

2019 2020

REPORT

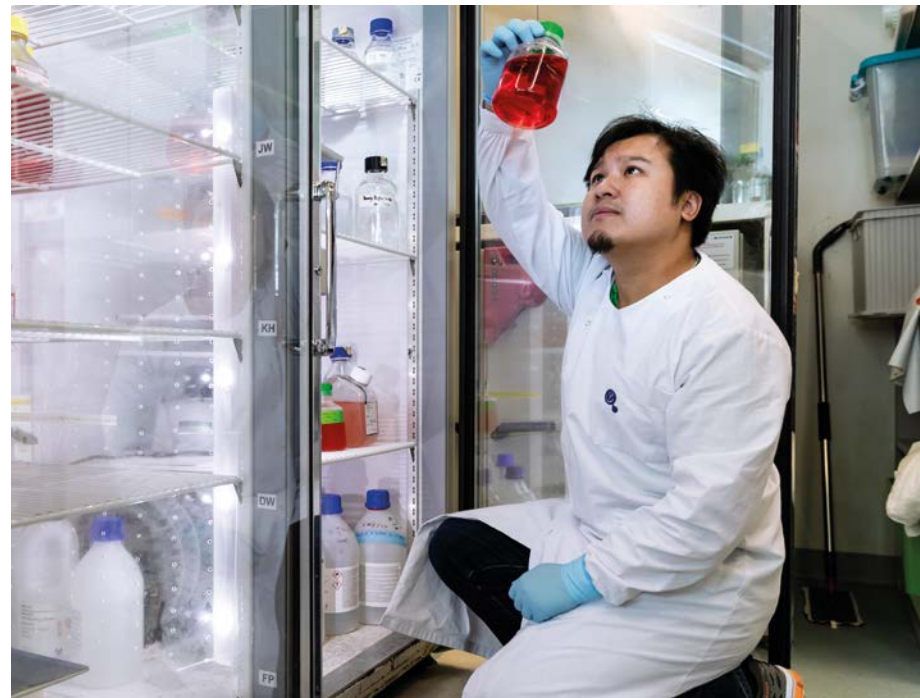


**PASTEUR
NETWORK**

United for Global Health

CONTENTS

- 01 2019-2020 key figures
- 02 Recent developments in the Pasteur Network
- 04 Pasteur Network membership map
- 06 National and international technical expertise
- 08 Missions and values
- 09 Interview with Stewart Cole and Pierre-Marie Girard
- 10 A shared scientific strategy
- 11 A public health network
- 12 The Institut Pasteur International Network becomes the Pasteur Network
- 13 Governance
- 14 Highlights of 2019-2020
- 18 A few key dates to get ready for the future



19

MOBILIZE

- 20 Key figures
- 21 SARS-COV-2, the story of unprecedented solidarity
- 24 An international response supported by the Institut Pasteur
- 26 Americas
- 28 Euro-Mediterranean
- 30 Africa
- 32 Asia-Pacific
- 34 COVID-19 highlights in 2020
- 38 Focus on the DOPAHYPOCOV and AFROSCREEN projects



39

SHARE

- 40 Capacity-building projects
- 42 Training and mobility
- 43 Key figures
- 44 International courses
- 45 PIC label, the mark of excellence for training programs
- 46 4-year research groups (G4)
- 48 Pasteur Network Talent Awards
- 48 PhD Ceremony



49

INNOVATE

- 50 Innovative technological tools
- 52 ACIP & PTR, calls for incentive programs
- 54 PIUs, collaborative international research
- 56 Partners and thanks

PASTEUR NETWORK 2019-2020 KEY FIGURES


33 members
in 25 countries
on 5 continents



17 
WHO Collaborating Centres

4 
members designated WHO
COVID-19 Reference Laboratory

9 
new collaborative projects
16 projects ongoing in 2019 and
21 in 2020 involving members
of the Pasteur Network*


34 
ACIP & PTR programs (12 ACIP and 22 PTR*)
33
projects coordinated with the COVID-19
Task Force*


110 
people awarded an international
scholarship*

18 
international courses funded**

5 
current 4-year research groups*

3 
international research units
formed*

5,377 
scientific papers published every year
on average by the members of the Pasteur
Network, either independently or jointly
with others. 2019: 5,054*** – 2020: 5,700****

1,193 
scientific papers submitted and available
online through HAL-RIIP, the Pasteur
Network's platform for submitting
and consulting scientific publications
free of charge

*Inter-Pasteurian Concerted Actions (ACIP) - Transversal Research Programs (PTR); Programs coordinated and/or funded by the Institut Pasteur.
** By the Pasteur Network association.
*** Publications from the Scopus database, including 1,651 involving the Fiocruz and 1,218 involving the Institut Pasteur (Paris).
**** Publications from the Scopus database, including 2,024 involving the Fiocruz and 1,260 involving the Institut Pasteur (Paris).

RECENT DEVELOPMENTS IN THE PASTEUR NETWORK

The Pasteur Network, formerly known as the Institut Pasteur International Network, has been working to improve public health for more than 130 years. Louis Pasteur was determined that his discoveries in vaccination and microbiology should be freely available to the international medical community. Today, the network he founded is present in 25 countries across five continents.

The Institut Pasteur was inaugurated on 14 November 1888, following an international appeal for funds, 17 months after its establishment by decree. One year later, the international renown of Louis Pasteur drew students from Europe and even further afield to enrol in the world's first ever microbiology course.

The Institut Pasteur quickly fulfilled its ambition of taking its advances in microbiology beyond its walls. The first institute outside Paris was founded in Saigon by Albert Calmette in 1891. Its mission was to widely spread vaccination against rabies and smallpox in Indochina. Albert Calmette went on to establish the Institut Pasteur de Lille in 1899 to stem the spread of diphtheria epidemics. He developed the BCG (Bacillus Calmette-Guérin) first tuberculosis vaccine there.

The Pasteur Network expanded at a steady pace from then on (see *timeline below*), mainly (although not exclusively)

in former French colonies, where local entities were established in epidemic or endemic infection hotspots, in direct contact with the populations. Several scientists from the Pasteur Network received the Nobel Prize for their work. In 1907, for example, Alphonse Laveran received it for his work on malaria at the Institut Pasteur d'Algérie. Jules Bordet was awarded the prize in 1919 for his work on immunity at the Institut Pasteur du Brabant (Belgium), and Charles Nicolle won recognition from the Nobel Assembly at Karolinska Institutet in 1928 for his discovery of how typhus is transmitted (the Institut Pasteur de Tunis).

By the 1960s, the Pasteur Network already had around 20 members. But it was in the 1970s that the network took a decisive step forwards, with the founding of the Directors' Meeting by Jacques Monod. The other key dates in the growth of the network are summarized on page 12 (see *sidebar*).

As of 2019, the network had 33 members, including one associate member, the Scientific Platform Pasteur-USP (University of São Paulo in Brazil). The Pasteur Network's current strategy is to deepen relationships and cooperation between its members, rather than to expand further.

In 2019, the Scientific Platform Pasteur-USP joined as an associate member. True to its mission of working on the ground to tackle epidemics, the network is also about to inaugurate the Institut Pasteur de Guinée.

In June 2015, a tripartite agreement was signed between the University of São Paulo, the Fiocruz (Oswaldo Cruz Foundation) and the Institut Pasteur (Paris) to share scientific knowledge and technological resources, giving priority to education. The network formed a coordinating committee to draft an action plan and scientific strategy, both of which were approved in August 2016.

The Scientific Platform became an associate member of the Pasteur Network – the 33rd member – on 4 July 2019, the day of its inauguration. With its 17 laboratories and 7 teams, this new scientific platform is housed in a 1,700 m² facility at the University of São Paulo.

And the story continues with the opening of a new institute in Conakry, the Institut Pasteur de Guinée. Located next to Gamal Abdel Nasser University, the building will be home to three research units, an insectarium, a biobank, a diagnostics platform and several laboratories. Construction started in August 2019 and the first team arrived in September 2020. The official opening will take place when public health conditions improve.

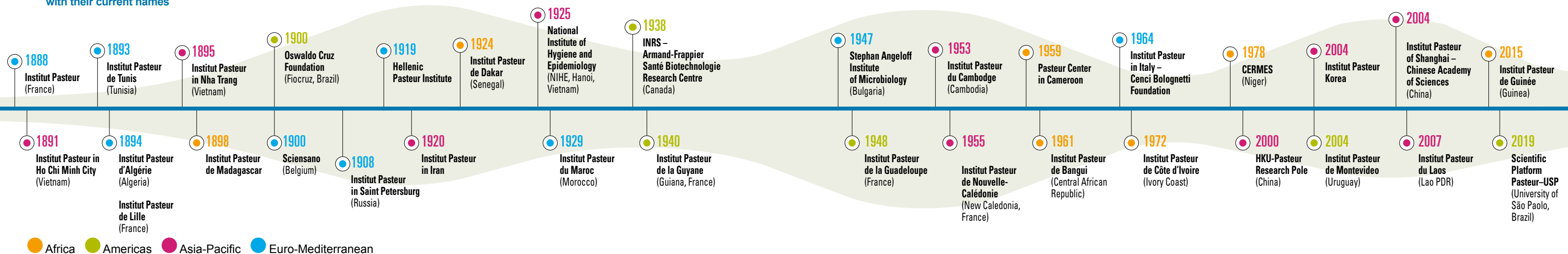
 For more information about the Scientific Platform Pasteur-USP: sppu.com.br/en/



ANNIVERSARIES

- 15th anniversary of the Institut Pasteur Korea (2019)
- Centenary of the Hellenic Pasteur Institute (2019)
- 60th anniversary of the Pasteur Center in Cameroon (2019)
- 20th anniversary of the HKU-Pasteur Research Pole (2020)
- Centenary of the Institut Pasteur in Iran (2020)

Timeline showing the accession of Pasteur Network members with their current names



PASTEUR NETWORK

Pasteur Network is a worldwide network of 33 members, united by Pasteurian missions and values, which contribute to the improvement of global health.



Americas

BRAZIL

- Oswaldo Cruz Foundation (Fiocruz) portal.fiocruz.br/en
- Scientific Platform Pasteur-USP*, sppu.com.br/en/

CANADA

- INRS – Armand-Frappier Santé Biotechnologie Research Centre inrs.ca/en/

FRANCE

- Institut Pasteur de la Guadeloupe web.pasteur-guadeloupe.fr
- Institut Pasteur de la Guyane pasteur-cayenne.fr

URUGUAY

- Institut Pasteur de Montevideo pasteur.uy/en

Euro-Mediterranean

ALGERIA

- Institut Pasteur d'Algérie pasteur.dz

BELGIUM

- Sciensano sciensano.be/en

BULGARIA

- Stephan Angeloff Institute of Microbiology microbio.bas.bg/wordpress/index.php/en/

FRANCE

- Institut Pasteur (Paris) pasteur.fr/en
- Institut Pasteur de Lille pasteur-lille.fr/en/

GREECE

- Hellenic Pasteur Institute pasteur.gr/en

ITALY

- Institut Pasteur in Italy – Cenci Bolognetti Foundation istitutopasteuritalia.it

MOROCCO

- Institut Pasteur du Maroc pasteur.ma

RUSSIA

- Institut Pasteur in Saint Petersburg pasteurorg.ru

TUNISIA

- Institut Pasteur de Tunis pasteur.tn

Africa

CAMEROON

- Pasteur Center in Cameroon pasteur-yaounde.org

IVORY COAST

- Institut Pasteur de Côte d'Ivoire pasteur.ci

GUINEA

- Institut Pasteur de Guinée www.pasteur-guinee.org

MADAGASCAR

- Institut Pasteur de Madagascar pasteur.mg

NIGER

- CERMES cermes.net

CENTRAL AFRICAN REPUBLIC

- Institut Pasteur de Bangui pasteur-bangui.org

SENEGAL

- Institut Pasteur de Dakar pasteur.sn/en

Asia-Pacific

CAMBODIA

- Institut Pasteur du Cambodge pasteur-kh.org

CHINA

- Institut Pasteur of Shanghai – Chinese Academy of Sciences english.shanghaipasteur.cas.cn/
- HKU-Pasteur Research Pole www.hkupasteur.hku.hk/

SOUTH KOREA

- Institut Pasteur Korea ip-korea.org

FRANCE

- Institut Pasteur de Nouvelle-Calédonie institutpasteur.nc

IRAN

- Institut Pasteur in Iran en.pasteur.ac.ir

LAO PDR

- Institut Pasteur du Laos pasteur.la

VIETNAM

- National Institute of Hygiene and Epidemiology (Hanoi) nihe.org.vn/en
- Institut Pasteur in Nha Trang <http://pasteur-nhatrang.org.vn/en>
- Institut Pasteur in Ho Chi Minh City pasteurhcm.gov.vn

*Associate member

NATIONAL AND INTERNATIONAL TECHNICAL EXPERTISE

The Pasteur Network houses many of the top international, national and regional health laboratories.

National and regional reference laboratories are recognized by national health authorities for their expertise in the field of diagnostics. Moreover, national reference centers act as monitoring centers for transmissible diseases in their host countries.

In the WHO's definition, "WHO collaborating centres" (WHOCC) are research institutes, university or academic departments designated by the Organization to carry out activities in support of national and international health programs*.

This table shows the laboratories provided by the members in the Pasteur Network database** and on the WHO website*, excluding COVID-19 data, available starting on page 19.



PASTEUR NETWORK MEMBERS	WHOCC	REGIONAL REFERENCE LABORATORIES	NATIONAL REFERENCE LABORATORIES
Oswaldo Cruz Foundation	Global health and South-South cooperation, public and environmental health, pharmacological policies, training of health technicians, leptospirosis, boosting the capacity of human milk banks	Tegumentary leishmaniasis, schistosomiasis, malaria, dengue, Chagas disease, filariasis, viral hepatitis, hantavirus, rickettsiae, AIDS, anthrax, histopathological diagnosis of infectious diseases, bacterial entero-infections, yellow fever, influenza, leprosy, hydatidosis, leptospirosis, systemic mycoses, plague	Cutaneous leishmaniasis, schistosomiasis, malaria, dengue, Chagas disease, filariasis, viral hepatitis, hantavirus, rickettsiae, AIDS, anthrax, histopathological diagnosis of infectious diseases, bacterial intestinal infections, yellow fever, influenza, leprosy, hydatid disease, leptospirosis, systemic mycosis, fever, polio and other enteroviruses, rotavirus, tuberculosis
Institut Pasteur (Paris)	Human African Trypanosomiasis biobank, entero-vaccines and viral vaccines, bacterial meningitis, rabies, food-origin listeriosis, salmonella, plague		Anaerobic bacteria and botulism, whooping cough and other bordetella infections, corynebacteria of the <i>diphtheriae</i> complex, <i>Escherichia coli</i> , <i>Shigella</i> , <i>Salmonella</i> , viral hemorrhagic fevers, hantavirus, leptospirosis, listeria, invasive mycoses and antifungal, Meningococci and <i>Haemophilus influenzae</i> , plague and other yersiniosis, rabies, vibrios and cholera, respiratory viruses (including influenza) ***
Institut Pasteur d'Algérie		Member of WHO Emerging and Dangerous Pathogens Laboratory Network (EDPLN)****	Toxoplasmosis, HIV
Institut Pasteur in Iran			Arbovirus, hemorrhagic fevers
Institut Pasteur de Dakar	Arboviruses and viral hemorrhagic fevers		
Institut Pasteur de la Guadeloupe		WHO Supranational Reference Laboratory for Tuberculosis (AMRO region)*****	
Institut Pasteur de la Guyane	Surveillance of resistance to anti-malarial drugs		
Institut Pasteur de Madagascar	Plague control and research	Poliovirus, measles, rubella, influenza	Poliovirus, measles, rubella, influenza
Institut Pasteur in Nha Trang		Measles, rubella, food safety	
Institut Pasteur de Nouvelle-Calédonie		Pacific Public Health Surveillance Network (PPHSN)	World Mosquito Program
Institut Pasteur in Saint Petersburg		Poliomyelitis, enterovirus, measles, rubella, viral hepatitis, salmonella, rickettsiae	WHO supranational centre for poliomyelitis, measles and rubella
Institut Pasteur de Tunis		Clinical virology laboratory, Anatomic pathology laboratory (poliovirus, measles)	Salmonellosis, shigella, measles, rubella
Institut Pasteur du Maroc		Tuberculosis, rabies, influenza, viral hepatitis	
National Institute of Hygiene and Epidemiology (Vietnam)			Influenza (National Influenza Center – NIC), Arbovirus laboratory, Respiratory virus laboratory, Enterovirus laboratory
HKU-Pasteur Research Pole	Epidemiology and infectious disease control		
Sciensano (Belgium)		European Union Reference Laboratory for foot-and-mouth disease, lumpy skin disease and sheep and goat pox	Measles, rubella, rabies

* <https://www.who.int/about/collaboration/collaborating-centres>

** August 2021.

*** www.pasteur.fr/fr/sante-publique/CNR/les-cnr.

**** Regional Emerging and Dangerous Pathogens Laboratory Network (EDPLN).

***** ASEAN+3 Macroeconomic Research Office.

MISSIONS AND VALUES OF THE PASTEUR NETWORK

The Pasteur Network is present in 25 countries across every continent. Working in numerous areas of endemic disease, the network has clearly shown that it has a key role to play in supporting local populations through the One Health approach. In addition to the independent public or private organizations that make up the network, this unique cooperative model draws on a wider scientific community, all fully committed to pulling together to address local and international health priorities, following a solidarity spirit.

With a prominent presence in areas of endemic or epidemic disease, the Pasteur Network is active in the struggle against infectious agents. Drawing on its expertise, the network is seeking to improve human health through its four core missions:

- biomedical research;
- public health;
- training;
- innovation and technology transfer.

These activities are based on local capacity building, respecting human rights and the environment. They are conducted with the will to promote sustainable development. The members of the Pasteur Network have adopted the **One Health approach**. In this way, they promote a global view

of health challenges, taking account not only of human and animal health, but also of the ecosystems in which diseases occur. The Pasteur Network's **diversity** is a major asset for conducting programs using this approach.

The 33 members are united by more than their missions, they share the Pasteur values set out in the **Pasteur Values Charter** signed by all network members.

These values include humanism, universalism, rigour and dedication, freedom of initiative, knowledge transfer and free access to information.

Lastly, **scientific solidarity**, meeting national and international needs, contributing to education and engagement with global public health

issues are the pillars of the network's work, illustrated by its response to the COVID-19 pandemic.

For more information: pasteur-network.org

Biomedical research



The HKU-Pasteur Research Pole.

Training



International workshop on rabies organized by the Institut Pasteur in Iran.

Public health



International vaccination center, the Institut Pasteur du Maroc, Casablanca.

Innovation and technology transfer



Researcher at an Institut Pasteur de Dakar laboratory.



Stewart Cole,
President of the Institut Pasteur
President of the Pasteur Network Foundation

The Pasteur Network has played a major role in the response to the COVID-19 crisis.

The priorities in the 2019-2023 strategic plan include building a more structured framework for the Pasteur Network (formerly the Institut Pasteur International Network), encouraging greater participation and improving efficiency.

The Pasteur Network has played a major role in the response to the COVID-19 crisis, setting up international programs and sharing human and material scientific resources. I would like to take this opportunity to praise the collegial spirit of the members of the Pasteur Network, who joined forces quickly and effectively to combat a virus that led to global upheaval on a scale that had not been seen since the Spanish Flu in 1918.

The Institut Pasteur lent its support to many projects in cooperation with the other members of the Pasteur Network (see pages 24-25 for more details) – thanks in large part to the generosity of the public.

However, when the first cluster of cases was reported in January 2020, SARS-CoV-2 also reminded us of the importance of the Pasteurian values of humanism and dedication.

Being Pasteurian means holding firm to the network's convictions, based on reason and fact, and leading by example. As the bicentenary of Louis Pasteur's birth draws near, the Pasteur Network is building a more structured governance framework to further its work. In 2021, the new articles of association and the establishment of the Pasteur Network foundation marked a major step forwards in shaping a more modern and effective network.

I have every confidence that these changes will bring positive results.

True to its values, the Pasteur Network is poised and ready to address the global challenges ahead.



The pandemic has boosted synergies as the scientific community came together to work on shared programs in the network. It also accelerated steps to complete the transition to the new identity: the Pasteur Network. The change in governance gives a bigger say to the network members in 25 countries around the world. Incorporating the Scientific Platform Pasteur-USP as the 33rd member of the network in 2019 is one example of this renewed energy.

The scientific expertise of the members positions the Pasteur Network as a leader in global health. And the work is increasingly collaborative as the Pasteur Network seeks to find solutions for disease that afflict populations around the world. Looking firmly to the future, the network gives priority to young scientists and setting up new teams, for example through the 4-year research groups. Training is also top of the agenda. The new Pasteur International Courses label is a stamp of excellence for the courses delivered in the network. As COVID-19 spreads around the globe, the 33 members are more committed than ever to the network's values. These include spreading knowledge and making discoveries freely available, as the examples outlined in this report show.

As lessons are learnt from the pandemic, network members are firm in their determination to address the health challenges of the future.

The commitment of the Pasteur Network's 33 members to their Pasteurian values is stronger than ever.

Pierre-Marie Girard,
Vice-President, Department of International Affairs of the Institut Pasteur



A SHARED SCIENTIFIC STRATEGY SETS THE PRIORITIES FOR THE COORDINATED ACTION OF THE PASTEUR NETWORK

The Pasteur Network Scientific Steering Committee (formerly COS-RIIP) was established in August 2019. Meeting for the first time in February 2020, the committee reiterated the four strategic priorities identified in 2017 for the network, to create a bold scientific strategy for a prominent global health player.

The role of the Scientific Steering Committee is to define scientific strategy for the Pasteur Network. It has 10 members, 8 of whom are appointed from the network's research community and 2 from the international scientific community. It examines opportunities for partnerships between the members, decides which actions take priority and recommends how to implement them.

Meeting for the first time on 17 and 18 February 2020, the committee singled out education and training in the life sciences as a top priority for the network with the introduction of the "Pasteur International Courses" label (see page 45). It also confirmed the four strategic pillars of the network's scientific strategy formulated in 2017.

In 2019 and 2020, the scientific community of the Pasteur Network devoted considerable efforts to the study of antimicrobial resistance and rabies.

1.

Explore the principal endemic or emergent zoonoses based on a One Health approach, drawing on its global footprint which gives it exceptional access to extensive diversity.

2.

Study vector-borne infectious disease focusing on the biology of vector insects and pathogen-vector interactions, concentrating especially on innovative vector control strategies.

3.

Explore the risk of infection in the first years of life, particularly in marginalized and migrant populations, for whom childhood, adolescence and maternity are periods of high risk for development pathologies and infectious agents.

4.

Study the impact of ageing and longevity on health in the context of the epidemiological transition underway in most countries. The study of chronic diseases such as metabolic syndromes, cancer and neurodegenerative conditions is part of this priority.



PASTEUR NETWORK, A PUBLIC HEALTH NETWORK IN THE SERVICE OF LOCAL POPULATIONS

Working directly with local populations, the Pasteur Network offers a wide range of public health services, including vaccinations, biomedical analyses and screening tests by dedicated laboratories from the network members. These activities contribute to the continuous monitoring of emerging infectious diseases and epidemic risks.

As research institutes as well as healthcare facilities, the network's members provide a wide range of services for populations. No fewer than 15 network members have opened their doors to vaccinate people as either a preventive measure or after exposure (to rabies, for example) as well as carrying out awareness and prevention campaigns. Diagnostic tests for infectious diseases, which also contribute to the surveillance of these diseases (see pages 6 and 7 on reference laboratories for more information), medical biology analyses and microbiological analyses of water and foodstuffs are also part of the activities carried out within the network to ensure the improvement of human health, alongside research activities.

Laboratory analyses cover a broad field. For instance, general and specialist biochemical analyses of blood samples measure tumor or cardiac markers, hormone levels, and so on. In microbiology, sample testing reveals bacteria, parasites, fungi or virus in order to identify an infection. Anatomocytopathology is another example of analysis that looks at tissues and cells to detect anomalies associated with cancers or inflammatory conditions. Genetic studies are used to characterize rare diseases and the genetic mutations that cause them.

In addition, the laboratories and their sampling centers see patients every day. Many are open 24/7 for urgent sample analysis and speedy delivery of test results to patients. This service contributes substantially to the improvement of patient care and to the public health mission of the Pasteur Network.

For example, 26,000 patients a year come to the Institut Pasteur du Cambodge for post-exposure anti-rabies vaccination after being bitten by an animal suspected of having rabies. This is the only therapy available to avert fatalities from rabies. This institute opened a third vaccination center in Kampong Cham in 2019, further strengthening its efforts against rabies. The "IPC" vaccination protocol (devised by the institute) is the first post-exposure rabies vaccination schedule administered over a short period (one week). It is currently recommended by the WHO.

For more information: <https://www.pasteur.fr/en/research-journal/news/rabies-new-prophylactic-and-therapeutic-avenues>

THE INSTITUT PASTEUR INTERNATIONAL NETWORK BECOMES THE PASTEUR NETWORK

A new system of governance has been established for the former “Institut Pasteur International Network” and its 33 members, legally represented by an association since 2011, and chaired by the Institut Pasteur’s President, Stewart Cole. Ten years on, the network is adopting a more participatory, balanced governance and a more structured business model. The Articles of Association of the association representing the Pasteur Network have been amended. A Sheltered Foundation has also been established, based at the Institut Pasteur, to serve as a financial body for the network. The organizational structure and new identity of the Pasteur Network reflect a continued commitment to tackling diseases, especially infectious and emerging diseases, through a One Health approach based on international solidarity and the development of a single voice.

Pasteur Network: a global scientific community with shared values and a future-oriented approach

The Pasteur Network is now looking forward with a strategy of consolidation aimed at optimizing the network’s impact on global health.

On Tuesday 8 June 2021, the new organizational structure, which was previously presented and approved on 4 June at the meeting of the Institut Pasteur Board of Governors was adopted. It is designed to represent all the Pasteur Network members more fairly and to facilitate a concerted approach to the major challenges of the 21st century such as the response to the COVID-19 pandemic.

Pasteur Network: shared governance and a stronger business model

To this end, a Sheltered Foundation has been established at the Institut Pasteur in order to develop a more efficient, structured business model. The foundation will contribute to the development of the Pasteur Network through capacity-building and infrastructure-strengthening measures.

As well as working to consolidate and increase funding for the Pasteur Network, which has a seed fund, the foundation will now take the lead in the major international programs it supports, which are intended to strengthen the capacities and infrastructure of its founders and partners. It also manages funds that encourage mobility (the Calmette & Yersin program and 4-Year Research Groups – G4s) and cooperation within the Pasteur Network (Pasteur International joint Research Unit – PIU).

For more information: pasteur-network.org

The Pasteur International Network association is changing and will now be known as the Pasteur Network association, after the network that it represents legally. Its Articles of Association will also be amended in order to develop a more balanced, participatory system of governance. The association is the representative body for the Pasteur Network; it is responsible for setting up and coordinating research projects involving several members, and for leading the network at regional and interregional level. To give the regions a greater voice, two representatives are

now elected for each region, increasing the number of representatives to 8 (including the President), compared with 5 previously (see graph on opposite page).

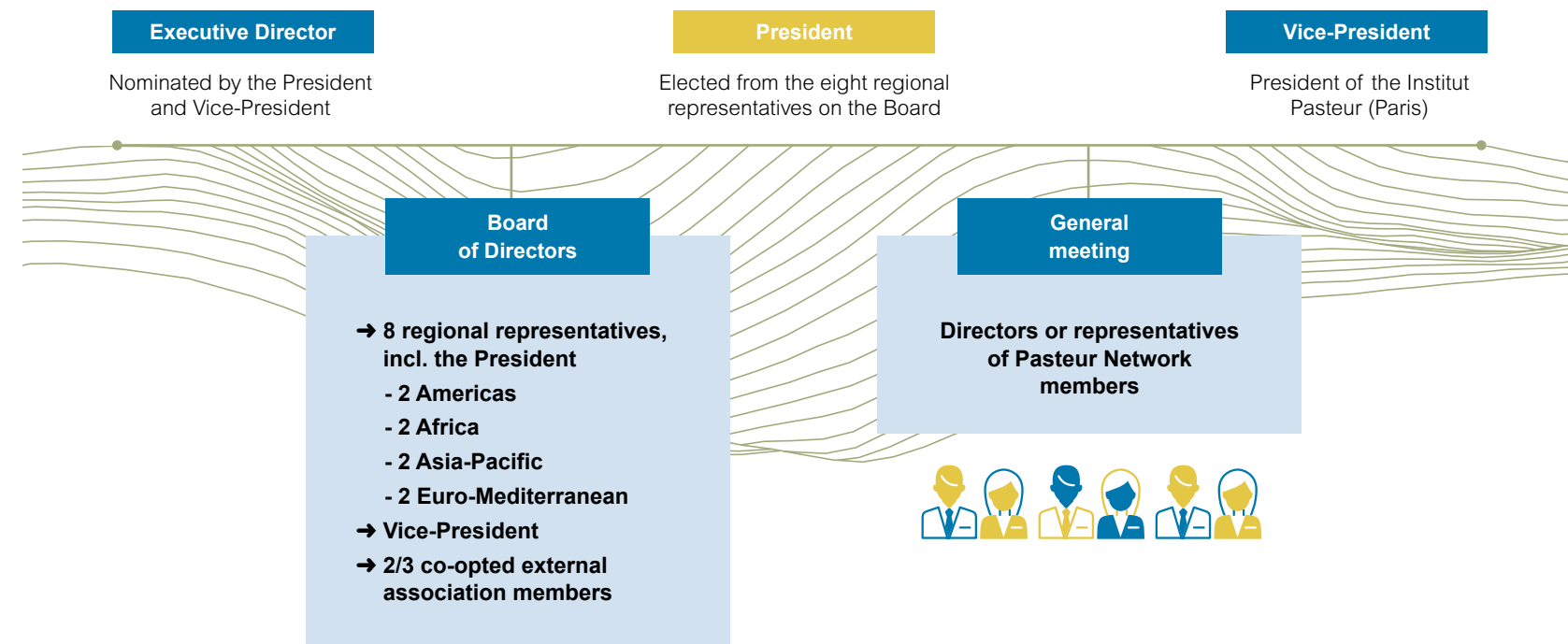
These changes will enable the association to act in cooperation and in perfect synergy with the foundation set up to serve the Pasteur Network members. All these changes are reflected in the network’s new visual identity and its new name. Network, members, association and foundation will now use the same brand, “Pasteur Network”.

PASTEUR NETWORK KEY DATES

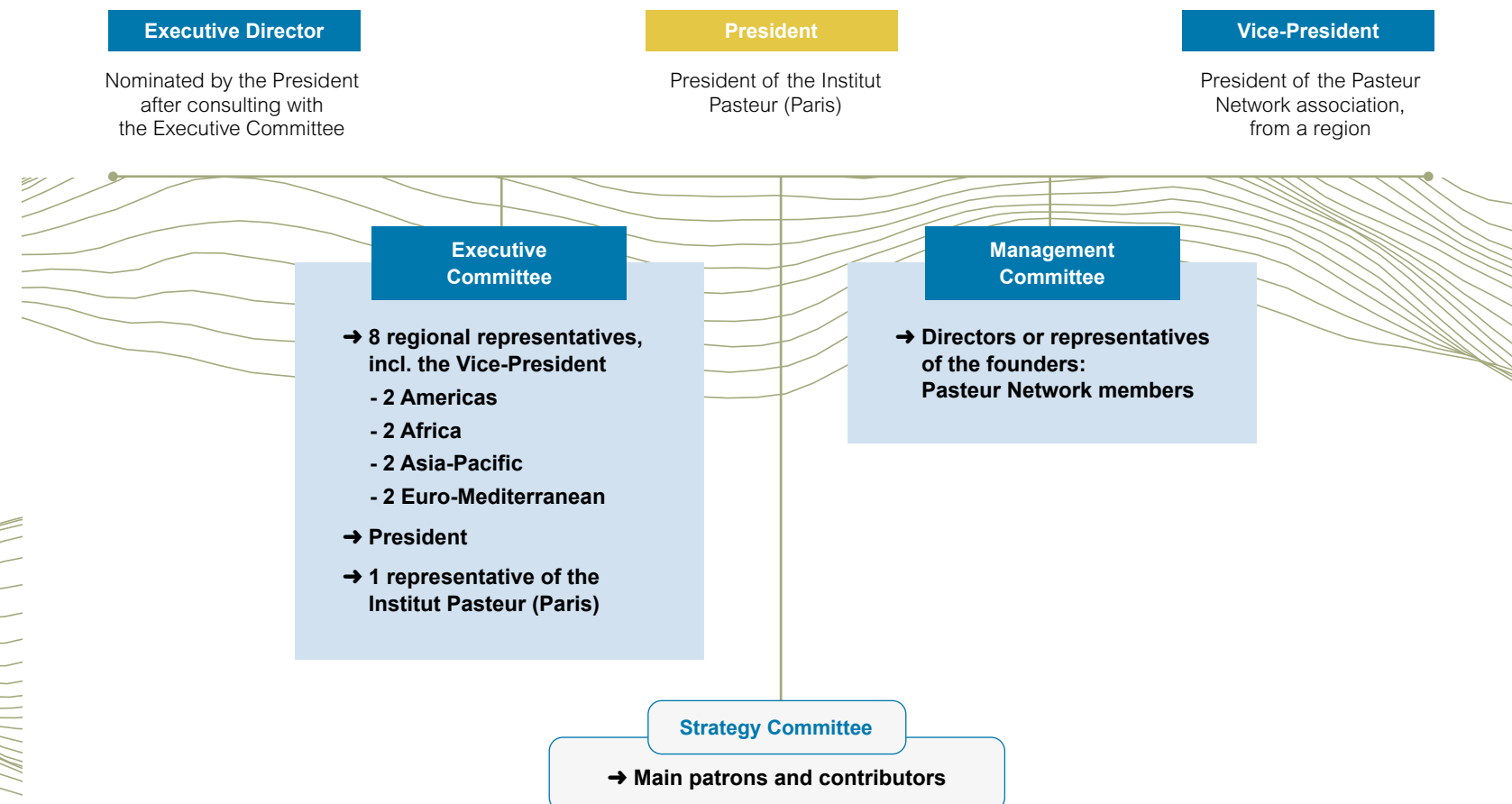
- 1888** Inauguration of the Institut Pasteur
- 1891** First institute opened outside mainland France in Saigon
- 1972** Network Directors’ Meeting formed
- 1988** The network becomes the Institut Pasteur International Network and Associated Institutes
- 1989** Signature of the General Scientific Cooperation Declaration
- 2004** Signature of the Declaration of common Pasteurian values and the Pasteurian values charter
- 2011** Creation of the Pasteur International Network association to represent the network
- 2021** Establishment of the Pasteur Network Foundation and amendment of the Articles of Association to reflect the name change: Pasteur Network

GOVERNANCE

→ ASSOCIATION



→ SHELTERED FOUNDATION UNDER THE AEGIS OF THE INSTITUT PASTEUR



HIGHLIGHTS OF 2019

Here is a selection of highlights based on reports from network members. This is not an exhaustive list, but you will find more information on members' websites and in their annual reports.

JANUARY 2019 France (Guadeloupe)

CREATION OF KARUBIONET

In addition to acquiring a MinION sequencer, the Institut Pasteur de la Guadeloupe established the KaruBioNet network. It is a platform for discussing, sharing, training and mutual aid between researchers in the field of bioinformatics. It brings together scientists from the Institut Pasteur de la Guadeloupe, the University of Antilles, INRA, CIRAD and IRD, amongst others.

APRIL 2019 Ivory Coast REGIONAL BIOBANK INAUGURATED IN IVORY COAST



The Ambassador of France to Ivory Coast, Minister for Higher Education and Scientific Research and the ECWAS representative.

The Regional Biobank of countries belonging to the Economic Community of West African States (ECWAS) was inaugurated on 25 April 2019. Located at the Institut Pasteur de Côte d'Ivoire at the Adiopodoumé (Abidjan-Dabou) site, the biobank is housed in the Institut's Biological Resources Center. It keeps high-risk microorganisms used for research in a safe and secure location.

For more information: (in French): <http://pasteur.ci/index.php/homepage/actualites/item/494-ceremonie-dinoguration-du-cereb-biobanque-regionale-des-pays-de-la-cedeao>

MAY 2019 Madagascar CHARACTERIZING THE PLAGUE EPIDEMIC IN MADAGASCAR

Researchers from the Institut Pasteur de Madagascar and the Institut Pasteur (Paris), in collaboration with the Malagasy Ministry of Public Health, the WHO and international experts, described the extent of the 2017 epidemic of pneumonic plague in Madagascar and the dynamics of transmission. The work showed that the pulmonary form was dominant and accounted for 78% of the 2,414 notified suspected clinical cases.



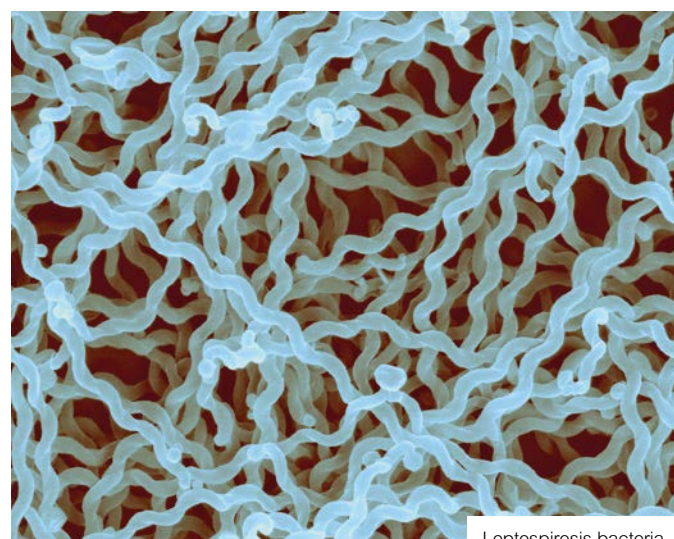
Lancet Infectious Diseases, May 2019, DOI: 10.1016/S1473-3099(18)30730-8

For more information: [https://www.thelancet.com/journals/laninf/article/PIIS1473-3099\(18\)30730-8/fulltext#%20](https://www.thelancet.com/journals/laninf/article/PIIS1473-3099(18)30730-8/fulltext#%20)

MAY 2019 Canada NEW SPECIES OF LEPTOSPIRA

A INRS–Armand-Frappier Santé Biotechnologie Research Centre team and their collaborators published a paper on the discovery of 30 species of *Leptospira*. The infectious strains of this bacterium are responsible for leptospirosis. An analysis of these environmental strains led to a more detailed classification and helped identify the specific genomic features of the infectious strains.

Plos Neglected Tropical diseases, May 2019, DOI:10.1371/journal.pntd.0007270



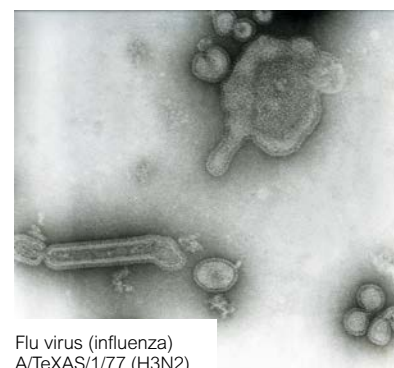
Leptospirosis bacteria.

JUNE 2019 China

PREVENTING DISRUPTIVE MUTATIONS IN THE FLU VACCINE

The effectiveness of seasonal H3N2 influenza vaccines can be compromised when antigenic changes arise. Researchers at the HKU-Pasteur Research Pole discovered that a specific mutation in the seasonal flu vaccine could prevent the emergence of an antigenic mutation. This research is important for the development of future vaccines.

Cell Host & Microbe, June 2019, DOI:10.1016/j.chom.2019.04.013



Flu virus (influenza) A/Texas/1/77 (H3N2).

JULY 2019 Belgium

STUDY OF ANTIMICROBIAL RESISTANCE BY NGS

The Sciensano National Reference Centers for human clinical microbiology received BELAC (the Belgian accreditation body) accreditation in July 2019. It enables them to conduct routine sequencing of bacterial isolates using high-throughput next-generation sequencing (NGS) to detect clusters of microbial disease and to analyze genes that are resistant to antimicrobials.

JULY 2019

France (New Caledonia)

LAUNCH OF WORLD MOSQUITO PROGRAM



First mosquito released in Nouméa (New Caledonia).

The first mosquitos to carry *Wolbachia*, a bacteria that prevents them from transmitting arboviruses like dengue and Zika to people, were released into the mosquito population on 10 July 2019 in Nouméa. This is an initiative of the "World Mosquito Program" to which the Institut Pasteur de Nouvelle-Calédonie is contributing. The aim is to breed *Wolbachia*-carrying mosquitos with wild mosquitos in order to produce a population of *Aedes aegypti* mosquitos that are unable to transmit viruses such as dengue and Zika.

For more information: <https://www.pasteur.fr/en/home/institut-pasteur/institut-pasteur-throughout-world/news/wolbachia-bacteria-combat-dengue>

SEPTEMBER 2019 Cambodia

RESIST-2, A NEW ANTI-RABIES PROTOCOL

An observational cohort study by the Institut Pasteur du Cambodge and the Institut Pasteur (Paris) confirmed the efficacy of the new post-exposure vaccine protocol for rabies developed in the Pasteur Network. Post-exposure vaccination will now be administered over one week instead of four. This improved protocol has already been adopted by the WHO.

The Lancet Infectious Diseases, September 2019, DOI: 10.1016/S1473-3099(19)30311-1

OCTOBER 2019 Guinea

TRACES OF EBOLAVIRUS IN PIGS



Study of Ebolavirus strains circulating in Guinea.

A paper published by the Friedrich-Loeffler-Institut, jointly with the Institut Pasteur de Guinée, shows that pigs can be hosts for Ebolavirus. Antibodies found in their blood suggest that they could play a role in transmitting the virus. The study provides important insights into the Ebolavirus viral cycle.

Transboundary and Emerging Diseases, October 2019, DOI: 10.1111/tbed.13391

HIGHLIGHTS OF 2019-2020



NOVEMBER 2019 Cameroon

51ST DIRECTORS' MEETING IN YAOUNDÉ

The international network's Directors' Meeting held its 51st meeting from 12 to 15 November 2019. The Pasteur Center in Cameroon hosted the meeting for the first time. On 12 November, the country's Minister for Health, Doctor Malachie Manaouda, officially opened a new building at the Pasteur Center in Cameroon, funded by the Cameroon government. The Minister was the guest of honor at the 60th anniversary gala event for the Pasteur Center in Cameroon on 13 November. Initiatives to mark the anniversary included a symposium on "Scientific Advances in Controlling Infectious Diseases", open days for the public and a cancer screening and prevention campaign from 18 to 22 November.



MAY 2020 France (Guiana)

ANTI-MALARIAL RESISTANCE IN AMAZONIA

Following the appearance in Asia of a mutation of the parasite responsible for malaria making it resistant to the anti-malarial drug, artemisinin, researchers at the Institut Pasteur de la Guyane looked into anti-malarial resistance in Amazonia. They found the same mutation, but of independent origin. The mutation also slowed the parasite's growth rate indicating that it may be resistant to other anti-malarials in the future.

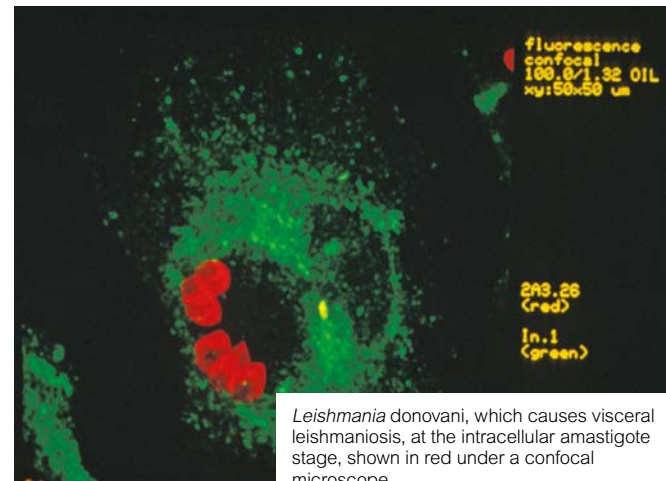
eLife, May 2020, DOI: 10.7554/eLife.51015

DECEMBER 2019 Bulgaria

MIMOTOPES TO STUDY IGM REACTIVITY

Researchers from the Department of Immunology at the Stephan Angeloff Institute of Microbiology have described a quasi-complete library of IgM mimotopes, molecules that mimic the part of the antigen that binds to antibodies. The library can be used to analyze the dynamics and reactivity of the public human immunoglobulin M (IgM) repertoires by structurally studying the interactions.

Frontiers in Immunology, December 2019, DOI: 10.3389/fimmu.2019.02796



Leishmania donovani, which causes visceral leishmaniasis, at the intracellular amastigote stage, shown in red under a confocal microscope.

JUNE 2020 Canada

ELUCIDATION OF THE MECHANISM OF ACTION OF *L. DONOVANI*

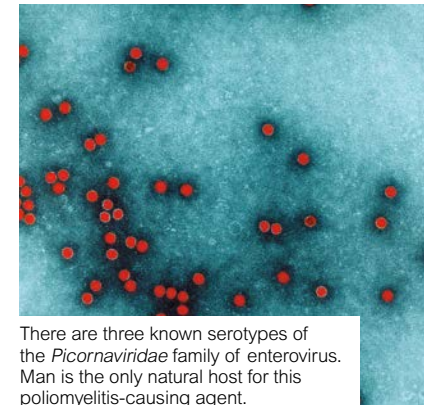
The INRS-Armand-Frappier Santé Biotechnologie Research Centre has shown that the *Leishmania donovani* parasite behind visceral leishmaniasis triggers a vast, but selective, reprogramming of the host cell translational activity early during infection. Some of these changes may be implicated in host defence mechanisms and others are part of parasite-driven survival strategies.

PLoS Pathogens, June 2020, DOI: 10.1371/journal.ppat.1008291

JUNE 2020 Central African Republic

ANOTHER COUNTRY "FREE OF WILD POLIO VIRUS"

Announced on 17 June 2020 by the WHO country bureau, the Central African Republic was declared "free of wild polio virus" by the Regional Certification Commission for the African Region. The poliomyelitis data provided by the WHO regional reference laboratory based at the Institut Pasteur de Bangui certified the finding: no cases of wild polio virus have been detected since 8 December 2011.



There are three known serotypes of the *Picornaviridae* family of enterovirus. Man is the only natural host for this poliomyelitis-causing agent.

JUNE 2020 France (Guiana)

MAYARO VIRUS IN GUIANA

The Institut Pasteur de la Guyane, working with the Laboratory for Urgent Response to Biological Threats (CIBU) at the Institut Pasteur (Paris), characterized the circulation of Mayaro virus, an emerging arbovirus. The teams assessed the risk of transmission to humans – a challenging task given its cross-reactivity with chikungunya virus. The researchers found solid evidence of an important sylvatic cycle for MAYV with higher seroprevalence in forests.

Nature communications, June 2020, DOI: 10.1038/s41467-020-16516-x

JULY 2020 Cameroon

NEW MOLECULES TO TREAT MALARIA

The malaria research laboratory at the Pasteur Center in Cameroon, in collaboration with the University of Buea, discovered a new class of anti-malarial agents with multiple modes of action using molecular hybridization techniques. This discovery is particularly important given that the compound is effective on multi-resistant strains and on all asexual stages of the parasite.

Scientific Reports, October 2020, DOI: 10.1038/s41598-020-74824-0

NOVEMBER 2020

Cambodia – France – Senegal

Aedes Aegypti MORE SUSCEPTIBLE TO ZIKA VIRUS



Aedes aegypti female raised at the vector research center at the Institut Pasteur de la Guyane.

A collaborative research program between a number of different laboratories including five run by members of the Pasteur Network, including the Institut Pasteur (Paris), the Institut Pasteur de la Guadeloupe, the Institut Pasteur de la Guyane, the Institut Pasteur du Cambodge and the Institut Pasteur de Dakar, has shown enhanced susceptibility of the *Aedes aegypti* mosquito to Zika virus, which explains its capacity to pick up and transmit the virus after a "domestic" form evolved. This discovery, together with the global expansion of *Aedes aegypti* explains the emergence of the arbovirus.

Science, November 2020, DOI: 10.1126/science.abd3663

NOVEMBER 2020 France

MOLECULAR DISCOVERY IN ALZHEIMER'S DISEASE

Researchers at the Institut Pasteur de Lille have discovered altered gene expression in some regions of the brain, such as the hippocampus, in the early stages of Alzheimer's disease (the main cause of dementia in the elderly). The findings shed more light on the molecular process of the early stages of the disease and could lead to identifying therapeutic targets.

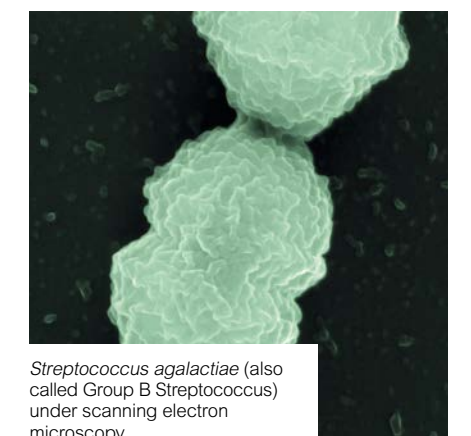
npj / Aging and Mechanisms of Disease, November 2020, DOI: 10.1038/s41514-020-00052-5

NOVEMBER 2020 Greece – France

NEW MODEL OF BRAIN INFECTION

The Institut Pasteur and the Hellenic Pasteur Institute are the authors of a paper highlighting the role of lipoproteins in the ability of Group B streptococci, the bacteria that cause meningitis, to cross the blood-brain barrier. Their work on drosophila and murine models has identified a new mechanism used by the pathogens to infect the brain.

Nature communications, November 2020, DOI: 10.1038/s41467-020-19826-2



Streptococcus agalactiae (also called Group B Streptococcus) under scanning electron microscopy.

A FEW KEY DATES TO GET READY FOR THE FUTURE

JUNE 2019

Asia

FIRST SYMPOSIUM IN THE LANCANG-MEKONG REGION

The first symposium in the Lancang-Mekong Cooperation Region took place on 25 September 2019 as part of an alliance between several Institut Pasteur in Asia, the Yunnan government and the Mériex Foundation. More than 50 international experts took part in the meeting entitled “Outbreak Readiness and Preparedness in the Lancang-Mekong Cooperation Region (LMCR)” to discuss how to manage infectious diseases.



JUNE 2019

Americas

FIRST REGIONAL MEETING OF THE PASTEUR NETWORK IN SÃO PAULO

From June 3 to 5, 2019, the Scientific Platform Pasteur-USP, a new associated member of the network, organized its first regional meeting in collaboration with the Institut Pasteur de la Guyane. The Pasteur Network members in the Americas region discussed the future of the network in the area as well as topics including biosciences, emerging diseases and antimicrobial resistance.

SEPTEMBER 2019

Korea

SYMPOSIUM ON PREPARING FOR EMERGING THREATS

The Institut Pasteur Korea organized a symposium entitled “Pasteur Network Fighting Emerging Threats” on 25 September 2019, attended by network members in the Asia-Pacific region and from the Institut Pasteur (Paris). The symposium focused on vector-borne flaviviruses that cause diseases like dengue, and discussed ways to counter emerging threats.



Female *Aedes aegypti* mosquito. In New Caledonia, *Aedes aegypti* is the main arbovirus vector (dengue, chikungunya, Zika).

Mobilize



Pasteur Network members have demonstrated unprecedented mobilization in response to the COVID-19 pandemic. Joining forces with the national authorities in their home countries, they played a key role on the frontline in diagnostics and surveillance. The network pooled its knowledge and research findings.

KEY FIGURES IN THE COLLECTIVE ACTION AGAINST SARS-COV-2

33 
members engaged and recognized as national reference by their local health authorities

4 
members designated as part of the WHO COVID-19 Reference Laboratory Network*

1st 
primers to detect the virus developed as early as 17 January 2020 by the HKU-Pasteur Research Pole

2 
International calls for projects from the Institut Pasteur
33 Pasteur Network projects selected and funded
27 members involved

10 
members involved in the REPAIR program in Africa (see page 30)

203 
m³ of equipment shipped to **14** countries in 2020 in **46** shipments

* The Institut Pasteur (Paris), the Institut Pasteur de Dakar, the Institut Pasteur du Cambodge, the Fiocruz.



Amadou Alpha Sall,

President of the Pasteur Network,
General Administrator of
the Institut Pasteur de Dakar

A COLLECTIVE RESPONSE ON A SCALE NEVER SEEN BEFORE

“All the members of the Pasteur Network have played a frontline role in their home countries. Faced with a completely new situation, they had to learn on the run as they fought the spreading pandemic. The network quickly set up a number of actions in the 33 structures around the globe.

The diversity of the members and the different political, health and environmental ecosystems in which they operate proved to be a clear advantage for the Pasteur Network.

More united than ever, the members showed exemplary community spirit in working together.

For example, the Institut Pasteur de Dakar volunteered to help other institutes in Africa with sequencing. The same happened in Asia, where the HKU-Pasteur Research Pole played a key role with an immediate proposal to share primers to help with diagnostics.

The Institut Pasteur acted as a catalyst, setting up a large-scale logistics platform to get equipment to where it was needed.

The story of these scientific advances is one of cooperative endeavor. Members stepped up their efforts and mobilized resources as never before, a clear sign of the trend towards more collaboration in the network, reflecting the more representative and participatory governance model. I am proud to be President of this cooperative organization. The emergence of the network on every continent will continue to strengthen synergies between members. The change in governance not only reflects the shared Pasteurian values, but is also a measure of the dedication of the entire network to working together as part of an international human community.”

SARS-COV-2, THE STORY OF UNPRECEDENTED SOLIDARITY

When the COVID-19 pandemic hit in 2020, national health authorities had to quickly put in place a massive and rapid response encompassing surveillance, research and protection of populations. Most members of the Pasteur Network became key players in diagnostics and surveillance, supporting their own national governments in their COVID-19 strategies.

their national health authorities were able to rely on them to effectively monitor virus circulation.

SUPPORT FOR THE ACTIVITY AND MISSIONS OF REFERENCE LABORATORIES, COORDINATED BY THE INSTITUT PASTEUR (PARIS)

Designated as reference laboratories by their national health authorities, most of the network’s members were propelled to the heart of the fight against COVID-19. The granting of this mandate has unfortunately not always been accompanied by a sufficient operating budget to enable them to accomplish this mission.

At the same time, the medical analysis laboratories, vaccination centers and other service activities of the institutes have been significantly slowed down due to a lack of sufficient staff or user attendance. Thus, the sustainability of these institutions, despite being major public health actors in their countries, is considerably weakened.

Faithful to its Pasteurian values and its missions of general interest, the Pasteur Network members have naturally mobilized with their respective national authorities to fight the COVID-19 pandemic. Mutualization was the cornerstone of their strategy as they shared their expertise, their research. They also pooled equipment orders to protect people health.

TRAINING IN DIAGNOSTICS FOR VIRUS SURVEILLANCE

The CIBU at the Institut Pasteur (Paris) also organized trainings in diagnostics and quality control for laboratories in 23 countries that asked for assistance in validating their initial diagnostics to confirm the first positive cases (see page 28). At the same time, the Institut Pasteur de Dakar (which was designated the Global Reference Laboratory for COVID-19 for the Africa region by the WHO) (see page 23), not only analyzed all diagnostic tests in Senegal, but also trained representatives of laboratories in 15 African countries. Laboratories were ready to identify the first positive cases before the outbreak in their countries. As a result, when the time came,

ESTABLISHING AND PROVIDING ACCESS TO DIAGNOSIS

When faced with previously unknown viruses, it is crucial to know the viral sequences to be able to develop diagnostic tests. As early as 17 January 2020, the HKU-Pasteur Research Pole developed the first primers to detect the virus. With the Berliner Charité, it was one of the first laboratories to succeed and shared them freely. One week later, the Institut Pasteur’s Laboratory for Urgent Response to Biological Threats (CIBU), the Pasteur Network association and the HKU-Pasteur Research Pole shared the diagnostic protocols and reagents developed by the Berliner Charité and the HKU-Pasteur Research Pole with network members in Africa, the Americas, Europe, South-East Asia and beyond, paving the way for diagnostic tests (RT-PCR), to detect SARS-CoV-2.



Laboratory for Urgent Response to Biological Threats (CIBU) at the Institut Pasteur.

Thanks to the financial support of the Agence française de Développement (AFD) and the European Commission (DG-DEVCO), historical funders of the Institut Pasteur (Paris), an exceptional budget has made it possible to provide emergency support to some of the institutes in the network via various initiatives set up alongside existing projects such as ECOMORE II and MediLabSecure.

Coordinated by the Institut Pasteur's Department of International Affairs, the initiatives aimed to ensure the continuity of the activities of the reference laboratories by:

- supplying reagents and consumables in sufficient quantities to test the local population, but also laboratory equipment and personal protective equipment for the staff that comply with safety standards;
- strengthening the human resources of front-line laboratories;
- promoting the training of laboratory staff and the transfer of skills (External Quality Assessment, sequencing and more);
- helping to set up and develop laboratory diagnostics in many countries, particularly:
 - in Sub-Saharan Africa (Guinea, Madagascar, Niger, Central African Republic and Senegal) through the "Support to several Pasteur Institutes in Sub-Saharan Africa" project;
 - in South-East Asia, through the ECOMORE II program (Cambodia, Lao PDR, Myanmar, Philippines and Vietnam);
 - as well as in many countries belonging to the MediLabSecure 2 network and beyond, through the Centers of Excellence initiative (Albania, Algeria, Bosnia, Burkina Faso, Cameroon, Egypt, Guinea, Jordan, Kosovo, Lebanon, Libya, Macedonia, Morocco, Mauritania, Montenegro, Niger, Palestine, Central African Republic, Democratic Republic of the Congo, Rwanda, Serbia, Tunisia and Turkey).

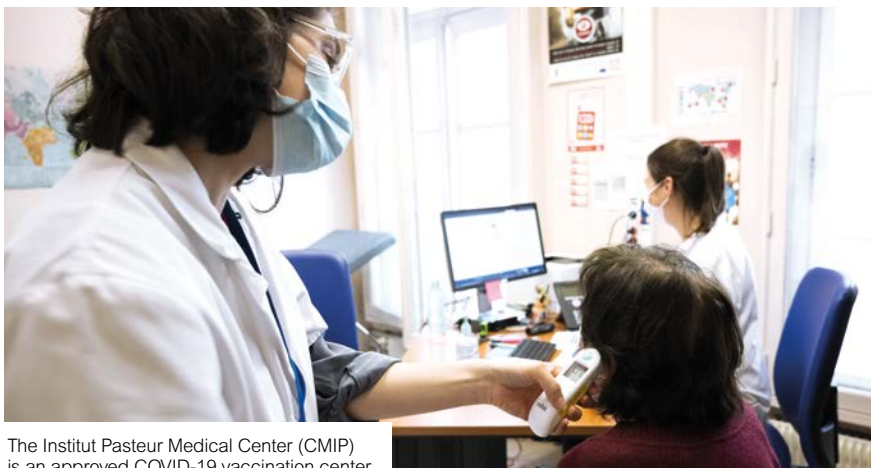


POOLING EQUIPMENT ORDERS: A FIRST IN THE PASTEUR NETWORK

To cope with the global shortage of protective equipment and consumables/reagents related to the SARS-CoV-2 diagnosis, the Pasteur Network has set up a pooled procedure to ensure grouped orders for the benefit of the most fragile countries. In practice, a logistics platform has been set up to ensure a proactive watch on the needs not covered locally by the institutes

as well as support throughout the supply chain: identification and certification of equipment, grouped orders and routing. This logistical support, financed by the support of institutional funders and the Institut Pasteur's funds (Paris), has made it possible to transport 203 m³ of equipment to 14 countries in 46 shipments.

"The responsiveness of major institutional funders such as the French Development Agency, the Ministry for Europe and Foreign



The Institut Pasteur Medical Center (CMIP) is an approved COVID-19 vaccination center.

Affairs and the European Union was exceptional and equal to the challenges of this potentially devastating COVID-19 pandemic. Associated with the time lag in the arrival of the epidemic on the African continent, these funds have certainly helped to limit the disaster announced by most experts. Public generosity and the involvement of donors have once again been essential in helping the Institut Pasteur carry out its missions." says Professor Pierre-Marie Girard, Director of the Department of International Affairs of the Institut Pasteur.

In parallel with this mobilizing support, the Pasteur Network members in Africa also put together a multidisciplinary project to study the pandemic in Africa called REPAIR (Recherche Pasteurienne Internationale en Réponse au Coronavirus en Afrique) (see page 30).

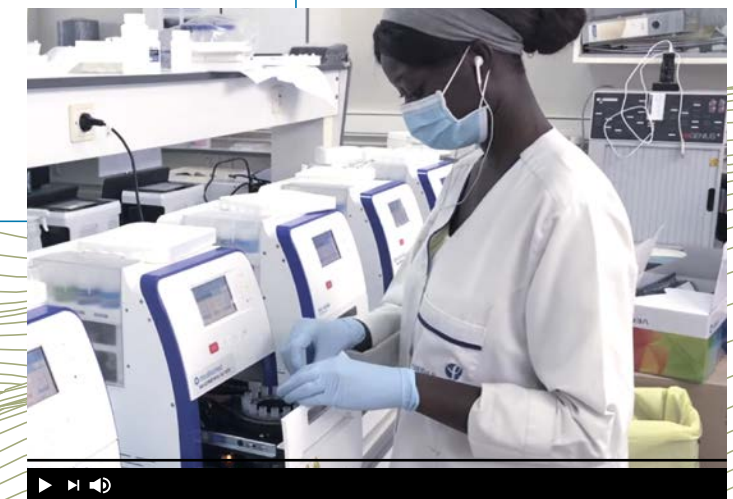
*Data/March 2021.



A MOBILIZATION RECOGNIZED BY THE WHO

The Institut Pasteur de Dakar, the Fiocruz (Oswaldo Cruz Foundation) Respiratory Viruses and Measles Laboratory, the Institut Pasteur (Paris) and the Institut Pasteur du Cambodge were designated members of the WHO Global Reference Laboratory Network for COVID-19. This move accelerated work on SARS-CoV-2 across the Pasteur Network's four regions. The WHO reference laboratories strengthen the diagnostic capacity of the structures on the ground in the WHO regions. They also perform confirmatory testing of unexpected results on samples sent by regional laboratories and monitor which variants are circulating.

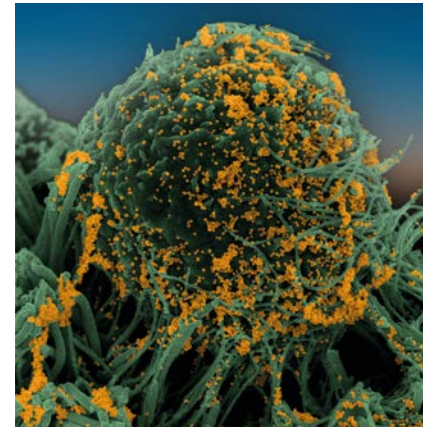
Watch the video: the Institut Pasteur de Dakar, reference laboratory at the heart of the COVID-19 response in Senegal https://www.youtube.com/watch?v=6UQwDqg_xq4&list=PLkkv17fytFIPQT76TorT47rtNTh9GQI_Y&index=19



AN INTERNATIONAL RESPONSE SUPPORTED BY THE INSTITUT PASTEUR

Given the urgency of this unprecedented health situation, a response was swiftly organized by the Pasteur Network, in collaboration with the Institut Pasteur (Paris). The latter created a Coronavirus “Task Force” to respond as effectively as possible to the spread of the virus. The Institut Pasteur (Paris) issued a call for projects through the task force and no fewer than 33 network projects were selected and funded.

Projects submitted for the call for projects came from every network region and targeted a range of subjects from the knowledge of the virus to clinical studies and development of tests and diagnostic tools. Here is the list of the 33 projects selected.



Researchers at the Institut Pasteur examined the attack strategy of the virus under a scanning electron microscope. This image shows a sample of cultured bronchial cells colored in blue-green. SARS-CoV-2 is shown in orange. Photo published in September 2020.

Project	Pasteur Network member(s) involved
Vaccination approach – Prophylaxis and vaccine candidates	
Development of novel nano-based multi-epitope vaccine against coronavirus SARS-CoV-2 - Generation of Humanised NSG transfer mouse model for vaccine testing	Stephan Angeloff Institute of Microbiology
Biology of SARS-CoV-2 – Knowledge of the virus and its pathogenesis	
Origins, natural reservoirs and interspecies transmission of SARS-CoV-2 and other SARS-like CoVs	Institut Pasteur du Laos, National Institute of Hygiene and Epidemiology, Institut Pasteur of Shanghai – Chinese Academy of Sciences
Tracking the origin and transmission/spillover of SARS-CoV-2 in Lao PDR and Vietnam: search for SARS-like viruses and detection of antibodies in vertebrates	Institut Pasteur (Paris), Institut Pasteur du Laos
Characterisation of variable systemic and mucosal immunity during SARS-CoV-2 infection and recovery	Institut Pasteur (Paris), HKU-Pasteur Research Pole
Evaluation of anti-SARS-CoV-2 antibody effector functions in a Cambodian patient cohort	Institut Pasteur du Cambodge, Institut Pasteur (Paris)
Investigation of SARS-CoV-2 mechanism of pathogenicity using organoids produced from human-induced pluripotent stem cells (hiPSC)	Scientific Platform Pasteur-USP, Hellenic Pasteur Institute
Study of the innate immunity and adaptive response in early stages of COVID-19 infection protecting African children against severe clinical manifestations: investigation in Madagascar and in Central African Republic	Institut Pasteur de Madagascar, Institut Pasteur de Bangui
Arthropods and SARS-CoV-2 transmission and dissemination	Institut Pasteur de Dakar, Institut Pasteur (Paris), Institut Pasteur du Maroc
Peptide Immunophenotyping of the B and T cell immune responses of COVID-19 patients against SARS-CoV-2 structural proteins	Institut Pasteur de Madagascar, Institut Pasteur de Dakar
Development of tests and diagnostic tools	
Development of straightforward COVID-19 serological tools and targeted serosurvey of at-risk human individuals	Institut Pasteur du Cambodge, Institut Pasteur (Paris)
Development of SARS-CoV-2 low-cost diagnostic platform based on reverse-transcription loop-mediated isothermal amplification (RT-LAMP). A solution for a rapid response of high laboratory diagnostic demand in virus outbreaks in the Pasteur Network	Scientific Platform Pasteur-USP

Project	Pasteur Network member(s) involved
Engineering an ACE2-derived polypeptide for label-free, real-time detection on a smartphone device and therapeutic intervention	Institut Pasteur de Montevideo
Padlock Probes for SARS-CoV-2 Detection at Point Of Care	INRS – Armand-Frappier Santé Biotechnologie Research Centre
The use of Artificial Intelligence Methods to Discriminate COVID-19 from other Community-Acquired Pneumonia using Chest X-Ray and CT images	Institut Pasteur du Maroc
Serological surveillance of SARS-CoV-2 and seasonal coronaviruses	Institut Pasteur (Paris), Institut Pasteur de Dakar, Pasteur Center in Cameroon, Institut Pasteur de Côte d'Ivoire
ELISA Assays development for SARS-CoV-2 within the Pasteur Network	Institut Pasteur de Tunis, Institut Pasteur (Paris), HKU-Pasteur Research Pole
Development of a high-throughput loop-mediated isothermal amplification (LAMP) assay for rapid mass testing of mobile populations to limit the spread of COVID-19 infections	Pasteur Center in Cameroon, Institut Pasteur Korea
Droplet Digital PCR application to SARS-CoV-2 detection in North and Sub-Saharan Africa	Institut Pasteur (Paris), Institut Pasteur du Maroc, Pasteur Center in Cameroon

Epidemiological modelling and clinical studies

Epidemiological, clinical and immunologic analysis of cases of SARS-CoV-2 in São Paulo Metropolis, Brazil: a descriptive study	Scientific Platform Pasteur-USP
Serological investigations of populations infected with SARS-CoV-2 in Cameroon	Pasteur Center in Cameroon, Institut Pasteur (Paris)
Evaluation of clinical presentation and evolution of SARS-CoV-2 coronavirus infection in Senegal	Institut Pasteur de Dakar
Household transmission investigation study in overseas territories for SARS-CoV-2	Institut Pasteur de la Guyane, Institut Pasteur de Nouvelle-Calédonie, Institut Pasteur de la Guadeloupe
Enquête sur les premiers cas d'infections par le coronavirus (COVID-19) et leurs contacts à Antananarivo, Madagascar	Institut Pasteur de Madagascar
COVID-19 risk evaluation among the healthcare workers in charge of the first cases in Africa	CERMES, Institut Pasteur de Dakar, Pasteur Center in Cameroon, Institut Pasteur de Madagascar
COVID-19 risk evaluation among the household contacts of the first cases in Africa	CERMES, Institut Pasteur de Dakar, Pasteur Center in Cameroon, Institut Pasteur de Madagascar
Oro- and nasopharyngeal bacterial community markers to predict COVID-19 complications	INRS – Armand-Frappier Santé Biotechnologie Research Centre, Institut Pasteur de Madagascar, Institut Pasteur (Paris)

Therapeutic research

Urgent discovery of drug candidates that target SARS-CoV-2	INRS – Armand-Frappier Santé Biotechnologie Research Centre
Identification and isolation of potent human neutralising antibodies against SARS-CoV-2	Institut Pasteur of Shanghai – Chinese Academy of Sciences, Institut Pasteur (Paris)
DrugDesign_SARS2: Find potent antiviral drugs against SARS-CoV-2 by targeting specific proteins essential to the viral cycle	Institut Pasteur in Italy – Cenci Bolognetti Foundation, Institut Pasteur (Paris), Institut Pasteur de Lille
Drug Repurposing & Design to inhibit the SARS-CoV-2 proteases	Institut Pasteur de Tunis, Institut Pasteur (Paris)
Implication of dopamine, serotonin and hypoxia-inducible-factor pathways as determinant factors of SARS-CoV-2 pathogenesis and COVID-19 severity: Towards therapeutic application	Hellenic Pasteur Institute, Institut Pasteur (Paris), Institut Pasteur in Ho Chi Minh City, Institut Pasteur du Maroc
In vitro evaluation of inhibitory effects of Artemisia annua and Artemisia afra extracts on SARS-CoV-2 and other human coronavirus	Institut Pasteur du Cambodge, Institut Pasteur (Paris)
Drug Discovery Against the Major Protease of SARS-CoV-2	Institut Pasteur de Montevideo, Institut Pasteur Korea, Institut Pasteur of Shanghai – Chinese Academy of Sciences, Fiocruz (Oswaldo Cruz Institute)

FOCUS ON HOW SARS-COV-2 AFFECTS THE CENTRAL NERVOUS SYSTEM

Although the effect of human coronaviruses on the brain has been suspected since 2016, it was brought into sharp relief by the COVID-19 pandemic. Researchers at the INRS - Armand-Frappier Santé Biotechnologie Research Centre in Canada and the Fiocruz in Brazil have joined forces with other Brazilian institutes to study the damaging effects of SARS-CoV-2 on the central nervous system.

In 2016, British and Quebecois teams, including Professor Talbot's team at the INRS - Armand-Frappier Santé Biotechnologie Research Centre, demonstrated a link between a human coronavirus strain and a case of neuropathology. Their study, published in the *New England Journal of Medicine*^{*}, focused on an 11-year old child who died from inflammation of the brain (encephalitis). Pierre Talbot has a long 40-year history of research into coronaviruses. He was the first to show that these viruses can invade the central nervous system (the brain and spinal cord).

Research on this virus family accelerated with the outbreak of the COVID-19 pandemic. The Armand-Frappier Santé Biotechnologie Research Centre published an article on the neuroinvasive capacities of coronaviruses – and specifically of COVID-19 – in the journal *Viruses*^{**} as early as January 2020. This ability to invade the central nervous system may be responsible for the loss of smell experienced by many patients. Nevertheless, the study underlines that this specific effect may be due to the close proximity of the olfactory neurons to the sensitive neurons of the nasal cavity, the mucous membranes targeted by coronaviruses. However, the risk



Containment laboratory 3 (CL3) for research on COVID-19 and other pathogens at the INRS- Armand-Frappier Santé Biotechnologie Research Centre in Laval, Quebec.

of invasion of the rest of the brain is low, even in immuno-depressed patients, who are more susceptible to developing encephalitis with severe consequences.

In September, another study was published on this topic with the Fiocruz Center for Health Technology Development (CDTS/ Fiocruz), the Institut D'Or (Idor) and the Federal University of Rio de Janeiro (UFRJ). It showed that, in young children, SARS-CoV-2 weakens the blood-brain barrier that protects the brain from a range of pathogens, allowing viruses to penetrate the brain and cause lesions^{***}. Therapeutic pathways are already being studied, as described in the findings recently published by the INRS in the *Journal of Virology*^{****}.

The virulence of the COVID-19 virus or its capacity to multiply can be modulated by cleavage of its Spike protein and Type 1 interferon, which is a primary controller of infection of the nervous system, pointing to potential future therapeutic options.

^{*} <https://www.nejm.org/doi/full/10.1056/NEJM1509458#article>
^{**} <https://www.mdpi.com/1999-4915/12/1/14/html>
^{***} <https://www.biorxiv.org/content/10.1101/2020.09.11.293951v1>
^{****} <https://journals.asm.org/doi/full/10.1128/JVI.00140-21>



INTERVIEW

Gonzalo Moratorio,

Head of the Experimental Evolution of Viruses Laboratory, Institut Pasteur de Montevideo

Pilar Moreno,

Senior Researcher, Experimental Evolution of Viruses Laboratory, Institut Pasteur de Montevideo

How did the Institut Pasteur de Montevideo mobilize in the fight against COVID-19 at the local and regional level?

Uruguay successfully navigated the COVID-19 health crisis during the first 9 months of the epidemic, with only 9,700 confirmed COVID-19 cases and less than 100 deaths. This was due to the rapid response of the scientific community, which allowed a rapid increase of testing capacity from hundreds to thousands of tests per day that was critical to implement the TETRIS (test, trace and isolate) strategy recommended by the World Health Organization. The Institut Pasteur de Montevideo (IPMon) had a central role in the fight against COVID-19, re-directing its infrastructure as well as its human and economic resources with our laboratory (Experimental Evolution of Viruses) leading all these actions. Consequently, during the first semester of 2020 the IPMon turned into the main public diagnostic center of Uruguay.

Why and how did you develop a new diagnostic test? What were the steps involved in the process?

Why? Because at the beginning of the pandemic, the same war we are facing now to get vaccines, was mainly due for testing capacity. For example, on June 3rd the editorial of *Nature Biotech* published "The COVID-19 Testing debacle". Thus, we took advantage of being the last to get hit and we rapidly generated our own molecular test. How? By designing and multiplexing probes that target two SARS-CoV-2 genomic regions and one human gene as sampling control. At that moment, as far as we know, this was the first test that in only one tube, one patient was fully analyzed.

What are the differences between your kit and a PCR test? Who is it intended for?

We developed an affordable molecular multiplex kit to detect SARS-CoV-2. This kit has many advantages: it is independent from commercial kits, it has high sensitivity and specificity, is adaptable to all qPCR machines and it has the potential to be optimized for SARS-CoV-2 variants of regional circulation. This methodology was transferred, free of charge, to research institutes, public hospitals and academic laboratories all around the country, creating a "Nationwide COVID-19 diagnostic laboratory network" where we also trained people. Importantly, in this network we carried out more than 40 % of the tests in our country until August 2020. This kit was also very useful to perform real time genomic surveillance as well as environmental monitoring (waste water and surfaces).

LABORATORY FOR URGENT RESPONSE TO BIOLOGICAL THREATS (CIBU), COLLABORATING FOR HUMAN HEALTH

Set up in 2002, the Laboratory for Urgent Response to Biological Threats (CIBU) is tasked with responding to microbiological emergencies that could pose a threat to human health in the event of epidemics, accidents or terrorist attacks. The CIBU's other missions include developing diagnostic and surveillance tools, training and international operational deployment for emerging diseases. These tasks have translated into numerous collaborations with Pasteur Network teams – all crucially important in battling the global COVID-19 crisis.

The year 2020 marked a period of collaboration and mutual assistance between Pasteur Network members in the fight against coronavirus. Protocols, reagents and positive controls to detect SARS-CoV-2 by RT-qPCR were distributed in cooperation with the Pasteur Network as early as February within the network and in the MediLabSecure network (see sidebar). They helped detect the first cases in a dozen or so countries, including Morocco and Algeria. MediLabSecure also offered training in diagnostics and external quality control of molecular diagnostics of COVID-19. Finally, it provided emergency assistance to institutes that needed it to sequence the first strains and variants of SARS-CoV-2 isolated, leading to new cooperative ventures, for example with the Institut Pasteur de Tunis or the CERMES Niger. The CIBU and the Institut Pasteur d'Algérie

organized training on sequencing with the MinION for a number of network members, including the experts at the Institut Pasteur d'Algérie and the Institut Pasteur de Tunis. The CIBU also provided auditing and consulting services to the laboratory of Virology at the Institut Pasteur d'Algérie, particularly their P3 laboratory. Sanger and MinION sequencing protocols were sent out to the network institutes interested in variant surveillance, with remote technical support. The CIBU also assisted with staff. It sent six technicians and engineers to the Institut Pasteur de la Guyane to work on molecular diagnostics over a nine-week period in mid-2020. Lastly a clinical trial was conducted jointly with the Institut Pasteur de la Guadeloupe to assess a rapid RT-LAMP test for COVID-19, developed through a partnership between the CIBU and industry.



MediLabSecure delivers training in Algeria.

MEDILABSECURE 2 AGAINST COVID-19

As leader of the human virology component of the European MediLabSecure project, the CIBU has supported beneficiary countries' SARS-CoV-2 diagnostic capabilities. The MediLabSecure project seeks to strengthen surveillance networks for emerging vector-borne diseases (transmitted by ticks and mosquitos) in 22 beneficiary countries around the Mediterranean and extending to the Black Sea and Sahel regions (see page 40). The MediLabSecure 2 teams have been directly involved in the SARS-CoV-2 epidemic response from the beginning, through support to national reference laboratories to scale up diagnostic capabilities (sharing protocols, sending primers and reagents, confirming the first diagnostic tests before the first cases were recorded in the country). The MediLabSecure project provided support to strengthen the surveillance and protection capabilities of health care workers through the development of distance learning for hospital-based case management (see web link) and an impact study conducted in hospitals in five African countries (see page 36).

For more information:
https://www.medilabsecure.com/public.aspx?page=covid19_activities_publichealth



INTERVIEW

Melika Ben Ahmed,

Head of the Clinical Immunology Laboratory, member of the Infection Transmission, Control and Immunobiology Laboratory, Institut Pasteur de Tunis

Chaouki Benabdessalem,

Instructor, member of the Infection Transmission, Control and Immunobiology Laboratory, Institut Pasteur de Tunis

How did your laboratory at the Institut Pasteur de Tunis contribute to the COVID-19 response in Tunisia?

As soon as the first cases of COVID-19 were recorded in Tunisia in March 2020, the staff at the Infection Transmission, Control and Immunobiology Laboratory, headed up by Prof. Barbouche at the Institut Pasteur de Tunis responded quickly.

A tripartite agreement between the Institut Pasteur de Tunis, the HKU-Pasteur Research Pole and the Institut Pasteur (Paris) was turned into a program known as "EASI". It was funded – thanks to the generosity of the public – by the call for projects issued by the COVID-19 Task Force of the Institut Pasteur (Paris) and open to Pasteur Network members.

Our program aimed to lay the groundwork for the REPAIR program (see page 30) by developing and validating ELISA serological tests based on the rS-RBD and rN proteins of SARS-CoV-2. One of the two ELISA tests developed was used in a survey of seroprevalence in Tunisia in May 2021, during the country's severe third wave of the pandemic.

10,000 samples were taken across the country and the study found a high degree of heterogeneity between regions. On average nationally, 30% of Tunisians had been in contact with SARS-CoV-2, but some regions were affected far more severely than others.

Can you describe how these tests work?

The Institut Pasteur de Tunis's team first produced large quantities of both the rS-RBD protein in the cell expression system of Sf9 insects and the recombinant N protein in *E. coli*. The team then developed, standardized and validated the ELISA IgG anti-N and anti-S-RBD tests. The tests delivered high performance levels, with a sensitivity and specificity of about 95%. A 10-person team worked non-stop on the project for 10 months during lockdown.

How has collaboration with the members of the Pasteur Network in the REPAIR program (mainly in the Africa region) advanced the development of these tests? What were the benefits of this collaborative effort?

REPAIR is a collaborative project that embodies the network members' commitment to pull together and work in close collaboration, exchanging information and resources to address the challenges of the pandemic. We made our serological tests available to the African partners from the Pasteur Network for them to conduct test validation and for their own sero-epidemiological studies.

The N and S-RBD recombinant proteins, positive and negative serums, anti-IgG human secondary antibodies and the test protocols were sent through the Institut Pasteur to the eight partners that requested them. The team at the Institut Pasteur de Tunis is currently assisting several partners to develop ELISA tests at various sites. A video tutorial was also shared. Five partner institutes (the Institut Pasteur de Bangui, the Institut Pasteur de Madagascar, the Institut Pasteur d'Algérie, the Institut Pasteur de Dakar, and the Pasteur Center in Cameroon) have tested the recombinant proteins and their feedback is positive.

TO BETTER UNDERSTAND SARS-COV-2 IN AFRICA: REPAIR PROJECT

In order to better understand the circulation and transmission of SARS-CoV-2 and its variants the REPAIR project involves all the Pasteur Network's members in Africa. It takes advantage of the environmental, social and economic specificities of each country and each geographical area to understand the impact of the epidemic.

The ten Pasteur Network members in Africa (Tunisia, Algeria, Morocco, Senegal, Ivory Coast, Guinea, Niger, Central African Republic, Cameroon, Madagascar) have set up a collaborative research program named REPAIR (Pasteurian International Research in Response to the Coronavirus in Africa) to better understand the SARS-CoV-2 evolution in the African continent. Coordinated by the Pasteur Network association and supported by the French Ministry of Europe and Foreign Affairs, REPAIR is organized around 5 work packages focused on: the development of diagnostic tests and the assessment of their performance, the study of the molecular epidemiology of the virus, the sero-epidemiological survey of SARS-CoV-2, the mathematical modelling of the viral spread and finally the study of the acceptability of social and public health measures.

DIAGNOSTIC TESTS: A FIRST STEP TOWARDS AUTONOMY IN THE RESPONSE TO OUTBREAKS

Several tests have been developed by the members: a single strand RPA test for the Institut Pasteur de Dakar, an ELISA test for the Institut Pasteur de Tunis and a colorimetric LAMP test for the Pasteur Center in Cameroon. All these reagents are available for the REPAIR consortium members to perform a multicentric evaluation of their performance in the diversity of the African context.



A technician at the Institut Pasteur de Dakar (Senegal) at the machine used to analyze COVID-19 samples.

COORDINATED AND SYSTEMATIC TRACKING OF VARIANTS

Through the shipping of full sequencing equipment and the training for their use, the ten member institutes of REPAIR have been provided with MinIon sequencers allowing the molecular characterization of the epidemic as well as the identification of dangerous variants.

ESTIMATING THE IMPACT OF THE EPIDEMIC ON POPULATIONS

With the geographical, social, economic, and ethnical diversity of the populations studied in these ten countries, it will be possible to better understand the various immune responses according to the infectious history of the individuals. Afterwards, it will be possible to model

the circulation and spread of the virus and correlate it to the peculiarity of the countries. Serological and molecular data will predict, among others, the impact of vaccination on the pandemic

For more information:
See the REPAIR page on the website, pasteur-network.org
<https://pasteur-network.org/en/what-we-do/collaborative-projects/repair/>



INTERVIEW

Dr. Sara Eyangoh,

Head of Science
Pasteur Center in Cameroon

How has the Pasteur Center in Cameroon (CPC) responded to the COVID-19 crisis?

The CPC wasted no time in addressing the crisis. Its response to COVID-19 was up and running on 1 February 2020. Cameroon was thus one of the very first countries in Africa to have the capability to diagnose suspected cases. After a few false positives, the CPC detected the first coronavirus infection (imported from France) on 5 March 2020. To date, there have been more than 81,870 confirmed cases in Cameroon and 1,331 deaths*. The CPC was the only laboratory authorized for PCR testing for the entire country. The workload built up straightaway and, despite 24/7 shifts, there were delays in producing test results and providing patient care. To remedy the situation, the Minister for Public Health assigned the CPC responsibility for decentralizing molecular diagnostics. I was given the role of supervising this activity. Cameroon now has a network of 16 other COVID-19 diagnostics laboratories. But shortages were a constant issue.

How has your center benefitted from working with the Institut Pasteur de Dakar, the WHO Global Reference Laboratory for COVID-19 for the Africa region and the regional lead?

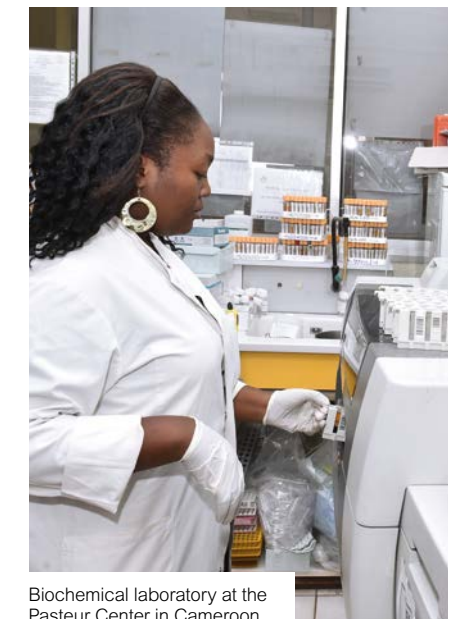
Belonging to the Pasteur Network has been a huge advantage: the Pasteur Center in Cameroon was able to quickly secure supplies of reagents from the Institut Pasteur (Paris) and the HKU-Pasteur Research Pole. On a regional level, staff received training at the Institut Pasteur de Dakar in the early stages of the pandemic. This regional collaboration was essential for staff training, quality control and sequencing of the first cases, and most importantly in the genomic surveillance of COVID-19 variants starting in January 2021, through sequencing of 116 complete genomes that confirmed the circulation of alpha and beta variants.

How did the center implement GeneXpert – normally used to screen for tuberculosis – for COVID-19 diagnostics?

GeneXpert was introduced gradually as there was a limited supply of tests available. The first batch of 5,000 tests received by Cameroon were allocated to the two regions with GeneXpert as their only diagnostic platform. Then supply was extended to the CPC National Tuberculosis Reference Laboratory and to the Regional Tuberculosis Reference Laboratories on the coast and in the north-west. The main limit on the large-scale use of GeneXpert for

COVID-19 diagnostics is the need for a biosafety cabinet, which is not a requirement for tuberculosis applications. Several laboratories that have GeneXpert to detect tuberculosis bacteria cannot use it for COVID-19 testing. The challenge was ensuring continuity of operations while planning the use of the machines.

*As of 5 August 2021.



Biochemical laboratory at the Pasteur Center in Cameroon.

SOUTH-EAST ASIA: RECOGNITION BY LOCAL AUTHORITIES

Geographically close to the initial center of the virus outbreak, Pasteur Network members in South-East Asia rapidly deployed operational support to their national health authorities. They were subsequently designated as national reference laboratories for COVID-19 for their unprecedented mobilization.

The network members in the region lost no time in developing protocols for molecular diagnostics of SARS-CoV-2 to get screening up and running. This was the case for the Institut Pasteur du Cambodge and the Institut Pasteur du Laos, both designated as first-line laboratories for COVID-19 diagnosis by their respective health authorities.

The Institut Pasteur du Cambodge worked closely with the Cambodian Centers for Disease Control and Prevention to report suspected cases, while facilitating data management, reporting and contact tracing alongside its research activities. This commitment resulted in its recognition by the WHO in April as a reference laboratory for COVID-19.

Observing a low number of reported cases of SARS-CoV-2 infection, the health

authorities of Lao PDR have mandated the Institut Pasteur du Laos to perform a seroprevalence study including more than 3,000 participants in order to understand whether there was an undetected circulation of SARS-CoV-2 within the country in 2020. At the same time, the institute has continued its research with, for example a program on the origin and transmission of the virus in the country's wildlife.

For more information:
<https://www.pasteur.fr/en/institut-pasteur/institut-pasteur-throughout-world/news-international/low-number-COVID-19-cases-lao-ptr-seroprevalence-study-confirm-figure>

The three network members in Vietnam – the National Institute of Hygiene and Epidemiology (NIHE), the Institut Pasteur in Ho Chi Minh City and the Institut Pasteur in Nha Trang – were also designated as national reference laboratories for COVID-19.

As such, the NIHE ran several studies on COVID-19, analyzing the first 100 days of control of SARS-CoV-2 in Vietnam, and identifying the factors associated with the length of hospital stay.

Concurrently the Institut Pasteur in Ho Chi Minh-City studied the clinical characteristics and genome sequence of SARS-CoV-2 in the country's first two COVID-19 patients. To cope with the increased workload as a result of reference laboratories designation, specific capacity building initiatives have been put in place with institutional support from backers, in addition to existing programs, such as ECOMORE II (see page 40) to boost their ability to fulfil their mission.

Watch the video:
The Institut Pasteur du Cambodge puts its resources to work to beat COVID-19:
https://www.youtube.com/watch?v=8dgrGjIEcDU&list=PLkkv17ftFIPQT-76TorT47rtNTh9GQI_Y&index=18



The Institut Pasteur du Cambodge laboratory.



INTERVIEW

Leo Poon Lit Man,

Co-Director, HKU-Pasteur Research Pole
Division Head, Division of Public Health Laboratory Sciences,
University of Hong Kong

Can you explain the response developed by the HKU-Pasteur Research Pole for COVID-19 with details of the protocol that you put in place?

Hong Kong is a research hub of emerging infectious diseases. We have extensive experience on zoonotic virus infections (e.g. animal influenza, SARS and MERS). One of our key research focuses is pandemic preparedness. With the effort of the teams of the School of Public Health of the University of Hong Kong, we started working on the implementation of a diagnosis protocol at the beginning of January 2020. Once we were confident enough that the assays were accurate, with evaluation using a panel of positive and negative controls, we started releasing the protocol. We managed to release it to the WHO on 16 January 2020, and then to all countries.

In addition, all teams re-oriented their research activities to contribute to the global effort to understand SARS-CoV-2 and COVID-19, leveraging their expertise in pathogen evolution, genomic surveillance, immune response and collaborating with clinicians to focus on human samples.

If we were to mention just three major advances on COVID-19 made by the HKU-Pasteur Research Pole, what would they be?

Of course, I would mention the development of sensitive molecular diagnostic tests in early January 2020, as well as those for serological studies. We made both platforms freely available to all to participate in the international effort. These tests are key tools for detecting COVID-19 patients and for better understanding of this new disease.

After that, the team led by Chris Mok, in collaboration with the Scripps Research Institute, studied the fine molecular and structural basis of antibody recognition of the Spike protein by the cellular receptor and antibody recognition by the immune system. The key findings reported in these two publications reveal critical differences between the receptor binding domains of SARS-CoV-2 and SARS-CoV that result in cross-reactive, but not cross-protecting antibodies in infected individuals. These observations are very important in the perspective of developing a safe and effective vaccine against SARS-CoV-2 with broad coverage.

Simultaneously, Sophie Valkenburg's team has taken an unbiased approach by obtaining a more complete landscape of antibody responses to a panel of SARS-CoV-2 proteins in COVID-19 patients. They made key discoveries that point to a combination of three viral proteins (termed N, ORF3b and ORF8)

that identify all COVID-19 patients even at early time points after onset of symptoms. This discovery will have many important implications for serology assays, vaccine development and understanding of immune response and pathogenesis.

How was the cooperation with other members of the Pasteur Network organized following the development of your SARS-CoV-2 detection protocol?

We know how important identification is in the early stage so, of course, we shared the protocol to the Pasteur Network members, and other institutes who asked for it. Especially in developing countries, like Cambodia, Vietnam, Madagascar and Senegal, where the network is well-established. We shared our protocols and diagnostic reagents (including controls) with 170 laboratories in 77 countries by end-April 2020. My laboratory also serves as a WHO COVID-19 Reference Laboratory. These all illustrate our leading role in pandemic preparedness.

We kept working with members of the network afterwards, like with the Institut Pasteur de Tunis for the EASI: ELISA Assays development for SARS-CoV-2 project funded by the Institut Pasteur COVID-19 Task Force. It allows obtaining crucial serological data on infection attack rates and assessing the development of population immunity, all essential pillars to estimate disease severity and effectiveness of control measures, which are currently lacking in most places.

COVID-19 HIGHLIGHTS IN 2020

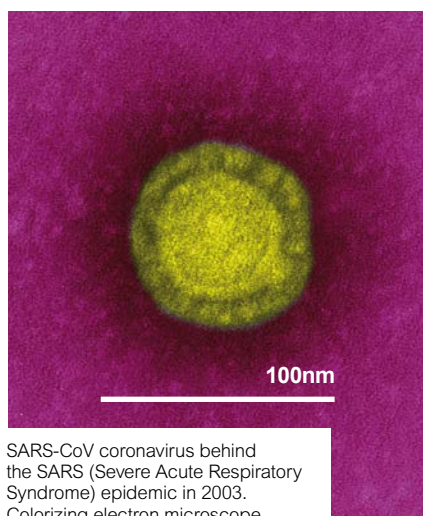
Here is a selection of highlights based on reports from network members. This is not an exhaustive list, but you will find more information on members' websites and in their annual reports.

BRAZIL

THE FIOCRUZ PLAYS AN ACTIVE ROLE IN THE RESPONSE TO COVID-19 IN THE AMERICAS

The Fiocruz, a Pasteur Network member in South America, was designated a WHO COVID-19 Reference Laboratory.

For more information, go to: <https://fiocruz.tghn.org/coronavirus/fiocruz-COVID-19-key-events/>



SARS-CoV coronavirus behind the SARS (Severe Acute Respiratory Syndrome) epidemic in 2003. Colorizing electron microscope.

BRAZIL

ACE2 ROLE IN SEVERE FORMS OF COVID-19

Researchers working with the Scientific Platform Pasteur-USP analyzed more than 700 pulmonary transcriptome samples of COVID-19 patients with comorbidities.

They found a higher expression of ACE2 (angiotensin converting enzyme 2), which is crucial for infection and increases susceptibility to developing more severe forms of the disease.

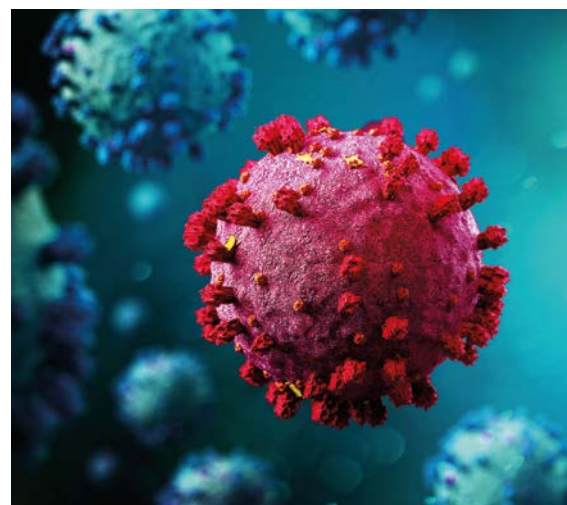
The Journal of Infectious Diseases, June 2020, DOI: 10.1093/infdis/jiaa332

URUGUAY

COMPLETE SEQUENCING OF THE VIRUS TO UNDERSTAND ITS ORIGIN

To understand the strains's origin of the virus circulating in Uruguay, researchers at the Institut Pasteur de Montevideo sequenced the 10 strains found in the country. As the data were compiled, they drew comparisons between local sequences to identify genetic similarities. They found that seven possibly came from Spain.

For more information: pasteur.uy/en/



BELGIUM

ANALYSIS OF WASTEWATER TO MAP THE SPREAD OF THE VIRUS

Driven by Sciensano within the Human Infectious Diseases Direction, the Food Pathogens Department has coordinated the establishment of a network of three wastewater testing laboratories to monitor and map COVID-19 as an early detection system for SARS-CoV-2 circulating in the Belgian population. Detection of variants in wastewater is also under investigation.

For more information: (in French): <https://www.sciensano.be/fr/coin-presse/COVID-19-surveillance-des-eaux-usees>

FRANCE

DIAGNOSTIC TEST FOR PATIENTS

In the second half of January 2020, the National Reference Center (CNR) for viral respiratory infections at the Institut Pasteur developed a test to directly detect SARS-CoV-2 using a molecular biology method known as RT-qPCR. This test was used to diagnose the first patients in France and subsequently rolled out in hospitals. It was the standard to develop other PCR tests in France.

For more information: <https://www.pasteur.fr/en/news-COVID-19>

FRANCE

A "REPOSITIONABLE" DRUG ABLE TO CURB REPLICATION OF THE VIRUS IDENTIFIED

Researchers at the Institut Pasteur de Lille have tested the active ingredients already in use for other diseases that may respond effectively to COVID-19. Their work, in collaboration with APTEEUS, a biotech company, tested more than 2,000 molecules and found one that was particularly effective against SARS-CoV-2. A clinical trial is planned for 2021.

For more information: <https://coronavirus.pasteur-lille.fr/recherche-COVID-19/>



COVID-19 HIGHLIGHTS IN 2020

IN THE REGIONS

RISKS FOR AFRICAN HEALTHCARE PROFESSIONALS

In May 2020, MediLabSecure teams launched a multicentric surveillance and impact study in 4 African countries: Burkina Faso and Niger (members of the MediLabSecure network), Central African Republic and Madagascar (members of the Pasteur Network); a fifth country, Cameroon* (also a member of the Pasteur Network), will participate in the study as well. This study aims to identify the key epidemiological characteristics in the dynamic of infection among healthcare workers in contact with COVID-19 patients when managing the first cases, through a longitudinal follow-up. One of the objectives is to inform Public Health decision-makers on the potential impact of SARS-CoV-2 infection**.

For more information: <https://www.pasteur.fr/en/COVID-19-risk-factors-surveillance-among-healthcare-workers-study-implemented-mediabsecure-project>

* Thanks to the support of the Coronavirus Task Force at Institut Pasteur (Paris) thanks to the generous support of the public.

** Study financed by the European Commission through the EU Instrument contributing to Stability and Peace and the CBRN CoE initiative.

SENEGAL

THE INSTITUT PASTEUR DE DAKAR DESIGNATED A REFERENCE CENTER

The Institut Pasteur de Dakar has been recognized as a regional reference center for sequencing and diagnosis partly thanks to its sequencing platform. This recognition was granted by the WHO as a reference laboratory for COVID-19, but also by the African Center for Disease Control and Prevention (CDC Africa) and the West African Health Organization (WAHO). The Institut Pasteur de Dakar inaugurated its diaTROPIX rapid diagnostic test production platform in November 2020. It is designed to diagnose COVID-19, as well as neglected tropical diseases at affordable prices to resource-limited countries in Africa.

For more information: <https://www.pasteur.sn/en/news/actualite-covid/launch-rapid-diagnostic-test-production-platform-institut-pasteur-dakar>

Watch the video: https://www.youtube.com/watch?v=6UQwDqg_xq4&t=1s



The Institut Pasteur de Dakar, IMI (Immunophysiopathology and Infectious Diseases) Center technicians conducting serological analysis for COVID-19.

CHINA

ANTI-COVID SURFACE COATING

Researchers at the HKU-Pasteur Research Pole and Virginia Tech have demonstrated that a surface coating containing copper oxide bound with polyurethane can inactivate SARS-CoV-2 in an hour, reducing the viral count by 99.9%. The surface coating can be easily applied to common materials such as metal, glass and door handles to reduce the risk of spreading the virus by indirect contact.

ACS Applied Materials & Interfaces, 13 July 2020.
DOI: 10.1021/acsmi.0c11425

LAO PDR

LOW NUMBER OF CASES CONFIRMED BY SEROPREVALENCE STUDY

In 2020 when many countries around the world struggled with a large burden of COVID-19 cases, Lao PDR stood out as a country with low reported numbers of SARS-CoV-2 infections.

Was it due to a low circulation of the virus or to an inadequate surveillance system? To answer this question, a seroprevalence study was conducted by the Institut Pasteur du Laos, in collaboration with the Institut Pasteur (Paris) among 3,000 people in Lao PDR. The results, published in the *Lancet Regional Health - Western Pacific*, showed that there was no unseen circulation of SARS-CoV-2 in Lao PDR in 2020.

For more information: <https://www.pasteur.fr/en/institut-pasteur/institut-pasteur-throughout-world/news-international/low-number-COVID-19-cases-lao-pt-seroprevalence-study-confirm-figure>

KOREA

SCREENING FOR DRUG DISCOVERY

The Institut Pasteur Korea has screened thousands of drugs either on the market or in clinical development to study their potential effectiveness against COVID-19. Two anticoagulants, nafamostat and camostat, used to treat chronic pancreatitis, show potent antiviral efficacy and will enter clinical trials.

For more information: https://www.ip-korea.org/community/release_view.php?page=3&board=press&seq=2838

CAMBODIA

VIDEO: THE INSTITUT PASTEUR DU CAMBODGE MOBILIZED TO COUNTER COVID-19

The WHO designated the Institut Pasteur du Cambodge a WHO COVID-19 Reference Laboratory. See what this means for the Institute's work.

Watch the video: <https://www.youtube.com/watch?v=8dgrGjEcDU&t=6s>



Virologist Narjis Boukli and her colleague Dr. Pharath Lim at work in their laboratory at the Institut Pasteur du Cambodge.

DOPAHYPOCOV PROJECT, TO IDENTIFY AGGRAVATING FACTORS

Scientists are looking into the possibility that a failure of the dopamine pathways may be implicated in severe forms of COVID-19. Indeed, the DopaDecarboxylase (DDC) gene shows a statistically significant coexpression link with the ACE2 locus encoding the SARS-CoV-2 receptor. The DDC enzyme synthesizes dopamine that acts as both a neurotransmitter and an immunoregulator. DDC and ACE2 are both negatively regulated by the lack of oxygen produced by SARS-CoV-2 which leads to inflammation. To study this failure, Niki Vassilaki, a researcher at the Hellenic Pasteur Institute, set up

the DopaHypoCov project as one of the 33 Pasteur Network projects funded by the Institut Pasteur. Her team conducted a study on a cohort of Greek, Moroccan and Vietnamese patients. Four members of the network are taking part in the research, the Hellenic Pasteur Institute, the Institut Pasteur du Maroc, the Institut Pasteur in Ho Chi Minh City and the Institut Pasteur (Paris), together with the National and Kapodistrian University of Athens. The collaborative project aims to identify patients who will require rapid treatment by identifying aggravating factors for the disease as well as discovering new drugs.

AFROSCREEN, TO STRENGTHEN SEQUENCING CAPACITY

The Agence française de Développement (AFD) and the ANRS | Maladies infectieuses émergentes, in partnership with the Institut Pasteur, IRD, and laboratories across 13 African countries, are launching the joint AFROSCREEN project. This project meets an urgent need for surveillance of the development of SARS-CoV-2 variants and other emerging pathogens by bolstering laboratory genomic sequencing capacity. The €10 million program has two main objectives:

- to bolster the sequencing capacity of laboratories in 13 African countries - Benin, Burkina Faso, Cameroon, Ghana, Guinea, Ivory Coast, Madagascar, Mali, Niger, Central African Republic, Democratic Republic of the Congo, Senegal, and Togo;

- to monitor patterns of spread by combining this effort with the implementation of preventive measures to control and limit the circulation of variants. It will run for a two-year period, and should make it possible to carry out approximately 34,000 sequences and 54,000 screening PCR tests, using 25 laboratories.

For more information:

<https://www.pasteur.fr/en/afroscreen-boosting-variant-surveillance-13-african-countries>

* Seven Pasteur Network member sites in the Central African Republic, Ivory Coast, Guinea, Senegal, Cameroon, Niger, Madagascar; six sites in collaboration with IRD in Togo, Democratic Republic of the Congo, Guinea, Cameroon, Benin, Ghana and six sites in collaboration with the ANRS | Emerging Infectious Diseases in Ivory Coast, Mali, Senegal and Burkina Faso.

Share



Beyond the shared Pasteurian values, the members of the Pasteur Network carry out capacity building projects together. They also benefit from international courses, training and mobility programs as well as opportunities for young researchers such as the 4-year Research Groups (G4).

CAPACITY-BUILDING PROJECTS

SHARING EXPERTISE IN THE FIELD

The SARS epidemic in 2006 and Ebola in 2014 made clear the need to strengthen national public health capacity to monitor, control and respond to future emerging or re-emerging epidemics. Thus, network members are collaborating on multi-center programs over several years to develop surveillance and monitoring systems with local actors.

MEDILABSECURE 2

The globalization of transportation, environmental disruptions such as urbanization and deforestation are all factors that favor the emergence and spread of vector-borne diseases. Because mosquitoes and ticks know no borders, the MediLabSecure project strengthens the capacities of 22 countries located around the Mediterranean basin, the Black Sea and the Sahel. The objective is to prevent diseases transmitted by these two insects by strengthening a network of laboratories in human and animal health as well as public health institutions, through a global and unified approach known as One Health. Coordinated by the Institut Pasteur, the project is funded by the European Union as part of the initiative for CBRN centers of excellence. After the launch of the second phase in 2019, including five Sahelian countries, training of experts to strengthen disease detection capacities were organized, advocacy materials for the One Health approach were developed, as well as numerous mosquito identification tools. With its mission to support the prevention of emerging vector-borne diseases, the MediLabSecure project has also quickly mobilized against the COVID-19 pandemic (see pages 28 and 36).



For more information:
<https://www.medilabsecure.com/>

RESER

The national reference centers and laboratories provide expertise in the microbiology and pathology of infectious agents. They play a role in epidemiological surveillance and trigger alerts when they detect the emergence of a pathogen. The pilot phase of the Réseau d'Étude et de Surveillance des pathogènes Émergents (RESER) from 2018 to 2019 sought to bolster bacteriological referencing and surveillance at the national reference centers of nine institutes in the Pasteur Network (Cameroon, Central African Republic, Ivory Coast, Guinea, Madagascar, Morocco, Niger, Senegal and Tunisia). RESER organized training and courses delivered by experts, primarily national reference centers at the Institut Pasteur (Paris). Phase 2 of RESER kicked off in 2020 expanding the program's reach to new countries and new topics, such as emerging antibiotic-resistant bacteria. A course will be held at the Institut Pasteur du Maroc with both theoretical and practical components, followed by *in situ* training by national reference center experts to assess how learning from phase 1 of the project is being applied. Phase 2 is funded by the Pasteur Network association and LabEx.

ECOMORE II

ECOMORE II Project or ECONomic development, ECOsystem MODifications, and emerging infectious diseases Risk Evaluation is funded by the Agence française de Développement (AFD) and coordinated by the Institut Pasteur. Ongoing in five countries in South-East Asia, it brings together the Institut Pasteur du Cambodge, the Institut Pasteur du Laos, the National Institute of Hygiene and Epidemiology in Vietnam, the National Health Laboratory in Myanmar, and the Research Institute for Tropical Medicine in the Philippines. Launched in 2017, this second stage of the One Health project ECOMORE aims to better understand the anthropogenic ecological changes responsible for the emergence of infectious diseases (urbanization, agricultural intensification, land use, population movements) and to measure the health risks for local communities. Strategies have also been put in place to improve patient care and to raise awareness among key players at the national and regional levels.

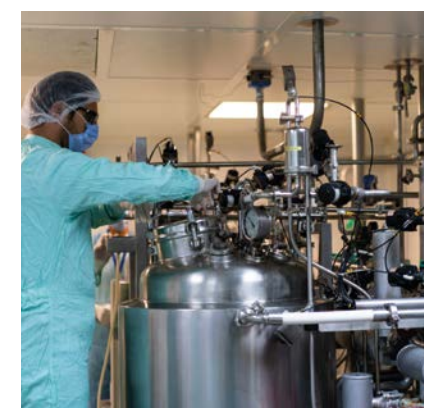


Sony Yean, entomologist at the Institut Pasteur du Cambodge, distributes literature on best practice to prevent dengue.

For more information:
ecomore.org

EBO-SURSY

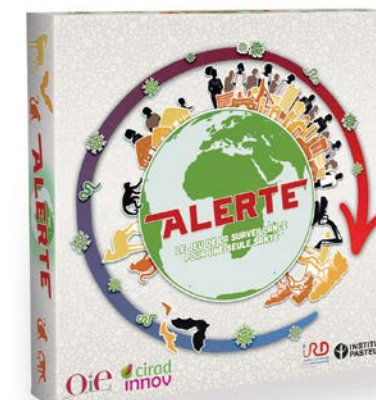
Funded by the European Union since 2017, EBO-SURSY aims to improve the early detection of viral hemorrhagic fevers (VHF), such as Ebola, at the wildlife/domestic wildlife/human/environment interface in ten countries in West and Central Africa,* to assess and prevent the risk of transmission to humans. The three program partners are the Institut Pasteur, the IRD and the CIRAD (French agricultural research and cooperation for development organization) under the leadership of the OIE, the World Organization for Animal Health. Work in the program involves collecting field samples, providing technical and academic training and developing diagnostic tools, all as part of a One Health approach. A course in the theory and practice of One Health was held in Guinea in October 2019, attended by 26 participants from the 10 countries. A Master's program in Immunology/Microbiology** open to students in the sub-region was also set up. The first class (2020) had 11 students in internships in laboratories in Guinea.*** Training delivered by the Institut Pasteur de Guinée and the CIBU included diagnosing Rift



Valley fever virus and Crimean-Congo virus, and biosecurity. Also under this project, third-generation sequencing equipment (MinION, Oxford Nanopore Technologies) was installed at the Institut Pasteur de Bangui. And to encourage community participation, a new educational card game, Alerte, has been developed and deployed on the ground to raise awareness around viral hemorrhagic fever.

For more information:
<https://research.pasteur.fr/fr/project/ebo-sursy-project/>

* Cameroon, Central African Republic, Ivory Coast, Democratic Republic of the Congo, Gabon, Guinea, Liberia, Republic of the Congo, Senegal and Sierra Leone
 ** Collaboration between Université Gamal Abdel Nasser de Conakry (UGANAC) and Montpellier University of Excellence (MUSE)
 *** Institut Pasteur de Guinée, Centre de Recherche et de Formation en Infectiologie (CERFIG), National Public Health Institute (INSP), Donka Hospital.



PHINDACCESS

The Institut Pasteur de Tunis is coordinating PHINDaccess, a partnership program with four leading European scientific institutions: the Institut Pasteur, the Center for Genomic Regulation (CRG), the Max Planck Institute for Molecular Genetics (MPG) and the Robert Koch Institute (RKI). Funded by the European Commission's Horizon 2020 (H2020), the aim of PHINDaccess is to develop optimized surveillance tools to improve the control of infectious diseases in Mediterranean countries, like tuberculosis and re-emerging viral diseases. The Institut Pasteur de Tunis is aiming to become a center of excellence in Omics research.

To advance this goal, the project's work packages range from expert missions to communication and dissemination of scientific results and training. Omics research involves the whole gamut of biological sciences whose names end in the suffix *omics*— genomics for DNA molecules, proteomics for proteins and transcriptomics for RNA molecules. Vital for deepening scientific understanding of organisms, this field of research combines systematic biological analysis and multidisciplinary studies of molecules.

For more information:
<http://phindaccess.org/>

TRAINING AND MOBILITY IN THE PASTEUR NETWORK

The Pasteur Network encourages men and women in the international scientific community to take part in training and improve their scientific skills throughout their careers. Through training and programs to promote mobility, they reinforce their long-term commitment to public service.

A COMMITMENT TO KNOWLEDGE

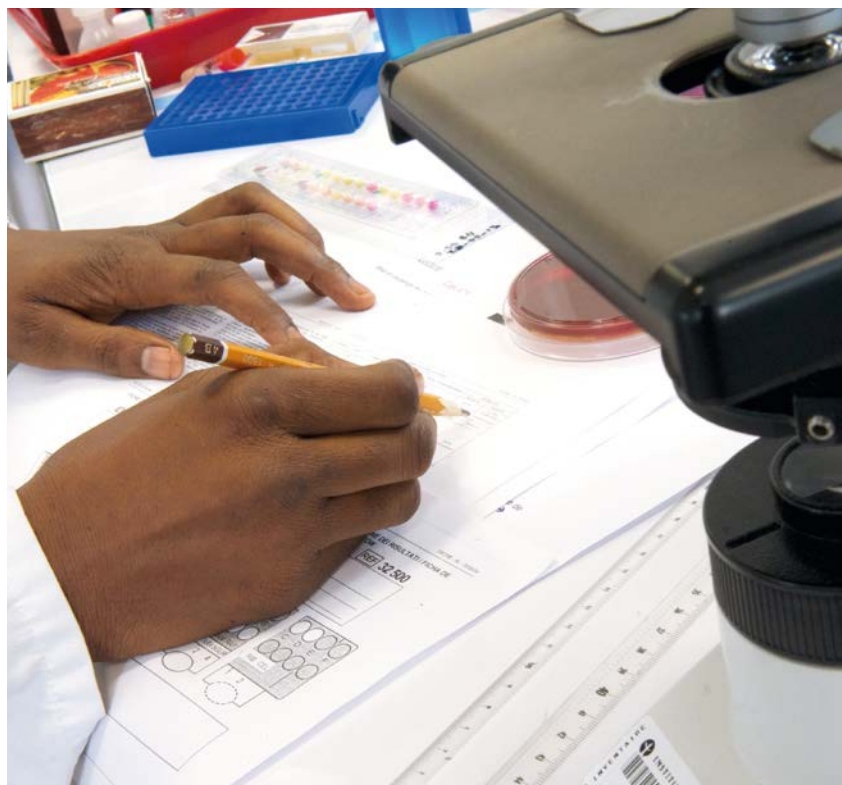
Reiterated as a priority in its strategic plan, training is a key part of the actions pursued by the Institut Pasteur, which finances some Pasteur Network programs. Trainings are available to students, experienced researchers and technicians, and are delivered in special centers in the network: Cameroon, Niger, Ivory Coast, Cambodia, Korea and Montevideo etc. It can take several forms, including internships, courses, thesis funding and seminars led by network scientists. Continuous professional training is a key ingredient in building the scientific capacities of the Pasteur Network.

A COMMITMENT TO MOBILITY

The opportunity to take up positions in other countries is a major asset of the network. Dedicated mobility programs allow the staff members to move around within this global network, thereby reinforcing the exchange of skills.

CONCRETE COMMITMENTS

These two commitments, turned into actions, strengthen the capacities of the Pasteur Network each and every year. They are confirmed by ever increasing figures (see graph opposite).

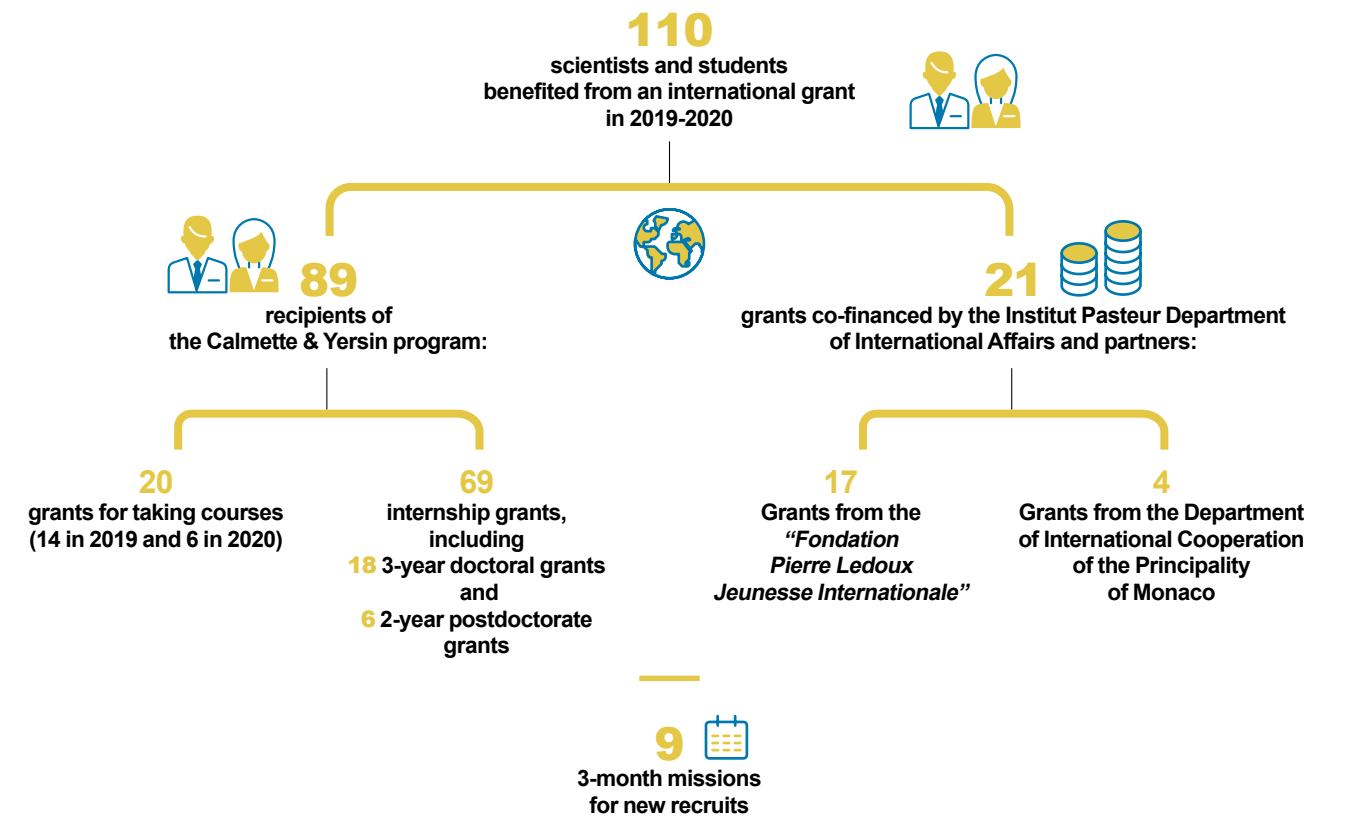


Medical bacteriological course at the Institut Pasteur Department of Education.

Training programs and mobility opportunities

- Pasteur Network international courses**
 About 10 courses are selected and funded every year in the network by the Pasteur Network association.
- Calmette & Yersin program**
 It funds grants for short (internships and study) and long (doctorate and post-doc) mobility.
- Grants "Fondation Pierre Ledoux Jeunesse Internationale"**
 This is a partnership between the Fondation de France and the Institut Pasteur for French students, funding biomedical research internships within a Pasteur Network member located in more limited resources country.
- Mission of the new Pasteurians within the Pasteur Network**
 Initiated by the Institut Pasteur in 2014, this program offers the opportunity for each newly recruited researcher to carry out a three-month scientific mission within a member of the Pasteur Network.

KEY FIGURES



SCIENCE SHOP AT THE INSTITUT PASTEUR DE TUNIS

The "Science Ensemble" Science Shop at the Institut Pasteur de Tunis was set up in 2017 as part of the European InSPIRES program, "Ingenious Science shops to promote Participatory Innovation, Research and Equity in Science".

It is a device that takes place within universities or research institutions to co-construct research projects with local associative actors in order to meet the needs expressed by civil society.

The aim is to come up with innovative solutions to social problems in the areas of health, the environment and vulnerable populations.

These outcomes will be used by associations to develop their advocacy with decision-makers.

The structure relies on volunteer students and gives them the opportunity to work on a specific social need through research in collaboration with non-profits.

Organizations submit their needs through an annual online submission. A selection committee made up of scientists, civil society representatives and the "Science Ensemble" team then selects projects.

Since 2017, "Science Ensemble" has coordinated 10 collaborative projects, including two cross-border and cross-cutting projects, on a wide range of issues or diseases such as: health risks for scavengers, perception of stigma experienced by people living with HIV, development of type-2 diabetes and high blood pressure in rural areas or early detection of hearing disorders in children.

For more information:

http://www.pasteur.tn/index.php?option=com_content&view=article&id=748&Itemid=8

PASTEUR NETWORK INTERNATIONAL COURSES

Training is a core mission of the Pasteur Network and every year courses are held in different network countries, funded by the network association. These international courses are selected for their scientific excellence in order to train the staff of the network members.

Here is the list of courses selected in 2019 and 2020. Courses that had been planned for 2020 were rescheduled to 2021 because of the pandemic.



2019

COURSE TITLE	ORGANIZER(S)	LOCATION
Systèmes d'information géographique appliqués à l'épidémiologie: introduction au logiciel QGIS 2. Analyses multicritères spatialisées: application en santé	F. Rakotomanana	Institut Pasteur de Madagascar
Vector Insects and Transmission of Pathogen Agents	AB. Failloux	Institut Pasteur du Laos
Third International Course on Viruses and Human Cancer	JP. Vartanian	Institut Pasteur in Italy – Cenci Bolognetti Foundation
Workshop on Surveillance and Control of Rabies	H. Bourhy	Institut Pasteur du Maroc
International Ethical standards applied to biomedical research	S. Ouchhi	Institut Pasteur de Tunis
Genome editing in mammals using CRISPR tools	M. Crispo	Institut Pasteur de Montevideo
Redox Chemistry and Biology of Thiols	M. Comini	School of Medicine, School of Chemistry and School of Science, Universidad de la República, Montevideo

2020

COURSE TITLE	ORGANIZER(S)	LOCATION
Bactériologie et santé publique	P. Martin/M. Lago	Institut Pasteur du Maroc
Proteome Analysis by Mass Spectrometry	R. Duran	Institut Pasteur de Montevideo
HKU-Pasteur Cell Biology Course	R. Bruzzone	HKU-Pasteur Research Pole
Data analysis using Stata	Y. Madec	National Institute of Hygiene Epidemiology, Hanoi
Second workshop on translational venom medicine challenging human envenoming issues – exploring & exploiting snake & scorpion venoms & antivenoms	N. Oukkach	Institut Pasteur du Maroc
The business of managing science: Scientific Management and Leadership skills for IPIN Scientific Research Infrastructures	S. Shorte	Institut Pasteur Korea
Visualization for Data Science (ViDi)	F. Guerfali	Institut Pasteur de Tunis
The First International Course on Molecular Cancer Genetics	JP. Vartanian	Institut Pasteur in Italy – Cenci Bolognetti Foundation
Identification et Suivi épidémiologique des Résistances aux Antibiotiques	L. Wakrim	Institut Pasteur du Maroc
Metagenomics and Health	S. Hamdi	Institut Pasteur du Maroc
Appui des sciences sociales dans la préparation et la réponse aux dimensions sociales des épidémies	C. Mattern	Institut Pasteur de Madagascar

PIC LABEL, THE MARK OF EXCELLENCE FOR TRAINING PROGRAMS

It is essential to keep strengthening the Pasteur Network scientific and medical community's access to the most advanced and up-to-date knowledge in their field while always meeting Pasteurian values. Especially as research accelerates and global health challenges become more complex. Thus, the certification of the Pasteur Network's workshops, training courses and MOOCs by the Pasteur International Courses – or PIC label – guarantees the excellence and expertise of these training programs.



In 2019, the Pasteur Network association and the Institut Pasteur launched the official Pasteur International Courses (PIC) label through its departments of Education and International Affairs. The label certifies the training programs, workshops and MOOCs (Massive Open Online Courses) in the network.

laboratory technicians and professionals. The label will also contribute to valorize the trainees who followed these courses. In practice, courses that apply for the PIC label are submitted to an external panel for evaluation. The first pre-labellations began in September 2021, preparing the global health leaders of tomorrow.



Researchers at the HKU-Pasteur Research Pole.

All the training provided under this unique label meets the same world-class standards. It certifies the quality standards and requirements specific to the Institut Pasteur, which are essential for preparing students and scientific or medical staff for the new public health challenges.

The PIC label guarantees not only the excellence of the topics covered in the courses, but also the high quality of procedures to recruit participants, as well as of the supervision, infrastructure, the partnerships created and final evaluations.

Training courses carrying this quality label may also attract students and researchers at all stages of their career, as well as

For more information:
pasteur-network.org/en/what-we-do/pic-label/



4-YEAR RESEARCH GROUPS (G4), AN OPPORTUNITY FOR YOUNG SCIENTISTS

4-year Research Groups (G4s) are an initiative of the Institut Pasteur to foster promising talent through research projects funded over four years. To this end, the G4s aim to enable young scientists to establish themselves permanently within a member of the Pasteur Network.

An opportunity for young researchers with international post-doctoral experience, G4s are selected on application, following an international call for applicants. This program offers emerging talent seed funds and the dynamic environment to build their research project around a competitive team in the network. Three researchers have been given positions in their host institute and developed their research team since the program was launched.

For more information:
pasteur.fr/en/education/fellowships-and-mobility-aids/4-year-research-groups-riip



Stem cell and development unit laboratory
Miria Ricchetti, Group Leader and young
post-doctoral researcher.

Jean-Pierre Peron
G4 2019-2023
Scientific Platform Pasteur-USP/
Arbovirus neuroimmunology

Amy Bei
G4 2019-2023
Institut Pasteur de Dakar/
Evaluating access to a candidate
vaccine in West Africa

Gary Wong
G4 2018-2022
Institut Pasteur of Shanghai –
Chinese Academy of Sciences/
Strengthened cooperation
in the field of emerging
and infectious diseases

Tineke Cantaert
G4 2015-2019
Institut Pasteur du Cambodge/
Immunology research group

Cheikh Loucoubar
G4 2015-2019
Institut Pasteur de Dakar/
Biostatistics, bioinformatics
and modelling



INTERVIEW

Amy Bei,
Institut Pasteur de Dakar

G4 “Assessing access to candidate
vaccines in West Africa”

What kind of opportunity does a G4 give a scientist at the start of their career?

The G4 program is a great opportunity to begin a career as an independent researcher within the Pasteur Network. One of the challenges of being an early-career researcher is making the transition from a post-doc to a group leader – especially when it comes to getting independent funding to help recruit and build a team and support a research program. One of the amazing benefits of the G4 program is that it funds the creation of an independent group while also making it part of the host institution and the Pasteur Network. This balance between independence, integration and collaboration is a very attractive proposition. A G4 also encourages collaboration and multidisciplinary, cross-cutting approaches. This environment has helped to establish our research agenda while also creating new opportunities for collaboration and fascinating research avenues.

What is your background and how does the G4 fit in?

My training is in parasitology, in particular the genetics and genomics of malaria parasites, with an emphasis on the use of experimental genetics to gain insight into the main processes that influence virulence: parasite invasion, drug resistance and immune escape. Our main G4 project aims to understand how the genetic diversity of vaccine candidate antigens influences vaccine efficacy. We use field approaches combined with laboratory methods to understand how specific mutations influence parasite invasion and immune evasion, whether the antibodies are naturally acquired or vaccine-induced. In the G4 program, I have been able to bring these

unique aspects of malaria research to the dynamic and world-renowned Institut Pasteur de Dakar, which has long been recognized for its contributions to malaria epidemiology and entomology. Starting a research group concentrating on combining *Plasmodium* genomics, experimental genetics and malaria vaccinology in Africa really is a dream come true.

How did you put together your research team?

I have always enjoyed doing science in a “team” atmosphere. So, I’m looking for young African scientists who are committed to making a difference in Africa. Young people who are creative

and innovative, who are not afraid to think outside the box, who want to work together to solve the many challenges we face – both scientific and logistical. On our G4 team we have researchers with a wide range of experience: technicians, interns, master’s students, PhDs and post-doctorates. I am extremely fortunate to have such talented, passionate and dedicated young African scientists on our team working to improve understanding and treatments for malaria in Senegal and around the world.




Assessing access to candidate vaccines in West Africa G4,
headed up by Amy Bei.

PASTEUR NETWORK TALENT AWARDS

The "Pasteur Network Talent Awards" recognize, support and encourage career development for talented researchers with the potential to become science leaders in the Pasteur Network. The €10,000 award is given to two researchers selected each year by the awards panel. In 2019 and 2020, the Pasteur Network Talent Awards went to:

- Dr. Paulo Carvalho, researcher at the Institut Carlos Chagas, Fiocruz (2019)
- Dr. Oumar Faye, researcher in the Virology department at the Institut Pasteur de Dakar (2019)

- Dr. Roman Thibeaux, researcher in the Unit for Research and Expertise in Leptospirosis at the Institut Pasteur de Nouvelle-Calédonie (2020)
- Dr. Sophie Valkenburg, assistant research professor at the HKU-Pasteur Research Pole (2020)

 **For more information:**
<https://www.pasteur.fr/fr/international/pasteur-network-talent-award>




2019 Talent Awards ceremony at the Directors' meeting in Yaoundé, Cameroon.

PHD CEREMONY

Since 2013, the Institut Pasteur has held an annual ceremony honoring the campus' PhD students who have successfully defended their science thesis during the year.

The event is both solemn and festive and all the Institut Pasteur staff are invited, together with representatives of partner organizations and students' guests. After the conference opening, the

graduates are all asked to introduce themselves and say a little about the subject of their thesis. They are then presented with an Institut Pasteur certificate marking their achievement. The ceremony ends with a relaxed gathering for the Pasteurian scientists. In 2019, 4 scientists from the Pasteur Network (outside Paris) attended and 9 in 2020.

 **For more information:**
<https://www.pasteur.fr/en/education/programs-and-courses/doctoral-and-post-doctoral-programs/ceremony-newly-graduated-students>



Innovate



Scientific platforms, tools and incentives foster collaboration and innovation across the Pasteur Network, furthering world class research built on the human and technical expertise of the network's members.

INNOVATIVE TECHNOLOGICAL TOOLS

To fulfil its missions for the benefit of the populations, the Pasteur Network harnesses extensive technological expertise. Scientific platforms or innovative tools distributed across the network encourage technical collaboration between members in order to optimize and share resources for the advancement of science.

THE “OMICS” SPACE, A TOOL TO PROCESS RESULTS

The “Omics” center consists of two facilities, the Biomics hub and the Department of Computational Biology giving the Pasteur Network big data capability. Mathematical modeling, statistics and computer science are all subjects dealt with by this multidisciplinary and transversal department. Working jointly with members of the Pasteur Network, its “bioinformatics and biostatistics hub” is consulted as a reference platform in bioinformatics, in addition to the training courses that are provided around the world, such as the one that took place in October 2019 at the Institut Pasteur d’Algérie.

For more information:

- <https://www.pasteur.fr/en/our-missions/research/departement-computational-biology>
- <https://www.pasteur.dz/fr/vie-scientifique-pasteur/actualite/268-cours-d-introduction-a-la-bio-informatique>



External view of the Institut Pasteur Korea.



Anopheles darlingi larvae bred at the Institut Pasteur de la Guyane Vectopole.

MOBILE LABORATORIES, A TOOL TO GET TO HARD-TO-REACH PLACES

Inaugurated on September 19, 2019, the mobile laboratory operated by the Institut Pasteur de Madagascar was funded by the United States Agency for International Development (USAID). It is especially valuable for monitoring malaria, plague and measles. This type of fully equipped and independent facility is used for on-the-ground testing and research to improve surveillance and epidemic response capability.

For more information:

<http://www.pasteur.mg/santepublique-inauguration-du-laboratoire-mobile-de-linstitut-pasteur-demadagascar/>



At the height of the COVID-19 crisis, the Institut Pasteur de Madagascar stepped up its activities with the creation of a mobile laboratory to reach isolated areas.

SCREENING PLATFORMS TO DISCOVER NEW DRUG CANDIDATES

Screening platforms help to identify molecules and new drug candidates to treat studied pathologies. The elucidation of pathological mechanisms is also possible thanks to numerous tests performed by these techniques involving the simultaneous reaction between a large number of molecules (over 500,000) and cell cultures. For example, the Institut Pasteur Korea and the Institut Pasteur de Lille both have screening units.

For more information:

- https://www.ip-korea.org/RDP/lab_screening.php
- <https://pasteur-lille.fr/centre-de-recherche/plateformes-technologiques/>

VECTOPOLE, A TOOL TO STUDY VECTOR INSECTS

The Émile Abonnenc Amazonian Vectopole at the Institut Pasteur de la Guyane carried out molecular taxonomy and surveillance as part of its study of vector insects. It seeks to gain insights into the mechanisms of action and behavioral changes in mosquitos that carry arboviruses.

In Paris, a vector-borne diseases research hub will open in 2025 to improve preparedness for epidemics and face them by conducting research spanning microbiology, virology and parasitology.

For more information:

- <https://www.pasteur-cayenne.fr/la-recherche/nos-equipements/ue/vectopole/>

SEQUENCING PLATFORMS TO READ GENOMES

The network holds various tools for the essential work of genome sequencing, including NGS and MinION at the Omics hub and at other member facilities. In particular, the ten African institutes have been equipped, within the framework of the REPAIR project (see page 30), with MinION sequencers, allowing the molecular characterization of the SARS-CoV-2 virus, during its diffusion in time and space and the tracking of dangerous variants. For instance, the Institut Pasteur in Dakar is a recognized regional sequencing platform for COVID-19.

For more information:

- <https://pasteur-bangui.org/8-novembre-2019-implementation-a-linstitut-pasteur-de-bangui-dun-sequenaceur-a-haut-debit-de-troisieme-generation-le-minion-dont-analyse-de-lapport-de-cette-technologie/>



Working on a 3G, high-throughput sequencer, the ONT MinION, at the Institut Pasteur de Bangui.

PIBNET, A BIO-RESOURCE SHARING TOOL

Born out of the ambition to combine micro-organism collections with their analysis methods, PIBnet is a project that brings together the Institut Pasteur and Pasteur Network expert laboratories. Pasteur International Bioresources Network is a collaborative program that involves many different entities for sharing biological data in the interests of public health, biological research and for industrial applications across the network.

For more information:

- https://research.pasteur.fr/en/program_project/pibnet-pasteur-international-bioresources-network/

HAL-RIIP, TO SHARE KNOWLEDGE

HAL-RIIP is an open archiving system for published and unpublished work for Pasteur Network members. The open access platform is designed to make it easier for members to share knowledge. It is connected to HAL, the French multidisciplinary open archive. Opened in 2009, the archive enables scientists to provide access to their work and to file it freely (scientific papers, theses, conference reports, book chapters and more).

For more information:

- <https://hal-riip.archives-ouvertes.fr/>

ACIP & PTR, CALLS FOR INCENTIVE PROGRAMS

Aimed at scientists from the Institut Pasteur and the Pasteur Network, the Inter-Pasteurian Concerted Actions (ACIP) and the Transversal Research Programs (PTR) are annual calls for projects managed by the Department for Scientific Programming and Incentive Actions (SPAIS) from the Institut Pasteur (Paris). Included in the Institut Pasteur's strategic plan, these incentive programs aim to encourage and strengthen scientific collaboration between Pasteurian teams.

From December to February every year, Pasteur Network members can submit their research projects to the Institut Pasteur's Department for Scientific Programming and Incentive Actions. Selected programs receive funding for two years, from 1 October of the year they were submitted.

ACIP, ENCOURAGING COLLABORATION

The main aim of Inter-Pasteurian Concerted Actions (ACIP) is to set up new collaborative projects by strengthening links between Pasteur Network teams, especially in the field of public health.

Projects submitted under this program must explore innovative scientific hypotheses to obtain preliminary results with the potential to lead to bolder and more ambitious prospects.

PTR, PROMOTING MULTIDISCIPLINARY AND AMBITIOUS RESEARCH PROJECTS

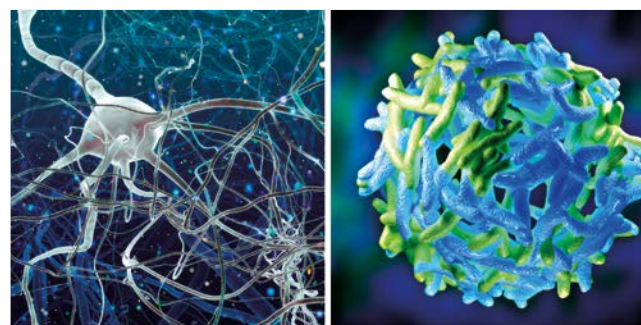
Transverse research programs (PTR) encourage the development of multidisciplinary, innovative and ambitious research projects which leverage cutting-edge technologies. These Institut Pasteur funding tools promote synergies to strengthen collaboration and further the careers of young scientists.

For more information:
<https://www.pasteur.fr/en/international/international-calls/incentive-programs>

34 projects funded, including:

> **12 ACIP**

> **22 PTR**



INTERVIEW

Teca Galvao,

Scientific coordinator of ACIP 358-2020: Evolution of regulatory interactions through the lens of antibiotic selective pressure (EvoSP), Functional Genomics and Bioinformatics Laboratory, Fiocruz

What reasons prompted you to apply for ACIP funding?

Antibiotic resistance is a serious emerging public health threat, and some estimates project that by 2050 more people will die from bacterial infections than from cancer. Research for understanding resistance is essential for the development of new treatments and control initiatives: understanding the problem is part of the solution. It is not known how bacteria resistant to polymyxins, a last resort class of antibiotics, can survive. Together with Ariel Mechaly, an expert on the proteins involved in polymyxin resistance at the Institut Pasteur (Paris), and Ana Paula Assef from the Fiocruz, whose laboratory is part of the Brazilian resistance surveillance network, we set out in a collaboration to discover the molecular details that enable survival in the presence of these antibiotics. Early results were exciting and ACIP funding seemed like an excellent way to ensure the project could be carried out.

How did you design your project?

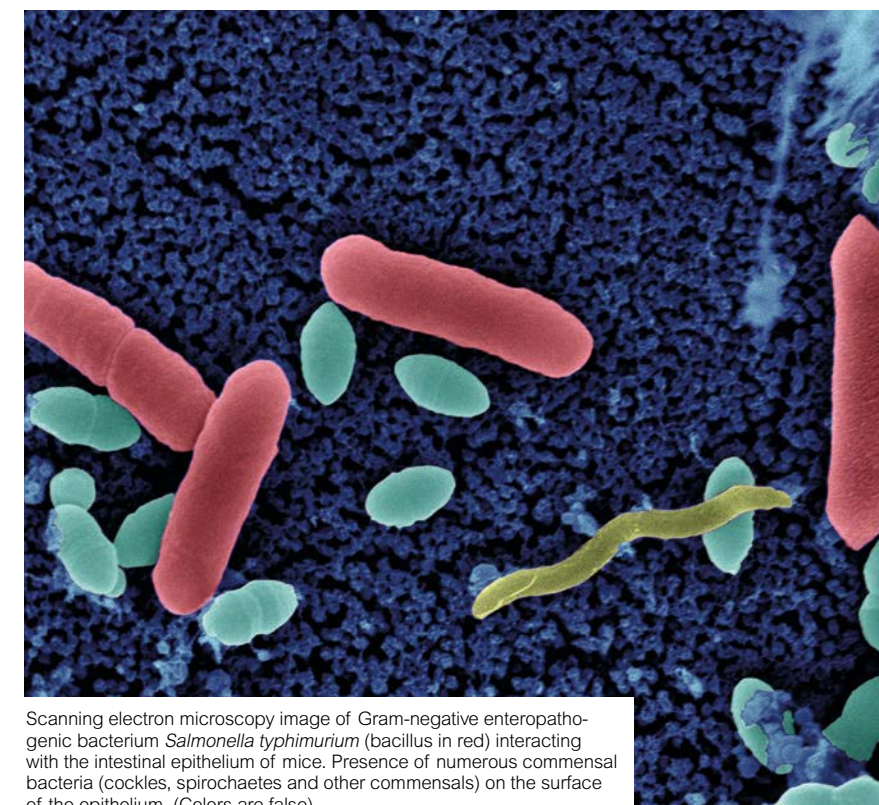
Just like in a population of people, there is diversity in a population of bacteria. So if a single bacteria in a patient has a change, a mutation, that gives it a greater chance to survive, then it will be selected, over other, susceptible, bacteria. In bacteria resistant to polymyxins, the mutations happen in proteins that we know have mechanisms for capturing and transmitting signals by associating changes in their structure and stability to their activity. It is assumed that the mutations change these proteins' behavior and lead to resistance, but – how? Given the powerful techniques available, it was clear that studying how the mutations change activity, structure, and stability

would reveal the mechanisms of resistance as well as give insights into how these proteins function.

How does collaboration with other members of the Pasteur Network contribute to your project and your team?

My team aims to understand how mutations in certain proteins make bacteria resistant to antibiotics. This work is connected to the Fiocruz's mission to serve the public health system as the mutations studied come from bacteria isolated from

patients in points of care, and may reflect lineages widespread across Brazil or even the world. The teams in this ACIP project are experts in looking at comparing the properties of the normal and mutant proteins, such that we can understand what antibiotics and evolution have done to them. The teams at the Institut Pasteur (Paris) and the Institut Pasteur de Montevideo master techniques for taking snapshots (X-ray crystallography and HDX-MS) or "short videos" (NMR) of proteins, showing different poses that reflect activity. These methods will reveal how these molecular machines change activity and structure, yielding resistant bacteria.



Scanning electron microscopy image of Gram-negative enteropathogenic bacterium *Salmonella typhimurium* (bacillus in red) interacting with the intestinal epithelium of mice. Presence of numerous commensal bacteria (cockles, spirochaetes and other commensals) on the surface of the epithelium. (Colors are false).

PIUs, COLLABORATIVE INTERNATIONAL RESEARCH

Pasteur International joint research Units (PIUs) are virtual research units involving up to three international teams, with at least one based at the Institut Pasteur. Over a five-year period, their aim is to strengthen partnerships with leading scientific institutions and boost their profile through both the quality of the scientific research and ability to raise substantial funding.

Built around scientific projects selected through a call for projects, these international units leverage the teams' complementary expertise to raise national or international funding for joint research. They are led by experienced researchers and facilitate the mobility of scientists from each partner structure, while also paving the way towards more dialog with local universities and research institutes.

For more information and to download an application:
<https://www.pasteur.fr/en/international-international-calls/pasteur-international-joint-research-unit-piu>

CURRENT PIUs

Since 2016

Malaria Translational Research Unit (MTRU)

Evolution and adaptation of *Plasmodium* parasites to their host.

- Jean-Christophe BARALE, Institut Pasteur (Paris) and
- Benoît WITKOWSKI,
- Didier MENARD, Institut Pasteur du Cambodge.

Integrative Microbiology of Zoonotic Pathogens Unit (IMiZA)

Leptospirosis and the persistence of leptospires in the environment.

- Mathieu PICARDEAU, Institut Pasteur (Paris), and
- Alejandro BUSCHIAZZO, Institut Pasteur de Montevideo.

Inflammation and Leishmania Infection Unit (InfleLeish)

Study of interactions between *Leishmania* parasites and their host.

- Gérald SPAETH, Institut Pasteur (Paris) and
- Guangxun MENG, Institut Pasteur of Shanghai – Chinese Academy of Sciences.

Vaccinomics Unit

Understanding the immunological mechanisms involved in heterogeneity of vaccine response.

- Anavaj SAKUNTABHAI, Institut Pasteur (Paris), and
- Fumihiko MATSUDA, Kyoto University, Japan.

Since 2017

Artificial Virus Evolution Unit (AVENUe)

Study of the natural evolution of viruses with synthetic biology.

- Marco VIGNUZZI, Institut Pasteur (Paris), and
- Benjamin TENOEVER, Icahn School of Medicine at Mount Sinai, United States.

Since 2018

Mucosal Immunomics Laboratory (MIL)

Genetic, environmental and local microbiome factors involved in respiratory immune response.

- Lars ROGGE,
- James DI SANTO, Institut Pasteur (Paris) and
- Ken ISHII, Institute of Medical Sciences at the University of Tokyo (IMSUT), Japan.

Since 2021

Emergence, persistence and spread of plague

Understand how *Yersinia pestis* evolves and compare how it interacts in different hosts in Madagascar to find out when and how new clones can emerge.

- Javier PIZZARO-CERDA, Institut Pasteur (Paris),
- Florent SEBBANE, Institut Pasteur de Lille,
- Minoarisoa RAJERISON and
- Mireille HARIMALALA, Institut Pasteur de Madagascar.

Neurodegenerative diseases

Pathogenic mechanisms and Parkinson's Disease.

- Chiara ZURZOLO, Institut Pasteur (Paris) and
- Rebecca MATSAS, Hellenic Pasteur Institute.

Artificial intelligence for image-based drug discovery & development (Ai3D)

Developing innovative methods based on AI/machine-deep learning technologies for drug discovery.

- Christophe ZIMMER, Institut Pasteur (Paris) and
- Spencer SHORTE, Institut Pasteur Korea.



INTERVIEW

Chiara Zurzolo,

Laboratory of Membrane Traffic and Pathogenesis, Department of Cell Biology & Infection, Institut Pasteur (Paris)

Rebecca Matsas,

Laboratory of Cellular and Molecular Neurobiology – Stem Cells, Department of Neurobiology, Hellenic Pasteur Institute

PIU “Study of the pathogenic mechanisms and the spread of Parkinson’s disease”

What is your joint scientific project?

Neurodegenerative diseases affect millions of people worldwide with increasing incidence as the population ages and therefore constitute a major area of concern. Therapies that stop or slow disease progression are still lacking, mainly due to incomplete understanding of the underlying mechanisms, particularly those that occur early and are potentially initiating. This is an important issue considering that most neurodegenerative conditions have a long prodromal phase before symptoms are manifested. Our project aims to investigate such early cellular and molecular mechanisms that eventually lead to neurodegeneration, using the paradigm of Parkinson's disease (PD). To this end, we will take advantage of patient-derived induced pluripotent stem cell-based models that display disease-associated phenotypes, such as protein aggregation, defective synaptic connectivity and axonal neuropathology. We will investigate not only neuronal pathology, but also neuron-glia interactions, particularly the protective or detrimental role of astrocytes in pathology.

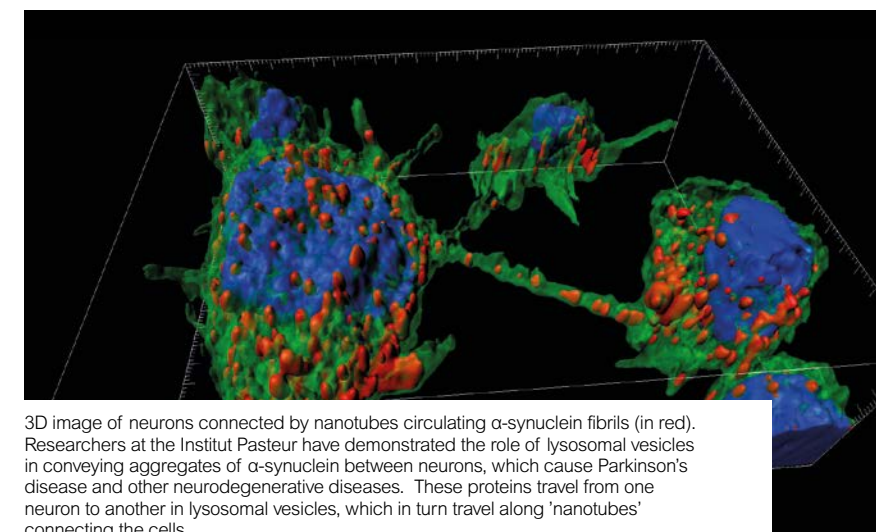
How does the creation of a PIU meet your expectations for this collaboration?

Chiara Zurzolo's laboratory at the Institut Pasteur (Paris) focuses on understanding fundamental cell biology processes, such as protein sorting and intracellular trafficking in neuronal cells, and on elucidating the mechanisms of protein and organelle exchanges between cells, with the aim of understanding how these pathways are altered in and contribute to

the pathogenesis of neurodegenerative diseases. Rebecca Matsas' laboratory at the Hellenic Pasteur Institute has applied cell reprogramming technologies to create patient-derived induced pluripotent stem cell-based models of PD, both 2D cellular systems and 3D brain organoids, aiming to understand early events in neurodegeneration. Creating synergies by combining resources and expertise, the two teams wish to understand how protein misfolding and propagation occurs in Parkinson disease. They try to figure out whether this is a triggering event or the consequence of broader cellular dysfunction at multiple levels. The PIU enhances their collaboration towards accelerating the development of novel tools and the discovery of new findings, assists in identifying gaps, multiplies impact and enhances visibility.

How are scientific exchanges organized within your “virtual” research unit – or PIU – and how important are they to your research project?

Due to restrictions posed by the COVID-19 pandemic and institutional lockdown at both ends, scientific exchanges have so far taken place through virtual meetings. Entering the next phase whereby laboratories will be fully functional, we envisage exchanges of young post-doctoral fellows and students that will travel for mutual transfer of technology and scientific expertise as well as access to available infrastructure. This is an important aspect for the success of the PIU.



3D image of neurons connected by nanotubes circulating α -synuclein fibrils (in red). Researchers at the Institut Pasteur have demonstrated the role of lysosomal vesicles in conveying aggregates of α -synuclein between neurons, which cause Parkinson's disease and other neurodegenerative diseases. These proteins travel from one neuron to another in lysosomal vesicles, which in turn travel along 'nanotubes' connecting the cells.

PARTNERS AND CONTRIBUTORS, VITAL SUPPORT FOR THE PASTEUR NETWORK

Ongoing collaborations, partnerships and support are essential for the members. They also help the Pasteur Network's work to thrive and flourish. Here are some examples from around the world.

MINISTRIES AND GOVERNMENT AGENCIES IN FRANCE AND ABROAD

- Chinese Academy of Sciences (CAS)
- African Academy of Sciences (AAS)
- Agence française de développement (AFD)
- Agence nationale de la recherche (French National Research Agency, ANR)
- French National Agency for Research on AIDS and Viral Hepatitis | Emerging Infectious Diseases (ANRS | MIE)
- Japanese International Cooperation Agency (JICA)
- Africa Centers for Disease Control and Prevention (Africa CDC)
- American Centers for Disease Control (CDC)
- Assistant Secretary for Preparedness and Response within the Department of Health and Human Services (ASPR/DHHS)
- Expertise France
- French Ministry of Europe and Foreign Affairs (MEAE)
- French Ministry of Higher education, Research and Innovation (MESRI)
- US Agency for International Development (USAID)
- Department of International Cooperation, Government of the Principality of Monaco
- Ministries of Health and Research in the host countries of Pasteur Network members

RESEARCH INSTITUTIONS

- All Aviesan member institutions
- Center national d'études spatiales (French National Space Center, CNES)
- Griffith University (Australia)
- Japanese Research Institution for Science and Technology (Riken)
- Monash University (Australia)
- National Center for Global Health and Medicine (Japan)
- The Peter Doherty Institute for Infection and Immunity (Australia)
- Hong Kong University (China)
- University of São Paulo (Brazil)
- Tokyo and Kyoto universities (Japan)

INTERNATIONAL ORGANIZATIONS

- European Commission
- European & Developing Countries Clinical Trials Partnership (EDCTP)
- Global Alliance for Vaccines & Immunisation (GAVI)
- Global Fund
- National Institutes of Health (NIH)
- World Health Organization (WHO)
- World Organization for Animal Health (OIE)
- United Nations Food and Agriculture Organization (UN FAO)

FOUNDATIONS, ASSOCIATIONS AND NGOS

- African Society for Laboratory Medicine (ASLM)
- Agence universitaire de la francophonie (AUF)
- Bill & Melinda Gates Foundation
- Monaco Scientific Center (CSM)
- Drugs for Neglected Diseases Initiative (DNDi)
- Fondation de France
- Mérieux Foundation
- Pierre Ledoux Jeunesse Internationale Foundation
- Fondation Prince Albert II de Monaco
- Rotary International Foundation and district 1660 Rotary clubs
- SUEZ Foundation
- Total Foundation
- JANSSEN HORIZON
- MSDAvenir
- Nutricia Research Foundation
- Odyssey Reinsurance Company
- São Paulo Research Foundation (FAPESP)
- Wellcome Trust

Thanks

We would like to thank all the collaborators working in the Pasteur Network, particularly those who allowed us to use their photo and/or who contributed to this report, which will increase the visibility of the network. We would also like to thank Françoise Barré-Sinoussi, honorary president of the Pasteur Network, together with the staff of the Pasteur Network association and the Department of International Affairs of the Institut Pasteur, for their day-to-day commitment.

We also take the opportunity to address our sincere thanks to all the teams at the Institut Pasteur (Paris) for their support and cooperation as well as to all the partners, institutions and donors, present and future, whose continuous support contributes to the development of cooperation programs within the Pasteur Network in the service for population health.

Institut Pasteur/Department of Communications and Fundraising
– 25-28, rue du Docteur-Roux – 75724 Paris Cedex 15, France.

Editor-in-chief: Juliette Hardy, Head of International Communication and Promotion of the Pasteur Network/Néphélie Godin, cominter@pasteur.fr

Photo credits: Marcos Santos/USP Imagens; William Beaucardet; François Gardy; Thet Htoo/AFD; Denis Guyenon/The Pulses; Isabelle Jeanne; Institut Pasteur/Nabil Zorkot; Institut Pasteur de Côte d'Ivoire; Institut Pasteur de Nouvelle-Calédonie; Pasteur Center in Cameroon; Géraldine Revillard/Adobe Stock; MediLabSecure; Institut Pasteur de Tunis; Institut Pasteur de Dakar/AFD; J. Jaymond/Institut Pasteur du Cambodge; Ricci Shryock/AFD; Charles Dauguet; Adeline Mallet; Barbara Grossmann; Thomas Cristofolletti/Ruom/AFD; Skander Zarrad; Greg Mo/AFD; Baptiste de Ville d'Avray; Jean-François Perigois; Institut Pasteur (Paris).

Design and production: **WAT** - wearetogether.fr - 2101_01844.





Pasteur Network

33 members in 25 countries

United for Global Health

pasteur-network.org

Institut Pasteur

25-28, Rue du Docteur Roux

75724 Paris Cedex 15

www.pasteur.fr