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The emergence of human population genetics and narratives about the formation of the Brazilian nation (1950–1960)

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ABSTRACT

This paper discusses the emergence of human population genetics in Brazil in the decades following World War II, and pays particular attention to narratives about the formation of the Brazilian nation. We analyze the institutionalization of this branch of genetics in the 1950s and 1960s, and look at research on the characteristics of the population of Brazil, which made use of new explanatory models of evolutionary dynamics. These developments were greatly influenced by the activities of the Rockefeller Foundation and by the presence of North American geneticists in Brazil, especially Theodosius Dobzhansky. One of the main points of this paper is to show that explanations of Brazilian human genetic diversity constructed in the mid-twentieth century closely followed interpretations that had been produced since the end of the nineteenth century, in which notions of 'racial mixing' played a central role. Even as population genetics was conditioned by nationalist concerns that had long marked Brazilian history, we argue that its emergence and institutionalization was closely associated with global, post-World War II socio-political contexts, especially with regards to modernization projects and growing scientific internationalization.

1. Introduction

> "In terms of racial mixing, no colonizing people in modern times has surpassed, or even equaled, the Portuguese. From the first contact on, the colonizers happily coupled with dark-skinned women and multiplied through mestizo children" (Freyre, 1933, p. 9)

> "The frequency of hybridization is probably variable in Brazil, according to the [Brazilian] states, as a consequence of the different attitude towards intermixture of the European immigrants settling in different places. [The] Portuguese, in contrast to most Europeans, are very fond of crossbreeding" (Saldanha, 1957, p. 307)

The above statements, which refer to the effect of the Portuguese tendency toward 'racial mixing[1]' on colonization, were written approximately a quarter century apart. Although the two quotes seem similar, they are based on interpretations constructed in different fields of research, each of which led its authors to reflect on the process through which the Brazilian nation was formed. The first comes from a classic work of anthropology/sociology from 1930s, the book *Casa-Grande & Senzala*, which later appeared in English with the title *The Master and the Slaves*; the second was published in the *American Journal of Human Genetics* in the 1950s. In the interpretation of sociologist Gilberto Freyre, the tendency for

[1] In this paper, we use such terms as 'race,' 'racial mixing,' 'racial crossing,' and 'racial mixture' because they were important to our actors, even though we do not regard them as useful for classifying groups of people. From this point forward we do not place them in quotes.

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racial blending was a primordial characteristic of the Portuguese people. For the geneticist Pedro Henrique Saldanha, the racial attitudes of the Portuguese, compared to those of other European immigrants, explained the widespread racial mixing and genetic diversity of the country.[2] For both writers, miscegenation was a foundational paradigm for understanding the Brazilian reality.

As is widely recognized, themes related to race and racial mixture are central when thinking about the formation of Brazil (Fry, 2000; Maio & Santos, 1996; Santos, Kent, & Gaspar-Neto, 2014; Schwarcz, 1993; Skidmore, 1974). Since at least the mid-nineteenth century, travelers and scientists, both foreign and Brazilian, have known the country as a 'racial laboratory' (Bilden, 1929; Freire-Maia, 1973; Lacerda, 1911; Roquette-Pinto, 1933). Despite having arrived at their conclusions in different ways, both Freyre's sociological interpretation and Saldanha's genetic perspective derived from the principle that the Brazilian 'mixture' may be explained by the intense racial interaction that had marked Brazilian history since the colonial period. In this way, Saldanha the population geneticist—whose field from the 1950s expanded greatly in Brazil and in the world—read Brazil similarly to Freyre, the social scientist.

The aim of this essay is to examine how, from the 1950s, population genetic narratives about the formation of Brazilian society came into being. We analyze how a branch of science that proposed to investigate human biological diversity on a population scale became institutionalized in the country.[3] We shall see that this process was not only closely associated with the development of human population genetics on a global scale, but also, specifically, with the activities of the Rockefeller Foundation in Latin America. This foundation promoted visits of foreign geneticists to Brazil in the 1940s and 1950s and funded research and the training of new researchers. Geneticists from different parts of the country, who had trained with *Drosophila* in the techniques and theories of experimental evolutionary biology, began to reframe the history of the biological formation of the Brazilian population, with an emphasis on questions of racial mixing.

We will see that, through the use of new models and scientific perspectives, population geneticists offered explanations that closely followed socio-anthropological interpretations of Brazil that had appeared at the end of the nineteenth century. In accordance with this intellectual tradition—in which race was a central theme to understand the country—the geneticists of the mid-twentieth century focused their attention on the significance of miscegenation, but from the perspective of biological diversity. At the same time that population genetics was conditioned by nationalist concerns that had long marked Brazilian history, we argue that its emergence and institutionalization was closely associated with global post World War II socio-political contexts, in particular with regards to modernization projects and growing scientific internationalization.[4]

2. Rockefeller and the institutionalization of genetics in Brazil

At the beginning of the twentieth century, genetics increasingly captured the interest of scientists and institutions from different countries. Initially dealing with variation and heredity in plants, genetics soon began to be applied in agricultural research to improve seeds and farm animals (Carlson, 2004; Mayr, 1982; Ruse, 1996). In the early decades of the twentieth century, genetics was also used in the fields of medicine, eugenics, and physical anthropology to study heredity, evolution, and racial differentiation in different parts of the world (Adams, 1990; Barkan, 1992; Bashford & Levine, 2010; Kevles, 1985; Muller-Wille & Rheinberger, 2005).

In Brazil, the first genetic studies were carried out between 1910 and 1920 in agronomy schools such as the *Escola Superior de Agricultura Luiz de Queiroz* (ESALQ or Luis de Queiroz Agricultural School) and the *Instituto Agronômico de Campinas* (IAC or the Campinas Institute of Agronomy), both located in the interior of São Paulo state. These institutes emphasized the teaching and researching of plant and animal genetics (Habib, 2010). At this time, as in other countries, the Brazilian eugenics movement also promoted genetics in Brazil (Hochman, Lima, & Maio, 2010; Santos, 2012; Souza, Santos, Coelho, Hannesch, & Rodrigues-Carvalho, 2009; Stepan, 1991).

Throughout the 1930s and 1940s, the founding of the first Brazilian universities gave scientific activities a fresh impulse in the country. Through the initiatives of André Dreyfus, the *Universidade*

[2] Although it is not our aim in this paper to discuss the gendered and sexualized imagery that abound in the genetic narratives on the formation of the Brazilian society, it should be stated from the outset that this is a central topic that deserves further investigation. The biological processes that have interested geneticists, such as gene flow, involved elements of sexual violence and coercion that, in the biological narratives, are often associated with what were regarded as specific psychological and moral attributes of the colonizers and the colonized (such as Portuguese men's 'natural' affinity for indigenous and African women). In the genetics literature we analyze in this study, these elements tend not to be problematized, although they closely pertain to sexual subjugation. While there have been recent efforts to explore these issues in the context of early twenty-first century human population genomic research in Latin America (see Wade, Beltrán, Restrepo, & Santos, 2014), attention is yet to be given to the gendered and sexualized imagery in human genetics research carried out in the post World War II context.

[3] This paper is based on the analysis of published sources, archival research, and interviews with key Brazilian and foreign human geneticists. In developing our bibliography of published sources, we used the Lattes Platform (http://www.lattes.cnpq.br), created and managed by the Brazilian Research Council (CNPq), the main federal research funding agency in Brazil. This database was an important point of departure in identifying the publication records of Brazilian geneticists who carried out research in the late 1950–1960s, the main period of interest for this paper. It contains self-maintained *resumés* by most active scientists in Brazil, since Lattes CVs have been required for most applications for Brazilian federal research funding over the past 20 years. This database proved particularly useful in the initial stage of mapping the scientific output of scientists like Eliane Azevedo, Francisco Salzano, Henrique Krieger and Pedro Henrique Saldanha. We then requested interviews with some key geneticists. Eliane Azevedo and Francisco Salzano not only agreed to be interviewed but also kindly provided us with published material from their bibliographic archives. In Salzano's office at the *Universidade Federal do Rio Grande do Sul*, we were granted access to his large collection of reprints, which is particularly rich for the period 1950–1970. Open-ended interviews were based on a pre-defined set of topics: training in science, and in human genetics in particular; participation in human population genetics projects in the 1950s and 1960s; involvement in international collaborations in human population genetics of Brazilian populations; their perspective on issues related to race and racial relations and their interface with genetic research; funding conditions for Brazilian science over the past decades and for genetics. The interview with Eliane Azevedo was held at the *Universidade Federal da Bahia*, in Salvador, Brazil, on July 31, 2012, lasting approximately four hours. Salzano was interviewed at the *Universidade Federal do Rio Grande do Sul*, in Porto Alegre, Brazil, on April 12–13, 2012, and lasted approximately seven hours. Due to time limitations on their part and/or health problems, we engaged in shorter conversations with Eduardo Krieger (in Rio de Janeiro, Brazil, on October 27, 2012) and Newton Morton (in Salisbury, UK, on January 13, 2013). All interviews were recorded and passages related to their scientific activities in the time period of interest to this paper were transcribed. We should mention that all original quotations in Portuguese were translated into English by the authors.

[4] In this volume, Suárez-Díaz (in this issue) presents a study on the development of genetics in another Latin American country, Mexico, which shows both parallels and differences with the Brazilian case. On one hand, we see in both countries how complex transnational processes in post World War II context helped to shape the production of knowledge on human biological diversity, often under the influence of modernizing sociopolitical agendas. On the other, the Brazilian and Mexican cases illuminate how different epistemic values were allocated to local Latin American populations with regard to the development of human population genetics. Whereas in Mexico genetic studies of indigenous populations were very much aligned with 'indigenismo' and its emphasis on the incorporation of indigenous peoples in the national context, those in Brazil in the 1950s and 1960s tended to focus on the 'isolate' and the 'primitive,' viewed as away from the influences of the socioeconomic and demographic influences of the nation state (see also Santos, Lindee, et al., in press).

de São Paulo (USP or University of São Paulo), founded in 1934, won prominence in developing research in genetics. Dreyfus, a graduate of the Medical School of Rio de Janeiro, was a pioneer in promoting Mendelian genetics in Brazil (Araújo, 2004; Glick, 1994; Monte Sião, 2007). Research in genetics at USP expanded significantly from the 1940s on, especially with the stimulus of the Rockefeller Foundation (Cueto, 1994; Marinho, 2001).

The Rockefeller Foundation's activities in Latin America had been well known since the 1910s, when it funded medical research and public health campaigns, especially to fight hookworm, yellow fever, and malaria. From the 1940s on, particularly owing to World War II, the Foundation further increased its influence in Latin America, emphasizing the fields of science and agriculture. One of the areas that received most funding was genetics, especially in universities and research institutes in Brazil, Mexico, and Colombia (Cueto, 1994, p. xiv). A significant part of the Foundation's overall expenditure in these countries was directed towards the development of genetics in Brazil, which between 1940 and 1970 received continuous funding for scientific training, research, building and equipping laboratories, and field studies (Pavan & Cunha, 2003; Salzano, 2011).

In 1943, the Foundation made a decision that proved to be fundamental to the future of genetics in Brazil. Geneticist Theodosius Dobzhansky was chosen to develop a scientific cooperation program with a group of scientists from USP, which came to be known as the 'Brazilian Program for Evolutionary Population Genetics.' Dreyfus negotiated Dobzhansky's coming to Brazil with Harry Miller, the Foundation's representative in Brazil and an enthusiastic promoter of genetics and evolutionary biology in Latin America (Glick, 1994; Salzano, 1991). Russian by origin, Dobzhansky had settled in the US in the 1920s. He taught at Columbia University, where he worked with T. H. Morgan's group, one of the world's most important centers for genetics research. This group pioneered the use of *Drosophila* fruit flies as a model in genetic studies (Kohler, 1994; Smocovits, 1996).

In the invitation by the Rockefeller Foundation to come to Brazil, Dobzhansky saw an opportunity to broaden his research by incorporating *Drosophila* species from tropical environments. Since 1941, the Russian geneticist had been doing studies with flies from Central America, also funded by the Rockefeller Foundation. As he explained to Harry Muller, one of the Foundation's representatives with whom he worked most closely, very little was known about the structure of natural populations in the tropics. As such, research on mutation rates and the migration of these species was of fundamental importance to evolutionary genetics (Glick, 1994). A few months before he left for Brazil, Dobzhansky wrote to his colleague Sewall Wright,

> "This Brazilian venture is, of course, a plan the execution of which would take a number of years. I think there is a possibility of much to be gained by studying the population structure in species living in a climate that changes as little as possible during the year" (as cited in Araújo, 2004, p. 470).

According to Pavan and Cunha (2003), Dobzhansky's line of research in Brazil was his main project outside the US, at least until the end of the 1950s.

On his first trip to Brazil in 1943, Dobzhansky stayed for four months. He made another trip in June of 1948, staying at USP until August, 1949. Over the next decade, he made two additional trips to Brazil to train young scientists and to do field research in cooperation with his students (Fig. 1). In his trips, especially those he made in 1943 and 1948/1949, Dobzhansky made scientific expeditions to the interior of the country, particularly the Amazon, collecting and analyzing wild species of *Drosophila*. During this period the Rockefeller Foundation not only increased its support of the USP Biology Department, but also funded stays of researchers from other states to train with Dobzhansky and Dreyfus. Among the members of this group were young scientists who would go on to found important genetics laboratories throughout Brazil. In Dobzhansky's program, this group specialized in population genetics, with emphasis on the study of the biological variability of different species of *Drosophila* (Cordeiro, 1949; Dobzhansky, 1952; Salzano, 1991).

In addition to its support for Dobzhansky, and Brazilians André Dreyfus, Crodowaldo Pavan and Antonio Brito da Cunha, the Rockefeller Foundation invested in Brazilian genetics through a variety of strategies. It offered other prominent geneticists incentives to teach courses and train Brazilian researchers. One of these was the American geneticist Hampton Carson, a professor at

Fig. 1. Tainhas, Rio Grande do Sul, Brazil, 1956. Collecting *Drosophila* for the study of the introduction of chromosome inversions in natural populations. From left to right: Antonio Rodrigues Cordeiro, Francisco Mauro Salzano, Danko Brncic, L. Glock and Theodosius Dobzhansky (Collection of the Museum of Genetics, Department of Genetics, Federal University of Rio Grande do Sul, Porto Alegre, Brazil).

Washington University and expert on *Drosophila*. Carson came to USP in 1951. As well as bringing Brazilian students from other states to São Paulo, the Rockefeller Foundation financed students from other parts of Latin America who wished to train with Dobzhansky and Dreyfus (Pavan & Cunha, 2003). Between 1940 and 1960, the Foundation also supported travel of Brazilian geneticists to complete post-doctoral training at American universities (Glick, 1994; Salzano, 2011).

After the 1950s, Brazilian genetics was consolidated and more broadly institutionalized. Research groups were established in various regions of the country, many of them mostly devoted to *Drosophila* research. Groups were founded in Porto Alegre, at the *Universidade Federal do Rio Grande do Sul* (UFRGS or Federal University of Rio Grande do Sul); in Curitiba, at the *Universidade Federal do Paraná* (UFPR or Federal University of Paraná); and in Rio de Janeiro, at the *Universidade do Brasil* (now the Federal University of Rio de Janeiro or UFRJ). In those places where animal, plant, and human genetics were studied, institutions built laboratories and departments of genetics. Later, graduate courses were added, further strengthening genetic research and teaching in Brazil. Public universities in other parts of the country, such as Bahia, Pernambuco, and Minas Gerais, followed the same trend (Ferrari, 2004; Salzano, 2011).

In addition to the resources from international agencies, after 1950 the Brazilian government began to invest more in the development of science. By the middle of the twentieth century, with economic growth and the processes of industrialization and modernization intensifying in the country, scientific research and strengthening higher education were viewed as strategies for development. The creation of the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq or Brazilian National Research Council), the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES or Coordination for the Improvement of Higher Education Personnel), as well as the *Sociedade Brasileira para o Progresso da Ciência* (SBPC or Brazilian Society for the Advancement of Science), date from this period. These institutions would come to have a fundamental role in organizing, regulating, and promoting Brazilian science (Botelho, 1990). Continuing this process, in 1955 the *Sociedade Brasileira de Genética* (SBG or Brazilian Society for Genetics) was founded, bringing together a large number of geneticists from different branches of the field.[5] With the continued support of the Rockefeller Foundation, which even supported the organization of the SBG, genetics was one of the most rapidly growing branches of science in Brazil (Salzano, 2011).

3. From flies to humans

With the theoretical and methodological expansion and consolidation of evolutionary biology in the early decades of the twentieth century,[6] especially with growing numbers of field studies on animal and plant populations, researchers began applying the study of evolutionary processes to the human species (Barkan, 1992; Dobzhansky, 1950; Dunn & Dobzhansky, 1946; Kevles, 1985; Muller-Wille & Rheinberger, 2005). In this context, investigation in Brazil of the effects of miscegenation and the evolutionary factors involved, gained prominence in the research programs of both Brazilian and foreign geneticists.

Beyond Dobzhansky's influence, this turn toward human population genetics may be explained by a number of factors. First there was the question of the biological make-up of the Brazilian population, which was seen as broadly mixed, but with a large number of groups considered genetically isolated, such as certain indigenous populations. A second aspect was related to the country's demography, including high migration as well as birth and death rates, which were important factors in studies aimed at investigating human population micro-evolutionary processes. A third factor was a long intellectual and scientific tradition in Brazil that held the 'race question' and public health problems to be the great dilemmas of the formation of the country (Lima, 2007; Maio & Santos, 1996; Santos, Kent, et al., 2014; Skidmore, 1974).

From the viewpoint of the historical formation of the field of genetics itself, two aspects in particular help us to understand the emergence of human population studies in Brazil at the middle of the twentieth century. They refer back to a previous period, and are strongly connected to the history of Brazilian genetics. On one hand, there was the mobilization around the eugenics movement between 1920 and 1930, which stimulated Brazilian interest in human genetics and concepts of Mendelian inheritance, such as consanguineous marriage and the effects of racial mixing (Hochman et al., 2010; Santos, 2012; Souza et al., 2009; Stepan, 1991). On the other, in the post holocaust political and intellectual climate of the 1950s, there was critical opposition to the scientific racism espoused by more radical eugenicists (Salzano, 1991).

Also significant were issues internal to the field of genetics, such as the research that took place between 1920 and 1940 on blood groups and gene distribution in the ABO system in Brazilian populations. During this period, a group of physicians and physical anthropologists carried out the first studies of genetic polymorphisms in populations from different regions of Brazil. They focused especially on indigenous populations and isolated communities in the interior of the country. These studies included research on blood groups and hereditary diseases like sickle cell anemia, as well as work on the process of racial mixing, and were carried out by researchers such as Ernani Silva, Fritz Ottensooser, Carlos Silva Lacaz, and Pedro Junqueira (Cavalcanti & Maio, 2011).

The interchange between the generation of Brazilians specializing in *Drosophila* studies—almost all trained by Dobzhansky—and influential American geneticists such as James Neel and Newton Morton was also decisive in the development of human population genetics in Brazil. With scholarships from the Rockefeller Foundation, young geneticists from Brazil went to the University of Michigan for doctoral or postdoctoral studies with James Neel, one of the foremost names in human genetics in the US (Fig. 2) (Lindee, 2001; Salzano, 2000, 2011; Santos, Lindee, & Souza, in press). In the 1960s, some Brazilian researchers also completed their doctoral studies at the University of Hawaii with Newton Morton (Ferrari, 2004; Salzano, 2011; Santos, Lindee, et al., in press).

These international collaborations involved the development of several research projects in Brazil. Starting in 1962, Neel, with close collaboration from Salzano and other Brazilian geneticists, carried out research on genetic, demographic, and biomedical aspects of several indigenous populations (Neel, 1994; Salzano & Callegari-Jacques, 1988; Santos, 2002; Santos, Lindee, et al., in press). These studies were largely aimed at developing theoretical models of human biological variability. Just as the study of isolated indigenous

[5] The SBG was originally founded through the initiative of 27 geneticists, many of whom had worked with Dobzhansky. By the 1960s, it had 160 members, and by the 1970s, when it started its own journal, the *Revista Brasileira de Genética*, it had 1100 members (on the SBG, see Salzano, 2011).

[6] The emergence of population genetics is closely linked with the theoretical and methodological developments that grew out of the 'evolutionary synthesis' of the 1930s and 1940s. This formulation led to the construction of explanatory models that sought to conciliate the premises of Mendelian genetics with Darwinian evolution. These models addressed issues ranging from the processes of production and maintenance of biological variability in individual and populations to questions about the origin of new species. Dobzhansky was an outstanding figure in promoting this framework, which was simultaneously theoretical and empirically driven. His book, *Genetics and the Origin of Species*, published in 1937, was considered a major work in the establishment of this neo-Darwinian synthesis (Allen, 1975; Mayr & Provine, 1998).

Fig. 2. Francisco M. Salzano with his son Felipe, his wife, Thereza (center), and Flávia (Newton Freire-Maia's wife) with her daughters in Ann Arbor, Michigan, in the 1950s, while pursuing postdoctoral training at the Department of Human Genetics (Collection of the Museum of Genetics, Department of Genetics, Federal University of Rio Grande do Sul, Porto Alegre, Brazil).

populations was a central topic for human geneticist in Brazil, they also studied the dynamics of admixture. Along similar lines, and also in 1962, Morton and several Brazilian collaborators initiated extensive research on mestizo populations from northeast Brazil (Krieger et al., 1965; Morton, 1964).[7]

As research in human genetics continued to expand, the First Brazilian Human Genetics Conference was held in 1958 at the *Universidade Federal do Paraná*. It was organized by Newton Freire-Maia, who in 1951 had set up a laboratory for human population genetics in Curitiba. A year later, with the support of the *Sociedade Brasileira de Genética* and the Rockefeller Foundation, the Commission of Human Genetics was formed, which would have an important role in setting up strategies for action, coordination, and integration of different human genetics research projects and teaching that were underway in various universities (Salzano, 1991).

In summary, from the 1950s human population genetics began to occupy more space in the research agendas of geneticists associated with universities throughout Brazil. To a large degree, the researchers responsible for the development of human genetics were originally trained in *Drosophila* genetics in laboratory and field settings. Their study of microevolutionary factors, such as mutation rates, natural selection, gene flow, and genetic drift, central in *Drosophila* studies, acquired novel configurations when applied to the Brazilian human population. As we shall see below, in a historical period marked by rapid social and economic transformations, which included massive migration from the impoverished regions of Northeast Brazil to the richer Southeast, topics such as inbreeding and racial mixing became concerns for human geneticists.

4. Studies of racial crossing in the post World War II

One of the themes in human population genetics that mobilized the interest of Brazilian geneticists was the study of race. Coinciding with the debate that arose after the World War II about the significance of racial differences in human populations (Barkan, 1992; Reardon, 2005; Stepan, 1982), these studies sought to understand the processes involved in producing biological variability. Brazilian and foreign geneticists alike agreed that the country provided exceptionally propitious conditions for studying racial crossing, in view of its genetic diversity and its prevailing social, demographic, and epidemiological conditions. Beyond the biological diversity already present in the so-called 'formative stocks,'—that is, Portuguese, African, and Amerindian—there was the influence of various flows of migrants coming to Brazil in the nineteenth and twentieth centuries, including French, Germans, Italians, Japanese, Middle Easterners (Turks and Arabs), Polish, Russians and Spanish. In the words of Salzano and Freire-Maia, these different populations "intercrossed among themselves and were subjected to the influence of very diverse climates, from the humid tropical rainforest of the Amazon basin to the arid regions of the northeast." Moreover, "the large medical and sanitary problems that these groups had to face created selective pressure of different magnitudes" (Salzano & Freire-Maia, 1970, pp. xv–xvi).

One pioneer in the genetic study of racial mixing in Brazil was the physician and hematologist Fritz Ottensooser, who dedicated his entire career to the study of so-called 'serological anthropology.' Of Jewish origin, he was born in Nuremberg, Germany in 1891, and arrived in Brazil in 1941, fleeing Nazi persecution. He settled in São Paulo. In the 1940s he worked at the *Laboratório Paulista de Biologia*

[7] We detail Morton's work in Brazil in Section 4. See also Santos, Lindee, et al. (in press) for a comparative analysis of Morton's and Neel's research agenda in Brazil in the early 1960s, including how the two scientists explored notions of 'purity,' 'admixture,' and 'primitiveness' and how their works fit in the larger picture of post-World War II biological and anthropological sciences, largely influenced by the Cold War.

(São Paulo Biology Laboratory), and from the end of the 1950s in the Genetics Laboratory of the Medical School of USP. He became known not only for his research on blood types and racial characteristics in Brazilian populations, but above all for his proposal of a mathematical formula to calculate degrees of racial mixture by serological analysis (Leon, 1975). This was published in 1941 in the *Revista Brasileira de Biologia* (*Brazilian Journal of Biology*) (Ottensooser, 1944) and was quite often used in the genetic study of miscegenation in Brazil after the World War II. Ottensooser first applied the formula to Amazonian populations of the Upper Rio Negro (Biocca & Ottensooser, 1944).

A decade later, the geneticists Bentley Glass, from Johns Hopkins University, and Chung Chin Li, from the University of Pittsburgh, published a new method that made it possible to calculate not only the degree of racial mixture but also gene flow over several generations. They stressed the pioneering character of formulas developed by researchers such as Bernstein, Boyd, and Ottensooser, citing the 1944 paper by Ottensooser that appeared in the Brazilian journal (Glass & Li, 1953).[8] Up to that time, formulas like Ottensooser's could only estimate the degree of racial mixture taking as reference two ancestral stocks, known as 'dihybrid' populations (that is, derived from two founding stocks). To analyze so-called 'trihybrid' populations—apparently significant for the case of Brazil, whose founding stocks came from diverse regions of Europe, Africa, and the Americas—other formulas were proposed by the early 1960s (Salzano & Freire-Maia, 1970). In 1962, Ottensooser himself developed a formula to calculate the proportion of 'trihybrid' admixture, which he applied in studies in the north and northeast regions of Brazil (Ottensooser, 1962).

Throughout the 1950s and 1960s, the geneticist Pedro Henrique Saldanha made numerous studies on racial mixing using the formulas developed by Ottensooser and by Glass and Li. Saldanha, who had a degree in natural history and was trained in genetics and evolution at the *Universidade do Brasil* in Rio de Janeiro, was one of the first Brazilian geneticists to use the new generation of mathematical procedures and genetic markers for Brazilian population studies. In 1957 Saldanha published one of his major scientific works in the *American Journal of Human Genetics*: an analysis of gene flow from the white population to the black population of Brazil (Saldanha, 1957). The article resulted from his doctoral research in human population genetics at USP with Crodowaldo Pavan as supervisor. He concluded his doctorate two years later, presenting a thesis entitled "The effect of migration on the genetics of a community of São Paulo" (Saldanha, 1959).

Based on studies by Raimundo Nina Rodrigues and Arthur Ramos—Brazilian writers who pioneered anthropological studies of the black population in the late nineteenth and early twentieth centuries—Saldanha argued that the African origin and the genetic constitution of blacks in Brazil was not yet fully known. Furthermore, he said, it was of the utmost importance to human genetics and anthropology in Brazil to continue to research this question. At first, Saldanha tried to use historical, anthropological, and demographic data to investigate the origin and territorial distribution of the main African groups brought to Brazil during the slave trade, such as the Bantu and the Sudanese. His next aim was to determine the gene flow between the population of African origin and the population of European origin, concentrating on samples from São Paulo, Rio de Janeiro, and Bahia. Based on information derived from the historian Affonso Taunay, Saldanha (1957) claimed that this inter-ethnic contact dated back more than 350 years, with miscegenation continuing over dozens of generations.

Saldanha's data indicated that gene flow in the northeast, and even in Rio de Janeiro, on the eastern coast, was considerably greater than in the south of Brazil. According to Saldanha, even though the process of racial mixing between blacks and whites continued with relatively high frequency in the southern states at least until the third quarter of the nineteenth century, it diminished considerably after that. This happened because

> "by this time the migration of several European peoples other than the Portuguese had begun, especially to the southern part of the country. These migrants have shown a greater resistance to crossing with Negroes than have the Portuguese" (Saldanha, 1957, p. 302).

Saldanha argued that, in contrast to what happened in the south of the country, in Rio de Janeiro and São Paulo the estimated 'white mixture' in blacks, including 'mulattos,' was quite high, around 55 percent, while the national average was around 40 percent.[9] This meant that in some regions of the country, mainly those with the greatest presence of Portuguese colonization, more than half the genes present in the black population had a European origin (Saldanha, 1957, p. 306).

Toward the end of the 1950s, Saldanha, then a professor in the Human Genetics Laboratory of the Medical Faculty of USP, traveled to the US to do postdoctoral work with Neel at Michigan. After returning to Brazil, Saldanha continued his studies on patterns of biological formation of the Brazilian population. In collaboration with a group of students and researchers from USP, including Oswaldo Frota-Pessoa and Ottensooser, Saldanha began a large research project on the anthropological characteristics of the Brazilian people, including not only the first 'racial stocks,' but also the new groups of immigrants that settled in the country from the end of the nineteenth century (Saldanha, 1961). This research included studies of communities in the interior of São Paulo state (Saldanha, 1960), as well as populations from the Brazilian northeast that could be found staying in *Hospedaria de Imigrantes* (Immigrant Hostel) in São Paulo city (Saldanha, 1962).[10]

Racial studies on groups from the northeast especially interested Saldanha, because according to him, the genetic makeup of this population was "a result of the mixture of three basic populations: white (Portuguese), blacks, and Indians" (Saldanha, 1961, p. 98). At this time, Saldanha increasingly turned to investigation of racial mixing among the so-called 'tri-hybrid' populations. His interest in the study of northeastern populations resulted in the paper published in 1962 in the *American Anthropologist* (Saldanha, 1962). According to Saldanha, some of the analyses reported in this paper were completed when he was a Rockefeller Foundation fellow at the University of Michigan. The data, collected at the Immigrant Hostel of São Paulo, showed that the genetic makeup of the population from the Brazilian northeast was 18 percent indigenous, 34 percent African, and 48 percent white Portuguese (Saldanha, 1962, pp. 754–755).

[8] On the history of racial mixture studies in anthropological genetics, see Marks (2012).

[9] Racial categories, such as 'black,' 'Caucasian,' 'Indian,' and 'mulatto', among many others, were recurrent in publications on human population genetics in Brazil in the 1950s and 1960s. While in some instances the scientists sought to define the criteria they used to classify their subjects (see, for instance, Krieger et al., 1965), in most instances how these categories were implemented was not made explicit.

[10] Created in the late nineteenth century, the *Hospedaria de Imigrantes* was an institution in the city of São Paulo for recently arrived migrants. Migrants were provided with some basic support until they received approval to work. In the late nineteenth century and in the early twentieth century, the *Hospedaria* would receive mostly foreign migrants, the majority from Europe. In the 1950–60s, the major influx of migrants to São Paulo was of domestic origin, in particular from the Northeast (see Paiva & Moura, 2008).

Saldanha was not only interested in exploring the process of racial mixture in different regions of Brazil, but also in drawing comparisons with other countries in South and North America. The geneticist paid particular attention to Brazil–US comparisons regarding gene flow between whites and blacks. He was interested in measuring the intensity of 'white mixture' in Brazilian blacks, work that he had begun during his studies of populations in São Paulo, Rio de Janeiro, and Bahia (Saldanha, 1957). According to him, the 'Caucasoid mixture' estimated for Brazilian blacks was on average 50 percent, meaning that Brazilian blacks were, generally speaking, 'mulattos,' with one 'pure Caucasoid' progenitor and one of African origin (Saldanha, 1965, p. 72). For comparison with black populations in the US, he relied on studies by Glass and Li (1953) and Roberts (1955), who had estimated around 20 percent 'Caucasoid mixture' in these groups. Both investigations had been performed in the US south, which, in Saldanha's view, was appropriate for comparison with miscegenation in Brazil. Comparing the results obtained for the black populations of the two countries, Saldanha concluded that "the Brazilian black is twice as white as his North American counterpart," which apparently resulted from different "degrees of racial segregation" in the two countries. The Brazilian geneticist argued that this was due, above all, to the attitude of the Portuguese colonizers, who had "great tolerance for hybrid marriages, in contrast with the majority of Europeans" (Saldanha, 1965, p. 83).

A study coordinated by North American geneticist Newton Morton was another major project on racial crossing carried out in Brazil in the decades following World War II (Krieger et al., 1965; Morton, 1964; see also Santos, Lindee, et al., in press). The project, which was funded by the U.S. Public Health Service with the support of USP and the Department of Immigration of São Paulo, involved collecting data at the *Hospedaria de Imigrantes*, the same site at which Saldanha and his collaborators did their research a few years earlier.[11] Morton collected his information—which included blood samples and medical examinations, as well as anthropological, demographic, epidemiological, and social characteristics—from 1068 families from various states of the Brazilian northeast. Morton, like other geneticists who previously had worked at the *Hospedaria*, chose the place because every year thousands of families passed through, seeking work in the southeast, the most highly developed region of Brazil. The main focus of Morton's research was to test hypotheses about the relationship between mortality levels, inbreeding, and genetic variability. He was especially interested in whether heterozygosity due to racial crossing would be associated with increased or decreased fitness (Krieger et al., 1965; Morton, 1964). A number of young geneticists, among them Henrique Krieger, Eliane Azevedo and Ademar Freire-Maia participated in Morton's research. The results were published during the 1960s and 1970s in various human genetics and physical anthropology journals (Azevedo et al., 1969; Krieger, 1970; Krieger et al., 1965; Morton, 1964).

For Morton, an important reason for working with populations from the northeast was that previous studies had found a high measure of genetic admixture in the people who passed through the Hostel. It was critical to work on groups with high levels of genetic admixture because the hypotheses under study were related to degree of heterozygosity in a given population (Krieger, 1970; Krieger et al., 1965; Morton, 1964). In this context, the racial classification of individuals was central. Based on morphological data collected by the physician and geneticist Eliane Azevedo ("pigmentation of the abdomen, hair colour and type, and conformation of the nose and lips"), Morton classified the population into eight categories: "white, light mestizo, dark mestizo, light mulatto, medium mulatto, dark mulatto and negro" (Krieger et al., 1965, pp. 115–116).

The genetic tests showed that the sample Morton investigated had "Caucasian, Negro, and Indian" levels of admixture of 69 percent, 30 percent, and 11 percent respectively (Krieger et al., 1965, p. 123). These results—which indicated high European ancestral levels, with African and indigenous ancestry secondary—were interpreted in light of the historical formation of the Brazilian nation. Similar to Saldanha's interpretation, Krieger et al. (1965, p. 177) emphasized that "the alacrity of the Portuguese males for miscegenation" could be seen as one of the main factors responsible for the high levels of genetic admixture observed in Brazil (Krieger et al., 1965, p. 116). The genetic admixture of families from the northeast was seen as the direct result of their colonial past, resulting from the interplay among historical and sociocultural dimensions such as internal migration, labor dynamics, reproduction, and gender relations in Brazilian society.

Morton's research findings led to the conclusion that a "relatively small increase in the heterozygosity, occurring by inter-racial crosses, is irrelevant to fitness" (see Krieger, 1970, p. 427). In other words, no association was observed between hybridity due to 'inter-racial crossing effects,' and disease or mortality, a conclusion in agreement with similar research in other regions of the world, such as Hawaii (see Krieger, 1970; Morton, Chung, & Ming-Pi, 1967).

In 1967, Francisco Salzano and Newton Freire-Maia published the book *Populações Brasileiras: Aspectos Demográficos, Genéticos e Antropológicos* in which they attempted to synthesize existing knowledge about the genetics of Brazilian populations. A few years later, a version in English, with the title *Problems in Human Biology: A Study of Brazilian Population*, appeared (Salzano & Freire-Maia, 1970).[12] The book is dedicated to the memory of Ernani da Silva and Edgard Roquette-Pinto, who the authors call, respectively, "pioneers of the genetic and anthropological investigation of Brazilian populations" (see Santos, 2012; Souza, 2012). A third dedication is to Harry Miller, the representative of the Rockefeller Foundation in Brazil. The authors point out that Miller "contributed in a significant way to the development of human genetics in Brazil" (Salzano & Freire-Maia, 1970, p. v).

The first part of *Problems in Human Biology* describes the process of colonization of Brazil and the history that led to the meeting of three races that formed Brazilian nationality: Portuguese, Amerindian, and African. Salzano and Freire-Maia described migratory movements and the expansion of miscegenation, beginning in the nineteenth century, which had made it possible, according to the authors, for Brazil to become one of the most genetically heterogeneous countries in the world. Making an argument similar to that advanced both by Saldanha (1962) and by Krieger et al. (1965), Salzano and Freire-Maia (1970, p. 54) argued that in Brazil "the widespread mixing of races" developed because there were few obstacles set by the colonists in their relations with blacks and

[11] According to Morton (1964, p. 69), "Our sample was taken from migrant families passing through the *Hospedaria de Imigrantes* in São Paulo to the interior of the states of São Paulo and Paraná. The migrants remained for about 24 hours in quarters of the Departamento de Imigração e Colonização, which provided free food, lodging, transportation, and medical attention." As with other research on human population genetics in Brazil, in particular those on indigenous populations (see note[14]), Morton's research was part of the International Biological Program (see Collins & Weiner, 1977).

[12] It is important to note that the version published in the US was translated in full, with only the addition of a Foreword by the American anthropologist Charles Wagley, who at the time was a professor of anthropology at Columbia University. For this article we use the version published in 1970 (Salzano & Freire-Maia, 1970). It should be mentioned that their use of the word 'problems' in the title of the English version of the book does not denote a negative perspective, but is closer in meaning to 'topics in human biology.'

Indians. The second part of the book analyzes demographic aspects of the country, discussing the high birth and death rates, and the marked endogamy of several Brazilian populations. The last part describes, on the one hand, theoretical and methodological aspects of research in human population genetics, and on the other, the characteristics of gene flow and genetic variability of the Brazilian population.

When *Problems in Human Biology* was published, both Francisco Salzano and Freire-Maia already had extensive training in research on human population genetics and had earned recognition as leaders in the field of Brazilian genetics. Both had specialized in *Drosophila* genetics at USP in the time of Dobzhansky, Dreyfus, and Pavan, and had begun their research in human genetics in the 1950s, setting up laboratories and forming research groups at the universities where they worked in the south of Brazil. Salzano and Freire-Maia had each done a one year residence at the University of Michigan, funded by the Rockefeller Foundation and supervised by James Neel (Salzano, 2000). The training they received there was decisive for the work that each later developed in human population genetics.

Since the 1950s, Freire-Maia had dedicated his career to research on genetic demography, consanguineous marriage, congenital malformations, and genetic counseling. He did his first studies in human genetics in rural communities in the state of Minas Gerais, analyzing the frequency and effects of consanguineous marriage in whites and blacks, and then expanded to other regions (Freire-Maia, 1963; Freire-Maia & Azevedo, 1967; Freire-Maia, Freire-Maia, & Quelce-Salgado, 1963). One of the conclusions from these studies was that consanguineous marriages produced stronger medically adverse effects in black families than in white ones (Freire-Maia, 1963; Freire-Maia et al., 1963). Years later, however, Freire-Maia revised his conclusion. In a paper co-authored with Henrique Krieger and J. B. C. Azevedo, Freire-Maia confirmed that the conclusions of his paper were misleading because of methodological biases, especially concerning the analysis of socio-economic factors affecting those populations (Krieger, Freire-Maia, & Azevedo, 1971).[13]

Salzano's major interest was the genetics of indigenous populations, but he also carried out studies on racial mixing at the beginning of the 1960s in conjunction with his investigation of the occurrence of sickle cell anemia in the black population of Porto Alegre (Salzano, 1963).[14] His data indicated that the 'white mixture' in the black population of Porto Alegre varied from 47 to 54 percent, which was close to the 55 percent presented by Saldanha (1957) for Rio de Janeiro and São Paulo, and to the 50 percent found by Ottensooser and his collaborators in São Paulo. Salzano, however, did not fail to point out that his estimates were higher than the 40 percent that Saldanha ascribed to the black population of Brazil. On the other hand, the gene flow from Indians to black was found to be minimal, which he attributed to the small size of the indigenous population in Rio Grande do Sul at the time of colonization (Salzano, 1963).

As we have seen in this overview of research led by the geneticists Saldanha, Morton, Salzano, and Freire-Maia, miscegenation and racial crossing were important concerns for human population geneticists in Brazil in the post World War II context. Scientists were addressing issues that had long played a central role in the debates about the historical formation of the Brazilian nation. However, at the same time a number of contextual elements of the post World War II period influenced the conditions under which human population genetic investigations were carried out, including the selection of research sites and populations. In Brazil, this period was marked by a rural exodus, the rapid acceleration of internal migration, and the transformation of urban centers. In large part, the interest of geneticists in studying northeastern populations (which were migrating *en masse* toward São Paulo and Rio de Janeiro), as well as rural communities and immigrant colonies, stemmed from their understanding that these rapid demographic and socio-economic transformations helped to shape human biological diversity patterns, some with medical implications.

5. Final remarks

The social anthropologist Charles Wagley, Franz Boas Professor of Anthropology at Columbia University, wrote the foreword to the American edition of the book *Problems in Human Biology*, by Salzano and Freire-Maia (1970). Since the 1940s Wagley had been doing research in Brazil, and had participated, in the 1950s and 60s, in a UNESCO promoted project on race relations in Brazil. It was from this perspective that Wagley commented that "the new science of population genetics with its proliferation of genetic markers, techniques and theories, has been used to confront sociological data and theories [about Brazil]" (Wagley, 1970, pp. xix–xx).[15]

Our main argument in this paper is that population genetics played an important role in the rise, during the 1950s, of a particular set of narratives, based on biological concepts, about the formation of the Brazilian society. As we have seen, the conditions for the emergence of these explanations were closely related to Dobzhansky's coming to Brazil in the 1940s. As a major exponent of the neo-Darwinian synthesis, Dobzhansky contributed to the formation of a generation of Brazilian geneticists trained in theories and methods that were, at the time, at the cutting edge of evolutionary biology. Some of these geneticists migrated from *Drosophila* studies to human population genetics in the 1950s.

We have emphasized that in the human genetics research carried out in Brazil in the post-World War II period, understanding miscegenation was at the core of biologists' interests. In dialog with the history of the colonization of national territory, with past and present migratory processes, and with Brazilian social reality, human population geneticists sought to understand the formation of Brazil through its genetic, anthropological, and demographic characteristics. With the introduction of new instruments and scientific perspectives, geneticists were interested in understanding the effects of broad processes of miscegenation taking place in

[13] In an interview many years later, in 1988, Freire-Maia emphasized how delighted he was with the results of a reanalysis of those data (available at http://www.canalciencia.ibict.br/notaveis/livros/newton_freire-maia_42.html, accessed April 20, 2014). This was because, if the initial publications suggested intrinsic differences between whites and blacks in genetic load levels, the reanalysis, which included control for socio-economic conditions, indicated that the differences were not due to intrinsic biological or racial factors.

[14] In 1960, Salzano defended his 'livre docência' at the *Universidade Federal do Rio Grande do Sul*. His thesis was entitled 'Genetic and demographic studies among the Indians of Rio Grande do Sul,' and based on research among Caingang and Guarani groups (Salzano, 1960; see also Salzano, 1961a, 1961b). In the early 1960s he carried out extensive research in collaboration with James Neel on Amazonian indigenous groups, including the Xavante, Kayapo, and Yanomami, and others (Neel, 1994; Neel & Salzano, 1964, 1967; Salzano & Callegari-Jacques, 1988). These studies aimed at investigating patterns of human biological variability in indigenous populations and several of them were part of the International Biological Program (IBP) (Collins & Weiner, 1977). See more on this topic in Lindee (2001, 2004), Santos (2002) and Santos, Lindee, et al. (in press).

[15] In 1964, Salzano participated in the 'Expert Meeting of the Biological Aspect of Race', held in Moscow, that resulted in the 1964 UNESCO statement on race. His paper addressed issues related to the biological and medical consequences of 'racial mixture,' in part drawing from research on human population genetics carried out in Brazil by him, and by Freire-Maia, Morton, and other geneticists (Salzano, 1965).

Brazil since the arrival of the earliest colonizers. As remarked by Wagley, research carried out by the geneticists echoed the centrality of miscegenation that had long been emphasized in social science discourses on Brazilian history. But the geneticists' attention was not exclusively directed to the past. Contemporary sociopolitical context also informed their interests, especially processes resulting from the modernization of Brazilian society, and population movement due to urbanization and industrialization. Understanding the biological and medical impacts of this context also occupied a central place in their research agendas.

Given its emphasis on concepts of racial crossing, the Brazilian case offers much material for debate about the theoretical status of the idea of race as it was understood in the studies on human biological diversity in the decades following World War II. The use of race in human biology is a question that has increasingly absorbed historians and anthropologists, especially the trajectory of the concept in science in the post war decades (Gannett & Griesemer, 2004; Gausemeier, Muller-Wille, & Ramsden, 2013; Lindee & Santos, 2012; Lipphardt, 2010; Reardon, 2005). Reardon (2005) opposes the view advanced by several authors that the use of the term was largely discontinued (Barkan, 1992; Kevles, 1985; Stepan, 1982; Stocking, 1968), Instead, she argues that the idea of race was not abandoned or substituted by other concepts in physical anthropology or population genetics after World War II. In reflecting on the contents of the UNESCO statements on race, she writes that "rather than dismissing race as mere ideology, following World War II students of human diversity sought to refine its definition and use so that it could advance knowledge without legitimating discrimination…" (Reardon, 2005, p. 18). What we find to a significant degree in the work of the Brazilian geneticists, in accordance with Reardon's argument, is the view that the concept of race should not be abandoned, but reframed under the light of theoretical and methodological advances that were in progress in human genetics at that time.

The research agendas of the Brazilian geneticists in the post-World War II period focused mainly on regional and national topics, such as the reconstruction of the historical, demographic and social specificities that operated in formation of the Brazilian population. However, at the same time, on the global stage, geneticists characterized Brazil as offering the singular research conditions needed to construct models of human microevolutionary processes, especially gene flow. This view of the country as a site of special interest to geneticists was widely recognized and promoted by Brazilian geneticists themselves. According to Salzano and Freire-Maia, Brazilian populations presented "the geneticist and anthropologist an excellent opportunity for the study of complex and fascinating problems" in view of "the extreme variety of their original ethnic groups, the widespread miscegenation, and their distribution in all kinds of environmental conditions" (Salzano & Freire-Maia, 1970, p. xv). In 1973, Freire-Maia published a small book of popular science entitled *Brasil: Laboratório Racial* ("Brazil: A Racial Laboratory"), in which he presented the history of the formation of the Brazilian people as derived from research in human population genetics developed since the 1950s (Freire-Maia, 1973; see also Salzano & Freire-Maia, 1967, 1970).

In histories of research on human biological diversity in the twentieth century, especially regarding race, several parts of the world have been considered special, to the degree of being seen as 'laboratories' for the observations of physical anthropologists and geneticists. For example, in a passage with many parallels to the notion of 'racial laboratory' as applied to Brazil, historian of science Warwick Anderson (2012a) speaks of the fascination of historians and physical anthropologists with Hawaii in the period between the wars. This sentiment was shown in such expressions as "an admirable observation post for those interested in interracial relations," the "melting pot", a "veritable ethnographic museum," a "racial laboratory," the "statistician's playground," and the "happy hunting ground" of the "racial enthusiast" (Roberts, 1927, as cited in Anderson, 2012a, p. S96). So we can state that Brazil, like certain other world regions, has become, since the 1950s, a "significant site of cognition" (Anderson, 2012b, p. 213) with regard to investigation of racial crossing in the context of the emerging field of human population genetics.

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