role of ML firmly in the area of discovery and identification of relationships observed in a heterogeneous patient population.

Firstly, the detection of anomalies — image patterns, their configurations or their co-occurrence with non-imaging findings — is picking up speed in the ML community. Methods such as generative adversarial networks can learn how imaging varies in a controlled population, so that the detection of novelty is becoming feasible, even if no labelled training data has been available. Currently, this is used to expand our vocabulary of markers, but it could also trigger the identification of novel emerging phenotypes.

Secondly, ML models could be an effective means to better understand the relationship between observed patient characteristics, disease course, and treatment needs and response based on early cases in the routine population before best practices are established. This could aid the identification of effective treatment and inform the creation of guidelines in the early phase of a pandemic.

Lessons learned: How to get there?

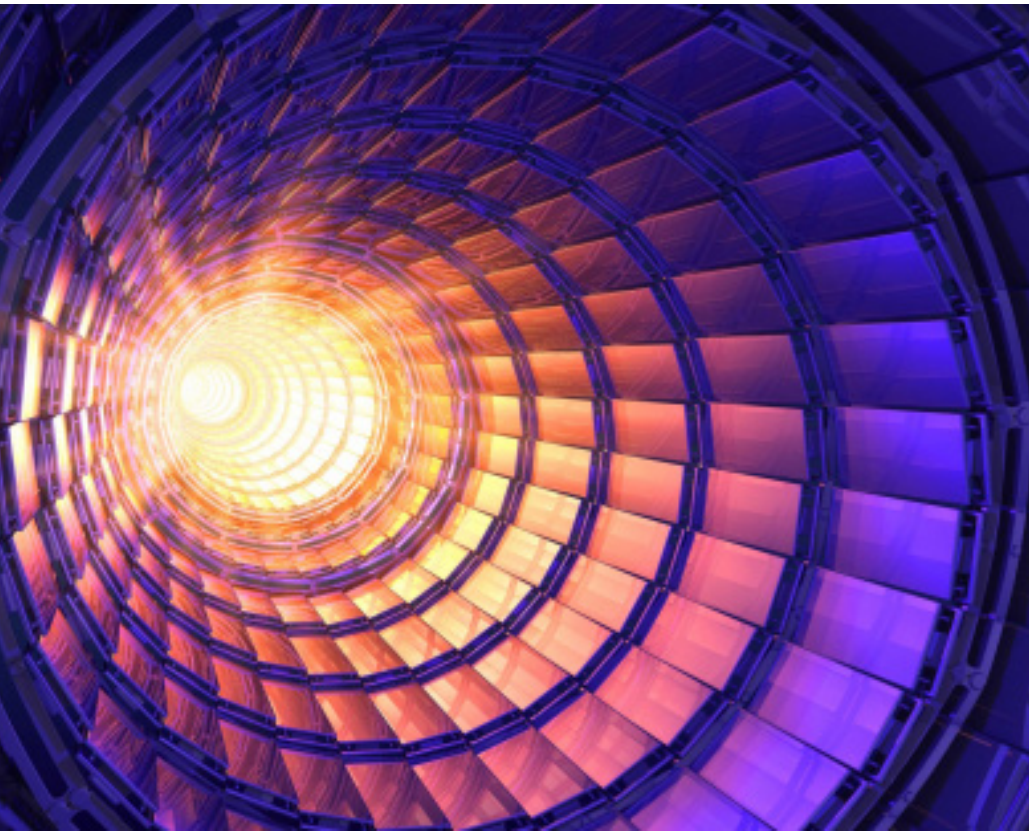
To enable the effective use of AI and imaging for future zoonotic diseases, we must overcome several obstacles. During the COVID-19 pandemic, barriers prohibiting the fast sharing of clinical (and imaging) data and its availability for the research community have had a crippling effect on the efficacy and robustness of the resulting ML models. We need to rapidly and transparently collect and curate such data globally to make it available to the research community. Shared data and benchmarks have a catalytic effect on the speed and quality of development.

On the methodological research side, we must advance our capability to deal with biases and confounders in data, stemming from the heterogeneity and diversity of the world. ML models don't have to only repeat results but be fair models that separate biological relationships from sub-optimal and possibly biased treatment decisions. We must ensure that the training of models is based on inclusive data sets that benefit the vast population and does not exclude communities, regions or individual groups.

Finally, we must engage the ML community to ensure we support and inspire innovative minds around the world to tackle the challenges of turning observations into tools that help us to detect emerging zoonotic diseases earlier, as well as to better manage prevalent ones. The community can help find the best and most precise treatment schemes to serve individual patients and develop techniques to accelerate the development of novel and innovative treatments.

(Photo: freepik.com)

IAEA Member States get special access to OECD/NEA nuclear software and data



The Nuclear Data pipeline (artist's view).
(Photo: NEA)

IAEA Member States that are not members of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA) are enjoying access to a vast array of OECD/NEA nuclear science software packages and databases thanks to a special arrangement between the two organizations.

As part of the arrangement, under which more than 25 requests per month are handled, IAEA Member States can access a wide range of modelling tools from the OECD/NEA Data Bank to support national activities in nuclear science, from spent fuel composition analysis to nuclear data visualization.

"This service is helping Brazil's National Metrology Laboratory of Ionizing Radiation (LNMRI) to simulate the response of ionizing radiation measuring instruments by facilitating access to updated computer codes," said Evaldo Simões da Fonseca of the LNMRI. "These simulations are one of the steps needed to ensure the calibration and traceability of the radiation beams used in thousands of treatments and diagnoses performed in Brazil every year."

The OECD/NEA Data Bank compiles, tests and disseminates over 1400 software packages, which have been developed by experts in more than 40 countries, and organizes training courses on widely used programmes to enhance nuclear knowledge sharing and preservation. Experts requesting access receive the packages in DVD form.

The tools have applications in a wide range of disciplines, from nuclear energy to medicine. They include the exhaustive Spent Fuel Isotopic Composition (SFCMPO) database, which contains details on the make-up of various types of spent fuel, and the International Reactor Physics Handbook Database and Analysis Tool (IDAT), which facilitates the study of nuclear reactor dynamics according to variables such as core configuration.

"The OECD/NEA Data Bank has a wealth of highly useful databases and analytical tools, and their renewed availability to Member State institutions is a boon to the scientific community," said Mikhail Chudakov, IAEA Deputy Director General and Head of the Department of Nuclear Energy. "We look forward to continuing to build on what has been a very productive, mutually beneficial partnership."

Countries that are not part of the OECD or the OECD/NEA can benefit from the service, which is operated through the IAEA's International Nuclear Information System (INIS). It provides access to all packages in the Data Bank archives, with the exception of those developed in the United States of America. Guidelines have been drawn up to assist IAEA Member States in requesting access to the Data Bank.

"The Data Bank services available to IAEA countries outside the OECD/NEA's membership is a solid example of the excellent cooperation between the two agencies," said William D. Magwood IV, Director-General of the OECD/NEA. "This arrangement bolsters the OECD/NEA Data Bank's mission to foster the international exchange of scientific knowledge."

Peaceful Uses Initiative

The service is supported by Peaceful Uses Initiative (PUI) funding from the United States of America. Since 2010, extrabudgetary contributions made through the PUI have been used to support a wide variety of IAEA activities aimed at promoting broad development goals in Member States.

— By Babatunde Adigun

Boosting tea plant diversity, quality and resilience in Sri Lanka

Tea was first introduced to Sri Lanka by the British in the 1820s and commercialized in 1867. Today, the tea industry is the country's leading foreign exchange earner and employs, directly or indirectly, two million Sri Lankans.

(Photo: Tea Research Institute of Sri Lanka)

Above all things, Sri Lanka is known for its tea. Introduced in the 19th century, Ceylon tea is today a multi-billion-dollar industry that brings in wealth and tourism. The country has plans to expand tea production and improve tea quality, but faces serious challenges from climate change and increasing global market competition. Scientists in Sri Lanka, through the IAEA's technical cooperation programme, are now looking to a nuclear technique to overcome these obstacles by enhancing tea plant productivity through increased genetic diversity.

Leading this effort is Mahasen A.B. Ranatunga, Head and Principal Research Officer at the Tea Research Institute of Sri Lanka's Plant Breeding Division. His institute is continuously looking for ways to develop and cultivate new breeds of tea. "Because tea is not native to Sri Lanka, there isn't much genetic diversity, and, despite our enormous tea output, we only have seven different types of regional tea. Working with the IAEA and the Food and Agriculture Organization of the United Nations (FAO), we're hoping to use new nuclear techniques, alongside conventional ones, to increase our island's tea diversity," Ranatunga said. Improving genetic diversity is important because genetically diverse crops are more resistant to diseases and can be more adaptive to changing weather patterns.

Inducing diversity

The nuclear technique Ranatunga is banking on is single-cell induced mutagenesis, an irradiation method involving a radioactive source and single plant cells. Using irradiation to develop new plant varieties is not new and has been used successfully around the world since the 1950s. What is new is adapting the technique for crops that live longer than two years — perennial plants.

"In Asia and the Pacific, irradiation is often used on seed crops, but there has been a bottleneck on its use in crops that are not propagated from seeds," said Shoba Sivasankar, Head of the Plant Breeding and Genetics Section at the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. Cultivating new plants from clippings is more complex than using seeds and requires specialized knowledge and equipment. Sivasankar's team is developing procedures to help experts from all over the world induce genetic diversity in perennial and tree crops using single-cell mutagenesis and regeneration, with important work recently conducted on coffee.

The technique uses individual cells from parts of tea plants not typically used in reproduction, including from leaf clippings. These cells are isolated in a suspended liquid medium and irradiated. The radiation spurs genetic mutations, and, when these single cells are then 'cultured' — grown and propagated — into collective tissue, they are genetically uniform. "Developing genetic diversity this way is less complicated and much faster than more conventional tissue culture techniques," said Sivasankar.

Facing climate change

The time frames offered by the nuclear technique — a new strain of tea can be developed in just ten years — are important, as Sri Lanka's tea industry faces pressures that could affect its position as a leading producer of one of the world's most widely consumed drinks (second only to water).

"Traditionally, one of the biggest threats we've faced is a disease called blister blight, but that typically only impacts some areas and primarily during wet seasons. We're concerned about the effect climate change will have on this, making blister blight more frequent and widespread, potentially impacting the quality of our tea," said Ranatunga.

"Some of the tea varieties we're hoping to develop will be able to deal with this change, particularly moisture variation, high temperatures and drought," he added. The Tea Research Institute of Sri Lanka's priority in using induced mutagenesis will be to increase tea yield, quality and resilience in order to mitigate the severity of these impacts.

This is the first time that the Joint FAO/IAEA Centre has supported a project on tea crop improvement using induced mutagenesis. The project's impact and lessons could help guide other countries considering enhancing their tea production using the technique.

For Sri Lanka, the severity of the effects of climate change on tea could critically impact the country's economy. Tea is the leading foreign exchange earner in the country, and two million Sri Lankans, roughly ten per cent of the country's population, are directly or indirectly employed in the tea industry. Furthermore, up to 70 per cent of Sri Lanka's tea production comes from smallholders, who are likely less able to weather the effects that climate change brings. Ranatunga says that they have identified some tea cultivating areas on the island that may be vulnerable to climate change and that they expect these areas to be severely affected.

Action is under way, and the IAEA's collaboration, through its technical cooperation programme, with the Tea Research Institute of Sri Lanka primarily involves helping train staff to use and establish the facilities for single-cell mutagenesis. Mykola Kurylchyk, the IAEA's Programme Management Officer for Sri Lanka, said that, even though the COVID-19 pandemic has delayed some of this training, the IAEA's support has helped establish the laboratories needed to undertake this four-year project.

"This is a good opportunity for us and the first time that Sri Lanka has used a technique like this on a plantation crop. We believe this will have a far-reaching impact on a critical industry," said Ranatunga.

— By Michael Amdi Madsen

Mexico: Butterfly migration studied using IAEA data

An IAEA database and the use of stable isotope methods are making it possible for scientists to determine the migration path of several types of insects, including butterflies. In a paper recently published in the journal Diversity, a group of scientists presented the results of a study on the migration of six species of butterflies, from Canada and the United States of America to Mexico. It is the first study of its kind to establish the origins and migration paths of several butterfly species in Mexico. Based on this scientific data, authorities can develop strategies to protect these insects on their journey.

"Knowing where butterflies come from during migration helps to inform conservation strategies that may be needed to protect the resources in their breeding areas. Similarly, knowing where they go in winter helps to protect those habitats during the time they are there," said Leonard Wassenaar, former Head of the IAEA's Isotope Hydrology Laboratory. "The linkage between geographic locations in the annual life cycle of butterflies cannot be established without using isotope methods."

The research is based on measuring deuterium — a rare isotope of hydrogen — in rainwater, which is directly ingested by animals and humans. As rainwater and its deuterium composition are unique to the area where it rains, rainwater deuterium content serves as a direct marker that scientists can use to identify the origin of individual animals that were born in different areas by measuring the amount of deuterium in hair, wings, claws, feathers or bones. For

Scientists studied the migration of six species of butterflies using isotopes: the American snout butterfly (*Libytheana carinenta*), the queen butterfly (*Danaus gilippus*), the cloudless sulphur butterfly (*Phoebis sennae*), the Empress Leilia butterfly (*Asterocampa leilia*), the variegated fritillary butterfly (*Euptoieta claudia*) and the southern dogface butterfly (*Zerene cesonia*). (Photo credits: S. Bright, V. Charny, J. Gallagher and J. Green)

butterflies, the deuterium content is measured in the wings and shows the area where an insect was born.

While isotopes have been used for decades to establish with precision the migration paths of some insects, such as the monarch butterfly (*Danaus plexippus*), the migration patterns and paths of dozens of other species of butterflies, insects and other migratory animals have yet to be established in Mexico and in other countries.

Butterfly migration patterns: chain, leapfrog and panmixia

The study revealed that, to survive the winter, four out of the six butterfly species travelled from the North of the United States of America or from Southern Canada to Mexico. The study also revealed further information on the migration style of the butterfly species.

The study found that the American snout butterfly (*Libytheana carinenta*) had the longest migration route and that its migration was a 'chain migration'. This means that American snout butterflies born in the northern parts of the subcontinent were found to settle in Mexico for the winter only after those born in the southern parts had already migrated further south.

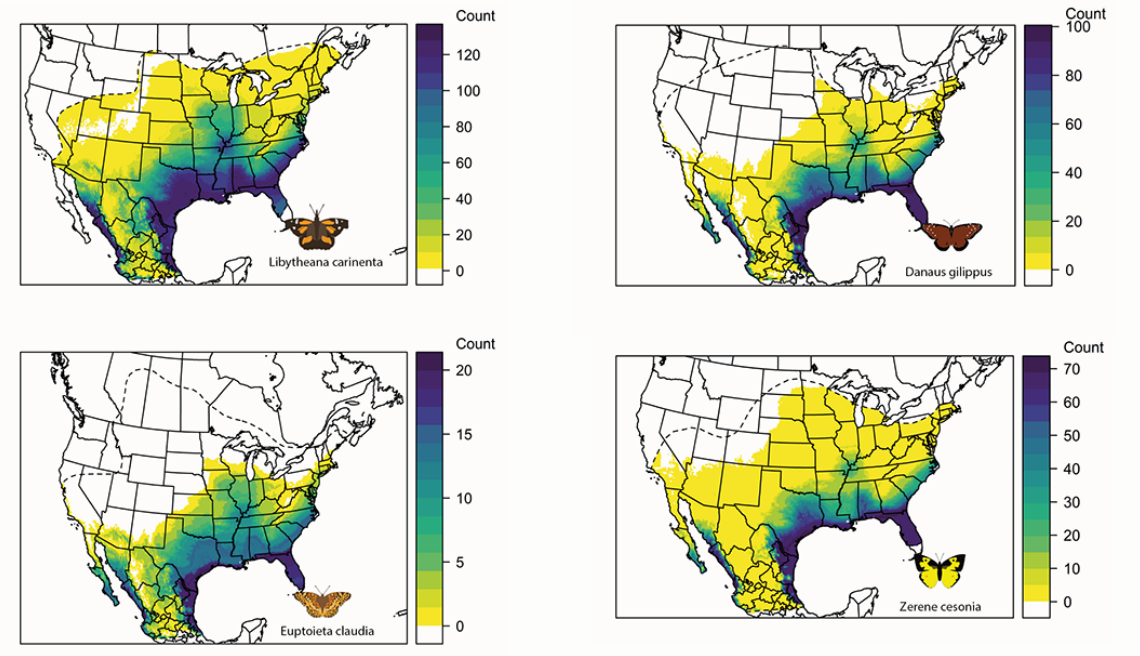
The queen butterfly (*Danaus gilippus*), on the other hand, was observed to have performed 'leapfrog migration' within the subcontinent. This means that individual queen butterflies born in southern parts of the subcontinent made a short journey further south. Their northern-born counterparts, however, were found to have travelled further south than the southern-born butterflies for the winter, in other words 'leapfrogging' past those born in more southern areas.

A third species, the southern dogface butterfly (*Zerene cesonia*), was shown to practice 'panmixia', meaning that individual butterflies would mix with one another and settle together during the migration path, regardless of their region of origin.

Determining butterflies' birthplaces from their wings

To study the migration paths of the six species, scientists collected samples of butterflies that had been killed by passing cars on a specific mountain valley road popular with several types of migrating butterflies. The samples were collected between September and November 2019. To establish the migration path, the scientists determined their place of birth by analysing the deuterium in their wings and comparing it to the data on rain isotopes present in an IAEA database.

"This type of research is important because, on the one hand, it helps us understand the evolution of the patterns in animals, and,



Long-distance migrants: *Libytheana carinenta*, *Euptoieta claudia*, *Danaus gilippus* and *Zerene cesonia*. The darker the areas of each map, the greater the presence of butterflies from those areas in Mexico.

(Image: University of Western Ontario)

on the other hand, from a conservation perspective, it helps us to predict which populations may be more vulnerable to events along the migration route, such as climate events, car collisions and habitat loss," said Keith Hobson, researcher at the University of Western Ontario in Canada and co-author of the study.

— By Andrea Galindo

IAEA donates specialized vehicle to Moldova to strengthen transport security

In support of Moldova's efforts to strengthen its national nuclear security infrastructure, the IAEA has donated a specialized cargo vehicle to the country to facilitate the safe and secure transport of radioactive sources to designated specialized storage locations.

"In recent years, the security of radioactive material has been highlighted as a key priority for Moldova, particularly related to locating and securing orphan sources — sources that are lost, missing or were just never registered — and transporting them to secure storage facilities," said Iulian Gisca, Director of the Moldovan National Radioactive Waste Management Company. "Part of this is ensuring that when these sources are located, they can be safely and securely transported to designated storage facilities. For this reason, this specialized cargo vehicle is vital."

Moldova has a number of radioactive sources, as well as small quantities of nuclear material, which are used in medical and industrial applications and for research purposes. The implementation of nuclear science and technology in Moldova has been supported by the IAEA through its technical cooperation programme, for which ensuring the safety and security of radioactive sources during use and storage is key.

It is estimated that, worldwide, around 20 million shipments of radioactive material take place every year. The IAEA assists governments and stakeholders globally to enhance their capabilities for ensuring both the safety and security of nuclear and other radioactive material during transport, use and storage.

Upon the request of the Moldovan Government, IAEA experts visited the country in 2018 to assess its capacity for the secure use, storage and transport of radioactive material. The experts

This donated vehicle has advanced features that will support Moldova in enhancing its transport security capabilities.

(Photo: D. Sirgedas/Polimaster)

subsequently recommended the purchase of a specialized truck to enable the safe and secure transport of radioactive sources.

The technical requirements of the vehicle were drawn up by the IAEA in close cooperation with the end user (the Moldovan National Radioactive Waste Company), the national nuclear authority and international experts. "The vehicle's state-of-the-art security system includes sophisticated detection measures, delay barriers, tracking and communication capabilities, which will significantly support Moldova's transport security capabilities," said David Ladsous, Head of the IAEA's Transport Security Unit. Following the completion of the specification, the IAEA procured the vehicle and donated it to the Moldovan Government. The procurement of the truck and the related training activities were financed by the German Government through the IAEA's Nuclear Security Fund.

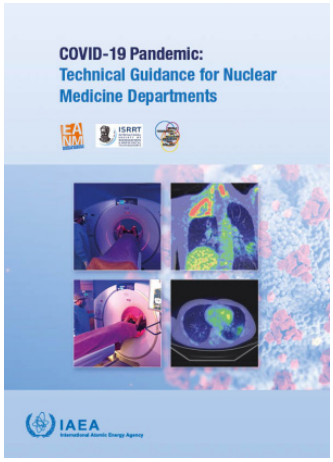
The vehicle is equipped to ensure that it can operate under harsh weather and poor road conditions, and that it fully complies with European Union transport safety requirements and international transport security guidance.

"This vehicle donation is just one way in which the IAEA assists its Member States in the development of their national physical protection regimes for the transport of nuclear and other radioactive material," explained Elena Buglova, Director of the IAEA's Division of Nuclear Security. "This support helps the international community to protect people, property and the environment from malicious acts that could occur during transport."

The IAEA is also assisting Moldova in drafting transport security regulations and conducting training courses for authority personnel. Following a successful workshop on transport security exercises held in Romania earlier this year, a regional workshop on the same topic was conducted from 10 to 13 May 2021 to support coordination between Moldova and Romania in cross-border shipments of radioactive sources. The significance of transport security will be highlighted at the IAEA's International Conference on the Safe and Secure Transport of Nuclear and Radioactive Materials, which will be held from 13 to 17 December 2021, in Vienna, Austria. The conference aims to support IAEA Member States in further developing their understanding of issues relating to transport safety, transport security and the interface between them.

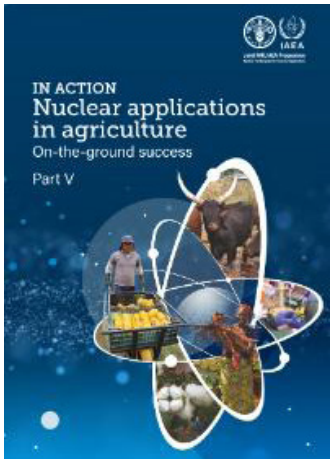
Furthermore, the IAEA provides international consensus guidance on all aspects of nuclear security, including transport security, which is covered in Security of Radioactive Material in Transport (IAEA Nuclear Security Series No. 9-G (Rev. 1)) and Security of Nuclear Material in Transport (IAEA Nuclear Security Series No. 26-G, also available in Arabic and French).

— By Sarah Henry Bolt



COVID-19 Pandemic: Technical Guidance for Nuclear Medicine Departments

is focused on the infection prevention and control measures that have to be taken into consideration while executing all the steps needed to perform nuclear medicine diagnostic or therapeutic procedures. The publication provides detailed guidance on the adjustment of all the steps involved in the delivery of nuclear medicine services, from scheduling to reporting, during the COVID-19 pandemic. While many institutions will have their own guidelines for clinicians and imaging experts to follow, these recommendations are meant to support nuclear medicine departments interested in developing or refining such policies.



In action - Nuclear applications in agriculture: On-the-ground success, Part V

is focused on successes of the partnership between the IAEA and the Food and Agriculture Organization of the United Nations (FAO), through the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture. The application of the Joint FAO/IAEA Centre's innovative technologies supports countries in meeting global challenges, including towards meeting the challenges of the COVID-19 pandemic. This and related stories are highlighted in this biennial publication, delving into how the IAEA and the FAO work together to help increase food security and improve nutrition in all its forms; protect, restore and promote sustainable use of terrestrial and marine ecosystems and combat climate change; combat rural poverty and promote inclusive, economic growth; and support sustainable consumption and production patterns through sustainable and inclusive supply chains.

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