# Pesquisa EAPESP

# LESS METHANE FROM PASTURE

Technological solutions could help reduce greenhouse gas emissions by livestock

1,000 years ago, Tupi-speaking ethnicities numbered up to 5 million Maria Victoria Benevides talks about the need for education in democracy Environmentally friendly asphalt uses mining and construction waste Lack of consensus on the concept of disinformation hinders the creation of new legislation Startup launches robotic guide dog to help the blind



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## LETTER FROM THE EDITOR

## FAPESP, 60 years

Alexandra Ozorio de Almeida | EDITOR-IN-CHIEF

t has been nearly three years since the last English edition of *Pesquisa FAPESP*. The pandemic and consequent suspension of face-to-face activities interrupted our periodic publication of articles originally published in Portuguese, although the English version of our website has been kept up to date (revistapesquisa.fapesp.br/en). Now, we are happy to return with a new printed English issue, which includes a selection of texts from January to June 2022.

In 2021, the official number of cattle in Brazil reached 224.6 million, greater than the human population. Livestock farming is a major economic sector in the country, but it also has significant downsides, such as the fact that it is a huge source of methane emissions, contributing to global warming. Methane represents 19% of Brazil's total greenhouse gas emissions. With more head of cattle than any other country in the world, Brazil has a responsibility to develop and implement technologies that allow the sector to reduce carbon emissions and its impact on the planet's climate (page 6). This issue's cover story describes some of the initiatives currently being used to reduce livestock emissions, such as the integration of cattle breeding with agricultural cultivation and forestry.

The Tupi language is used by various peoples across South America. The population has dispersed across the subcontinent in a territorial movement that started almost 3,000 years ago. Analysis of current Tupi genetics suggest that this dispersion was accompanied by a population explosion, which may have reached as many as 5 million individuals. The results offer an insight into the expansion of the Tupi peoples. When compared with data on ethnic groups that speak other languages, contradict the widely held belief that the physical barrier imposed by the Andes prevented genetic mixing between populations from either side.

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In May 2022, the São Paulo Research Foundation (FAPESP) celebrated its 60<sup>th</sup> anniversary. Established in the São Paulo State Constitution of 1947, the foundation was created in October 1960 and began operating a year and a half later. The pioneering institution is the largest state-level science and research agency in Brazil, serving as a national and international benchmark.

It operates on several related fronts simultaneously, one of which is to communicate scientific knowledge to society. To achieve the objective of promoting and supporting the publication of research results, FAPESP created a virtual library (bv.fapesp. br) that contains the abstracts of every research grant funded by FAPESP throughout its history. The foundation's vision of the importance of communication also led to the creation of Pesquisa FAPESP in the 1990s. As a result of their impact and recognition, several of FAPESP's initiatives have served as inspiration for other agencies (page 26). The international reach of Brazilian science, something the agency has actively promoted in recent years, is presented in a report on foreign researchers who have come to Brazil for postdoctoral fellowships (page 22).



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**Cover** Claudia Warrak with photo by Léo Ramos Chaves





# ONPCARBON LIVESTOCK

## With more head of commercial cattle than any other country in the world, Brazil faces the challenge of reducing greenhouse gas emissions associated with this sector

## **Domingos Zaparolli and Yuri Vasconcelos**

PUBLISHED IN APRIL 2022

orumbiara farm, located in the Brazilian state of Rondônia near the border with Mato Grosso, has 16,000 head of Nelore cattle, the most common breed in the country, on its 16,800 hectares (ha) of land. Until six years ago, productivity at the ranch was low, and few environmental sustainability practices had been implemented. Pasture areas were degraded, suffering from increasing erosion, and the herd drank water from springs located in permanent preservation areas (PPAs),legally-designated nature reserves that cattle are not permitted to access.

Changes came with the adoption of a system based on integrated agriculture and livestock farming (IAL) conceived by the Brazilian Agricultural Research Corporation (Embrapa) in the 1990s. Under the IAL system, land use is alternated between agricultural and livestock activities with the aim of increasing the efficiency of natural resources and reducing the environmental impact of livestock. Well-managed crop fields and pasture areas can sequester carbon from the atmosphere, offsetting livestock emissions; cattle are a major generator of methane (CH<sub>4</sub>), one of the greenhouse gases (GHGs) responsible for global warming.

The results quickly became apparent. Today, every ton of meat produced at Corumbiara generates 11.5 tons of carbon dioxide equivalent (tCO<sub>2</sub>e). Although still considered high, this volume is approximately 40% lower than the global average, which is estimated at 19.9 tCO<sub>2</sub>e. The carbon dioxide equivalent is used to represent the greenhouse gases in the form of CO<sub>2</sub>. The data are from a pioneering Brazilian study by the Institute of Forest and Agricultural Management and Certification (IMAFLORA), a nongovernmental organization that measured the carbon balance of suppliers of Minerva Foods in South America.

Corumbiara currently has 1,850 ha dedicated to IAL, equivalent to 22% of the property's 8,400 ha usable for farming; the rest of the land, by law, cannot be exploited. Another 1,250 ha of the usable area is PPA, which was fenced off for recovery via the planting of native vegetation. The division between crops and livestock works is as follows: in September, soybeans are planted, which are later harvested and sold. In February, maize is planted, together with a highly digestible grass, Brachiaria ruziziensis. The maize is harvested in May and used over time as cattle feed, complementing their grass-based diet. The combination sustains the animals in the dry period between June and August, when the IAL area is used by the cattle.

In addition to absorbing carbon, the grass allows production in the area to be intensified, with three heads of cattle occupying each ha, while the average in non-IAL areas is 1.5 heads per ha. Good nutrition in the dry season helps cattle in the IAL area reach the ideal weight for slaughter in 22 months, approximately a year earlier than the standard. The shorter the animal's life, the less GHGs emitted per kilogram (kg) of meat produced.

Growing grass also offers other benefits. Its roots and remains add organic matter into the soil, storing carbon as a result. At the same time, grass helps decompact the earth after it has been trampled by cattle, promoting better recycling of soil nutrients. "The IAL system improves productivity and sustainability," says agronomist Fábio Souza, manager of Corumbiara. "Over the next two years, we plan to expand the IAL area to 4,000 ha. We want to reduce our environmental impact even more."

## THE IMPACT OF METHANE

The production system that integrates agriculture and forestation (IAF), in addition to a broader version that includes livestock (IALF), is one of the solutions being implemented in Brazil



SOURCE FLÁVIO PORTELA SANTOS / "GASES DE EFEITO ESTUFA E A SUSTENTABILIDADE DE FAZENDAS DE PRODUÇÃO DE CARNE BOVINA" (GREENHOUSE GASES AND THE SUSTAINABILITY OF CATTLE FARMS), BY JOÃO JOSÉ ASSUMPÇÃO DE ABREU DEMARCHI, ZOOTECHNICAL INSTITUTE

to make cattle farming more environmentally friendly. Brazil has more commercial cattle than any other country in the world, with 218 million animals, ahead of China and the USA. In 2020, it exported more meat than any other nation, at 2.2 million tons (t), 14% of the global market.

> n important source of foreign income, livestock has been targeted by the environmental movement since it generates high volumes of GHGs, particularly CH4, that are released into the air. The digestive process of ruminants, known as enteric fermentation, produces methane in the rumen, one of the four

compartments of the bovine stomach, which is then released mainly by eructation, better known as burping or belching (*see infographic above*). Its potential to raise the global temperature in as little as 20 years is 80 times higher than CO<sub>2</sub>; over the course of 100 years, it is 28 times higher. Deforestation in the Amazon rainforest to make room for cattle pasture and crops also indirectly contributes to carbon emissions generated by the agricultural sector. Another gas generated by livestock is nitrous oxide (N<sub>2</sub>O), which comes from animal feces in pasture areas. Nitrogen fertilizers applied to crops to correct soil acidity also release the gas.

GHG emissions in Brazil totaled 1,467 teragrams (Tg) of CO<sub>2</sub>e in 2016; one Tg is equivalent to one million tons. The data were contained in the report "Fourth National Communication of Brazil to the UNFCCC [United Nations Framework Convention on Climate Change]," issued by the Brazilian government in 2020. Agriculture emitted more GHGs than any other sector, with 33% of the total, and the subsector for enteric fermentation, which accounts for the methane released by ruminants (cattle, buffalo, goats, and sheep), represented 19% of the total. Cattle farming alone was responsible for 97% of livestock emissions. Cattle belching was the source of 18.5% of GHGs generated in the country (*see infographic on Page 10*).

At the United Nations Conference on Climate Change (COP26) in Glasgow, Scotland, last year, Brazil was one of approximately 100 countries that signed the Global Methane Pledge, an agreement to reduce emissions of the gas by 30% by 2030. To fulfill its commitment, Brazil will have to make its livestock industry cleaner.

"It is a major challenge, but the conditions needed to achieve the COP26 target are there. We currently have 165 million hectares of pasture and plenty of space to manage these areas in order to make them more sustainable," explains Flávio Augusto Portela Santos, an agronomist from the Luiz de Queiroz College of Agriculture (ESALQ) at the University of São Paulo (USP) who specializes in bovine production and nutrition.

According to the researcher, Brazil has several technologies available to increase the efficiency of the livestock sector by lowering carbon emissions. In addition to the IAL system and its variants, which have already been implemented in an estimated 16 million ha of pasture, there are other techniques for correctly managing pasture and supplementing feed with additives to reduce methane generation (*see report on Page 12*). Genetic improvements to produce more easily digestible grass and breed cattle that can reach slaughter weight earlier (*see* FAPESP's 50-Year Special Issue) are also potential solutions.

"Research has advanced a lot in recent years. Now this knowledge needs to be put into practice and the technologies applied on a larger scale in the production process," emphasizes Santos, who led a project funded by FAPESP on cattle feed supplementation in tropical pastures.

One of the agronomist's current lines of research is the processing of corn and sorghum to improve feed efficiency and reduce the amount of methane generated per kilogram of meat and liter of milk produced. Another study, in partnership with multinational agrichemical company Syngenta, is focusing on genetically modified corn, given an enzyme called amylase that helps animals digest the grain. "With more efficient digestion, we were able to reduce methane generation," he explains.

## MITIGATION STRATEGIES

Guilhermo Congio, an agronomist who specializes in mitigating greenhouse gas emissions in ruminant production systems, also believes it is possible to make Brazilian livestock more climatefriendly. "Several studies carried out in the country in recent years indicate that the sector can offset emissions by adopting new technologies that allow it to sequester more greenhouse gases from the environment than it emits," he explains.

Congio earned his PhD from the Graduate Program in Animal Science and Pastures at ESALQ, USP, and was one of the coordinators of the recently concluded Latin America Methane Project (LAMP), an international research project that carried out a meta-analysis of 34 potential enteric methane mitigation strategies. The approaches were divided into three groups: animal genetic improvement, nutrition, and rumen manipulation.

"Of the 34 strategies evaluated, 16 reduced at least one metric related to methane emission without compromising animal production. Of these 16, three reduced absolute methane emissions from cattle, measured in grams per day, and 13 reduced relative emissions, measured in grams of methane per kg of meat or liter of milk produced or per kg of food ingested by the animal," says Congio. The study involved 80 researchers from 26 institutions in eight countries across Latin America and the Caribbean. The results were published in the *Journal of Cleaner Production* in August 2021.

> ongio explains that methods to make livestock more environmentally friendly generally focus on reducing enteric methane emissions and nitrous oxide emissions from the soil and animal feces or on absorbing carbon from the environment to offset emissions by the sector. The use of additives in animal feed is an example of the former,

while planting forests alongside pasture areas is an example of the latter. "Although cattle farming accounts for a considerable percentage of Brazilian emissions, well-managed pastures and integrated production systems that include trees have a great capacity to sequester CO<sub>2</sub> from the atmosphere," says Congio. To offset 1 kg of methane emissions by animals, 28 kg of CO<sub>2</sub> needs to be removed from the environment.

Alexandre Costa, a climate scientist from the State University of Ceará (UECE), questions the effort the country has made to reduce the meat

industry's carbon footprint and argues that the sector needs to review its practices. "The Brazilian model is not sustainable," he says. Costa, who was one of the authors of the first report by the Brazilian Panel on Climate Change (BPCC), highlights that agriculture has expanded in biomes such as the Cerrado (wooded savanna) and the Amazon, causing widespread destruction. "As we know, deforestation results in CO2 emissions."

A Brazilian study published in the scientific journal *Communications Earth & Environment* in 2001 showed that the Amazon produces 8% of the planet's methane, with 11% of this volume generated by livestock (*see* Pesquisa FAPESP issue *no. 312*).

The endeavor to decarbonize Brazilian livestock is not new. Universities and research centers have been searching for solutions to Experiments conducted in the laboratory at ESALQ, USP, to evaluate nutritional ingredients that could potentially reduce methane emissions by cattle



the problem for more than two decades, and in 2010, the government launched Plan ABC (standing for low-carbon agriculture in Portuguese). The plan was created by the Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA) to increase the use of sustainable technologies and improve productivity in rural Brazil. It includes establishing the IALF system and its variants, as well as the recovery of degraded pastures and treatment of animal waste, as public policy.

Fernanda Garcia Sampaio, a zootechnician from MAPA's Department for Climate Change and Conservationist Agriculture, explains that the government's approach is divided into supporting technological developments, offering technical assistance to give producers access to innovations, and funding various other programs. In 10 years, Plan ABC signed 38,000 credit agreements aimed at stimulating more sustainable practices in the countryside, worth a total of R\$32 billion.

The plan, now renamed ABC+, has incorporated new practices for the 2020–2030 period, including a method known as intensive termination, which reduces the time taken for cattle to reach slaughter weight. The objective is to expand the agricultural land using the technologies outlined in the plan by 72 million ha—the

# THE IMPACT OF LIVESTOCK ON GLOBAL WARMING

Cattle is one of the largest generators of greenhouse gases in Brazil





# **EMISSIONS FROM THE AGRICULTURAL SECTOR OVER TIME**

The largest volume of gases is methane, the result of enteric fermentation in cattle



SOURCE ANNUAL ESTIMATE OF GREENHOUSE GAS EMISSIONS IN BRAZIL, 2020

area is currently close to 50 million ha—and achieve an estimated mitigation capacity of 1.1 billion tCO<sub>2</sub>e by 2030.

According to Plan ABC+, areas using the IALF system are projected to expand by over 10 million ha in the period. If successful, the integration of crops, forests, and livestock will account for approximately 23% of Brazil's 112 million ha of pasture. Every ha of IALF pasture has the potential to remove an average of 3.79 tCO<sub>2</sub>e from the atmosphere per year.

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study led by José Ricardo Pezzopane, an agronomist from Embrapa Southeast Livestock in São Carlos, São Paulo, proved that planting eucalyptus in an IALF production system benefits the global climate. Seedlings were planted on 12 ha of land in simple lines, with 15 meters (m) between each line and 2

m between each tree, resulting in a density of 333 eucalyptus trees per ha. "The eucalyptus trees accumulated 65 tons of carbon per ha over eight years until they were cut, generating 225 cubic meters (m3) of wood—an extra source of income for the farmer. An article describing the study was published in the journal *Agriculture, Ecosystems & Environment* last year.

According to Pezzopane, which tree species to plant in an IALF system depends on several factors related to the pursuit of environmental, economic, and social benefits. "There are many options, including native and exotic species, as well as decisions to be made on planting density [number of trees per hectare]," he explains. Some types of trees, such as fruit or nut trees, theoretically remain in the environment for longer and can absorb more carbon than species destined for timber.

The IALF production strategy is also being adopted outside Brazil in countries that include Australia and New Zealand. In these two countries, the system is an important part of policies being implemented to achieve zero net livestock carbon emissions by 2050.

Other global meat producers are also investing in ways to make their livestock cleaner. In November 2021, Joe Biden's administration launched an ambitious plan that includes decarbonizing the USA's livestock industry. The USA is also leading the Global Methane Initiative, an international partnership that includes Brazil and aims to reduce methane emissions in various sectors, including agriculture.

All research projects and scientific articles consulted for this feature are listed in the online version.

# FOCUS ON ORAZING AND NUTRION

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## Efficient pasture management and changes in livestock feeding strategies can reduce the impact on the global climate

ccording to experts, the predominant livestock model in Brazil, in which cattle are raised on large areas of planted or natural pasture, offers much potential for mitigating greenhouse gas (GHG) emissions through photosynthesis. When poorly managed, however, this system results in low productivity and land degradation and a constant need to seek new pasture areas. It is estimated that approximately 82 million hectares (ha) of Brazil's pasture area, comprising 50% of the total, shows some degree of degradation.

One of the most promising ways to reduce GHG emissions in livestock farming is to manage soil and pasture more efficiently. "Inadequate pasture management, mainly caused by not adjusting the stocking density [number of animals per ha] in response to the forage available, together with a lack of fertilization and supplementation of the animals' diet in periods of forage shortage, are the main factors that increase greenhouse gas emissions and soil degradation, which also contributes to the emission of CO<sub>2</sub> [carbon dioxide]," says Ricardo Andrade Reis, a zootechnician from the School of Agrarian and Veterinary Sciences at São Paulo State University (UNESP), Jabuticabal campus.

Reis leads a project funded by FAPESP that is studying management strategies for reducing the environmental impacts of beef cattle production systems. "Managing pastures to avoid elongation of stems and growth of leaves, which have a high fiber content and are thus less easily digestible, has been used with success in our research," says Reis. "Enteric methane [CH4] emission is highly related to fiber-rich forage intake, which leads to the development of methanogenic [methanegenerating] organisms in the rumen." An article describing the results of the study was published in the journal *Agronomy* in 2020.

Research carried out by the Brazilian Agricultural Research Corporation (Embrapa) with funding from FAPESP also concluded that raising cattle in properly managed pasture areas with the appropriate number of animals per ha can increase carbon sequestration. The study, described in the scientific journal *Animal* in 2020, showed that steers—young cattle in the growth phase—raised under this system had a positive impact on the environment, equivalent to the annual growth of six eucalyptus trees.

According to Patrícia Perondi Anchão Oliveira, the agronomist who led the study, these results were obtained in the Atlantic Forest biome on a ranch where a previously degraded pasture area was recovered with chemical correctives and fertilizers. The area was occupied with 3.3 animal units (AUs) per ha—one animal unit corresponds to 450 kg of live weight. The carbon balance was calculated based on GHG emissions from animals and from the manufacturing and application of fertilizers.

In a degraded area where correctives and fertilizers are not used and the occupation is 1.4 AU/ha, 64 trees per steer need to be planted to balance the emissions. "Cattle farming with proper pasture management and occupation can even generate a carbon surplus, while raising animals in degraded areas results in poor economic performance and a high environmental impact," says Anchão.

Recent tests carried out at ESALQ with funding from FAPESP have also revealed the benefits of well-kept pasture areas. "A study of dairy cattle showed that it is possible to increase daily milk production per cow by 15%, increase pasture stocking rate by 33%, and increase milk production per ha per day by 51% just by putting the animals out to graze at the right time [when the pasture is at the appropriate height]," says agronomist Sila Carneiro da Silva, one of the coordinators of the study.

According to Silva, there was also a 21% reduction in enteric methane emission by the cows, which was measured in grams of CH<sub>4</sub> per liter of milk produced, and an approximately 40% decrease in nitrous oxide emission from the soil compared to inadequate pasture management. "Correcting when animals are put out to graze

Animal wearing a device that measures the amount of methane it emits by belching and removed from the pasture is a zero-cost technology. There is no need for any new investment," says Silva. The results of the research, carried out as part of agronomist Guilhermo Congio's PhD, were published in the journal *Science of the Total Environment* in 2018 and 2019.

### CATTLE BURPS

While cattle ranchers are making progress in developing more efficient farming systems that sustainably balance GHG emissions, they are facing another more complex challenge: how to reduce emissions inherent to cattle farming, such as the gases generated in the ruminant digestive process and released by belching.

"Scientists are looking for ways to directly manipulate the fermentation process to reduce methane emissions," explains Alexandre Berndt, a researcher at Embrapa Southeast Livestock in São Carlos, São Paulo. Two approaches are being studied at research centers around the world: the first is food that is more easily digestible by cattle, and the second is nutritional dietary additives that reduce the emission of potentially harmful gases.

The challenge in researching food additives is to create alternative substances that reduce CH4 generation without impacting the health and food safety of the animals. One promising ingredient with great potential to reduce enteric methane emissions is the solvent bromoform, which is found naturally in a microalgae called red algae (*Asparagopsis taxiformis*) that is common to Australia. In March 2021, scientists from the University of California in the USA and James Cook University in Australia published an article in the journal *PLOS One* showing that adding red algae to the diet of beef steers can reduce methane emissions by up to 87%, with no impact on their weight gain.

In the Netherlands, DSM Animal Nutrition & Health developed an organic compound called 3-nitrooxypropanol (3NOP), which is formed of nitrate and a biological type of alcohol and sold under the trade name Bovaer. Giving ruminants one teaspoon of the additive per day can have an impact on the microorganisms in the rumen and reduce methane emissions, Gareth Mead, senior director of global communications at DSM, told *Pesquisa FAPESP*.

The development of 3NOP took a decade, with 50 scientific articles published on the topic. According to the company, enteric emissions can be reduced by approximately 30% in dairy cows, but the impact can be even greater in beef cattle, at approximately 90%. A study led by Reis from UNESP found that the additive can reduce methane emissions in Nelore bulls by more than 40%. The results were published in the *Journal* of Animal Science in November 2020.

In September 2021, Brazil and Chile were the first countries to approve the sale of the product. The European Union later followed



Cattle grazing at the Embrapa farm in São Carlos, São Paulo; a researcher measures the height of the pasture



Cattle feeding from a trough on a farm in Altair, in the interior of São Paulo State



suit and authorized Bovaer for commercial use. Mead pointed out that DSM has not yet started selling the product, but it plans to do so in the next few months.



nother line of research into additives is studying tannins, a type of polymer found in acacia, fruit, and leguminous trees. "Tannins are antimicrobial and can potentially reduce the degradation of food proteins in the rumen, leading to a reduction in methane production," explains Renata Helena Branco Arnandes,

a doctor of zootechnics from the Zootechnic Institute (IZ), which is linked to the São Paulo State Department of Agriculture and Food Supply.

In 2021, with funding from FAPESP's State Research Institute Modernization Program, IZ inaugurated a Laboratory for Ruminal Fermentation and Beef Cattle Nutrition. One of the lab's first tasks was to validate and test a tannin-based additive developed in partnership by Italian company SilvaTeam, which created the active ingredient, and Brazilian food-processing company JBS. The aim was to establish the absolute methane reduction provided by the additive and to obtain data on the appropriate dosage.

"Silvafeed has already been sold in several countries, including Brazil, but it was our research that demonstrated its impact on methane emissions," says Arnandes. "Adding this molecule [the tannin-based additive] to the diet decreased enteric methane emissions by approximately 10% compared to cattle given a control diet." The IZ is also partnered with the School of Veterinary Medicine and Zootechnics (FMVZ) at the University of São Paulo (USP) and Embrapa for a project funded by FAPESP to investigate ways of mitigating livestock GHG emissions. The research is being led by Paulo Henrique Mazza Rodrigues, a veterinarian from FMVZ.

One of the main areas of study is the use of forage reserves (grasses and legumes) as feed in the winter and dry period, in combination with protein supplementation with salt and nitrate instead of the traditional mineral supplementation of salt and urea. Nitrate, like urea, is a source of nonprotein nitrogen for cattle. However, it has the potential to dissipate hydrogen in rumen fermentation, reducing methane production.

The two institutions are also working together to research foods that are easier to digest, which results in lower GHG emissions. One study is examining the use of integrated legume and grass pastures. The most promising approach combines the grass *Brachiaria brizantha* with legumes such as *Macrotyloma axillare* and *Cajanus cajan*. The mixture improves biological activity in the soil and increases carbon stocks and pasture productivity. Despite the potential improvements to productivity and sustainability offered by intercrop pastures, the practice is still not widely used due to a lack of knowledge of the subject in Brazil.

All research projects and scientific articles consulted for this feature are listed in the online version.



## **INTERVIEW** Maria Victoria de Mesquita Benevides

# THE RIGHT TO DEMOCRACY

Sociologist fosters the creation of the field of education in human rights in Brazil

Christina Queiroz | PORTRAIT BY Léo Ramos Chaves

PUBLISHED IN FEBRUARY 2022

ith a specialization in political science, sociologist Maria Victoria de Mesquita Benevides is the granddaughter of baroness Maria José Villas Boas Antunes de Siqueira de Mesquita (1862–1953), but she never benefitted much from this familial connection. Her mother, who was widowed at 43 years of age at the end of her tenth pregnancy, encouraged her six daughters to pursue a career and be independent. Benevides followed her advice. Born in Niterói, she pursued a career in teaching and research, and today she is a retired tenured professor from the Faculty of Education at the University of São Paulo (FE-USP).

In an interview that lasted an afternoon in her own living room in São Paulo, Benevides spoke about her research involving the government of Juscelino Kubitschek (1902-1976), which she undertook during the Brazilian military dictatorship (1964-1985), and about her study of political parties, arguing how inequality prevents the advancement of democracy in Brazil. Her most recent work is focused on the sociology of education, specifically education for democracy. During her 27 years at FE-USP, she was able to take concepts developed in political science to the fields of education and human rights. Following this trajectory, she worked with the concept of active citizenship, developing ideas to defend political participation through institutional measures beyond elections, including plebiscites and referendums. Regarding her teaching, she speaks about how the work with the Dom Paulo Evaristo Arns Human Rights Commission, founded in 2019, motivated her to keep going during the pandemic. Four years ago, she became widowed after losing her husband, astronomer and USP professor Paulo Benevides Soares (1939-2017), with whom she has three daughters and five grandchildren.

**AGE** 79

## FIELD OF EXPERTISE

Political Sociology and Sociology of Education

INSTITUTION

Faculty of Education at the University of São Paulo

## EDUCATIONAL BACKGROUND

Bachelor's degree (1971) in social sciences, master's (1975) and PhD (1980) in Sociology from the School of Philosophy, Languages and Literature, and Humanities at the University of São Paulo (FFLCH-USP)

## PUBLISHED WORKS

30 scientific articles and 13 books

## Shall we talk about your childhood?

I am a mixture of the Niterói and Rio de Janeiro cultures. I was born in Niterói, but I grew up in the city of Rio de Janeiro. Until I got married, I lived with my brothers and sisters, my mother, and my maternal grandmother in a house in the Rio Comprido neighborhood. My mother's family was from Niterói, and my father's family was from the state of Minas Gerais. I had nine siblings. I am the eighth child, or the ninth, because I have a twin sister. My childhood was marked by losses and death. At 20 years of age, my eldest brother, José Jeronymo, enlisted as a volunteer in the Brazilian Expeditionary Force. In November 1944, at the end of World War II [1939–1945], he died in a battle in Italy. At that time, I was 2 years old, and my mother was at the end of her tenth pregnancy. When we received the news, my father had a heart attack and died. Besides the death of my eldest brother, another brother also died in a household accident. One of my strongest memories of this time was how much we admired my mother, who dreamt of being a doctor. She was a courageous woman. Her grandfather was a doctor as was her first daughter. This sister was the only woman in her class at the School of Medicine at the former National University of Rio de Janeiro.

## How was life in a family with so many women?

We had a strict upbringing. Our mother always said, "Marriage is not a profession." She motivated us to be independent, to study, and to build a career. Today, I have three siblings left, one brother and two sisters. Another notable characteristic of my mother was her political beliefs. She was discreetly liberal, living in a family that was very traditional, monarchist, and religious. My mother's three sisters were nuns. My maternal grandmother was from Germany and a Lutheran. On my father's side, my grandmother was a baroness, and I did not see her much. My father's family was very wealthy, but he had already been disowned by the time he got married. My father was sent to study in London at nine vears of age. He studied engineering in London, philosophy in France, and architecture in Florence. He lived a life of luxury in Europe until he was 32 but remained close to his "gauche," who helped him financially. By the time he returned

to Brazil, he had spent a fortune, and his mother, who was already widowed, thought it outrageous for him to inherit anything more. To be able to marry my mother, my maternal grandfather made him get a job with the government, which was not difficult with his engineering diploma. Growing up, we all worked and got scholarships. I remember a friend saying the following, which sums up this time well: "Your family eats with china plates and silverware, but it's rice and beans, eggs, and ground beef." We lived in a house with libraries in every bedroom and even a chapel. We studied French and English. We all have children, and we spent a lot of time together, which only changed with the pandemic.

## How did you get into sociology?

I got married in February 1964, just before the military coup. My husband, Paulo Benevides, was an engineer with a degree from the Aeronautical Institute of Technology, where he also studied astronomy. He was invited by the Centre National de la Recherche Scientifique [French National Centre for Scientific Research] [CNRS] in France to work at

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Democracy requires effort. It demands the effort of those who govern and those who are governed. We must participate and inform ourselves the Besancon Astronomical Observatory. We moved in March and stayed there for four and a half years. At the beginning, we did not hear much from Brazil. Phoning was expensive. We followed the news in Brazil through the newspaper Le Monde. Besancon is a small city that dates back to medieval times and has a population of 100,000, but it has a university, theaters, museums, and even a symphony orchestra. Our first child was born there. We returned to Brazil in 1968, soon after the AI-5. We came to São Paulo because Paulo was hired by the Institute of Astronomy and Geophysics at USP. I had begun my bachelor's in sociology and political science at PUC-RJ in 1963. When we arrived here, I requested a transfer to social sciences at USP. I had always earned scholarships, including at PUC. During my master's and PhD, I received a FAPESP scholarship. I pursued my postdoctoral research and my work as an adjunct professor with funding from the Brazilian National Council for Scientific and Technological Development [CNPq] and from the Social Sciences Research Center.

## You were already a mother when you started at USP. What do you remember of your undergraduate studies?

My life at USP was good, but it was not a typical university experience. I did not participate in political groups or student social activities. When I began my master's in sociology, I had three young children: Daniel, André, and Marina. I did not have help from my family as they lived in Rio. I was an old-fashioned housewife; that is, I knew how to cook and sew. While it was difficult, for me it was imperative to have children. I could not imagine my life without being a mother.

## With your master's, where did the idea come from to research the Kubitschek administration?

I truly liked research and was very interested in learning everything about Brazilian politics due to the situation at the time. I was captivated by the thesis of political scientist Braz José de Araújo [1941– 2004], about the external politics of Jânio Quadros [1917–1992], which he defended in 1970. When I spoke with my husband, who was from the hard sciences but who was very open culturally, he suggested that I do a master's on Juscelino, calling



At left, with Juscelino Kubitschek, at the launch of her book in 1976. Below, with literary critic Antonio Candido



attention to the fact that his government arose during a tense period-between the suicide of Getúlio Vargas [1882-1954] and the resignation of Jânio Quadros-but had a strong impact on the history of industrialization and democracy in Brazil, which, as we know, is limited. I presented a project to political scientist Francisco Weffort [1937-2021], who liked the idea. I wanted to understand what guaranteed the stability of the JK government during such a turbulent period. I interviewed 15 members of parties, such as the Social Democratic Party [PSD] and the Brazilian Workers Party [PTB], in addition to Kubitschek himself who said to me: "I was the only civilian president after the New State [1937-1945] who governed according to the Constitution." This first interview took place on April 1, 1974, on the very day when the 10-year suspension of his political rights came to an end. During our conversation, he received a call and became very angry. I got chills and was afraid he would have a heart attack. When he hung up, he told me that, while he could now vote, he could not run for election.

## Your master's attracted the attention of academics and politicians alike, and the book that resulted was considered an essential analysis of the JK government. How do you feel about the outcome of your work?

I defended my dissertation in November 1975, soon after the assassination of jour-

nalist Vladimir Herzog [1937-1975]. The classroom was packed and included the likes of Florestan Fernandes [1920-1995], literary critic Antonio Candido [1918-2017], and historian Caio Prado Junior [1907-1990]. The topic of my master's, which focused on the relationship between democracy and development and the period in which it was developed, contributed to attracting attention. The Jornal do Brasil, for example, dedicated an entire page to presenting the research with the title: "Professor uses thesis to demonstrate why the JK government did not fall." Modesty aside, my dissertation appeared to be a PhD thesis due to the originality of the topic, the academic references, and the interviews. I identified that the relative political stability of the Kubitschek government could be attributed to three factors: the co-opting of military personnel, who were committed to national development; the partnership between the PSD and the PTB, which grouped together the interests of the bourgeoisie farmers and urban workers; and the Goals Program, which advanced the industrialization process and created jobs.

## How did you research the Kubitschek government while it was a full dictatorship?

I was welcomed warmly in all my interviews. I was not connected with political groups, and I was mistaken for having wealth—which I never had. This prevented mistrust of my motives. I was not a "rebel." My research led to the book *Governo Kubitschek – Desenvolvimento econômico e estabilidade política: 1956-1961* [Kubitschek Government – Economic development and political stability: 1956– 1961], published by Paz e Terra in 1976. At the beginning, I did not realize the impact it would have. Kubitschek participated in the launch, which took place at Casa de Rui Barbosa in Rio. He died one month later. In a way, the success of it weighed heavily on me. There is a lot of competition in the academic arena, and I am not a competitive person.

## How did that happen?

I thought that my path would be a university career. In 1982, they opened positions with the Department of Social Sciences at FFLCH. I heard opinions that it would be better not to apply, as I supposedly did not have the right profile. At that point, I had already published two books, and I had a good CV. My credentials were strong because of my master's. However, they told me that the department preferred someone younger, at the beginning of their career, and with a stronger connection to sociology, rather than political science. I was 40 years old. I ended up not applying. Elisabeth Lobo [1943-1991] and Régis Stephan de Castro Andrade [1939-2002] were selected. I always had an excellent relationship with both of them.

## And your PhD?

While writing my thesis, I studied at UDN [National Democratic Union] from the time it was established, in 1945, until the State coup in 1964—an event in which this party was the protagonist. I finished my thesis confirming that the UDN was born out of the involvement of well-known liberal names, such as Virgílio de Melo Franco [1897-1948], members of the democratic and socialist left, but ended "with sadness rather than success." This statement earned commentary from sociologist and political scientist Bolívar Lamounier, one of the PhD jurists that I never forgot: "You might be a good researcher, but you've ended up bringing UDN to an end." Out of my research on political parties came books such as A UDN e o udenismo - Ambiguidades do liberalismo brasileiro [The UDN and udenismo- Ambiguities of Brazilian liberalism] [Paz e Terra, 1981] and O PTB e o trabalhismo – Partido, sindicato e

governo em São Paulo [The PTB and the work – Party, syndicate, and government in São Paulo] [CEDEC/Brasiliense 1989].

## Did your work with the Center for Study of Contemporary Culture change your research journey?

In 1977, I participated in the founding of CEDEC, and I remained there until 1985. I only left because I was chosen in a public competition by the School of Education. My years with CEDEC opened up possibilities for me to develop new studies, beyond giving me opportunities for rich collaboration with researchers and politicians, both within Brazil and abroad, and everyone interested in creating the conditions for much-needed democracy. I analyzed, for example, urban violence and the rights of citizens.

# How did the public competition with the School of Education go?

Celso de Rui Beisiegel [1935–2017], sociologist and head of the School of Philosophy and Education Sciences, knew my work. In 1985, he invited me to join the teaching body. I remember having said to him: "But I don't know anything about education; I haven't even read Jean Piaget [1896–1980], for example." He responded that the faculty needed someone to give classes on political sociology. I was selected and, over my 27 years there, I advised 12 master's students and 15 PhD students, I taught undergraduate and graduate classes, and I created a discipline for human rights.

# In what way did your work with FE-USP impact your thinking and way of seeing the world?

With the mind of a political scientist, I returned to the dialogue between education and democracy, seeking to understand what an actual emancipating education would be. I also became interested in education and Brazilian culture, so I created a field on this subject, with the works of sociologists Gilberto Freyre [1900–1987] and Sérgio Buarque de Holanda [1902-1982] and literary critics Antonio Candido and Roberto Schwartz. I was happy there and even had an advantage: as I was not from education, I did not have to fight for space. I never wanted to be a faculty dean, nor be part of the State Board of Education, for example. The only time I competed was in 1996, when

I participated in the public competition for tenured professor. There were three of us applying, and I got the only spot. At that time, I had already worked on human rights. I joined USP's Education Professorship for Peace with the support of The United Nations Educational, Scientific and Cultural Organization [UNESCO]. I helped the faculty build a field on the education of human rights, which became a discipline that was distributed throughout universities, faculties, and not-for-profit organizations. Today, I am a board member of the Vladimir Herzog Institute, the Sérgio Buarque de Holanda Center of the Perseu Abramo Foundation, and the Dom Paulo Evaristo Arns Committee for the Defense of Human Rights. I am also part of the Brazilian Network for the Education of Human Rights and the Department of Human Rights and Citizenship for the city of São Paulo. All of these entities have plans for the education of human rights.

## You also had a strong institutional role at USP.

For two terms, I was the FE representative on the University board of directors. I was so involved that, at one point, the chancellor asked the dean of my faculty

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Active citizenship is contrasted by passive citizenship, which relates to obedience to the law and to citizen obligations to not elect Benevides anymore. "Every time she puts up her hand, I go pale," he said. I also spent two terms with the Legislative and Resource Committee and the International Relations Committee. My university life was intense, and I ended up seeing much of Brazil because I was invited often to participate on juries in various states.

## Brazilian democracy takes center stage in your academic works. What challenges do you see today?

In Brazil, we have never experienced true democracy in terms of being a sovereign nation. We have always had intervention from economic groups and from people who have historically held power in our country. In the Latinobarómetro research-an annual public opinion poll with approximately 20,000 interviewees from 18 Latin American countries-the level of popular interest in democracy is measured. When asked "if there were jobs and food for everyone, would you prefer to live under a dictatorship or a democracy?" in Brazil, there are those whose responses include "I don't care" or even the option of a dictatorship. Our main problem is unfathomable inequality. We had almost 400 years of legal slavery and, today, we still have people working in situations of slavery. Studies show that democracy has a greater chance of taking root and working when the middle class represents the majority of the population, which is the case in some European countries. To share a personal example, I lived in France in the 1960s, when social welfare was fully supported by the State. While pregnant, I needed a housekeeper who came once per week for two hours. When her work was done, we had tea together and she would go home, driving her popular Renault. When she got pregnant, she did her prenatal exams at the same place as I did, and she had her baby in the same clinic as I did. Our children went to the same school. Can you imagine, in Brazil, an employer and employee being patients of the same gynecologist and their children at the same school? [During] the years I lived in this European city, my husband was a member of the intellectual elite, and we never saw one person put their child in a private school. Public schools are truly democratic institutions in the majority of European countries.

# What is unique about the middle class in Brazil?

In our society, the idea that privileges are rights, albeit wrong, is entrenched. I always told my students that the word "privilege" comes from the Latin word privilegium, meaning private law, which is absurd since a private law does not exist. Every law is public. The middle and upper classes have become accustomed to privileges determined by class. For example, in a situation where inflation is 10%, the last thing most employers consider is adjusting the salary of their employees by this percentage. However, these same individuals will complain about an increase in IPTU [property tax]. The middle class has always been racist. This is one of the topics I covered in the field of human rights. It's difficult to claim that one is not racist. Even today, a denial of racism disintegrates with simple questions such as "Have you had a black friend or professor? Do your children have black friends? If your daughter dated a black guy, would your family accept him?" The answers are embarrassing. The first consequences of deep-rooted racism are violence and the devaluation of work. There is great distance between manual labor and intellectual work. Even if intellectual work is bureaucratic and poorly remunerated, it is still considered of greater value than the work of an excellent stone laver, wood worker, electrician, or even housekeeper. Perspectives such as this make it difficult to understand what democracy and having rights in Brazil would be like.

# The concept of participatory democracy is central in your thinking. What is this exactly?

Democracy is a political regime where power entitlement is-or should be-popular sovereignty. This means that, ultimately, the people rule. However, everything in a democracy, including popular sovereignty, is ruled in accordance with the rule of law and the Constitution. The rule of law can be understood as the validity and transparency of equal standards for all, with full respect for minorities and control divided among branches of government. Furthermore, human rights prevail and must be recognized by the State and by society. Their effectiveness comes from constitutional principles and social victories. Social, economic, and environmental rights-which here are the most

# The first consequences of deep-rooted racism are violence and the devaluation of work

disrespected—should be guaranteed by public policy, leaving space for promoting new rights. In other words, as stated by lawyer Fábio Konder Comparato, human rights follow a line from the rights of the individual to the rights of peoples, social groups, and even the rights of all humanity, with a commitment to the future of new generations. Regarding the rights of humanity, what is important today is the right to life on this planet and to the defense of the environment and climatic balance, a sustainable economy, and native and traditional peoples.

## If a dictatorship is considered able to offer employment and food, why is a democracy better?

The dictatorial regime can even guarantee economic rights and ensure that people do not die of hunger, but society is deprived of many other rights that are equally important—such as those related to freedom of expression and diversity of culture, religion, politics, and gender. There is an essential link between democracy and the guarantee of human rights.

## And what does active citizenship involve, a concept you have also worked with?

I wrote my adjunct professor thesis on participative democracy, where I talked about the instruments of direct democracy, such as referenda, plebiscites, and popular legislative initiatives. These constitutional mechanisms facilitate the improvement of the system of representative democracy. I studied how these work in Europe, in some countries of South America, and in the United States, where they take place every two years, primarily in states such as California and Oregon. Active citizenship is contrasted by passive citizenship, which only relates to obedience to the law and to citizen obligations. Active citizenship is the right and obligation of the people to political participation, to democratic processes of control and the determination of fiscal authorities. This includes not only voting but also making an effort to be involved in decision-making processes, keeping informed and participating in community debates that can be held in groups, such as neighborhoods or political parties. Democracy requires effort. It demands the effort of those who govern and those who are governed.

## Has your academic background helped you move forward during the circumstances our country is currently facing?

I'm retired, but during the pandemic, I was part of five dissertation committees in various areas, such as philosophy, law, and communications. I continue to hold a strong interest in writing proposals about brutal social inequality, including inequality in education. In these almost two years of the pandemic, my grandchildren have had online and in-person classes, studied languages, and sat for the national entrance exam-they did not miss out on very much in terms of formal education. However, the losses were horrific for the vast majority of children and young people of families who are now very vulnerable. Many have gone hungry because the only source of food was at school. I had COVID-19, but I was already vaccinated, so the symptoms were light. I was isolated in a comfortable house, thinking the entire time of our friends who had died or required intubation. Of people going hungry and living in the streets. When I thought about all of this, what kept me strong was my involvement with the Arns Commission, founded by 22 people at the beginning of the current administration to condemn and fight human rights abuse throughout the country. However, regarding my academic background, what has kept me going and helped me deal with social and political anxiety during the pandemic has been my involvement with the Commission.

I had received offers from European universities but decided to stay in Brazil as I already felt at home in the country and had been awarded a FAPESP postdoc fellowship at IME-USP KIFAYAT ULLAH



# DIVERSITY IN SCIENCE

Brazil remains attractive for foreign postdocs, but applications have declined in recent years

## Rodrigo de Oliveira Andrade

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hile studying for his master's degree, the Pakistani computer scientist Kifayat Ullah heard from friends in Brazil about life as a researcher in the South American country. "They told me about the quality of the researchers and their laboratories, and how welcoming and collaborative the academic environment was," he said. Excited by the prospect, Ullah contacted Edson Santos Moreira, an electrical engineer at the Institute of Mathematical and Computer Sciences at the University of São Paulo (ICMC-USP) in São Carlos, who agreed to advise him on his doctorate in vehicular *ad hoc* networks. On completing his PhD in 2016, he returned to Pakistan to work as an assistant professor at the CECOS University of Information Technology and Emerging Sciences in Peshawar but later returned to Brazil for a postdoctoral internship. "I had received offers from European universities but decided to stay in Brazil as I already felt at home in the

country and had been awarded a FAPESP fellowship to continue my research on smart vehicular networks at the USP Institute of Mathematics and Statistics [IME]," Ullah said.

Even with the funding crunch and uncertainties surrounding the pandemic, FAPESP has still been relatively successful at attracting and retaining scientists from abroad doing postdoctoral research in Brazil. A total of 115 fellowships have been awarded in the last two years, according to data from the foundation. Students from all around the world join world-class research groups at institutions in São Paulo, doing high-impact research, exploring new fields of investigation and helping to train new researchers.

Admittedly, the number of applicants used to be higher. Since 2018, the foundation has seen a decline in postdoctoral fellowship applications and awards to candidates from other countries. Some believe the pandemic may have impacted the influx of scientists, whereas others attribute the drop to worsening social and economic con-



Foreign researchers are unable to live and do research in Brazil without financial aid ELISA ATALIA DANIEL MUIANGA

ditions in Brazil. "Science funding is limited and inflation and a weakening [Brazilian] real have made the country less attractive," said Jaroslava Valentova, a Czech anthropologist who has served as a professor at the Institute of Psychology (IP) at USP since 2015. "I thought it would be easy to bring postdocs over from abroad, but I've been unsuccessful thus far."

Neuroscientist Luiz Eugênio Mello, scientific director at FAPESP, explains that a country's ability to attract high-caliber foreign scientists depends on multiple factors, such as the availability of funds for grants and research groups that produce competitive science. "However," he added, "there are also factors outside the academic environment, such as the level of city violence, economic and political stability, and perceived openness to foreigners. I think that several of these aspects have also taken a turn for the worse in recent years in Brazil."

Even so, the country remains attractive to foreign researchers. Some are looking to study issues specific to Brazilian reality and culture or its unique biodiversity. This was the case for Spanish psychologist Irene Delval. She came to Brazil in 2011 to study the behavior of free-living primates. "It would have been impossible to do this kind of research in Europe or North America," she said. Delval completed the research for her doctoral degree in 2019 under the supervision of Patrícia Izar, a biologist at IP-USP. "I had thought about going back to Spain but decided to stay in Brazil for a while longer and try a postdoc." And she was successful. In late 2021, she was awarded a FAPESP grant to research the sexual behavior of capuchin monkeys at IP-USP.

Brazil also attracts researchers looking to study indigenous populations—the country harbors a wide diversity of cultural groups and world-renowned indigenous scholars. "I arrived in Brazil for the first time in 2009 hoping to earn a master's degree at the Federal University of Bahia [UFBA]," said French anthropologist Cyril Menta, who has researched the Pankararu and Pankararé for over a decade. "I was unable to enter a master's program, but during the six months I spent in Salvador, I met researchers who introduced me to a whole new field of research, so I returned to France with plans of going back to Brazil to continue my studies in that field."

In 2014, Menta was awarded a fellowship from the Rio de Janeiro State Research Foundation (FAPERJ) to do part of his doctorate at the National Museum of the Federal University of Rio de Janeiro (UFRJ). "Brazilian indigenous scholars are widely recognized for the quality of their

## **INTERNATIONAL INTEREST**

Applications for FAPESP fellowships from foreign researchers, by field



SOURCE: FAPESP

research," he said. "This is what attracted me to do research here." He is now preparing to start his postdoctoral work at the School of Philosophy, Languages and Literature, and Human Sciences (FFLCH) at USP, with a fellowship from FAPESP. Under the supervision of anthropologist Maria Manuela Carneiro da Cunha, he plans to study how Pankararu rituals are transmitted from one generation to another.

"The mechanisms for attracting and retaining foreign scientists are still largely based on grants and fellowships," noted Tiago Pereira, a mathematician at ICMC-USP who has supervised five postdocs from abroad in recent years. "Foreign researchers are unable to live and do research in Brazil without financial aid," said Elisa Atalia Daniel Muianga, a civil engineer from Mozambique who has been living in Brazil since 2013. She is currently doing a postdoctoral internship under the supervision of architect Doris Kowaltowski at the School of Civil Engineering, Architecture, and Urban Design at the State University of Campinas (UNICAMP), supported by a FAPESP fellowship. "Without a fellowship, you're also unable to get a Brazilian visa," added Kifayat Ullah.

"High-quality research groups and laboratory infrastructure are also important factors," said another FAPESP fellowship recipient, Chilean immunologist Camila Morales Fénero, who started a postdoctoral internship in January this year at the São Paulo School of Medicine at the Federal University of São Paulo (UNIFESP). She came to Brazil in 2013 and never left. "I wanted to work at a prestigious institution and with researchers producing competitive science," she said. Fénero found what she was looking for in a group led by immunologist Niels Olsen Saraiva Câmara at the Institute of Biomedical Sciences (ICB) at USP, who supervised her master's and doctoral studies.

Foreign researchers are valued by Brazilian scientists because they bring new insights and research perspectives. "The experience is also enriching for the visiting researchers," said historian Marcelo Cândido da Silva, from the Department of History at USP. "They have the opportunity to work with world-class researchers, broaden their research horizons, and interact with teams with different cultures and working styles. This experience will later be useful in setting up and managing their own laboratories."

One way foreign researchers can contribute to Brazilian science is by introducing new research fields to the country or teaching new research methods to graduate students. Cândido da Silva began using this strategy several years ago, inviting postdocs from abroad to his department. One was French archaeologist and historian Adrien Bayard, who was invited for an internship to train young researchers in medieval archaeology, a I came to Brazil because I wanted to work at a prestigious institution and with researchers producing competitive science CAMILA MORALES FÉNERO



field still incipient in Brazil. "Two students he helped train later took part in archaeological digs in Albania and France," noted Cândido da Silva.

ore recently, he invited French archaeologist Julie Renou to help implement new tools for archaeological analysis in studying trade in the High Middle Ages. "Postdoc studies are an important stage in the professional life of researchers looking to pursue an academic career," said Renou. "FAPESP fellowships can be a great opportunity in this regard, as they allow young foreign scientists to do cutting-edge research in a high-level exchange program," she noted.

FAPESP offers two-year fellowships, renewable for one or even two additional years if the researcher is linked to a Thematic Project or Young Investigator grant program. Fellows receive a monthly stipend of R\$8,479.20, plus a "technical reserve" equal to 10% of the annual amount. "This makes it attractive to scientists from some countries as they know they will have the peace of mind to do their research while also having the opportunity to attend conferences in other states and countries," said André Brunoni, a professor of psychiatry at the School of Medicine (FM) at USP.

Of course, many of them leave the country after their fellowships expire. "However, the relationships they build here often develop into collaborative networks that give Brazilian scientists the opportunity to join international projects, coauthor high-impact papers, access foreign funding, and organize student exchanges with these scientists' home institutions," said Edson My postdoc internship at UNICAMP will be a great opportunity to develop skills specific to my field NUSRAT JAHAN LISA

# FROM THE WORLD TO SÃO PAULO

FAPESP fellowships awarded to foreign researchers



SOURCE: FAPESP

Antonio Ticianelli, a professor of chemistry at the São Carlos Institute of Chemistry (IQSC) at USP.

Efforts to establish lasting partnerships with research groups from other countries also help Brazilian laboratories internationalize, which in turn can attract more foreign researchers to the country. This was the case for Colombian chemical engineer Ana Maria Marín. "I was working at the University of Alicante, in Spain, when a professor who knew Ticianelli's group told me about a postdoc opportunity in his laboratory that I might be interested in applying for," she said. "I was accepted and came to Brazil in 2015 to do research on the use of nanostructured electrocatalysts in the production and oxidation of hydrogen."

hese scientists will often remain in Brazil. adding to the body of local researchers. Marín, for example, is now an assistant lecturer in the Chemistry Department of the Aeronautics Institute of Technology (ITA) in São José dos Campos. Spanish chemical engineer José Joaquín Linares León had a similar experience. He came to Brazil in 2010 to do a postdoc at IQSC-USP. In mid-2012, as his fellowship neared expiry, he started looking for new opportunities. "I did interviews at the National Hydrogen Center in Spain and at a fuel cell company in Denmark," he said. Brazil, however, was then expanding its network of universities. "I decided to apply for tenure before accepting the position I was offered in Denmark. I was accepted at the University of Brasília [UnB] and am now a professor at the Institute of Chemistry."

Mello, from FAPESP, noted that there are "many different countries vying for talent and this creates competition." He added, "Internationalization and attracting foreign researchers to stimulate the flow of ideas are therefore a core part of FAPESP's mission." The foundation has invested over the years in a range of strategies to attract foreign talent by offering fellowships and other initiatives, such as the São Paulo School of Advanced Science Program, a grant mechanism that allows researchers in São Paulo to organize short programs to be attended by scientists and students from around the world. The goal is to showcase research opportunities in São Paulo to students and scientists from abroad.

FAPESP also requires the researchers it funds to advertise postdoc fellowships linked to their projects in English on international websites, helping to raise the profile of available vacancies and attract foreign researchers. This was how Bangladeshi computer scientist Nusrat Jahan Lisa learned about a vacancy in the laboratory run by electrical engineer Guido Araujo at the UNICAMP Institute of Computing. "I was working as an assistant lecturer at the Ahsanullah University of Science and Technology in Bangladesh, and I often visited websites like Euroxess, which post information about fellowship and job opportunities for scientists in different institutions around the world," she said. "I came across an advert for a postdoctoral fellowship in Araujo's laboratory to work on a project in my field of expertise." Lisa said she had already heard about UNICAMP but that this would be her first collaboration with Brazilian scientists. "It will be a great opportunity to develop skills specific to my field," she said.

# BEYOND Borders

In its six decades, São Paulo's FAPESP has helped strengthen Brazil's broader science, technology, and innovation ecosystem

## Fabrício Marques

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ince its founding 60 years ago this May, FAPESP has funded some 320,000 research projects at institutions in São Paulo across all fields, helping consolidate the state's nationally leading position in scientific output. However, the Foundation's influence on higher education and basic and applied research has extended beyond São Paulo's borders, imprinting a lasting mark on Brazil's wider science and technology landscape. On many occasions, programs developed at FAPESP have inspired other initiatives on a national scale.

In the late 1990s, the FAPESP Genoma program, which brought together 192 researchers in a virtual network of 60 laboratories to sequence the DNA of multiple organisms, led to several other similar initiatives around the country. In 2000, the year Nature published the results of the genome sequencing of the bacterium Xylella fastidiosa, the Brazilian National Council for Scientific and Technological Development (CNPq) established a nationwide network for the Brazilian Genome Program, comprising 240 scientists from 18 states, which was initially tasked with cracking the genome of Chromobacterium violaceum, a bacterium with important applications in biotechnology. "CNPq, not surprisingly, chose biochemist Andrew Simpson,

the FAPESP program's DNA coordinator, to head the federal initiative," says physicist José Fernando Perez, who served as the scientific director of FAPESP from 1993 to 2005. He recalls a telephone call he received from Wanderley de Souza, then Rio's Science and Technology secretary: "He said that the governor of Rio de Janeiro was impressed by our program and was proposing a partnership." A collaboration was established with Jesus Ferro, a researcher at São Paulo State University (UNESP) in Jaboticabal and one of the scientists heading the FAPESP Genoma program, to develop a DNA library for his counterparts in Rio.

Another case in point is the FAPESP Technological Innovation in Small Businesses (RISB, or PIPE in Portuguese) program, launched in 1997. Like the FAPESP Genoma program, RISB was modeled on a US initiative. It mirrored the format of the Small Business Innovation Research (SBIR) Program, created in 1982 to funnel funding from US research agencies to support innovative small businesses. RISB was in its fifth year when the Brazilian Funding Authority for Studies and Projects (FINEP), a federal agency, launched a similar initiative: the Research Support for Businesses Program (PAPPE). However, in São Paulo, the federal program took a different format. Under an agreement between



São Paulo Governor Carlos Alberto Alves de Carvalho Pinto (*seated*), signing FAPESP's articles of association on May 23, 1962

FAPESP's Science Board and the then chairman of FINEP, Sergio Machado Rezende, PAPPE funded only Phase 3 RISB projects—those that had already received FAPESP funding, were at an advanced stage and were close to commercial application. In other states, FINEP also funded earlier-stage projects.

While the Foundation does not have a mandate to directly fund researchers and institutions in other states, the impacts of its programs have reached across borders. In 2008, FAPESP performed a survey to profile its scientific initiation, master's, doctoral, and postdoctoral grant beneficiaries from 1992 to 2002. A map showing the subsequent professional careers of former grant beneficiaries in 12 different fields revealed that while most-between 70.3% and 83.8%, depending on the field-were still in São Paulo, a significant number of them were employed in other states and even other countries. In the fields of health care, crop science, and veterinary science, former grant beneficiaries were found in 24 states. "For many years, FAPESP-funded researchers and higher education institutions in São Paulo accounted for 70% of PhD researchers in Brazil." writes FAPESP Chairman Marco Antonio Zago in an article published this year in the journal Estudos Avançados: "As of 1996, 67% of PhDs were completed in São Paulo, and

from 1996 to 2017 the state accounted for 44.3% of the total. So, you could say that FAPESP has indirectly supported the development of federal universities in all the states of Brazil."

APESP has also grant-funded São Paulo-based researchers with research interests outside the state, as well as collaborations with scientists in other states and internationally. For example, FAPESP has been the single largest funder of Amazon research, provisioning 895 projects and 1,612 grants, many linked to the Foundation's special programs. "The Amazon has always been a key research interest for us, given the importance of the region for Brazil and for the world," says physicist Carlos Henrique de Brito Cruz, who served as chairman of the FAPESP Board of Trustees from 1996 to 2002 and scientific director from 2005 to 2020. In 2014, he attended a symposium in Washington where he presented the results of research projects on the Amazon's tropical forests. "The Amazon is part of the scope of two of FAPESP's flagship programs," he explains, referring to the Research Program on Biodiversity Characterization, Conservation, Restoration, and Sustainable Use (BIOTA) and the Global Climate Change Research program.

However, perhaps FAPESP's biggest contribution to Brazil's science and technology ecosystem is the way it has served as a blueprint that research-funding agencies in other states have replicated. Granted, it took several years for FAPESP's pioneering model to find its way to other states. Rio Grande do Sul became the first state to institute a counterpart funding agency (FAPERGS) in 1964, while the states of Minas Gerais and Rio de Janeiro would not follow suit until the 1980s. Although Brazil now has similar foundations in 26 of its 27 states (all but Roraima), it was only in the 2000s that most of them were created, often under the provisions of their state constitutions. "FAPESP helped structure many of these foundations," says Brito Cruz.

In addition to assisting with more formal matters, FAPESP was active in discussions regarding the approaches to research funding in these states. Flávio Fava de Moraes, FAPESP's scientific director between 1985 and 1993. recalls a landmark battle that the Foundation championed in the state legislature, which sent waves across country when it lobbied to raise FAPESP's allocation of state tax from 0.5% to 1% under São Paulo's 1989 Constitution. "São Paulo's science community, led by the Foundation, decided to ask for a larger slice of funding," explains Fava, who, accompanied by the then chairman of the FAPESP Executive Board, Alberto Carvalho da Silva (1916-2002), went from office to office in the State Assembly and visited Palácio dos Bandeirantes, the seat of the São Paulo state government, to advocate for the change.

"I remember receiving a late-night call from a professor at USP alerting me that the funding increase was being discussed at that very moment by the deputies and was at risk of being carved out. I got in my car and drove as fast as I could to the Assembly," recalls Fava. He was able to talk to the rapporteur of the new Constitution, deputy Barros Munhoz, who described the impasse as follows: one group of deputies argued that a fixed tax allocation for FAPESP would be unfair to other state agencies—either they should all have a constitutional allocation, or none of them should. This gridlock was only resolved, says Fava, when, in consultation with the then Governor Orestes Quércia, a proposition was made. FAPESP's funding should be applied not only to scientific but also to technological development—a change that expanded the agency's scope and challenges: "The 1% was unanimously approved. This was great for the Foundation, helping it to better fulfill its mission to support research across all fields of knowledge."

his funding increase in São Paulo soon began to be discussed in the legislatures of other states. Alberto Carvalho da Silva visited several other states to hold discussions with governors and deputies, advocating that they replicate FAPESP's funding model. "I remember the chairman of the state assembly in Rio Grande do Sul was enthusiastic about the idea of earmarking state taxes for FAPERGS. He had strong support from colleagues who were familiar with São's Paulo successful model," says Fava. Ultimately, that state's Constitution set aside an even larger percentage than in São Paulo–1.5%—for its funding agency.

This had a limited impact, however, with many states failing to meet their constitutional allocation or having to adjust during budgetary crises. São Paulo alone maintained an impeccable record: since the 1% tax transfer was written into the Constitution in 1989, the state has never been late on its payments to FAPESP. Created as a private foundation, FAPESP manages its budget independently. It can also invest its funding and use dividends as a long-term source of cash for research grants and projects.

Former foreign minister Celso Lafer, who served as the chairman of FAPESP between 2007 and 2015, explains that the Foundation's model was influenced by the landmark report, "Science, the endless frontier," published in July 1945 by American engineer Vannevar Bush (1890-1974), in which he asserted the interdependence of basic and applied science and called for a free and independent scientific community and greater participation by industry and private business in research efforts. "Since it was founded, FAPESP has never made a distinction between basic and applied science and has instead funded research across all fields. It began by providing over-thecounter grants but soon expanded its scope to

## FAPESP HAS Provided A model For research-Funding Foundations In other states



On December 15, 1997, the then Governor Mario Covas announced the first companies selected for the RISB program in Bandeirantes Palace

include more ambitious and longer-term programs and projects," says Lafer, whose tenure at FAPESP was marked by efforts to internationalize the organization by creating a network of collaboration with research institutes and universities around the world.

he assurance of sufficient funding to meet the scientific community's research needs has allowed the Foundation to expand its focus on developing innovative initiatives over time. Flavio Fava de Moraes mentions the Biochemistry Development Program (Bioq-FAPESP), launched in 1971, as an example. This was the Foundation's first foray into funding research in an emerging field. "Bioq-FAPESP also encouraged different research groups to collaborate and served as a pilot, during my tenure, for the introduction of a category of projects operating as research networks, known at FAPESP as thematic projects," says Fava.

"FAPESP was able to implement aspirational programs that leveraged this potential," says José Fernando Perez. The Foundation, he continues, created a fertile environment not found in any other agency: "Subject-matter coordinators would meet on a weekly basis, and I, as scientific director, had the opportunity to interact with leading figures in the science community to discuss FAPESP's vision. This highly interactive environment is maybe one of the things that distinguishes FAPESP from other agencies." Moreover, he says. "The somewhat invisible interface that exists between FAPESP and the community is behind a number of its pioneering programs." Based on the recommendations of assistant and subject-matter coordinators, says Perez, several programs were launched during his tenure, including Genoma, SciELO, Biota, and RISB—many of them based on international experience.

Neuroscientist Luiz Eugênio Mello, FAPESP's current scientific director, recalls how, during his time as an assistant coordinator from 2003 to 2006, he was involved in discussions that would later result in important programs. "There's a Brazilian saying that goes, 'it's easy to engineer a finished building,' or to prophesy in hindsight," he says. Hence, "Many of FAPESP's most successful initiatives (thematic projects, Genoma, SciELO, to name a few) were initially met with opposition from the community. Maybe that's the way it always is with challenges and new terrain. Different forces pulling hither and thither helped to shape the development of FAPESP's new projects and programs. Indeed, science flourishes from scientific disagreement, provided it does not devolve into personal attacks."



## Lack of consensus on the concept of disinformation hinders regulatory efforts to control the spread of false content online

## Christina Queiroz | ILLUSTRATIONS Gustavo Nascimento

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he first records of the impact of disinformation on political processes date back to Ancient Rome (753 BC to 476 AD), when Caesar Augustus (63 BC to 14 AD) used short phrases on coins to defame his rivals and become the first ruler of the Roman Empire (27 BC to 476 AD). However, as Portuguese historian Fernando Catroga of the University of Coimbra recalled in an article published in 2020,

the emergence of digital technology has given the phenomenon new life, including the ability to go beyond manipulating the facts. Now, the aim seems to be to replace reality itself. A study on political disinformation, carried out by researchers from the University of São Paulo's Law School (FD-USP) between April 2020 and June 2021 with funding from FAPESP, analyzed how Brazilian legal organizations reacted to false information spread online during the 2018 election period. A lack of consensus on the concept of disinformation and difficulties measuring its consequences were identified as central to the failure of proposing an legislation.

Celso Fernandes Campilongo, the legal scholar from FD-USP who led the study, noted that 15 years ago, public opinion was mostly formed and influenced by long, reflective analyses disseminated centrally by the mainstream media. "Today, people are faced with an avalanche of short and discontinuous information published by people with a strong presence on social media. In a way, memes and jokes have replaced analytical texts," he pointed out. Campilongo cited the Continuous National Household Sample Survey – Information and Communication Technology (Continuous PNAD – TIC), published in April 2020 by the Brazilian Institute of Geography and Statistics (IBGE), to highlight that access to social media can be seen as more democratic. The survey indicated that in 2019, three of every four Brazilians used the internet, with cell phones being the device most frequently used for this purpose. It also showed that 95.7% of people in the country with internet access use apps to send or receive image, text, or voice messages.

Campilongo pointed out that since the Proclamation of the Republic in 1889, elections in Brazil have been marked by authoritarian actions. As an example, he cited the Credentials Verification Commission, which was created during the Empire of Brazil and gained importance during the First Republic, especially from 1899 onward, under the rule of President Manuel Ferraz de Campos Sales (1841-1913). The commission allowed the central government to remove opposition candidates from political office, even elected officials. For Campilongo, other examples of the phenomenon include the fact that people who cannot read or write were only given the right to vote in 1988 and the ongoing use of the socalled "controlled vote," where people vote for candidates hand-picked by political chiefs or electoral leaders.

"Considering this history, the 2018 elections were marked by the unprecedented role played by digital communication, including social media and private messaging services, which became channels for the massive dissemination of disinformation. We analyzed the repercussions this has had on the legal system," said Marco Antonio Loschiavo Leme de Barros, a jurist from Mackenzie Presbyterian University and one of five authors of the article. In 2015, Brazil's Supreme Court (STF) prohibited companies from funding political parties and campaigns with

# **DEFINING CONCEPTS**

The United Nations Educational, Scientific and Cultural Organization (UNESCO) advises against the use of the term "fake news," noting that the word "news" refers to verifiable information of public interest. Information that cannot be classified as such should not be called news. In place of "fake news," the organization suggests using the term "disinformation" in reference to deliberate attempts to confuse or manipulate people via the transmission of falsities. The term "misinformation," meanwhile, should refer to misleading content disseminated with no intent to mislead anyone.

the aim of reducing the influence of money in elections and giving representatives from disadvantaged social groups a more equal platform. According to Loschiavo, the move ended up destabilizing the electoral market, with formerly direct financial support migrating to other environments—business owners began paying for huge amounts of information to be shared on social media as a way of ensuring that their best interests were upheld.

Regulation for the online environment began even before 2018. FD-USP legal expert Lucas Fucci Amato, another member of the research team, explained that the Brazilian Civil Rights Framework for the Internet, in force since 2014, was the first legislation passed to control the flow of disinformation, establishing principles, guarantees, rights, and duties for internet users, as well as guidelines for state involvement. Another milestone was the General Data Protection Law (LGPD), passed in 2018, which governed the processing of personal data online. In 2019, the Electoral Code prohibited mass broadcast messaging through mobile apps.

On the spread of political disinformation, Amato recalled that the Electoral Code establishes the crimes of slander, defamation, and libel related to the dissemination of untrue information. In addition, Law 9.504/1997, known as the Election Law, provides for the right to respond when untrue or offensive information is shared, making it a crime to publish content online that is harmful to the image of political candidates, parties, or coalitions. "These laws were created to govern the actions of large corporations and regulate situations relating to slander, defamation, and libel that occur centrally. With the emergence of digital platforms, communication has become faster and more decentralized, and the controls established in the legislation are no longer effective," said Loschiavo.

"As a result of these changes, we found that the justice system has found it difficult to deal with international flows of communication and to regulate the dissemination of false information online," said Amato about the results of the study. The researchers analyzed recent efforts by the public authorities to control disinformation, finding that the judicial system has taken cautious steps to protect the digital environment. "In the legislative branch, disputes have led to successive delays in voting on bills and postponements to the enforcement of others that have already passed. To resolve cases involving allegations of disinformation, judges have resorted to indeterminate, generalized principles, instead of establishing clear and precise rules, as well as leaning on the assistance of experts in technology and digital law, including companies in the sector," said the legal scholar.

With respect to Brazil's Superior Electoral Court (TSE), Amato highlighted that until early 2021, its decisions were monocratic, meaning they were made by a single judge rather than a commission, which does not contribute to the establishment of good jurisprudence. "These elements show that the TSE acted in favor of freedom of expression, avoiding censorship to the detriment of greater control over the dissemination of false content via private messaging apps and social networks," said Amato.



Loschiavo noted that the research also identified that the primary means adopted by the Brazilian courts to combat disinformation was to demand the removal of intentionally false content, in addition to requiring platforms to flag potential untrue information. "The concepts of fake news and disinformation remain unclear. There is no definition for them in electoral law, which poses an interpretation problem for the courts," he explained.

nother challenge for the justice system, according to Loschiavo, is the difficulty of proving the potential harmful use of disinformation and its ability to interfere with the outcome of elections. "In the survey, we identified that after 2018, the judiciary realized that the most effective way to deal with disinformation is through preventive action. As a result, the TSE

started inviting platforms to sign agreements undertaking to adhere to programs that combat disinformation, moderate content, check sources, limit message forwarding, and block fake accounts," he said.

The discussions triggered by the 2018 election led to the formulation of PLS 2630/2020, known as the Fake News Bill, which is currently in the Brazilian House of Representatives. The bill outlines the need for digital platforms to flag advertisements so that users can differentiate them



# ANTI-DISINFORMATION ALGORITHM

Researchers from the Center for Mathematical Sciences Applied to Industry (CEMEAI), based at the Institute of Mathematics and Computer Sciences of the University of São Paulo (ICMC-USP), one of the Research, Innovation, and Dissemination Centers (RIDCs) funded by FAPESP, have created an algorithm capable of detecting false information with 96% accuracy. The tool, which combines mathematical models created from more than 100,000 news items published in the last five years, can be accessed at www.fakenewsbr.com. "The algorithm tends to understand texts with an imperative tone or a sense of urgency, for example, as fallacious, but it also analyzes the context of the words before making a prediction about whether or not the content in question is false," explains statistician Francisco Louzada Neto, Director of Technology Transfer at CEMEAI. According to Neto, the platform has received more than 4,000 hits since February 2022 and will be continuously updated to keep up with the latest false information being spread.

from news and establishes that international companies must have representatives in Brazil capable of responding to the judicial system when requested. According to Loschiavo, it also states that technology companies are expected to identify and warn of abusive behavior, such as fake accounts that disseminate massive amounts of content designed to destabilize public debate. He highlighted the concept of "combined selfregulation" introduced by the bill, which calls for the creation of a collaborative entity involving digital communication companies, members of the government, and citizens more broadly to jointly develop regulations for the digital environment. "This mechanism, however, carries a risk that public interests will be overshadowed by private ones," he pointed out when reflecting on the weaknesses of the proposed new law.

Ivan Paganotti, a researcher at the Methodist University of São Paulo, also believes the bill's lack of a clear definition of the concept of disinformation could threaten the right to freedom of expression, as has occurred with legislation in other nations, such as Malaysia. "The Asian country's law defines disinformation so broadly that any data not legally confirmed can be considered false. Since the law came into force in 2018, many people have been unfairly penalized," said Paganotti, who has been researching the topic of online disinformation for four years. He pointed out that the dynamic is similar in Russia, where legislation to combat disinformation is being used to curtail any news that is critical of the country's war against Ukraine.

The research project, scientific articles, books, and documents consulted for this feature are listed in the online version.

# INTERACTIVE ATLAS OF RIO DE JANEIRO

The map of the city shows the geographical and urban transformations since 1500

Dafne Sampaio PUBLISHED IN JUNE 2022 n interactive map of Rio de Janeiro has just been released with photos, paintings, and graphic representations, all dated and geographically identified. With imagine Rio, it is possible to follow more than 500 years of changes, growth, and transformations, some radical, to the landscape of the state capital of Rio de Janeiro. "Imagine Rio began to be conceived in 2010 out of the necessity of two professors from the University of Rice, in Houston, Texas," remembered Martin Passos, urbanist and researcher from the Moreira Salles Institute (IMS). He continued, "Alida C. Metcalf and Farès el-Dahdah are North American Brazilianists who teach the history of Rio

de Janeiro to a student body that does not speak Portuguese. When they got to urban evolution, they felt [there was] a lack of something more visual, such as cartographic and historiographical material, so the students could understand the changes of the city."

View of Botafogo and Sugarloaf Mountain from Mirante Dona Marta in a photograph probably taken in 1910 "Metcalf studies colonial Brazil, the history of water in Rio, and the consequent evolution of the city," explained social scientist Sérgio Burgi, responsible for the coordination and curation of photography for the IMS, "whereas el-Dahdah is a specialist in modern Brazilian architecture, Oscar Niemeyer [1907–2012], Lúcio Costa [1902– 1998], and Burle Marx [1909–1994]." According to Burgi, the genesis of imagineRio is the combination of these two interests, colonial and modern.

At Rice, Metcalf and el-Dahdah joined a group of programmers to make the first platform for the project, superimposing old maps over the current relief of the city, made available online by Google. In 2012, approximately two years later, the university established a partnership with the North American company Axis Maps, which created a second, more cartographically accurate platform with intuitive and immersive navigation.

However, something important was missing from the maps project: images, thousands of them. In 2015, during an international seminar on digital cartography held in Rio, the team from Rice discovered the IMS, and the synergy was immediate. The institute was already developing virtual reality projects for photography exhibitions, in addition to having a large collection of images of the city. The union was inevitable: the digital platform and cartography from Rice and the collection of photographs and territorial expertise from IMS.

The third and most complete version of imagineRio is the product of the coming together of these two institutions as well as a history of digital art scholarship awarded by the Getty Foundation at the end of 2018 to the Rice-IMS consortium. The US\$200,000 funding package from Getty was originally planned to end after 24 months, but due to the pandemic and other delays, funding



for the project was extended until the end of this vear. With this funding, the IMS was able to scan or rescan over 3,000 photos from its collection in high quality, join them with the maps from Rice and improve the interactive map, which has been officially available since the start of 2022. "The maintenance of the website continues to be done by the University of Rice, which counts on support from the institution itself and external aid from Axis Maps, as well as the work of students of all levels," says Passos. An important detail and one of the requirements of the Getty Foundation is that all the available images must be in the public domain and can now be shared freely. The same applies for image metadata, that is, the information regarding the authorship of these images, the year they were taken, and dimensions, etc.

With the photographer positioned at the back of Santa Casa de Misericórdia, the image shows jets of water used to remove dirt from Morro do Castelo in 1922

Below left, the palm grove at the Botanical Garden with Morro Dois Irmãos in the background. Right, the Municipal Theater next to the National School of Fine Arts. It is estimated that the first photo was taken in 1890 and the second in 1910





"In Rio, the last year of high school uses the city as the final topic of the core curriculum. The use of a robust cartographic tool, digitalized images, and a vast document collection is, methodologically, what can make the difference in approaches inside the classroom," says geographer Walmir Pimentel, who has taught in state and municipal schools in Petrópolis, in the mountainous region of the state, for 20 years.

"Considering that history is constructed as knowledge from the interconnection of oral, written, iconographic, and musical sources, among others, imagineRio provides access to extremely valuable images and cartographic data for those interested in studying the city from a broader perspective, understanding and broadening perceptions of the relationships between the population, land, and public power,"says writer Luiz Antônio Simas, also a high school history teacher in Rio. "The uses of a platform such as imagineRio are as varied as the people who will use it," he says.

istorian Flávio Gomes, coordinator of the Laboratory of Atlantic History Studies of the Federal University of Rio de Janeiro (LEHA-UFRJ), has other ideas for using the interactive map. "I am monitoring, in a large research project, the movement of African occupation in different parts of the city. With the tools from imagineRio and the comparison with databases, we are already able to see how Rio has been organizing itself into different ethnic territories, many of which are linked with commerce, religious identities, and different socialities," he explains.

Simas says that he is interested "above all in the uses that allow understanding of how the city has been changing in an impacting way and to what extent these changes have affected the daily lives of people from Rio de Janeiro. The urban reorganizations of the First Republic, such as the Passos Reform between 1903 and 1906, the occupation of the suburbs, and the demolition of Morro do Castelo between 1920 and 1922, are compelling examples of these dramatic transformations."

Burgi adds, "imagineRio is an attempt to join together multiple confluences—many entry points—so ideally the platform will be collectively appropriated by researchers, by institutions that preserve memory, and by the population that just wants to wander through the history of the city." In the future, he anticipates that the platform may house historical surface models. It will be possible, for example, to walk around the center of Rio de Janeiro in 1808, in a 3D projection faithful to the city's relief, as you can today with Google Earth.

Until this future arrives, those responsible for the project are attempting to go beyond the clas-



sic images immortalized in the photographs of Marc Ferrez (1843–1923), Augusto Malta (1864– 1957), and Jorge Kfuri (1893–1965) or even the paintings by Jean Baptiste Debret (1768–1848), Thomas Ender (1793–1875), and Johann Moritz Rugendas (1802–1858). In partnership with the Images of the People program of the Favelas Observatory, 50 images of the Maré region were acquired that will allow the insertion of these territories on the map. From top to bottom, the first two maps show the occupation of the city of Rio de Janeiro in 1600 and 1900, respectively. Photograph taken approximately in 1866 by Georges Leuzinger from Morro de São Bento, showing the perspective of the view of Ilha das Cobras on the third map

THE AMAZON PRODUCES 8% OF THE PLANET'S METHANE

Approximately 75% of the methane released by the Amazon comes from wetlands, according to an INPE study

CLIMATE

## Most of the gas emitted in the biome comes from wetlands, but the rise in livestock farming and fires has increased emissions associated with human occupation

#### **Marcos Pivetta**

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he production of methane (CH<sub>4</sub>) in the Amazon accounts for 8% of global emissions of this greenhouse gas, the second most abundant greenhouse gas after carbon dioxide (CO<sub>2</sub>). This figure remained stable between 2010 and 2018. Approximately three-quarters of the methane released in the region, which comprises nine countries and of which 60% is located in Brazil, was produced by the natural decomposition of biomass-essentially trees and vegetation-in wetlands that partially or totally flood over the course of the year. The remainder was emitted as a byproduct of two activities related to human occupation: fires (16% of the total) and cattle farming (11% of the total).

These figures are from an article published in the scientific journal *Communications Earth & Environment* in December 2021. "The Amazon is a major global source of methane, but our data indicate that the region has not contributed significantly to the recent increase in emissions," explains the study's lead author, Luana Santamaria Basso, a biologist currently on a postdoctoral fellowship at the Greenhouse Gases Laboratory (LAGEE) at the Brazilian National Institute for Space Research (INPE). Between 2010 and 2018, the Amazon emitted approximately 46 million tons of methane per year, according to the article.

Based on how much of the rainforest is located in Brazil, the country is responsible for 60% of the South American biome's annual methane emissions: approximately 29 million tons. This equates to 5% of all methane emissions on the planet. "Although the Amazon should not be singled out as a villain in regard to global methane emissions, the article highlights that emission of the gas due to anthropic [human] activities in the region is greater in the most deforested areas than in the most preserved," explains Luciana Vanni Gatti, a chemist, LAGEE coordinator, and coauthor of the study. She is also head of a thematic research project under the scope of FAPESP's Research Program on Global Climate Change (PFPMCG), which monitors the methane balance in the Amazon.

In the last two decades, at least seven studies by international groups with distinct methodologies, including the use of satellite data, have reached very different values on methane production in the region. According to the article cited above, the amount of CH4 released by the rainforest could vary from less than 10 to approximately 50 million tons per year. Furthermore, studies do not always consider the same geographical area. The article by Basso, Gatti, and colleagues estimated emissions for an area of 7.2 million square kilometers (km<sup>2</sup>), the most widely accepted size of the Amazon, which encompasses the nine countries in the region. Studies that considered similar geographical areas of between 6 and 8 million km2 arrived at results with a similar order of magnitude; they indicated that from 30 to 47 million tons of methane are produced every year. A study that used an area of just 3.7 million km2 estimated the amount of CH<sub>4</sub> released by the biome at just over 9 million tons per year.

Once known as swamp gas, methane is produced by the decomposition or decay of organic



matter in geological or biological processes. The former process includes the production of oil, coal, and natural gas. The latter process includes the fermentation of vegetation in wetlands, incomplete burning of biomass, putrefaction of organic waste in landfills, and above all, agricultural activities, such as food digestion by ruminants and, to a lesser extent, rice cultivation in paddy fields.



ccording to data from an international survey published in the journal *Earth System Science Data* in July 2020, 62% of the 580 million tons of CH4 emitted annually worldwide

are attributed to anthropic activities, especially to farming ruminants, such as cattle, sheep, and goats. Microorganisms in these animals' stomachs ferment food during the digestive process, producing methane. By releasing stomach gases through their mouths, ruminants expel CH4 into the atmosphere. "It's not flatulence that causes cattle to release methane. It is their burps," explains INPE agronomist Jean Ometto, who was not part of the study by his colleagues Basso and Gatti. "Investing in pasture quality is one way to reduce methane production by enteric fermentation."

The new article calculated the amount of CH<sub>4</sub> emitted in the Amazon based on concentrations in 590 air samples obtained during the study. A small plane was used to collect vertical atmospheric profiles twice a month, between 300 meters (m) and 4.4 kilometers (km) of altitude in four regions of the Amazon: 100 km north of Alta Floresta in Mato Grosso, in the southeast; 40 km south of Santarém, in the northeast of Pará; 300 km east of Rio Branco in Acre, in the southwest; and Tabatinga and Tefé, in Amazonas, in the northwest. These same profiles were used in other studies by Gatti's group to calculate CO<sub>2</sub> emissions in the Amazon in the period (*see* Pesquisa FAPESP *issue no. 306*).

"High methane production in Amazonian wetlands is no surprise," says Philip Fearnside, a biologist from the Brazilian National Institute of Amazonian Research (INPA) who did not participate in the INPE study. "These estimates have increased recently, partly due to the discovery of substantial emissions by trees in wetland forests." The scientist notes that significant volumes of methane are also released from the reservoirs created by large hydroelectric plants built in the Amazon, such as the Balbina Dam in Amazonas and the Belo Monte Dam in Pará, both of which flooded vast areas of the rainforest. Rivers whose flow rates are controlled by dams are also sources of this greenhouse gas. Studies indicate that in Brazil, most of the methane produced by enteric fermentation in ruminants occurs outside the Amazon, where more than half of the country's 220 million head of cattle live. Brazil is home to more cattle than any other country in the world. "Currently, approximately 40% of them are raised in the Amazon, but this percentage is continuously growing," says Gatti.

Although the contribution of forest fires and agriculture to methane production in the Amazon is still relatively modest, these activities Human activities, fires, and cattle farming produce a quarter of the methane emitted in the South American rainforest



# Origins of methane in the Amazon

Processes that generated the greenhouse gas between 2010 and 2018



SOURCE BASSO, L. S. ET AL. COMMUNICATIONS EARTH & ENVIRONMENT. 2021

are having a growing influence as deforestation increases in one sector of the biome. In the southeast of the rainforest—the region most impacted by human occupation—cattle farming and fires are the source of 48% of total CH<sub>4</sub> emissions. In the northeast, natural methane production is up to three times higher than expected.



lobal warming is caused by an increased concentration of greenhouse gases in the Earth's atmosphere compared to the preindustrial period of the mid-nineteenth century.

These gases absorb energy and retain heat in the air that surrounds the globe. Since the industrial revolution, the average temperature of the



planet's atmosphere has increased by approximately 1.1 degrees Celsius (°C). Over the past 150 years, the cumulative contribution of methane to global warming has been approximately one--third less than that of carbon dioxide.

Due to this and other particularities of CH<sub>4</sub>, such as its short half-life in the atmosphere (approximately 12 years, while CO<sub>2</sub> has a half-life of 120 years), discussions on combating climate change have primarily focused on reducing carbon dioxide emissions. However, this has changed in recent years, and studies on methane have become increasingly prominent in scientific papers and in reports by the Intergovernmental Panel on Climate Change (IPCC). At the most recent United Nations Climate Change Conference (more commonly referred to as COP26) held in November 2021, Brazil was one of just over 100 countries that committed to reducing methane emissions by 30% by 2030. The country is the fifth-largest annual emitter of methane on the planet, behind only China, Russia, the USA, and India.

"Investing in the reduction of methane emissions could more quickly impact global warming and climate change," says Ometto. The explanation is simple. Over a two-decade period, one kilogram of methane generates 80 times more heat in the atmosphere than the same amount of carbon dioxide. "CH<sub>4</sub> has a huge impact in the first few years after emission, but it remains in the atmosphere for a short time. In contrast, CO<sub>2</sub> has a milder effect on a yearly basis, but it lasts approximately 10 times longer," explains Fearnside. The problem is that after going through a period of stability between 1999 and 2006, global methane emissions started to rise again. In September 2021, it reached the highest concentration in history, at 1,900 parts per billion. "In addition to the known sources, there could be other less understood processes associated with methane production. In our study, for example, we observed that there is a major source of methane in northeastern Amazonia that is as yet unidentified. We have not been able to determine where it's coming from," says Basso.

#### Project

Interannual variation of Amazon Basin greenhouse gas balances and their controls in a warming and increasingly variable climate – CAR-BAM: the Amazon carbon balance long-term study (No. 16/02018-2); **Grant Mechanism** Thematic Project; Global Climate Change Research Program; **Principal Investigator** Luciana Vanni Gatti (Inpe); **Investment** R\$4,436,420.43.

#### Scientific articles

BASSO, L. S. *et al.* Amazon methane budget derived from multiyear airborne observations highlights regional variations in emissions. **Communications Earth & Environment**. Nov. 29, 2021. SAUNOIS, M. *et al.* The Global Methane Budget 2000–2017. **Earth System Science Data**. v. 12, i. 3. July 2020.

# THE LAND OF TREES



Rainforests in South America are home to four times as many tree species than those in Africa

Eduardo Geraque

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outh America has more known tree species than any other continent, with approximately 40% of the global total. Much of its richness in tree biodiversity is concentrated in tropical areas. In warmer regions, there is more water available, and there is less contrast between the seasons-these conditions are more favorable to the emergence of new forms of plant life than temperate or cold environments. A study published in the scientific journal PNAS in March suggests that South American rainforests, such as the Amazon and the Atlantic Forest, have nearly four times as many tree species as similar forests in Africa. This trend is also seen-to a lesser extent-in plant formations where water availability is more limited, e.g., biomes in South America, such as the Cerrado (wooded savanna), are home to twice as many tree species as African savannas.

Researchers do not know why South America has more tree species than Africa despite being only 59% of the size. Possible explanations include the extre-



previous page) and jabuticaba tree, two species typical of South America

mely arid conditions and reduction in forest area in Africa, in addition to the greater fragmentation of the continent's vegetation cover due to glaciation cycles throughout its geological history. In South America, the greater water availability and more varied range of natural environments may have promoted the emergence of more species.

According to the PNAS article, approximately 50% of the greater tropical tree species diversity in South America is explained by the exceptional development of just eight or nine large tree families. Of this group, four megadiverse families in particular stand out: Fabaceae, commonly known as the legume family, such as beans, lentils, and peas and even Brazilwood; Lauraceae, which includes avocado, cinnamon, and bay laurel; Myrtaceae, which includes many fruit species, such as the rose apple, Brazilian cherry, guava, and jabuticaba; and Melastomataceae, which includes species with a prominent role in areas under environmental restoration.

This small number of botanical groups covers many forms of plant life on both continents, but in South America, the variety of tropical plants is much greater, at 2,837 species compared to 657 in Africa. "Most of the species in these four families are from hot and humid biomes. such as the Amazon and the Atlantic Forest, but some are also found in drier areas," says the study's lead author, Brazilian biologist Pedro Luiz Silva de Miranda, who is currently on a postdoctoral fellowship at the University of Liège in Belgium. The article was coauthored by his colleagues from other universities in Europe and Brazil.

o reach their conclusion, the researchers consulted several international databases of tropical tree species found in South America and Africa. They analyzed the species found in 1,444 forested areas (722 on each continent) in both wet and drv-but always warm-biomes. On the South American side of the Atlantic, they counted 152 families and 8,842 species. On the other side, they found 131 families and 3,048 species. There were 99 families present on both continents, covering 95% of the species identified in South America and 97% of those in Africa. Families found on just one of the continents accounted for only 5% of South American tree species and 3% of African species.

he flora of each continent was generally organized around the same groups of tree species. In both South America and Africa, a small number of botanical families comprised most of the local tree species. In South America, however, the role of four megadiverse families was even more dominant. "This intriguing result sends an important message to biodiversity researchers: dissecting the evolutionary processes of these key families could be an effective way to unravel the mechanisms behind the formation and maintenance of plant diversity patterns in savannas and tropical forests," says Danilo Neves, an ecologist from UFMG who did not participate in the study.

Many botanists think the two continents have similar floras because they were part of a single contiguous continental mass in the west of the ancient supercontinent Gondwana between 550 million and 130 million years ago. This long period of shared geological history is likely to have led to a homogenization of plant species before the South Atlantic separated Africa from South America.

However, the new study's analysis of tree species data suggests that the reality may have been different. "We found that most of the botanical families shared by the two continents emerged when they were already separated and isolated, after the great extinction event that occurred at the end of the Cretaceous period, 65 million years ago," explains Miranda. The observed similarities are therefore probably linked to transoceanic dispersal between the two continents via land bridges that crossed the Atlantic."

## Scientific article

MIRANDA, P. L. S. et al. Dissecting the difference in tree species richness between Africa and South America. PNAS. v. 19, i. 14. Mar. 29, 2022.



Indigenous people from the Guarani-Kaiowá ethnic group, speakers of Tupi

# THE RISE AND FALL OF



## Speakers of the language may have numbered 4 to 5 million a millennium ago but began declining sharply before Europeans arrived on the continent

## **Ricardo Zorzetto**

PUBLISHED IN JANUARY 2022

ver a period of nearly 10 centuries, the native Tupi speakers of South America prospered and dispersed over vast areas of the continent. In a demographic and migratory event that began almost 3,000 years ago, they left the southwestern part of the Amazon, crossed rivers and land until they occupied from the Atlantic coast of South America, at its easternmost point, to the foothill of the Andes, in the west, even reaching south of the La Plata River-some of these territories are more than 5,000 kilometers (km) apart. Known as the Tupi expansion, the diaspora lasted more than a millennium and may only be paralleled by the spread of Bantu-speaking peoples from west to central and southern Africa, which occurred around the same time period.

An analysis of the genetic characteristics of 75 individuals from 13 current Tupi-speaking peoples suggests that this territorial expansion may have been accompanied by significant demographic growth, with the Tupi population multiplying by 100. By comparing genome stretches from members of these ethnicities, a team led by Tábita Hünemeier, a geneticist from the University of São Paulo (USP), concluded that the population increase started approximately 2,100 years ago and reached its peak around the year 1000 AD, when according to calculations, the Tupi population may have totaled 4 to 5 million individuals, almost equaling the population of the Incan Empire that would occupy the Andes mountains centuries later.

Immediately after the peak, the vast Tupi nation began a sharp decline over the following five centuries, worsened by the arrival of European colonizers, according to figures presented in an article published in the journal *Molecular Biology and Evolution* on December 7, 2021. "We had no idea how devastating the Tupi population decline may have been. Previous estimates suggested a 90% decrease. Our data indicate that it was 99%, surpassed only by the collapse of the Aztecs after the arrival of the Spanish conquistadors," says Hünemeier.

"This paper is everything an archaeologist wants to read about the Tupi expansion because it provides genetic information to a debate that until now was based on archaeology and linguistics," says Adriana Schmidt Dias, an archaeologist from the Federal University of Rio Grande do Sul (UFRGS) who specializes in indigenous history and precolonial archaeology.

The major population growth suggested by the genetic analysis reinforces a hypothesis presented in 1984 by archaeologist José Proenza Brochado. Based on evidence that ancestors of the Tupi-speaking peoples produced ceramic objects and practiced an early form of agriculture, Brochado proposed that the Tupi diaspora was driven by continuous population growth and the need for new land to produce food rather than climate change. In the 1920s, anthropologists and linguists theorized that as the climate caused the rainforest to shrink, the ancestors of Tupi speakers, who survived by hunting, fishing, and gathering, were forced to migrate in search of food (*see* Pesquisa FAPESP *issue no. 288*).

One impact this expansion may have had at the time is the likely cultural assimilation of the Kokama people from the Peruvian Amazon. The Kokama have been speaking Tupi for many generations, but the USP team found that they are genetically much more similar to their Arawak-speaking neighbors, the Chamicuro, than to other Tupi-speaking groups. "This may be the first confirmation of cultural assimilation as a result of the Tupi expansion, something that has been suggested by linguistic studies but never demonstrated by other approaches," says Hünemeier.

The estimates of what happened to the Tupi population over the course of almost 100 generations is part of a broader analysis by the USP team, which has been attempting to understand how native ethnic groups interacted before Europeans arrived in South America and how the influences that they had on each other shaped today's indigenous groups. In the paper published in Molecular Biology and Evolution, which was based on one of the largest samples of genetic material from South American native populations ever studied, lead author Marcos Araújo Castro e Silva also compared the genetic characteristics of the Tupi-speaking groups against 229 individuals from 39 indigenous peoples who speak other languages from across central Brazil, the Amazon, the Andes, and the Pacific coast.

This comparison, part of Castro e Silva's doctorate under Hünemeier's supervision, led to a conclusion that con-

# THE RISE AND FALL OF NATIVE SOUTH AMERICANS

The graph below shows the demographic evolution of four indigenous groups as they expanded and contracted



scale for ease of understanding

tradicts the long-held belief of many archaeologists and anthropologists that due to the physical separation of the Andes, the peoples from the Andean highlands and the Pacific coast in the far west of the continent would be genetically distinct from the inhabitants of the vast lowlands, forests, and savannas of the east. However, the study identified no major differences.

erhaps influenced by the historical narrative of the Spanish conquistadors who invaded the Andes and, like the Incas, saw the Amazon rainforest as fearsome and impenetrable, this theory known as the Andes-Amazonia Divide—only began

to be questioned more vigorously in the past 15 years. For a long time, scholars of the native peoples of South America have seen the uniquely extreme and sudden change in landscape between the peaks of the Andes and the lowlands of the Amazon as an almost insurmountable physical barrier. As a result, the populations that arrived in South America at least 15,000 years ago and settled in the east and west of the continent would have had little contact. This theory was supported by historical evidence and even early genetic data that indicated that the Andes and the Pacific coast were home to large, complex, connected societies, while the Amazon was dominated by small, isolated groups.

In the new study, the USP team did not observe a marked genetic difference between present-day people in the east and the west, which would be expected if there were a clear Andes-Amazonia divide. Instead, the data show a gradual transition from east to west, with a slight but noticeable decrease in genetic diversity, explained by the fact that the mountains and the Pacific coast were home to populations that were at times very large and well connected, encouraging greater homogeneity across different groups over the generations, with no loss of diversity. Smaller populations with less contact, such as those in the lowlands of the Amazon, tend to be less diverse and more internally homogeneous, as well as more distinct from other populations. "Native peoples from the Amazon may have the lowest genetic diversity in the Americasand probably among the lowest in the world," says Castro e Silva.

Despite the lower diversity, there was no genetic isolation between the east and west. The peoples of western Amazonia and the eastern slopes of the Andes maintain a genetic connection with those from the highlands and the Pacific coast, similar to the link observed between them and groups from further east in the Amazon. As a result, the Kokama and the Chamicuro in Peru and the Paiter, Karitiana, Munduruku, and Gavião in the western Amazon function as bridge populations between those in the east and west of the continent. While contact-and consequent genetic exchanges-between peoples in the lowlands of Amazonia and those in the Andes and on the Pacific coast decreased after the arrival of European colonizers, it was much higher in the pre-Columbian period, as shown by the existence of identical genome segments in different current populations.

"The genetic mixture of Andean and Amazonian lineages in populations from the eastern slopes of the Andes eliminates any misconceptions about a strict divide between the Andes and Amazonia, but we have yet to reconcile these genetic findings with cultural evidence of trading and exchanges in the opposite direction, from the Amazon to the Andes," Chiara Barbieri, an Italian molecular anthropologist from the University of Zurich, Switzerland, told Pesquisa FAPESP. Barbieri visited South America vears ago and collected genetic samples from Andean peoples in Peru, Colombia, and Bolivia.

SOURCE Adapted from CASTRO E SILVA et al. Molecular Biology and Evolution. Dec. 8, 2021

# VACCINATING PRIMATES AGAINST YELLOW FEVER

Early trials suggest that human vaccines are effective in wild primate species susceptible to the yellow fever virus

## **Carlos Fioravanti**

PUBLISHED IN FEBRUARY 2022

Researchers have begun vaccinating golden lion tamarins on the Poço das Antas Reserve

atastrophic" is how Júlio César Bicca-Marques, a " biologist at the Pontifical Catholic University of Rio Grande do Sul (PUC-RS), describes the population decline in some species of wild monkeys as a result of yellow fever outbreaks in southeastern and southern Brazil. Since 2016, when the current yellow fever outbreak was first detected, the virus has killed approximately 80% of Brazil's population of howler monkeys (Alouatta spp.), a particularly vulnerable species. Populations of buffy-headed marmosets (Callithrix flaviceps) and black-fronted titis (Callicebus nigrifrons) have declined at the same rate, while the contingent of tufted capuchin monkeys (Sapajus spp.) has been halved. Golden lion tamarins (Leontopithecus rosalia), largely found in the Atlantic coastal forests of Rio de Janeiro state, have lost 30% of their population. These estimates were published in an October 2021 paper in the American Journal of Primatology, coauthored by Bicca-Marques.

"Yellow fever was a coup de grace for many populations of wild primates, which were already suffering from forest fragmentation, poaching and trafficking, roadkill, electrocution, other diseases, and competition with invasive species," notes Leandro Jerusalinsky, a biologist who heads the National Center for Research and Conservation of Brazilian Primates (CPB) at the Chico Mendes Institute for Biodiversity Conservation (ICMBIO). The Ministry of Health reported 23,000 primate deaths suspected to be from yellow fever from 2014 to 2019, including among endangered species—in most cases, yellow fever was confirmed to be the cause of death.

o protect animals that are being transferred to depopulated areas, researchers in Rio de Janeiro are using human vaccines for the first time against yellow fever in primate species susceptible to the virus, including both captive animals and any wild animals that they are able to capture. To date, 44 golden-headed lion tamarins (Leontopithecus chrysomelas), 19 golden lion tamarins (L. rosalia) and black lion tamarins (L. chrysopygus), and 11 howler monkeys (Alouatta clamitans, A. discolor, and A. caraya) at the Primate Center of Rio de Janeiro (CPRJ) in Guapimirim, Greater Rio de Janeiro, have been vaccinated.

Researchers are looking to determine the optimal dose for each species, which is lower than that for humans. A fractional dose—1/5 of the full dose applied

in 2018 during the yellow fever outbreak in humans-was shown to be as effective as a full dose. "Seroconversion [the rate of antibody production] is higher than 90%," says veterinarian Marcos Freire, a scientific advisor to the Immunobiological Technology Institute (BIO-MAN-GUINHOS) at the Oswaldo Cruz Foundation (FIOCRUZ), where the vaccine is produced. "The risk of it causing serious adverse events in animals has been shown to be very low, as with people." The results from the CPRJ's vaccine trial with howler monkeys were reported in a paper published in the Journal of Medical Primatology in February 2021.

Veterinarian Alcides Pissinatti first thought of vaccinating the animals at CPRJ, which he manages, in 2016, fearing that the yellow fever outbreak could spread to Rio de Janeiro from Minas Gerais and Espírito Santo. His idea to immunize wild animals was unconventional, however, and was initially met with resistance from primatologists and ecologists. However, Freire was on board immediately. The first animals to be vaccinated in 2017-to compare the effects of different doses and formulationswere 44 golden-headed lion tamarins (L. chrysomelas), which had been inappropriately released as invasive species in forests in Niterói and later captured by the nongovernmental organization Pri.matas and taken to CPRJ. "Soon after, the first primate deaths from yellow

fever were reported in forests in Rio de Janeiro," says Pissinatti.

The trial at CPRJ has now been expanded and, if successful, will confirm the vaccine to be effective in primates. In mid-2021, Carlos Ruiz-Miranda, a biologist at Norte Fluminense State University (UENF), along with his team and colleagues at Bio-Manguinhos and Associação Mico-Leão-Dourado, started vaccinating free-ranging golden lion tamarins living in forest patches near the Poço das Antas Biological Reserve in the central region of Rio de Janeiro state using methods recommended by CPRJ.

Of an estimated 150 tamarins in the experimental phase, the researchers vaccinated approximately 120. "In an early assessment, we detected antibodies in 47 of the 50 animals from which we collected blood samples," says Ruiz-Miranda. "We've found no evidence of an adverse effect from the vaccine."

Tamarins are captured with relative ease: they are small-bodied—up to 30 centimeters (cm) long and weighing approximately 800 grams—and can be lured with bananas. Vaccinated animals

Howler monkeys like this one, at the Sorocaba Zoo in São Paulo state, southeastern Brazil, are the primate species most susceptible to the yellow fever virus in the wild





are tagged with microchips and tattooed with a "V" on their inner thigh so they can be tracked after they are returned to the wild.

Biomedical researcher Zelinda Hirano plans to start vaccinating 44 howler monkeys this month at the Indaial Biological Research Center (CEPESBI), which she founded and now manages as a volunteer in Brazil's southern state of Santa Catarina. Unlike the tamarins on the Poço das Antas Reserve, these animals are in captivity.

In 2019, the yellow fever epidemic spread to Santa Catarina. One of the primates at CEPESBI was infected and died, prompting the vaccination of residents in nearby areas. To prevent further deaths, Hirano installed netting around the monkeys' enclosures to keep out virus-transmitting mosquitoes. While she observed that the animals were bothered by the warmer temperature and the difficulty seeing outside, no further monkeys became infected. The virus, however, continued to spread in the area. The State Health Department reported 137 primate deaths from yellow fever in 2021 as well as 8 human infections resulting in 3 deaths; none of those who died had been vaccinated.

In March 2021, after the state government lifted its ban on expeditions due to the pandemic, Hirano returned to the 40-hectare forest near CEPESBI (1 hectare is equal to 10,000 square meters). "There were previously 57 howler monkeys living there in five groups. Some I had known for 30 years. I wept when I found there were only three left in one of the groups."

Following vaccination, captive howler monkeys could be used to replenish the populations that have collapsed. "We will have to carefully consider when, where, and how to release the vaccinated animals," notes Hirano. "We also have to consider the chromosomal variation that exists among populations of howler monkeys in Atlantic Forest areas. We can't mix different groups together randomly." Her plan is aligned with guidance issued in September 2021 by CPBfollowing three months of discussion with experts from different research institutions-recommending the vaccination of howler monkey individuals used to replenish wild populations.

n addition to this recommendation, which informs local action plans for the conservation of endangered species, there are other considerations that need to be addressed when moving an animal from one place to another. "To improve animals' chances of success in the wild, we need to know their origin, ensure they are in good health, understand their behavior, consider that they are social animals that live in groups, and find a well-suited area for their release," says Jerusalinsky.

"Free-ranging howler monkeyswhich serve as sentinels for yellow fever-will not be vaccinated, but surviving populations will be augmented with animals vaccinated in captivity," says Pissinatti. When the yellow fever virus spreads to a given region, howler monkeys infected by disease-carrying mosquitoes are soon found dead, prompting epidemiological surveillance teams to launch vaccination campaigns for residents in nearby areas.

Adriano Pinter, a veterinary science and epidemiology researcher at the En-

Researchers vaccinating the first free-ranging tamarins in October 2021 at Associação Mico-Leão-Dourado in Rio de Janeiro state

demic Diseases Oversight Office (SU-CEN), who did not participate in the research, suggests that "Perhaps animals in public parks, such as Horto Florestal or Parque Fontes do Ipiranga, in São Paulo, could be vaccinated as a way to reduce the risk of urban yellow fever outbreaks in areas where howler monkeys could be bitten by urban vector mosquitoes." As an immediate measure, the Wildlife Division (DFS) of the municipal government of São Paulo, working with colleagues at the University of São Paulo's Institute of Tropical Medicine (IMT-USP) and SUCEN, is preparing to vaccinate 34 brown howlers kept in a conservation center at Anhanguera Park, in the city's northern district, over the first half of next year, using the methods developed by CPRJ and FIOCRUZ.

"After vaccination, we plan to replenish lost populations such as those in Cantareira and Horto," says Marcello Schiavo Nardi, a veterinarian at DFS. Unlike tamarins, it is fairly difficult to capture free-ranging howlers to vaccinate them. Howler monkeys are 45 to 60 cm long and weigh 4 to 7 kilograms (kg). They eat leaves (not bananas) and typically live between 20 and 30 meters (m) high in the forest canopy, rarely venturing down to the ground.

In 2014, Marcelo Rheingantz, a biologist at the Federal University of Rio de Janeiro (UFRJ), coordinated the release of four howler monkeys (two males and two females) at Tijuca National Park, as reported in an October 2017 paper in Perspectives in Ecology and Conservation. "We expected the howler monkeys to stay together, but they dispersed shortly after release," he says. One of the females eventually died, and the other joined a male and had five young. To replenish the howler population in the park, he plans to release seven more animals from CPRJ (six females and one male) after they are vaccinated.

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PHOTOS

The scientific articles consulted for this feature are listed in the online version

BIOTECHNOLOGY

# 



Image created from photos of a pig's heart: the animal's cells are green, and the human cardiomyocytes are shown in pink and red (*close-up*)

# Company changes business plans and invests in regenerative medicine in search of cures for diseases that currently have no treatment

## Suzel Tunes

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or academic researchers, entrepreneurship requires determination, knowledge of the risks, and a good dose of courage to navigate the countless obstacles that will be encountered along the way. Therefore, imagine the hurdles that one must overcome when leaving a well-known field to invest in a more complex and challenging field. This is what the founders of the São Paulo-based

company Pluricell Biotech decided to do. In 2014, less than a year after it was founded, the biotechnology startup obtained its initial funding from FAPESP's Research for Innovation in Small Businesses (RISB, or PIPE in Portuguese) program for a project aiming to produce human cardiomyocytes. At the time, the company's objective was to offer these cells, which are responsible for making the heart muscle pulsate, to academic researchers aiming to conduct in vitro testing of new drugs.

Almost eight years later, the startup changed course. In April 2021, the company name was changed to LizarBio Therapeutics as it shifted its attention to the international market. It began focusing on the potential use of cardiomyocyte grafts for regenerating injured heart tissue in people who have suffered heart attacks. The biotech company's new goal was to develop cell therapies for diseases for which there is currently no cure—a much more challenging objective than offering cells for research into new compounds. The RISB program was awarded funding for this new scope in 2021.

In the corporate world, this type of change in business direction is known as pivoting. Some people compare it to the pivot of a basketball player who keeps one foot on the ground as a fixed base while rotating his or her body, searching for the best move to make. The base, in this instance, was the subject biologist Diogo Biagi, one of the founders of Pluricell, studied during his PhD studies between 2011 and 2014.

To investigate changes in the heart cells of individuals with heart disease, Biagi used their skin cells to generate induced pluripotent stem cells (iPSCs), which are similar to embryonic stem cells, and then transformed them into cardiomyocytes. His PhD work, carried out at the Heart Institute (InCor) of the Hospital das Clínicas, School of Medicine, University of São Paulo (USP), was funded by a grant from FAPESP.

The technology needed to produce iPSCs was developed and published in 2007 by the Japanese scientist Shinya Yamanaka, who won a Nobel Prize in Medicine five years later. The technology's primary application, according to Biagi, has been in modeling diseases and developing new drugs. Cells are obtained from patients and used as experimental models that allow scientists to observe the behavior of diseased cell tissues and their reactions to new compounds.

When Pluricell was founded by Biagi and two of his colleagues—biologist Marcos Valadares and cardiologist Alexandre Pereira, who is no longer with the company—producing iPSCs for Brazilian laboratories seemed to be a natural direction for the business. Biagi's doctoral supervisor José Eduardo Krieger, director of InCor's Laboratory of Molecular Genetics and Cardiology, was unsure about the decision. "I found the initial business model strange. They wanted to sell cells, but there was no market. The sector they are working in now—regeneration—is more suitable," says the physiologist, who was one of the pioneers of stem-cell studies for cardiac regeneration in Brazil in the 2000s.

The partners of the startup, which today numbers 10 researchers, six of whom hold PhDs, soon reached the same conclusion. "We made the decision to pivot at the end of 2017, after concluding that the research market in this field is small and dispersed, even worldwide," says Valadares, CEO of LizarBio. "We realized there would be more added value in medicine if we offered the product to patients rather than researchers."



the startup stopped selling to the medical research market and thus lost its only source of revenue. However, it chose to remain at the forefront of the incipient field of regenerative medicine in Brazil, relying solely on investments from fund-

ith this change in direction,

ing agencies and the private sector. In 2019, it received US \$1 million from the pharmaceutical company Libbs Farmacêutica to study regenerative cell therapy for cardiovascular diseases, and in 2021, it was given R \$2 million by an undisclosed investment firm. It has also obtained approval from FAPESP for eight RISB projects, totaling approximately R \$4.5 million.

The startup's decision to move into cell therapy for cardiac regeneration was followed by efforts to internationalize. A partnership was formed with the Brazilian neuroscientist Alysson Muotri of the University of California, San Diego, who uses pluripotent stem cells to study Rett syndrome, a neurological disease caused by a genetic mutation that occurs primarily in girls (*see* Pesquisa FAPESP issue *no. 173*).

"Children who suffer from Rett syndrome begin to show signs of developmental delay in the first few years of life. They usually have motor problems and speech and communication difficulties," says Estela Cruvinel, a biologist and project manager at LizarBio. "It is a spectrum similar to autism."

Muotri uses iPSCs to create cerebral organoids: pea-sized, three-dimensional cell models that mimic the behavior of the human brain. With these mini-brains, he has been studying drugs that could treat Rett syndrome, which currently has no cure or specific medication. "I met the Pluricell team some time ago, and I was impressed. The connection between us was inevitable, and LizarBio was created soon after, incorporating my research on Rett syndrome and other neurological diseases," says the neuroscientist, who is a cofounder of the new company.

Pursuing a potential future treatment for Rett syndrome, the researchers are differentiating iP-SCs into glial cells—a varied range of cells found in the brain and other organs of the central nervous system affected by the disease. "Tests using pluripotent stem cells in mice have been started in Alysson's lab. The first results should be released in the coming months," says Cruvinel.

### BOTTLENECKS AND CHALLENGES

Since it was founded, LizarBio has been based at USP's Center for Innovation, Entrepreneurship, and Technology (CIETEC), but it plans to move to its own headquarters soon. "The aim of the next round of investments is to move into a more adequate space," says Valadares. The new funds will also be used to study how cardiomyocytes can alleviate heart failure, an area of research at a more advanced stage than nerve tissue cell research.

According to Biagi, the RISB phase 2 funding includes the first stage of a study assessing the potential for grafting cardiomyocytes into cardiac tissue, which involves producing and multiplying the cells on a large scale. "The next step, which is an assessment of cardiomyocytes in pigs, still requires further investment, which we hope to obtain soon." The company has already conducted initial tests to validate the methodology that it will use in preclinical trials involving eight pigs, half of which will receive the stem cells while the other half serve as controls.

Tests on rats have yielded promising results, which are described in an article published in the *Journal of Personalized Medicine* in April 2021. "The injected cells improved cardiac function, although it is impossible to say how many of the cardiomyocytes were retained in the heart," says Biagi. These are the results he hopes to obtain from the studies on pigs, whose heart muscles are of a similar size to those of humans.

According to Krieger, this is one of the largest bottlenecks of the research on cardiac regeneration. "We have successfully developed cardiomyocytes in the lab. The problem is now how to deliver these cells to the heart so that they are incorporated into the organ and function properly." The physiologist explains that cardiomyocytes made from stem cells are still immature cells. While they are good at proliferating—something that is necessary for cardiac tissue regeneration—there is also a great risk that they will be rejected or cause arrhythmias. "Cardiac function is rhythmic; the cells need to work together," explains Krieger.

Another challenge is the number of cells that need to be produced for the experimental treatment. While the group injected approximately 10 million cardiomyocytes into rats, the pig trial will require approximately 1 billion cells per animal. This number is similar to the number of cells a human loses when he or she suffers a heart attack. The optimal number of cells to graft into heart tissue is still being investigated at LizarBio. Lab work: a researcher holds up pig heart histological slides (*right*) and another looks at human heart cells produced from iPSCs





To increase its production capacity, the company entered into a partnership with the São Paulo State Institute for Technological Research (IPT) via USP's Interunit Graduate Program in Biotechnology. Under the supervision of IPT researcher Patrícia Leo, LizarBio's Sirlene Rodrigues is studying the cultivation, multiplication, and differentiation of iPSCs into cardiomyocytes as part of her master's degree, with funding from FAPESP. The goal of this partnership with the IPT is to master mass production, which would reduce the cost of producing cardiomyocytes.



nother obstacle to regenerative medicine is the current regulations on the use of stem cells; however, as Valadares highlights, Brazil has made an important advance in recent years in this regard. "Until 2018, there was no formal regulatory framework allowing for the registration of advanced therapeutic products," he says. "In February 2020, Brazil's

Health Regulatory Agency [ANVISA] published RDC [Collegiate Board Resolution] 338, which governs the registration of these products."

In Japan, the government authorized clinical trials using iPSCs in 2013. Several research groups from other countries have continued to look for an effective cell therapy. "Encouraging results are attracting more funding from companies. When the risk decreases, private capital input increases," says Krieger. There is still no guarantee that regenerative therapy will be available in the short term, says Marimelia Aparecida Porcionatto, a professor of molecular biology at the Federal University of São Paulo (UNIFESP) and researcher at the National Institute of Science and Technology for Regenerative Medicine (INCT-Regenera), a research network composed of 28 associated laboratories from different institutions. "The entire development process can take 10 to 20 years—it's hard to predict," she says. "There has been a lot of progress since the 2000s, when labs began more actively studying mesenchymal stem cells isolated from adult tissue. It was thought that they would fix all evils, but they didn't."

Mesenchymal stem cells have not proven effective for cardiac regeneration, for example. "Today, we know that they play a more immunomodulatory role, reducing local inflammation," explains Porcionatto. However, they could still play an important role in repairing diseased hearts. Krieger agrees: "It is a new technique with great potential for improvements, but it is not a miracle cure."

With much hope now placed on induced pluripotent stem cells, the researchers at LizarBio know that in addition to overcoming technical, economic, and legal challenges, they have to deal with high expectations. "We know how long things can take and we are carefully planning each step," concludes Valadares.

The research projects and scientific articles consulted for this feature are listed in the online version.

PHYSICS

# AI FOR FINDING MATERIALS

## Machine learning could accelerate the discovery of two-dimensional crystals similar to graphene with specific properties

## **Marcos Pivetta**

PUBLISHED IN MAY 2022

he first two-dimensional (2D) or single-layer material to be isolated in a lab, graphene, was initially "manufactured" prosaically in 2004. Andre Geim and Konstantin Novoselov, two physicists from the University of Manchester in the UK, obtained the crystalline solid by using sticky tape to exfoliate graphite. Both materials are composed solely of carbon atoms. However, the geometry of the carbons in graphene is different from that in graphite, which gives it certain unique properties. In graphene, the carbon atoms form a single sheet in a hexagonal mesh, similar to a honeycomb. In graphite, several layers of graphene separate from each other are included. Since graphene was first discovered in this re-

latively banal way, the methods used to search

for other 2D materials with unique properties have become more sophisticated. Currently, one of the most promising methods of searching for materials of interest formed exclusively by one layer of atoms, which are often composed of more than one chemical element, is with artificial intelligence (AI), especially machine learning. This computational tool uses statistical models to predict the most likely characteristics of a 2D material, whether experimentally manufactured or purely theoretical.

The reverse path can also be taken with this approach. "We can use machine learning to search databases for two-dimensional materials more likely to exhibit one or more properties of interest to us," explains Gustavo Dalpian, a physicist from the Federal University of ABC (UFABC) who is studying the topic with

Depiction of the honeycomb-shaped structure of carbon atoms that make up graphene



Adalberto Fazzio of the Brazilian Center for Research in Energy and Materials (CNPEM), with funding from FAPESP. "This is a relatively new area of research called materials informatics, and this research is allowing us to move toward using big data to process a large amount of information."

Two recent studies by the UFABC group illustrate how this approach can generate knowledge of 2D materials, whose tiny scale, on the order of nanometers, and particular properties can lead to even greater advances for existing devices as well as the creation of new equipment. An article published in the journal ACS Applied Materials & interfaces in February indicates that machine learning is highly effective, with approximately 90% accuracy, at predicting whether a 2D material is magnetic. In another study, Dalpian and his colleagues used a similar methodology to identify structures formed by a single layer of atoms that tend to have a specific spin texture-an intrinsic quantum property of subatomic particles, such as electrons, associated with angular momentum. A paper was published in *Scientific Data* describing the research on April 29.

achine learning systems are taught to recognize different patterns associated with conditions or characteristics within a large dataset. Samples with one of these expected signatures are separated and classified. "This is a knowledge discovery process," says Osvaldo Novais de Oliveira

Júnior, a physicist from the São Carlos Institute of Physics (IFSC) at the University of São Paulo (USP) who did not participate in the studies by Dalpian's team. "Humans make inferences from a small amount of data."

In oncology, for example, a machine-learning algorithm can be programmed to recognize the key visual features that distinguish certain types of skin cancer, such as shape and color, from a benign mark. The system examines images of skin lesions and separates those with the determined characteristics that indicate a high probability of the lesion being a tumor from those that do not fit the profile.

The same logic can be used in the search for molecules or compounds with specific attributes. The machine-learning algorithm must simply be taught to recognize patterns associated with magnetism in 2D materials, the subject of the first study by the UFABC group, and the system is ready. Magnetism is a fundamental property in the construction of information-storage devices, such as computer hard drives. The use of 2D ma-

## TWO-DIMENSIONAL Materials are Formed by a single Layer of atoms

terials with this property could lead to an even greater reduction in the size of such devices.

"The problem is that the typical magnetic signature of a 2D crystal is unknown," says physicist Carlos Mera, who is doing a postdoctoral fellowship with Dalpian's team and was a coauthor of both articles. "Until about five years ago, it was thought that the internal geometry of 2D materials generated instabilities that made them incompatible with magnetism."

In 2016, a group led by scientists from the Institute of Basic Science in Seoul, South Korea, measured antiferromagnetism, a type of magnetism, in films of nickel phosphorus triIllustration of a quantum sensor used to measure the magnetic properties of a two-dimensional material called chromium triiodide (CrI<sub>3</sub>). On the opposite page: an image of the hexagonal structure of the material Cr<sub>2</sub>Ge<sub>2</sub>Te<sub>6</sub>





sulfide (NiPS<sub>3</sub>), a 2D material. The following year, a group from the University of California, Berkeley, observed ferromagnetism, another form of magnetism, in 2D chromium germanium telluride (Cr<sub>2</sub>Ge<sub>2</sub>Te<sub>6</sub>) crystals. Since then, magnetism has been observed in more 2D materials.

In response to this trend, the UFABC team decided to analyze the Technical University of Denmark's Computational 2D Materials Database (C2DB). When the study began, the database contained records on some 3,400 materials (now 4,000). The objective of the research was to determine if there is a set of characteristics that could function as a strong indicator of magnetism in crystals formed by just one layer of atoms. In other words, there is a typical configuration associated with this property in 2D materials, much like the standard skin cancer diagnosis based on the shape and color of a mark on the skin.

> he strategy was successful. By analyzing the characteristics of three key parameters of 2D materials, the machine-learning system was able to predict whether a crystal had a high probability of being magnetic with 85% accuracy. The program was even more precise, with 96% certainty, at estimating whether a material was

not magnetic. The parameters analyzed were the chemical composition, crystal structure, and strength of the spin-orbit interaction (a quantum property).

The study was based on the premise that 2D materials composed of atoms of a transition metal (chemical elements from groups 3 to 12 of the periodic table), with hexagonal (such as graphene), square, or triangular crystal structures and strong spin-orbit interactions are highly likely to be magnetic. According to the predictions of the machine-learning system, 478 materials in the database are magnetic, of which 373 are ferromagnetic and 105 antiferromagnetic.

The C2DB database actually included information on the magnetism of each material before the Brazilian researchers started their work. Knowing this information was essential to determining the accuracy of the machine-learning technique and validating the method. "What we did was to determine whether a small number of properties are capable of functioning as filters to allow us to predict—with the help of big data techniques—whether a 2D material is likely to be magnetic or not," explains Dalpian. "We were able to achieve this goal, and we can even tell whether the material tends to be ferromagnetic or antiferromagnetic."

It is therefore possible, when searching for new magnetic 2D materials, to immediately discard any of crystals that the system determines to have a very low chance of being magnetic. Scientists thus waste less time and effort on unknown compounds that are unlikely to be magnetic and can focus on more promising materials.

In the second study, the researchers used the C2DB database to search for materials that had a quantum effect associated with an electron configuration known as spin splitting. According to the electrons' spin state (or angular momentum), whether they point up or down, the atoms of a material exhibit different configurations that in some cases can change their energy levels. There are four known variations of spin splitting: Zeeman, Rashba, Dreshelhaus, and higher order.

"We calculated that 436 materials in the database likely present some form of spin splitting. For each crystal, we determined which kind of this effect it is likely to present," says Elton Ogoshi, a materials engineer doing a doctorate at UFABC and coauthor of the study. In theory, the spin control of 2D materials can serve as the basis of spintronics, a form of computation based on manipulating this quantum property to store and process information.

In addition to machine-learning algorithms, this second article by the group was based on the use of a statistical technique known as Bayesian inference, which is widely used in AI to update the probability of a hypothesis occurring as more evidence or information becomes available. "Bayesian inference is a way of classifying data," says Oliveira Júnior. It is used to choose the most likely hypothesis. While it increases the chance of success, it does not fully eliminate errors.

The projects and articles consulted for this feature are referenced in the online version.

# A ROBOTIC GUIDE GUIDE DOG

Startup from Espírito Santo state prelaunches autonomous machine to help visually impaired people move around in closed spaces

#### **Frances Jones**

PUBLISHED IN APRIL 2022



4-kilogram robot, 40 centimeters tall and shaped like a small suitcase with a retractable handle and wheels, could become a common sight in the coming months, accompanying people with visual impairments in malls, stores, and airports in Espírito Santo, Rio de Janeiro, and São Paulo. Lysa, a robotic guide dog, has been under development by

the startup Vixsystem since 2014 and was launched on the market for indoor use in late 2021.

With its own bespoke software, a mobile app, artificial intelligence, an array of sensors, a camera, and a Lidar (Light Detection and Ranging) laser system, the Lysa robot maps the location, traces a route to the destination, and guides the user to their desired point. While moving, it emits audible warnings and vibrations (*see infographic on page 61*).

"It identifies objects in front of and above the user, moves around them, and alerts the user if there is a person or group in their path. In other words, it gives precise directions and is much smarter than a cane," says Neide Sellin, CEO of the startup, who has a degree in computer science. She is referring to the smart canes that already exist on the market and are capable of identifying obstacles not only on the ground but also at head height, such as tree branches and hanging plants, which often cause problems for blind people.

"This month [March] we have orders for 20 units," says Sellin. "Of these, some are sales and others are being sent to customers to test. Because it is a new project, companies want to test them first, determine the demand, and then make purchases." Each robot is sold for R\$15,000.

The startup expects to have a new version equipped with GPS available for outdoor use by next year. "We still need to resolve some issues before it is able to navigate the streets. The biggest challenge is when there is no sidewalk." Since 2021, Sellin has been receiving funding from FAPESP, under its Research for Innovation in Small Businesses (RISB, or PIPE in Portuguese) program to develop the outdoor version of the robot.

Vixsystem was selected through a call for bids for strategic internet research issued by FAPESP, Brazil's Ministry of Science, Technology, and Innovation (MCTI) and Ministry of Communications (MCOM), and the Brazilian Internet Steering Committee (CGI.br). It was the first time a startup from outside São Paulo has been funded by the RISB program. Research outside São Paulo can be funded by FAPESP in partnership with MCTI, MCOM, and CGI.br.

### HANDMADE PROTOTYPE

The entrepreneur says she had the idea of creating a robot guide dog in 2011 while teaching robotics classes at a public high school in Serra, a municipality in the metropolitan area of Vitória, the state capital of Espírito Santo. "After researching and verifying that there was demand, I built a prototype with my students using parts from other robots. We tested it and invited 20 visually impaired people to give their opinions," she recalls. "And they wanted to buy one, even

a camera, and artificial intelligence, Lysa is sold for R\$15,000

Equipped with sensors,

though it was just a handmade prototype. That truly made me realize the demand and importance of developing a product like this. I was not able do it as quickly as I wanted, but I did it."

> he initial impetus to create the prototype arose from a research project funded by the Brazilian National Council for Scientific and Technological Development (CNPq) in 2014. The institution's support allowed Sellin to hire two researchers with master's degrees one an electrical engineer and the other a computer engineer—to advance the project. "There was a lot of prototyping, a lot of testing.

I came up with the concept for Lysa thanks to the feedback of over 200 visually impaired people."

In 2017, after participating in the Brazilian version of the entrepreneurship reality TV show Shark Tank, she earned R\$200,000 in investment, and the publicity helped in the search for other sources of funding. Vixsystem also received investment from the Brazilian Funding Authority for Studies and Projects (FINEP) and the Espírito Santo State Foundation for Research and Innovation (FAPES).

For Marcelo Panico, a legal consultant for institutional relations at the Dorina Nowill Foundation for the Blind in São Paulo, the idea of a robot guide dog is promising, but because it is a new technology, it needs to be assessed with caution. He believes that in addition to the cost of the robot, the advantages and disadvantages of the new technology also need to be analyzed from a social perspective. "Guide dogs are respected by society, and their presence in the environment is covered by law. A dog can also become a companion for the blind person and can help improve their self-esteem."

Panico indicates, however, that guide dogs are rarely used in Brazil. It is estimated that there are only 200 of them nationwide in a country with approximately 6.5 million visually impaired people. Guide dogs, he points out, are usually trained abroad at a cost of US\$10,000, and the wait time to get one is up to two years. The training costs are usually covered by partner institutions and projects.

#### **ROBOT WITH PAWS**

Lysa is not the only robotic dog product in the developing world. Another robotic guide dog has been taking shape since 2017 in Catanduva, a town in the interior of São Paulo. The initiative is led by Diego Renan Bruno, a graduate student at the Mobile Robotics Laboratory (LRM) of the Institute of Mathematics and Computer Science (ICMC) at the University of São Paulo (USP), São Carlos campus, and his former student at the Catanduva School of Technology (FATEC), Marcelo Assis.

The researchers have already developed two prototypes, the second of which they made in 2019 as part of Red Bull Basement, a program by the energy drink company that encourages students to make their technology solutions real. The first version was built from the parts of a used vacuum cleaner. "Ours is not a final product yet; it's under development and the next version, the third, will be a robot with paws," said Bruno. "I



Boston Dynamics, from the USA, demonstrates its robotic dog Spot at an event held in Las Vegas

# **HOW LYSA WORKS**

The robot uses a camera, infrared sensors, and laser beams to guide blind people

The user downloads the Lysa app on their cell phone. The user then indicates where they want to go using voice commands or by tapping the options menu

2. The lidar sensor's laser beams and eight infrared sensors man the

sensors map the environment. These features also aid navigation

**3.** A **2D map** is generated. The robot plans and follows a route to the destination while avoiding people and objects not previously mapped

Embedded Retractable handle software/ application Internet antenna Upward sensor Camera Rear Lidar senso Eight-hour batterv Two motors Set of eight Audio output infrared sensors 4. The handle is equipped with a vibrating motor that alerts the user to obstacles ahead if they choose to turn off the audio

## **b.** An upward-pointing infrared sensor checks for overhead obstacles and warns the user of their presence

**D**. The camera identifies objects during movement, such as chairs, pots, or stairs, and the user is given an audio alert

SOURCE VIX SYSTEM

think if you're going to call it a guide dog, it has to do what a real guide dog does."

The fact that a guide robot uses wheels, says Bruno, is a problem because it can only reach places that are accessible to wheelchairs, for example. Sellin from Vixsystem, however, believes that because it is small and light, the Lysa robot—the first of its kind launched anywhere in the world, according to the entrepreneur—is perfectly suitable for accompanying the visually impaired since it can be transported easily in cars and can even be carried by hand. "It stops and warns the user when there is an escalator, for example, and they can then carry the device like a shopping basket."

For Bruno, the four-legged robotic dog developed and sold by the American company Boston Dynamics is the benchmark for other companies worldwide and can be used to assist blind people. Called Spot, it is already used in the construction and mining industries for tasks such as land inspections and reconnaissance. One obstacle to access by the general public, however, is the price: Spot costs over US\$70,000 in the USA.

"Other companies in China, Japan, and Germany have created dog-like robots inspired by Boston Dynamics. Despite being a great model, it's a long way from our goal of developing something low-cost," says Bruno. A much cheaper Chinese version of a four-legged robot is already on the market. Unitree Robotics offers six robotic dog models, the most basic of which sells for US\$2,700. None of them, however, are designed to be used as a guide for the visually impaired; they are intended for underground inspections, surveillance, and detecting explosives, among other applications.

#### Project

PHOTO MARK RALSTON / AFP VIA GETTY IMAGES INFOGRAPHIC ALEXANDRE AFFONSO

Lysa: a GPS robot to help guide the visually impaired (No. 20/05195-8); Grant Mechanism Research for Innovation in Small Businesses (RISB/ PIPE); Agreement MCTI/MC; Principal Investigator Nedinalva de Araújo Sellin (Vixsystem); Investment R\$532,606.26.

## TRANSPORT ENGINEERING





Reusing tailings from mining, rubble from construction and demolition, and other types of waste reduces the consumption of gravel, natural sand, and petroleum products in paving roads and highways

### Domingos Zaparolli

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onstruction of a 425-meter-long experimental lane was completed in March at the Cauê mine, belonging to the mining company Vale, in Itabira, Minas Gerais State. Over the next two years, the site will act as a testing ground to evaluate the use of sand obtained from iron mining tailings as an aggregate for asphalt paving. Aggregates are materials, such as crushed stone, grit, gravel, ground rock, and sand, used in construction. Using sand from mining for this purpose could boost the circular economy by reusing a material traditionally deposited in dams or in dry stacks of tailings, thus reducing the need to mine natural gravel and sand. The circular economy is an economic model that values reducing, reusing, and recycling natural resources that are commonly used in industry.

According to the Brazilian Association of Construction Aggregate Producers (ANEPAC), on average, every kilometer (km) of paved road consumes 9,800 tons (t) of aggregates. "In a preliminary evaluation, it is possible to substitute 7,000 t of aggregates for every km with sand from mining," estimates Sérgio Pacifico Soncim, a civil engineer from the mobility engineering course at the Federal University of Itajubá (UNIFEI) who is responsible for the tests in Itabira.

ANEPAC calculates that in 2022, Brazil will need to extract 400 million tons of sand and 392 million tons of gravel to meet the consumption of 692 million tons of aggregate. Sand is the second most exploited natural resource in the world; water is the first. The United Nations (UN) calculates that between 40 and 50 billion tons of sand are extracted annually, with a significant impact on river and marine ecosystems.

On the other hand, sand represents 80% of tailings from the final stage of iron beneficiation, called concentration, in which the iron is separated from the impurities. At Vale, 55 million tons of sand are produced each year. "We have been studying how to use the material since 2014. Its use in construction allows for environmental gains and generates value for the company," says André Vilhena, New Business manager at Vale.

Using sand from mining as an aggregate for paving came about through a partnership with UNIFEI in 2017 and has already acquired over R\$7 million in investments. The first task was to determine the characterization of the iron ore tailings. In this stage, the need to improve the physical and chemical properties of the tailings was identified.

According to Laís Resende, the engineer responsible for the research at Vale, sandy tailings are generated during the iron ore beneficiation process. To transform this material into sand, process routes were created that included concentration, classification, and humidity reduction stages. The sand produced by Vale contains over 92% silica, and its use can increase the lifespan of some materials, such as road paving.

Sand produced in this manner has uniform granulometry. "It is a material with higher quality control than the sand extracted from rivers, which usually contains a significant portion of food waste and decomposed soil. These organic materials can reduce the quality of the applications," says Resende.

Tests performed at UNIFEI showed that sand from mining, due to its uniformity and high silica



Reused sand from iron mine tailings from Vale's Cauê mine in Itabira. Minas Gerais state content, increases the performance parameters used to estimate the lifespan of a road by up to 50% compared to conventional sand. It also reduces demand by 6% for petroleum asphalt cement, a petroleum product used as an aggregate binding agent in the surface layer of the paving, called the surface course.

A highway lane is composed of several layers of paving. The most common formation has four layers: subgrade, subbase, base, and surface, which can be asphalt or concrete (see infographic below). The 425-meter lane in Itabira will be used to evaluate the results obtained in the laboratory under real conditions and determine the most suitable composition of mining sand in the aggregate mix for each layer.

"The lane was divided into four subsections. each with a different solution in its composition," explains Soncim. A total of 96 sensors were installed, including deformity, pressure, temperature, and humidity meters, and are subjected to constant traffic consisting of vehicles with heavy loads. The studies are being conducted by UNI-FEI in partnership with the Alberto Luiz Coimbra Institute for Graduate Studies and Research in Engineering at the Federal University of Rio de Janeiro (COPPE-UFRJ). The institutions are part of the Petrobras Asphalt Technology Network, and the results will be shared with the National Department of Transport Infrastructure (DNIT).

The expectation at Vale is that the test under real conditions will confirm the results from laboratory tests conducted at UNIFEI. In April, the mining company published a study in partnership with the universities of Queensland in Australia and Geneva in Switzerland, which from a technical perspective pointed to the viability of using sand from mining in asphalt paving and tile manufacturing.

## OTHER AGGREGATES

Like mining, the steel industry also creates waste that is being reused. The predominant destination for the waste is construction, mainly in cement production, but a portion of the waste is also used in paving. The Brazilian Steel Institute, an entity that unites companies from within the sector, stated in its 2020 sustainability report that approximately 600 kilos of slag are created for every ton of crude steel produced, of which 65% is material from blast furnaces and steel mills with potential for use as construction aggregates. In 2021, Brazil produced 36.2 million tons of crude steel, generating approximately 14 million tons of steel aggregates.

The most used materials in the world as substitutes for natural aggregates in paving are rubble from construction demolition and milled material, the name given to the deteriorated asphalt

## THE GEOMETRY OF A HIGHWAY

The number of layers and the composition of aggregates varies in accordance with the need of each location

## Asphalt covering

With a thickness of 5 to 10 centimeters, the wearing course is made up of asphalt and a mixture of aggregates



#### Base and subbase

Composed of a mix of harder materials, such as gravel and crushed stone, they serve to rectify the ground, stabilize and increase its resistance, and generate support for the upper layer

#### Subgrade

The innermost layer of the road is formed mainly from sand or rock dust and has a similar function to the two layers above it



surface removed from pavements using milling machines. However, these materials are still underused in Brazil.

"There is ignorance and prejudice regarding the use of waste," says civil engineer Liedi Légi Bariani Bernucci, CEO of the São Paulo State Institute for Technological Research (IPT) and former coordinator of the Paving Technology Laboratory (LTP) at the Polytechnic School of the University of São Paulo (POLI-USP). "It is mistakenly believed that it is a low-quality material that will produce bad works and will present problems quickly," says the engineer, who is part of the FAPESP Board of Trustees. "Treated properly, removing leftover wood, plaster, and metal, construction waste is as efficient as natural material."

According to Bernucci, the problem is not the construction companies, which have information about the quality of the recycled material, but the lack of technical preparation by some of the public administrators responsible for contracting the paving. "The construction company follows the contract notice for the service. Few of the technicians in public administration are capable of structuring a contract notice that encourages the use of recycled material and reduces the environmental impact of the work," he explains.

> wo types of surfaces are used for the wearing course of roads: one is flexible, made with petroleum asphalt, and the other is rigid, made from Portland cement concrete. Over 95% of works in Brazil use asphalt covering, as in most countries, due to its lower implementation cost, simpler maintenance, and the greater avail-

ability of qualified service providers. However, the concrete covering presents greater durability. It is designed to last more than 20 years, whereas the flexible covering lasts for 10 to 15 years. There is no consensus among specialists about using one covering or the other, but the majority suggest using more concrete on roads that receive heavy traffic, such as bus lanes and highways, and for locations where maintenance is difficult and there is a prevalence of asphalt on the other roads. For civil engineer Kamilla Vasconcelos Savasini, current coordinator of the LTP and associate professor of the Department of Transport Engineering at POLI-USP, the production processes of the inputs used in asphalt and concrete have a large environmental impact. An analysis of the production cycle of each work determines the biggest impact of asphalt or concrete, which varies depending on the regional availability of inputs, location, and characteristics of the roads being paved, among other variables.

Asphalt consumption in Brazil reached 1.6 million tons in 2021, according to Petrobras, which is below the yearly average of approximately 2 million tons prior to the COVID-19 pandemic. According to Savasini, every kilometer of asphalt paving with a thickness of ten centimeters on a single 3.5-meter-wide lane of road consumes approximately 50 tons of asphalt. "Reducing the environmental impact of a road or urban work can be done by reusing materials, developing technologies capable of substituting high-impact inputs, such as petroleum products, and by reducing the distances the materials are transported," says the researcher.

Research centers in the USA and Europe have dedicated themselves to the study of biobinders, chemical products from renewable sources capable of replacing petroleum asphalt as the aggregate binding agent in the surface layer of paving. The research is still in the early stages.

With support from FAPESP, Savasini coordinates research focused on sustainability in asphalt paving, which includes the development of a biobinder as a possible alternative to petroleum asphalt being one of the aims. The project team has been investigating different biomasses found in the country.

A few years ago, the Paving Technology Laboratory at POLI-USP took part in research re-



A pothole: lack of preventative maintenance is one of the causes of bad urban paving in the country

# LOW-QUALITY PAVING

## A study by the Brazilian National Confederation of Transport points out flaws in the Brazilian highway network

The 2021 Highways Study by the Brazilian National Confederation of Transport (CNT) evaluated the conditions of 109,100 kilometers of Brazilian highways and disapproved of the general state of 61.8% of the studied road network. The characteristics studied are the paving, signposting, and geometry of the road. The work, conducted by the CNT, identified the existence of some type of problem with paving for 57,000 km, slightly over half the total. The asphalt covering was classified as bad for 17,300 km and terrible for 6,300 km.

According to civil engineer Liedi Légi Bariani Bernucci, director of the São Paulo State Institute for Technological Research (IPT) and former coordinator of the Paving Technology Laboratory (LTP) at the Polytechnic School of the University of São Paulo (POLI--USP), the highways in Brazil presented a lower quality than those verified in Europe and the USA, but not because of the asphalt used, which has equivalent technical characteristics to that found abroad. "Our biggest problems are the lower lifespan of the paving normally stipulated in the project, the lack of technological resources of some executors, and the inadequate inspection of work preparation," she says.

Among the causes of paving defects, the CNT identified the lack of both preventative maintenance and inspection of vehicles traveling on roads with excess weight. The problems occur more frequently on public highways. The CNT Highway Study disapproved of the general state of 72% of the sections of highway under public management and 26% of those under private concession.

In urban centers, the quality of asphalt paving is also affected by the disorganized intervention of water, sewage, gas, and other concessionary services that carry out work beneath roads and avenues. Pothole resurfacing compromises the integrity of the asphalt layer, often resulting in cracks and splits where rainwater penetrates, causing ruptures and new potholes.

garding a biobinder obtained from an imported byproduct of pine wood, capable of replacing traditional asphalt. The biobinder was developed with Greca Asfaltos and Quimigel from Paraná and São Paulo, respectively, companies specializing in asphalt additives. The new product was tested in 2017 on BR-050, which connects Brasília to Santos, São Paulo State. The results were published in the magazine *Construction and Building Materials* in 2021.

"The efficiency of the biobinder is proven, but its production is not economically viable in Brazil," laments Wander Omena, Research and Development manager at Greca. The production of the biobinder tested in 2017, he explains, depends on a substance obtained from processing black liquor, a byproduct from the cellulose industry, in a biorefinery. "We do not have a biorefinery for this in Brazil, and the cost of importing the input is prohibitive," he says.

Greca was responsible for introducing rubberized asphalt to the country 21 years ago; this asphalt is made with rubber dust from tires. The innovation originated in the USA, but the asphalt used there contains up to 10% rubber, whereas the Brazilian version uses 15% rubber. Another national innovation is the addition of additives to stabilize the viscosity of the material. The rubber increases the durability of the asphalt, and according to a study by the Paving Laboratory at the Federal University of Rio Grande do Sul (UFRGS), the mixture is capable of decreasing crack propagation by 5.5 times, reducing the need for repair services.



nother advantage is the promotion of the circular economy in the tire industry. Every kilometer of seven-meter-wide paving with the mixture uses a thousand discarded tires. In 2021, Greca completed of 13,000 km of roads resurfaced with rubberized asphalt and 13 million reused tires. Added to the works

of other rubberized asphalt suppliers, the total reaches 17,000 km of roads, which is still only a fraction, given the 221,000 km of paved highways in Brazil.

Rubberized asphalt is mainly used by private concessionaires. The Anchieta and Imigrantes highways in São Paulo State, which connect the state capital to the south coast, were completely resurfaced with rubberized asphalt, and the concessionaire EcoRodovias is using the material as a standard for resurfacing the highways it manages. The concessionaires CCR and Arteris also use the product.

The price of rubberized asphalt is approximately 15% higher than that of conventional asphalt, but it has greater durability. In Omena's opinion, the main obstacle to the material being more widely used in public works is the lack of technical knowledge of most contractors. Abroad, the Brazilian rubberized asphalt formula has already been regulated in China and is being evaluated for use in European countries.

The research projects and scientific articles consulted for this feature are listed in the online version.

