JORDAN CENTER FOR DISEASE CONTROL
المركز الوطني لمكافحة الأوبئة والأمراض السارية

Genomic Surveillance Strategy for Emerging and Reemerging Infectious Diseases and Antimicrobial Resistance (AMR) in Jordan

January 2025

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وزارة الصحة

Ministry of Health

المركز الوطني لمكافحة الأوبئة والأمراض السارية

Jordan Center for Disease Control

Ministry of Environment

Hashemite Kingdom of Jordan

Ministry Of
Water And Irrigation

PHBC

الجَمعيّة العِلميّة المَلكيّة
Royal Scientific Society

مركز الحسين للسرطان
King Hussein Cancer Center

biolab
مختبر بيولاب الطبي

Preface

It gives me great pride to present the *Genomic Surveillance Strategy for Emerging and Re-emerging Infectious Diseases and Antimicrobial Resistance (AMR) in Jordan – January 2025*. This strategy marks an important national milestone in strengthening Jordan's readiness, resilience, and scientific capability to detect, monitor, and respond to current and future public health threats.

Guided and coordinated by the Jordan Center for Disease Control and Prevention (JCDC), this strategy is the product of extensive collaboration across all One Health sectors—human, animal, environmental, and food—as well as the valued contributions of public, private, academic, and research institutions. This collective national effort reflects Jordan's commitment to evidence-based public health, early warning, and integrated surveillance systems that safeguard the health of our citizens and future generations.

Genomic surveillance has become a mandatory tool in understanding pathogen evolution, identifying emerging variants, and detecting antimicrobial resistance. By building a unified national framework and advancing laboratory, data, and workforce capacities, Jordan is taking a decisive step toward strengthening preparedness and ensuring timely, informed public health action.

On behalf of JCDC, I extend my deepest appreciation to all national partners and technical teams whose expertise and dedication made this strategy possible. Their collaborative spirit embodies the core principles of One Health and demonstrates Jordan's commitment to proactive and coordinated disease control.

Together, we look forward to translating this strategy into practice and advancing a stronger, more resilient health security system for the Kingdom.

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Jordan CDC President

His Excellency

Dr. Adel Al Belbaisi

Genomic Surveillance Strategy for Emerging and Reemerging Infectious Diseases and Antimicrobial Resistance (AMR) Strategy in Jordan

Background

Since SARS-CoV-2 variants have been detected, genomic surveillance has become vital for effectively mitigating and containing the COVID-19 pandemic. Before spreading them worldwide, obtaining reliable evidence about whether they are more contagious, virulent, or resistant to the available COVID-19 vaccines was crucial. Genomic surveillance with next-generation Sequencing (NGS) can track infectious disease transmission and identify novel viruses and other emerging pathogens. This can substantially reduce the disease burden through timely data dissemination to optimize research priorities, therapeutics development, public health responses, and clinical care.

On the other hand, addressing the burgeoning issue of antimicrobial resistance (**AMR**) in Jordan becomes paramount. AMR poses a significant threat to public health, economic stability, and global security, making it a critical focus area within our national surveillance strategies. The rise of AMR in Jordan mirrors an international trend where misuse and overuse of antibiotics in human medicine, agriculture, and livestock sectors lead to the evolution of resistant strains of bacteria, rendering standard treatments ineffective. Genomic surveillance can identify and track the spread of drug-resistant bacteria, helping healthcare providers and policymakers understand resistance patterns and transmission dynamics within the community and healthcare settings.

In Jordan, we believe a robust and sustainable infrastructure for genomic surveillance at the country level is imperative for national security. Based on experience from the COVID-19 pandemic, dedicated efforts from different sectors, including public health authorities, universities, and commercial laboratories, have been made to promote and enhance genomic surveillance capabilities. **The goal is to achieve a well-integrated national genomic surveillance consortium by providing essential information for better decision-making at all levels.** Jordan's Center for Disease Control (JCDC) is committed to collaborating with all national stakeholders to strengthen genomic surveillance capabilities within the existing resources by leveraging our national network of expertise and capabilities more effectively and through targeted enhancements that benefit the sectors.

Genomic surveillance strategies generally comprise clinical sample collection, viral genetic analysis, linkage to metadata (and possibly clinical) data, reporting, and communication with public health agencies to facilitate timely decision-making, whether a health incident is a naturally occurring phenomenon, accidental or deliberate. The integration of AMR surveillance within our national genomic surveillance efforts ensures a comprehensive approach to tackling not only viral pathogens but also the escalating challenge of bacterial infections that are increasingly resistant to existing treatments. With a strong foundation of national public health capacities and private abilities, Jordan can enhance the approach by focusing on a few core functions and increasing the integration of efforts across the country.

Our strategy is to integrate and enhance national genomic surveillance efforts to answer specific key questions that guide decision-making in times of crisis, enable more rapid detection, and foster improved situational awareness by further extending a dynamic, distributed national network of expertise and capabilities and put into practice new thinking to facilitate decision-making processes in conditions of significant ambiguity. **This enhanced national genomic surveillance capability will be applied broadly to identify and understand potential human, animal, or plant health impacts resulting from biological threats, such as SARS-COV-2, influenza, polio, measles, respiratory syncytial virus (RSV), vector-borne diseases (Dengue fever virus, Crimean-Congo hemorrhagic fever virus, Rift Valley fever, West Nile fever), Antimicrobial Resistance (AMR), and other public health trends**, all of which may also be leveraged in the service of global health efforts.

Objectives for emerging and reemerging infectious diseases genomic surveillance and Antimicrobial Resistance (AMR) strategy in Jordan:

1. **Strengthen Genomic Surveillance and Data Sharing**: Enhance regional genomic surveillance, data sharing systems, and the development of genomic SOPs and standards.
2. **Improve Public Health Integration**: Address the integration of human-animal laboratory interfaces and ensure genomics information is translated into actionable public health policies.
3. **Monitor and Control Infectious Diseases**: Identify, characterize, and develop countermeasures for emerging and reemerging infectious diseases, including monitoring transmission and geographic spread.
4. **Enhance Surveillance for Antimicrobial Resistance**: Establish and improve national surveillance systems to monitor antimicrobial resistance across human health, animal health, agriculture, and the environment.

Stakeholders:

This Strategy intends to add value across the national entities and beyond to strengthen the national Genomic Surveillance approach. Specific guiding principles form the foundation of our Strategy aimed at evolving and enhancing our national genomic surveillance entities: (1) leverage existing capabilities; (2) embrace an all-of-nation approach; (3) add value for all participants; and (4) maintain a global health perspective.

1. Jordan Center for Disease Control (JCDC).
2. Ministry of Health
3. Ministry of Agriculture
4. Ministry of Environment.
5. Royal Medical Services.
6. Academic represented by:
    a. Jordan University of Science and Technology
        i. Prince Haya Biotechnology Center
        ii. Molecular Biology and Virology laboratory/faculty of Veterinary Medicine.

    b. Hashemite University
        i. Microbial Genomics Laboratory.
7. King Hussein Cancer Center
8. The private sector .
9. Royal Scientific Society

A genomic surveillance strategy for emerging and reemerging diseases:

A genomic surveillance strategy for emerging and re-emerging diseases involves using genomic technologies and data analysis methods to detect and respond to the spread of diseases in real-time. This strategy includes the following components:

1. Sequencing the genomes of pathogens causing emerging and reemerging diseases to identify unique genetic markers that can be used for rapid and accurate diagnosis and tracking of outbreaks.
2. Setting up cross-sectoral teams to monitor and control the spread of AMR pathogens, employing genomic sequencing to understand resistance mechanisms, and developing targeted interventions based on real-time surveillance data.
3. Collecting and analyzing samples from patients and potential disease reservoirs to identify the presence of pathogens and monitor changes in their genomes over time.
4. Sharing data and collaborating with national and international public health organizations, academic institutions, and other relevant stakeholders to enhance disease detection and response speed and accuracy.
5. Using advanced bioinformatics tools and methods to analyze genomic data and identify patterns and trends in the spread of diseases.
6. Establishing and maintaining surveillance networks that involve healthcare providers, public health officials, and other relevant stakeholders to ensure timely and effective reporting and response to disease outbreaks.

By incorporating these components, a genomic surveillance strategy can help detect and respond to emerging and reemerging diseases more quickly and effectively, reducing their impact on public health and the economy.

Organizational structure:

This Strategy articulates an overarching goal supported by core functions. It also includes guiding principles that provide a foundation for genomic Sequencing surveillance activities and specific enablers to achieve a well-integrated, national Genomic surveillance Consortium Through emphasis on the identified core functions and enabling focus area. The aim is to enhance the Nation’s ability to detect, track, investigate, and navigate human, animal, and plant health incidents, thereby better protecting safety and well-being.

Governance

1- Management of genomic surveillance:

A genomic surveillance **steering committee** is a group of individuals responsible for overseeing and guiding a genomic surveillance program's planning, implementation, and evaluation. The committee's role is to ensure that the program is conducted responsibly and ethically and meets its objectives regarding scientific and public health outcomes.

Typically, a steering committee for genomic surveillance will comprise diverse experts, including scientists, public health professionals, medical professionals, and representatives from affected communities.

- Director of laboratory directorate /JCDC
- Director of CPHL/MOH
- Director of the laboratory directorate CVL/MOA
- Director of Princess Haya Biotechnology Center
- Head of Research and Development department at Biolab Diagnostic Laboratories.
- Head of Molecular and Genetics lab /Royal medical services.
- Head of Microbiology and Molecular Biology laboratory /The Hashemite University.
- Head of the Molecular Biology and Virology laboratory/ Faculty of Veterinary Medicine/ Jordan University of Science and Technology.

The responsibilities of a steering committee for genomic surveillance can include:

1. Developing and reviewing policies and protocols for the program
2. Ensuring that the program is conducted following ethical and legal requirements.
3. Overseeing the collection and analysis of genomic data
4. Ensuring that participants are fully informed about the program and have provided informed consent.
5. Monitoring the progress of the program and making recommendations for improvement
6. Evaluating the scientific and public health outcomes of the program

The steering committee is an essential component of a genomics surveillance program. It provides oversight and ensures that the program is conducted responsibly and ethically. By working closely with the program staff, the committee can help ensure that the program meets its goals and provides valuable insights into the genetic basis of diseases.

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2- Coordination of the consortium of laboratories:

A technical committee for genomic surveillance is a group of individuals responsible for the technical aspects of a genomics surveillance program. The committee's role is to ensure that the program is implemented efficiently and effectively and meets the scientific and technical standards required for high-quality genomics research.

Typically, a technical committee for genomic surveillance will comprise scientists and technical experts with expertise in genomics, epidemiology, bioinformatics, and laboratory science. The committee's composition should reflect the different scientific and technical skills required for the program.

The responsibilities of a technical committee for genomic surveillance can include:

1. Developing and implementing the genomics surveillance protocols.
2. Monitor and report AMR trends.
3. Ensuring that the quality of the genomic data is maintained.
4. Providing technical guidance to the laboratory and bioinformatics staff
5. Developing and maintaining the database for the genomic data
6. Analyzing genomic data to identify potential outbreaks or new diseases.
7. Collaborating with other scientists and technical experts to advance the field of genomics surveillance.

The technical committee is an essential component of a genomics surveillance program. It provides the technical expertise required to implement the program and analyze the genomic data. By working closely with the steering committee and other stakeholders, the technical committee can help ensure the program meets its scientific and public health objectives.

- Ministry of Health
- Royal Medical services
- Ministry of Agriculture
- Ministry of Water and Irrigation
- Ministry of Environment
- Private sector .
- Jordan Center for Disease Control (JCDC)
- Jordan Food and Drug Administration (JFDA)
- Royal Scientific Society
- King Hussein Cancer Center
- NGO (USAID, DTRA, WHO, Walter Reed army forces, CRDF and FAO)*
- Academia Reed
    - Jordan University of Science and Technology.

        - Princess Haya Biotechnology Center.
        - Molecular Biology and Virology laboratories.
    - Hashemite University.
        - Microbiology and Molecular Biology laboratory.

    * Observer member.

3. Committee of Experts

A committee made up of experts representing the different laboratories of the consortium involved in sequencing, as well as the surveillance department, will be responsible for:

1. Carry out a regular technological and genomic watch.
2. Update the genomic monitoring strategy according to the epidemiological situation.
3. Develop practical procedures and modalities for investigation methods and approaches for suspected cases.
4. Confirm the sequences of interest before their publication.
5. Carry out a risk analysis in the event of detection of a new variant.

Experts Committee:

1. Prof. Mohammad Borhan Al-Zghoul/ Molecular Biology and Virology Laboratory/ Faculty of Veterinary Medicine/ Jordan University of Science and Technology.
2. Prof. Mustafa Mohammad Ababneh/ Molecular Biology and Virology Laboratory/ Faculty of Veterinary Medicine/ Jordan University of Science and Technology.
3. Dr. Rame Hamdi Khasawneh/ Molecular Genetic Pathology Laboratory/ Royal Medical Services.
4. Dr. Luai Al.Anagreh/ Microbial Genomics Laboratory/ The Hashemite University.
5. Eng. Eiad Atweh/ CEO of Next Generation Co. For Genetics & Consultancies
6. Dr. Issa Abudeyyeh/ Head of Research and Development department at Biolab Diagnostic Laboratories.

Flow of Information:

Rapidly disseminating pathogen genomic sequencing and epidemiological and clinical data will maximize genomic sequencing's impact on public health response. SARSCoV-2 sequences, diagnostic protocols, sequencing protocols, and samples have been widely shared.

Participating laboratories in the Jordan Genomics Project use record-keeping software, such as the Sondos software system utilized by the Central Public Health Laboratory, to track the samples' metadata and results. The sequencing data and metadata for each sample should be uploaded to a modified Sondos system (which can be modified to allow for the upload of sequencing and metadata).

The GISAID platform is the primary option for sharing SARS-CoV-2, Avian influenza, and monkeypox genomic sequence data globally. After checking the Quality of the sequenced data using the quality control parameters for each sequencing technology and testing the sequencing data using the nextstrain.org website, samples should be uploaded to this platform.

The local data deposit platform for genetic material in Jordan would feature a robust database structure that organizes genetic data by species, geographic origin, and intended use, ensuring efficient storage and retrieval. It would provide tiered access, allowing researchers, institutions, and other stakeholders to access data based on their needs while maintaining data integrity. Integration with global genetic databases would enable knowledge sharing and collaboration, expanding research opportunities. Advanced security measures like encryption and access control would safeguard sensitive information and ensure compliance with ethical and legal standards.

The Jordan genomic project's collaborating labs must have defined tasks and pathogens of interest to work on. For example, the Molecular Biology and Virology laboratory/Faculty of Veterinary Medicine can work on specific zoonotic pathogens such as MERS-CoV, avian influenza, and brucellosis. The same could be said for other labs.

The Prince Haya Biotechnology Center and the Molecular Biology and Virology laboratory/Veterinary Medicine faculty can work on research and development (R&D) to explore new techniques and protocols.

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Viral evolution at the human-animal interface

Viral evolution at the human-animal interface can lead to the emergence of new and potentially dangerous viruses. To prevent viral evolution at this interface, several strategies can be employed:

1. The One-Health approach recognizes that human health is closely linked to the health of animals, the environment, and the food we eat. It encourages collaboration between human and animal health experts to address health issues at the human-animal interface.
2. Regular surveillance and monitoring of animal viruses can help identify new or emerging viruses that can potentially cause human infections. This information can be used to implement control measures to reduce the risk of transmission to humans.
3. Biosecurity measures can help prevent the virus from spreading from animals to humans. For example, quarantining new animals before mixing them with the existing herd in

livestock operations, maintaining good hygiene practices, and controlling access to the facility can help reduce the risk of viral transmission.

4. Improving veterinary care for animals, including providing vaccines, can help reduce the incidence of viral infections in animals, reducing the risk of transmission to humans.
5. Investing in zoonotic disease research can help improve our understanding of how viruses evolve and spread between animals and humans. This information can then be used to develop new strategies for preventing or controlling zoonotic diseases.

It is important to note that preventing viral evolution at the human-animal interface requires a coordinated and multidisciplinary approach involving human and animal health experts, researchers, and policymakers.

Ethical considerations

Genomics surveillance, which involves collecting and analyzing genetic data, has the potential to significantly improve our understanding of diseases and inform public health interventions. However, it is essential to consider the ethical implications of this type of research and develop guidelines to ensure that it is conducted responsibly and ethically.

Here are some of the key ethical considerations that should be considered during genomics surveillance:

1. Genomic data can reveal sensitive information about an individual's health, ancestry, and other personal characteristics. Therefore, it is essential to protect the privacy of individuals who participate in genomics surveillance and to ensure that measures are in place to prevent unauthorized access to or use of their genetic information.
2. Participants in genomics surveillance should be fully informed about the study's nature and purpose and the risks and benefits of participation. They should also be allowed to provide informed consent, which should be freely given and without coercion.
3. Genomic data is particularly sensitive and requires secure storage and handling. Appropriate measures should be in place to protect its confidentiality and security.
4. Genomics surveillance can raise questions about race, ethnicity, and ancestry. It is important to ensure that the study is culturally sensitive and that individuals from different ethnic and racial groups are treated with respect and dignity.
5. Participants in genomics surveillance may expect to receive benefits from the study, such as improved health outcomes or access to new treatments. However, it is important to ensure that benefits are shared fairly and equitably among participants and that the study is designed to maximize the benefits to society.

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By considering these and other ethical considerations, genomics surveillance can be conducted responsibly and ethically, which can help advance our understanding of diseases and improve public health outcomes.

Monitoring and evaluation (M&E):

Monitoring and evaluating a genomic surveillance strategy involves regularly tracking and assessing its implementation, effectiveness, and impact on the targeted population and disease control efforts. This can include:

1. Collecting and analyzing data on the number of samples tested, positive cases detected, and related public health actions taken.
2. Developing and tracking performance indicators such as the timeliness and accuracy of test results and the speed of disease detection and response.
3. Gathering feedback from stakeholders, such as healthcare providers, patients, and public health officials, on the effectiveness and usefulness of the surveillance strategy.
4. Assessing the cost-effectiveness of the surveillance strategy in terms of resources used and benefits obtained.
5. Assessing the impact of the surveillance strategy on disease control, public health outcomes, and overall healthcare system performance.

These monitoring and evaluation activities help to ensure that the genomic surveillance strategy is achieving its goals and can provide valuable information for making ongoing improvements and adaptations to the strategy as needed.

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Annex: Capacity of each laboratory

1. **Jordan Center for Disease Control (JCDC):**

The Jordan Center for Disease Control (JCDC) has built advanced genomic sequencing capabilities to strengthen its response to communicable diseases. Using first and next-generation sequencing (NGS) platforms, JCDC precisely identifies genetic variations in pathogens. This technology allows for detailed mapping of outbreaks, enabling the detection of mutations that may influence disease spread or treatment resistance. The center's sequencing work supports the early detection of emerging health threats, providing actionable insights for policymakers and public health professionals.

In addition, the JCDC lab is equipped with all the AMR equipment needed to identify pathogens and their sensitivity to antimicrobials, such as MALDI-TOF, Vitek, and the Bactalert system.

JCDC collaborates with global and regional networks to share genomic data, contributing to global health security. The center integrates its sequencing output with robust bioinformatics tools to analyze large datasets and detect patterns. This supports efforts such as antimicrobial resistance monitoring and vaccine development. These capabilities enhance Jordan's preparedness and ability to respond to public health crises while aligning with international strategies to combat infectious diseases.

One notable achievement is that the first case of JN.1/COVID-19 in Jordan was identified by the JCDC Laboratory through its Genomic Sequencing Department.

2. **The Central Public Health Laboratory (CPHL)/ Ministry of Heath**

The Central Public Health Laboratory (CPHL) has advanced genomic sequencing capabilities supporting public health initiatives. By leveraging next-generation sequencing (NGS) technology, the laboratory accurately identifies pathogens, enabling detailed analysis of disease outbreaks. These capabilities are crucial for tracking the spread of infectious diseases, monitoring mutations, and identifying antimicrobial resistance. CPHL's sequencing work strengthens the early detection and response to emerging and re-emerging health threats.

CPHL integrates genomic data with epidemiological surveillance to inform public health strategies. Its sequencing efforts contribute to understanding the genetic evolution of viruses, bacteria, and other pathogens, supporting the development of vaccines and treatment protocols. The laboratory collaborates with national and international health organizations to share data and expertise, aligning its efforts with global health security frameworks. These sequencing capabilities are vital in improving disease control measures and protecting population health.

3. **Central Veterinary Laboratory (CVL)/ Ministry of Agriculture**

The Central Veterinary Laboratory (CVL) in the Ministry of Agriculture is purchasing the Third-generation sequencing machine. This capability will enable the laboratory to identify and study pathogens affecting livestock, poultry, and other animals. Using next-generation

sequencing (NGS), CVL will help detect emerging diseases, track outbreaks, and analyze genetic mutations that may impact virulence or treatment resistance. This allows for precise diagnostics and supports the implementation of targeted disease control measures. The laboratory's genomic sequencing efforts will contribute to the surveillance of zoonotic diseases, ensuring a proactive response to threats that may affect animal and human health. By combining sequencing data with epidemiological insights, the CVL will support the development of vaccines, diagnostic tools, and management strategies. Partnerships with international laboratories and research institutions enhance its technical expertise, aligning its work with global best practices. These capabilities strengthen the country's veterinary services and safeguard the livestock sector. Currently, there is a twining project with the Pirbright Institution for Foot and Mouth Disease (FMD) detecting and Sequencing in collaboration with the Molecular Biology and Virology Laboratory at Jordan University of Science and Technology.

4. Jordan University of Science and Technology.

a. Molecular Biology and Virology Laboratory:

The molecular biology and virology laboratory is a core diagnostic laboratory in the faculty of veterinary medicine/Jordan University of Science and Technology. The lab provides diagnostic services for veterinary teaching hospitals and the major Dairy and poultry production facilities in Jordan, Saudi Arabia, and other Gulf countries. The lab was established with the generous support of the Deanship of Research, Faculty of Veterinary Medicine, and another generous support from Echo-health and the US embassy. In this laboratory, different molecular biology techniques are used to detect viral pathogens that influence animal species and possible pathogens that can be transmitted to humans.

The laboratory was also involved in several surveillance projects.

1- 2016, we are involved and execute surveillance for bats' coronaviruses, paramyxovirus, filovirus, and Influenza viruses in the northern, middle, and southern parts of Jordanian camels (Echohealth Alliance)
2- 2016, we are involved and execute surveillance for Middle East respiratory syndrome coronavirus (MERS-CoV) in Jordanian camels
3- In 2016, we did surveillance for Lump skin disease (TAD project)
4- In 2018, we identified a Viral agent behind mass mortalities in Carp fish in Iraq.
5- In 2020, in collaboration with (Princess Haya Biotechnology Center), we were the first in Jordan to do Whole genome sequencing for SARS Corona 2 (covid 19) (UK variant) by 3rd generation sequencing (NGS)

Molecular Biology and virology capacity: the laboratory has an advanced RNA/ DNA sequencing facility, which provides access to advanced technologies beyond the reach of many individual laboratories in the region. The facility has two MinION Mk1C and two MinIon Nanopore DNA sequencing devices. Additionally, the sequencing unit is supported by all other supporting equipment, including several thermal cyclers and a Real-Time PCR Detection System, QIAcuity Digital PCR System, Qubit 4, and an automated DNA/RNA extraction system. The sequencing unit can offer training and performing research to include:

1. DNA and RNA extraction
2. RNA and DNA libraries preparation
3. Targeted genomic DNA amplification and sequencing.
4. Targeted and Metagenomics NGS analysis.
5. Bioinformatics tools for data analysis using different alignment tools and databases.

Selected Publication:

1. Ababneh MM, Lafi SQ, Abutarbush SM, Khalifeh MS, Hijazeen ZSK, Ramadneh WA, Al Ameer MS, Abukhalifeh FY, Kutkut TA, Dodeen RA, El Masry I, von Dobschuetz S. Longitudinal and abattoir-based surveillance of MERS-CoV in camels in Jordan, 2018-2020. Heliyon. 2021 Oct 12;7(10):e08166. doi: 10.1016/j.heliyon.2021.e08166.

2. Alanagreh L, Ababneh M, Al-Shudifat AE, Ajlouny M, Abu-Shaikh H, Alzoughool F, Al-Zghoul MB, Atoum M, Mahafzeh A. New SARS-CoV-2 Variant from Jordan. Microbiol Resour Announc. 2021 Jul;10(26):e0053221. doi: 10.1128/MRA.00532-21. Epub 2021 Jul 1.

3. Ababneh M, Hananeh W, Alzghoul M. Mass mortality associated with koi herpesvirus in common carp in Iraq. Heliyon. 2020 Aug 31;6(8):e04827. doi: 10.1016/j.heliyon.2020.e04827.

4. Ababneh M, Dalab AE, Alsaad S, Al-Zghoul M. Presence of Infectious Bronchitis Virus Strain CK/CH/LDL/97I in the Middle East. ISRN Vet Sci. 2012 Apr 11;2012:201721. doi: 10.5402/2012/201721.

5. Alaboudi AR, Ababneh M, Osaili TM, Al Shloul K. Detection, Identification, and Prevalence of Pathogenic Vibrio parahaemolyticus in Fish and Coastal Environment in Jordan. J Food Sci. 2016 Jan;81(1):M130-4. doi: 10.1111/1750-3841.13151.

6. Ababneh M, Ferreira HL, Khalifeh M, Suarez DL, Afonso CL. First Genome Sequence of Newcastle Disease Virus of Genotype VIIi from Jordan. Microbiol Resour Announc. 2018 Dec 13;7(23):e01136-18. doi: 10.1128/MRA.01136-18.

b. Princess Haya Biotechnology Center:

The Princess Haya Biotechnology Center (PHBC) is located at the Jordan University of Science & Technology in the north of Jordan, with unmatched regional accessibility to research, diagnostic, and training capabilities in molecular genomics, proteomics, metabolomics, and Biorisk management.

Molecular capacity:

On March 6, 2003, the biotechnology center was established at JUST and housed by King Abdullah University Hospital (KAUH). In 2005, the center was consolidated into Princess Haya Biotechnology Center (PHBC), commensurate with ordinance 998/2005 issued by the Council of Higher Education on March 10, 2005. Since its establishment, the Center has continued to provide JUST faculty members, graduate and undergraduate students, and local and regional organizations with a robust and advanced scientific infrastructure to support experimental research in biotechnology, particularly in genomics, metabolomics, and proteomics. PHBC currently comprises sixteen research laboratories and occupies approximately 1,500 square meters. At the core.

The Center's research and training are fundamental to furthering regional stability and security by pursuing innovative science and technology applications. Current regional dynamics have highlighted the importance of surveillance, detection, and response to emerging biological threats. Since its establishment, PHBC has developed an integrated network of international collaborative partnerships that it continues to cultivate in order to support its aim of improving regional health security.

PHBC houses an advanced DNA sequencing facility, which provides access to advanced technologies beyond the reach of many regional laboratories. The facility has two ABI PRISM Genetic Analyzers, one Pyrosequencer-Qiagen, and one MiSeq System-Illumina. Additionally, the sequencing unit is augmented by all other supporting equipment, including several Thermal cyclers and a Real-Time PCR Detection System, a PCR primers synthesis unit, a Nano-Drop fluorometer, and automated DNA extraction systems. The sequencing unit can offer training and performing research to include:

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1. DNA and RNA extraction
2. RNA and DNA libraries preparation
3. Targeted genomic DNA amplification and sequencing.
4. Quantitative gene expression, SNPs genotyping by Taq-Man probe.
5. Targeted and Metagenomics NGS analysis.
6. Bioinformatics tools for data analysis using different alignment tools and databases.

Selected publications:

1. Haddad, H & Al-Zyoud, W. miRNA target prediction might explain the reduced transmission of SARS-CoV-2 in Jordan, Middle East. Non-coding RNA research. DOI:10.1016/j.ncrna.2020.08.002 (2020).

2. Al-Zyoud, W. & Haddad, H. Dynamics prediction of emerging notable spike protein mutations in SARS-CoV-2 implies a need for updated vaccines. Biochimie. https://doi.org/10.1016/j.biochi.2021.08.011 (2021).

3. Al-Zyoud, W. & Haddad, H. Potential linear B-cells epitope change to a helix structure in the spike of Omicron 21L or BA.2 predicts increased SARS-CoV-2 antibodies evasion. Virology. https://doi.org/10.1016/j.virol.2022.06.010 (2022)

5. The Hashemite University

a. Microbial Genomics Laboratory

The microbial genomics laboratory employs multiple complementary approaches, coupling computation and experimentation to study the diversity of the human pathogens' genomes, molecular evolution, and its role in human infections using NGS technology. We use genomics, metagenomics, bioinformatics, bacteriology, and virology as fundamental tools to achieve this. The information we generate helps us to understand the underlying evolutionary mechanisms that shape the acquisition of antibiotic resistance, host adaptation, and transmission between hosts and the environment. Accordingly, our work contributes to generating new diagnostic approaches for infectious diseases, analyzing epidemiological patterns of infections, and identifying biomarkers in microbial communities associated with several diseases. Currently, we are working on the following projects:

- 2020–present, genomic surveillance of SARS-CoV-2 in Jordan.
- 2022–present, whole genome sequencing of methicillin resistance Staphylococcus aureus (MRSA) strains in Jordan
- 2022–present, molecular epidemiology of Influenza A virus (IAV) in Jordan for 2022/2023 winter

Microbial genomics lab capacity:

The microbial genomics lab originates, plans, and conducts independent, collaborative research using widespread molecular techniques. The facility has Illumina sequencing technology (iSeq 100), Bioanalyzer, real-time PCR, and other necessary equipment to support the NGS technology. Moreover, A pivotal limitation to the widespread utilization of microbial genomics in clinical and public health laboratories in Jordan is the need for robust, streamlined, simple-to-use bioinformatic pipelines to generate clinically meaningful data from raw whole genome sequencing (WGS) data. The lab is an expert in bioinformatics analysis. We can use different bioinformatic pipelines to allow genome assembly and annotation, comparative genomics to extract standard typing information, and other genetic features associated with relevant clinical phenotypes.

Selected Publications:

1. Alanagreh L, Ababneh M, Al-Shudifat AE, Ajlouny M, Abu-Shaikh H, Alzoughool
F, Al-Zghoul MB, Atoum M, Mahafzeh A. New SARS-CoV-2 Variant from Jordan.

Microbiol Resour Announc. 2021 Jul;10(26):e0053221. doi: 10.1128/MRA.00532-21.
Epub 2021 Jul 1.

2. Alanagreh L, Alzoughool F, Atoum M. The Human Coronavirus Disease COVID-19:
Its Origin, Characteristics, and Insights into Potential Drugs and Its Mechanisms. Pathogens. 2020 Apr 29;9(5):331. doi: 10.3390/pathogens9050331.

3. Abdelqader R, Hasan H, Alanagreh L. Epidemiology of Human Bocavirus in the Middle East and North Africa: Systematic Review. Pathogens. 2021 Nov 10;10(11):1456. doi: 10.3390/pathogens10111456.

4. Alanagreh L, Pegg C, Harikumar A, Buchheim M. Assessing intragenomic variation of the internal transcribed spacer two: Adapting the Illumina metagenomics protocol. PLoS One. 2017 Jul 18;12(7):e0181491. doi: 10.1371/journal.pone.0181491.

6. Royal Medical Services - Molecular Genetic Pathology Laboratory:

A state-of-the-art molecular genetics pathology lab is one of the Military Oncology labs. The lab serves the center and the whole medical laboratory network in RMS. The services cover clinical, medical, and genetic disciplines, including molecular microbiology. The lab has a couple of PCR platforms, from point-of-care machines to Real-time PCR. Also, a high throughput Luminex platform that applies magnetic beady technology with PCR multiplexing power. In addition to conventional Sanger sequencing technology, two NGS platforms are in place and operational; the MiSeq system and the ion torrents both apply the power of massively parallel sequencing capabilities. The lab conducted a genomic surveillance project in 2021 and published the outcome of the project in 2022:

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1. Khasawneh RH, Almharat SS, Al-Smadi RA, Abasi L, Al-Amr M, Alhuniti AS, Almuhasen AM, Dojan MA, Alshdifat OI, Faheem A. Factors affecting SARS-CoV-2 variant distribution in military hospitals in Jordan. Diagn Microbiol Infect Dis. 2022 Nov;104(3):115771. doi: 10.1016/j.diagmicrobio.2022.115771.

A. The lab conducted a genomic surveillance project from July 2022 to February 2023; the lab will perform another project involving SARS-CoV-2 samples.

B. The lab seeks national and international accreditation to maintain the best available service.

C. The FDA has approved the lab for clinical and laboratory research studies.

The Mobile Biological Laboratory:

It's a **mobile biological laboratory (Truck)**, It can handle high-risk biological hazards and highly pathogenic samples "Epidemic and contagious diseases", and then Identify, diagnose, and Neutralization safely and effectively out of danger on employees or Surrounding community and environment.

The facility is considered an enhanced Biosafety Level 2 laboratory as it meets the criteria for a Level 2 laboratory but also has a Class III cabinet. The facility can be used to process safely samples for RT-PCR that are suspected of containing pathogens capable of causing severe disease. The laboratory is capable of deploying to support the investigation of an outbreak.

The laboratory operates at negative pressure relative to the entry room. The main laboratory is designed to allow the sample to be loaded from a special window (passbox) With the possibility of moving to any geographical location upon request and maintaining a state of readiness for any epidemic situation.

The mobile biological lab effectively aided the coronavirus pandemic by providing an accurate and reliable diagnosis.

A Mobile biological laboratory brings testing services to the patient in an efficient, modern, 42 sq meter high throughput facility. Our clients use this rapidly deployable & compliant facility for standard diagnostics lab testing, clinical research, genomics/molecular testing, and pre-clinical analytics development.

Princess Iman Center - Microbiology and Virology Department

The Microbiology and Virology Department at Princess Iman Center is a cornerstone of the diagnostic services provided by the Royal Medical Services in Jordan. The department specializes in conducting comprehensive microbiological and virological tests, serving as a central hub for advanced diagnostics across all central and peripheral hospitals.
This department is responsible for a wide range of tests using cutting-edge technology, including:

* Vitek Systems: For antimicrobial sensitivity testing and pathogen identification.
* Bactec Systems: For blood culture diagnostics.
* MGIT BD BACTEC System: Dedicated to tuberculosis culture and diagnosis.
* PCR Systems: For molecular-level analysis of bacterial and viral pathogens.

Recent Developments and Upgrades:

To enhance its capacity and keep up with the latest advancements in medical diagnostics, the department has implemented the following upgrades:

A. Increased Capacity for Blood Cultures:

* Expanded the supply of blood culture bottles to accommodate a higher number of cases.

* Introduced additional blood incubators to improve efficiency and reduce the turnaround time for results.

B. Expanded Vitek Systems:

* More Vitek devices were added to enhance antimicrobial sensitivity testing and ensure precise pathogen identification.

* Ensured a consistent supply of reagents and consumables to support continuous operations.

C. Introduction of Advanced Technology:

- BioFire System: Recently installed for rapid diagnostics, including panels for CSF (cerebrospinal fluid), Blood, and respiratory infections. This system provides faster and more accurate detection of critical infections.

- PCR for TB: A new PCR system dedicated to tuberculosis detection is currently undergoing a trial phase for accreditation, aiming to enhance diagnostic precision and complement the MGIT BD BACTEC system.

Distributed Network of Laboratories:

The department's capabilities extend to microbiology labs established in all central and peripheral hospitals under the Royal Medical Services. Each lab is equipped with:

* Vitek Devices: Ensuring standardized testing for all locations.
* Bactec Systems: Supporting blood culture analysis with high efficiency.
* PCR Machines: Providing molecular diagnostic capabilities across the network.

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7. King Hussein Cancer Center

The microbiology laboratory at King Hussein Cancer Center (KHCC) is equipped with MALDI-TOF system. Furthermore, it houses a point-of-care closed genomic-based assay (Biofire) equipped with diverse panels for rapid diagnostics of viral and other microbial pathogens.

The molecular laboratory possesses several next-generation sequencing (NGS) and conventional polymerase chain reaction (PCR) systems for detecting viral and other microbial agents. Additionally, closed panel-based systems are also available. The laboratory's test menu encompasses a comprehensive range of human pathogens.

Selected publications:

1. Non-Dexamethasone Corticosteroid Therapy's Effect on COVID-19 Prognosis in Cancer Patients: A Retrospective Study. Souan L, Al-Khairy Z, Battah A, Sughayer MA. Vaccines (Basel). 2023 Jan 28;11(2):290. doi: 10.3390/vaccines11020290.

2. Enhanced RBD-Specific Antibody Responses and SARS-CoV-2-Relevant T-Cell Activity in Healthcare Workers Following Booster Vaccination. Souan L, Abdel-Razeq H, Sughayer MA. Curr Issues Mol Biol. 2024 Oct 2;46(10):11124-11135. doi: 10.3390/cimb46100660.

3. The Effect of Dexamethasone Treatment on COVID-19 Prognosis in Cancer Patients. Souan L, Al-Khairy Z, Al-Binni MA, Battah A, Sughayer MA. Vaccines (Basel). 2022 Oct 26;10(11):1798. doi: 10.3390/vaccines10111798.

4. An update on the impact of SARS-CoV-2 pandemic public awareness on cancer patients' COVID-19 vaccine compliance: Outcomes and recommendations. Souan L, Sughayer MA, Abu Alhowr M, Ammar K, Bader SA. Front Public Health. 2022 Jul 22;10:923815. doi: 10.3389/fpubh.2022.923815.

8. Biolab Diagnostic Laboratories

Biolab Laboratories is a chain of nationally and internationally accredited labs in Jordan with wide geographic distribution across the country. Their research department utilizes cutting-edge PCR and genomic sequencing technologies to support advanced diagnostics and research in molecular biology. With their next-generation sequencing (NGS) capabilities (Ion torrent S5 platform), Biolab identifies genetic markers, analyzes microbial genomes, and performs comprehensive DNA sequencing. These capabilities are pivotal in understanding complex biological systems and supporting precision medicine. Biolab's services are widely used in clinical diagnostics, academic research, and pharmaceutical development.

Their genomic sequencing infrastructure is largely automated and supports identifying pathogens, tracking genetic mutations, and studying antimicrobial resistance. Biolab collaborates with healthcare providers, research institutions, and global organizations to apply these insights in disease prevention and treatment. Combining sequencing with bioinformatics tools, Biolab delivers actionable data that drives innovation and enhances understanding of genetic and molecular processes. This makes it a vital resource in advancing genomic applications across various sectors.

During the COVID-19 pandemic, Biolab’s research department produced and published 1086 full high-coverage SARS-CoV2 sequences to GISAID, covering almost all weeks from the beginning of the pandemic until March 2022 (>75% of nationally published high-coverage sequences at the time). Their COVID work culminated in two

important publications, one published in Nature Communications and the other in Influenza and other Respiratory Viruses

Selected publications:

1- Parker E, Anderson C, Zeller M, Tibi A, Havens JL, Laroche G, Benlarbi M, Ariana A, Robles-Sikisaka R, Latif AA, Watts A, Awidi A, Jaradat SA, Gangavarapu K, Ramesh K, Kurzban E, Matteson NL, Han AX, Hughes LD, McGraw M, Spencer E, Nicholson L, Khan K, Suchard MA, Wertheim JO, Wohl S, Côté M, Abdelnour A, Andersen KG, Abu-Dayyeh I. Regional connectivity drove bidirectional transmission of SARS-CoV-2 in the Middle East during travel restrictions. Nat Commun. 2022 Aug 15;13(1):4784. doi: 10.1038/s41467-022-32536-1.

2- Abu-Dayyeh I, Naber Z, Meredith LW, Alsawalha L, Nassar D, Sumrain L, Ghunaim M, Hasan T, Abdelnour A A model for public-private partnership during the COVID-19 pandemic: Lessons from Biolab and public laboratories working in the Hashemite Kingdom of Jordan. Influenza Other Respir Viruses. 2023;17(10):e13209. doi: 10.1111/irv.13209.

3- Fuentes A*, Abu-Dayyeh I*, de Salazar A, Khasharmeh R, Al-Shabatat F, Jebrin S, Chueca N, Hamdan FM, Albtoush Y, Al-Shaer OA, Rashid MM, AlMohsen O, Al-Jbour M, Abdelnour A, García F. Molecular characterization of patients with chronic hepatitis C virus infection in Jordan: implications on response to direct-acting antiviral therapy. Int J Infect Dis. 2023 Oct;135:63-66. doi: 10.1016/j.ijid.2023.08.004. Epub 2023 Aug 9.

4- Abu-Dayyeh I, Chemaitelly H, Ghunaim M, Hasan T, Abdelnour A, Abu-Raddad LJ Patterns and trends of hepatitis C virus infection in Jordan: an observational study. Front Public Health. 2023 Dec 7;11:1280427. doi: 10.3389/fpubh.2023.1280427.

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Annex: Organizational structure:

Steering committee:

1. Director of laboratory directorate /JCDC
2. Director of CPHL/MOH
3. Director of the laboratory directorate CVL/MOA
4. Director of Princess Haya Biotechnology Center
5. Head of molecular and Genetics lab /Royal medical services.
6. Head of the Molecular Biology and Virology laboratory/ Faculty of Veterinary Medicine/ Jordan University of Science and Technology
7. Head of Microbial Genomics Laboratory- The Hashemite University.
8. Head of Research and Development department at Biolab Diagnostic Laboratories
9. Director of laboratories/ King Hussein Cancer Center

Technical committee:

Include a member from the following institutes that will be nominated from their side according to the situation and the experience that will be needed:

- Ministry of Health /CPHL.
- Jordan Center for Disease Control (JCDC)
- Royal Medical services
- Ministry of Agriculture
- Ministry of Water and Irrigation
- Ministry of Environment
- Private sector.
- Jordan Food and Drug Administration (JFDA)
- Royal Scientific Society
- King Hussein Cancer Center
- NGO (USAID, DTRA, WHO, Walter Reed army forces, CRDF and FAO) *
- Academia
    - Jordan University of Science and Technology.
        - Princess Haya Biotechnology Center.
        - Molecular Biology and Virology laboratories.

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- Hashemite University.
    - Microbiology and Molecular Biology laboratory.

* Observer member.

Experts Committee:

1. Prof. Mohammad Borhan Al-Zghoul/ Molecular Biology and Virology Laboratory/ Faculty of Veterinary Medicine- Jordan University of Science and Technology.
2. Prof. Mustafa Mohammad Ababneh/ Molecular Biology and Virology Laboratory/ Faculty of Veterinary Medicine- Jordan University of Science and Technology.
3. Dr.Rame Hamdi Khasawneh/ Molecular Genetic Pathology Laboratory- Royal Medical Services.
4. Dr. Luai Al.Anagreh/ Microbial Genomics Laboratory- The Hashemite University.
5. Eng. Eiad Atweh/ CEO of Next Generation Co. For Genetics & Consultancies
6. Dr. Issa Abudeyyeh- Head of Research and Development department at Biolab Diagnostic Laboratories

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