Horizons

A Global History of Science

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Introduction: The Origins of Modern Science

Where did modern science come from? Until very recently, most historians would tell you the following story. Sometime between 1500 and 1700, modern science was invented in Europe. This is a history which usually begins with the Polish astronomer Nicolaus Copernicus. In *On the Revolutions of the Heavenly Spheres* (1543), Copernicus argued that the Earth goes around the Sun. This was a radical idea. Since the time of the ancient Greeks, astronomers had believed that the Earth was at the centre of the universe. For the first time, scientific thinkers in sixteenth-century Europe started to challenge ancient wisdom. Copernicus was followed by other pioneers of what is often called the 'scientific revolution' – the Italian astronomer Galileo Galilei, who first observed the moons of Jupiter in 1609, and the English mathematician Isaac Newton, who set out the laws of motion in 1687. Most historians would then tell you that this pattern continued for the next 400 years. The history of modern science, as traditionally told, is a story focused almost exclusively on men like Charles Darwin, the nineteenth-century British naturalist who advanced the theory of evolution by natural selection, and Albert Einstein, the twentieth-century German physicist who proposed the theory of special relativity. From evolutionary thought in the nineteenth century to cosmic physics in the twentieth century, modern science – we are told – is a product of Europe alone.[1]

This story is a myth. In this book, I want to tell a very different story about the origins of modern science. Science was not a product of a unique European culture. Rather, modern science has always depended upon bringing together people and ideas from different cultures around the world. Copernicus is a good example of this. He was writing at a time when Europe was forging new connections with Asia, with caravans travelling along the Silk Road as well as galleons sailing across the Indian Ocean. In his scientific work, Copernicus relied upon mathematical techniques borrowed from Arabic and Persian texts, many of which had only recently been imported into Europe. Similar kinds of scientific exchange were taking place throughout Asia and Africa. This was the same period in which Ottoman astronomers journeyed across the Mediterranean, combining their knowledge of Islamic science with new ideas borrowed from Christian and Jewish thinkers. In West Africa, at the courts of Timbuktu and Kano, mathematicians studied Arabic manuscripts imported from across the Sahara. To the east, astronomers in Beijing read Chinese classics alongside Latin scientific texts. And in India, a wealthy maharaja employed Hindu, Muslim, and Christian mathematicians to compile some of the most accurate astronomical tables ever made.[2]

All this suggests a very different way of understanding the history of modern science. In this book, I argue that we need to think of the history of modern science in terms of key moments in global history. We begin with the colonization of the Americas in the fifteenth century and move all the way through to the present. Along the way we explore major developments in the history of science, from the new astronomy of the sixteenth century through to genetics in the twenty-first. In each case, I show how the development of modern science depended upon global cultural exchange. It is worth emphasizing, however, that this is not simply a story of the triumph of globalization. After all, cultural exchange came in lots of different forms, many of which were deeply exploitative. For much of the early modern period, science was shaped by the growth of slavery and empire. In the nineteenth century, science was transformed by the development of industrial capitalism. Whilst in the twentieth century, the history of science is best explained in terms of the Cold War and decolonization. Yet despite these deep imbalances of power, people from across the world made significant contributions to the development of modern science. Whatever period we look at, the history of science cannot be told as a story which focuses solely on Europe.[3]

The need for such a history has never been so great. The balance of the scientific world is shifting. China has already overtaken the United States in terms of science funding, and for the last few years researchers based in China have produced more scientific articles than anywhere else in the world. The United Arab Emirates launched an unmanned mission to Mars in the summer of 2020, whilst computer scientists in

Kenya and Ghana play an increasingly important role in the development of artificial intelligence. At the same time, European scientists face the fallout from Brexit, whilst Russian and American security services continue to wage cyberwarfare.[4]

Science itself is plagued by controversy. In November 2018, the Chinese biologist He Jiankui shocked the world by announcing that he had successfully edited the genes of two human babies. Many scientists believed that such a procedure was too risky to justify trying on human subjects. However, as the world quickly learned, it is very hard to enforce an international code of scientific ethics. Officially, the Chinese government distanced itself from He's research, serving him with a three-year prison sentence. But in 2021, researchers in Russia are already threatening to replicate his controversial experiment. Alongside issues surrounding ethics, science today, as in the past, suffers from deep inequalities. Scientists from minority ethnic backgrounds are underrepresented at the top of the profession, Jewish scientists and students continue to suffer antisemitic abuse, whilst researchers working outside of Europe and the United States are often denied visas for travel to international conferences. If we are to tackle such problems, we need a new history of science, one that better reflects the world in which we live.[5]

Scientists today are quick to acknowledge the international nature of their work. But they tend to think of this as a relatively recent phenomenon, a product of the 'big science' of the twentieth century, rather than something with a history stretching back more than 500 years. When contributions to science from outside of Europe are acknowledged, they are typically relegated to the distant past, not part of the story of the scientific revolution and the rise of modern science. We hear a lot about the 'golden age' of medieval Islamic science, the period around the ninth and tenth centuries, when scientific thinkers in Baghdad first developed algebra and many other new mathematical techniques. There is a similar emphasis on the scientific accomplishments of ancient China, such as the invention of the compass and gunpowder, both well over 1,000 years ago. But these stories only serve to reinforce the narrative that places like China and the Middle East have little to do with the history of modern science. Indeed, we often forget that the notion of a 'golden age' had originally been invented during the nineteenth century in order to justify the expansion of European empires. British and French imperialists promoted the false idea that the civilizations of Asia and the Middle East had been in decline since the medieval period, and so needed to modernize.[6]

Perhaps surprisingly, these stories are still just as popular in Asia as they are in Europe. Cast your mind back to the 2008 Beijing Olympics. The opening ceremony began with an enormous scroll unfolding, signifying the invention of paper in ancient China. Throughout the ceremony, a television audience of over one billion watched as China showcased its other ancient scientific achievements, including the compass. Fittingly, the ceremony closed with a spectacular display of another Chinese discovery. Fireworks lit up the sky above the Bird's Nest Stadium, a nod towards the invention of gunpowder during the Song dynasty. Yet throughout the ceremony, there was very little reference to the many scientific breakthroughs that China has contributed to since then, such as the development of natural history in the eighteenth century or quantum mechanics in the twentieth century. The same is true of the Middle East. In 2016, the Turkish President, Recep Tayyip Erdoğan, gave a lecture at the Turkish–Arab Congress on Higher Education in Istanbul. In his talk, Erdoğan described the 'golden age of Islamic civilization', the medieval period in which 'Islamic cities . . . acted as a science center'. Yet Erdoğan was seemingly unaware of the fact that many Muslims, including those living in what is today modern Turkey, had also contributed just as much to the development of modern science. From astronomy in sixteenth-century Istanbul to human genetics in twentieth-century Cairo, the Islamic world of scientific advance continued well beyond the medieval 'golden age'.[7]

Why are these stories so common? Like many myths, the idea that modern science was invented in Europe did not come about by accident. During the middle of the twentieth century, a group of historians in Britain and the United States started to publish books with titles like *The Origins of Modern Science*. Almost all were convinced that modern science – and with it modern civilization – originated in Europe, sometime around the sixteenth century. 'The scientific revolution we must regard . . . as a creative product of the West,' wrote the influential Cambridge historian Herbert Butterfield in 1949. Similar views were expressed on the other side of the Atlantic. Students at Yale University in the 1950s were taught that 'the West generated the natural sciences . . . the East did not', whilst readers of *Science* – one of the most prestigious scientific magazines in the world – were informed that 'a small circle of Western European nations provided the original home for modern science'.[8]

The politics of all this couldn't be clearer. These historians lived through the early decades of the Cold War, a period in which the struggle between capitalism and communism dominated world politics. They thought about the contemporary world in terms of a strict divide between East and West, and then – whether intentionally or not – projected this back onto the past. During this period, science and technology were widely seen as markers of political success, particularly after the Soviet Union launched Sputnik, the first artificial satellite, in October 1957. The idea that modern science was invented in Europe therefore served as a convenient fiction. For leaders in Western Europe and the United States, it was essential that their citizens saw themselves on the right side of history, as bearers of scientific and technological progress. This was also a history of science designed to convince post-colonial states around the world to follow the path of capitalism, and to steer clear of communism. Throughout the Cold War, the United States spent billions of dollars on foreign aid, promoting a combination of free market economics and scientific development in countries across Asia, Africa, and Latin America. This was intended to counter the foreign assistance programme run by the Soviet Union. 'Western science', when combined with 'market economies', promised nothing less than an economic 'miracle', at least according to American policymakers.[9]

Somewhat ironically, Soviet historians ended up reinforcing a very similar narrative concerning the origins of modern science. They tended to ignore the earlier achievements of Russian scientists working under the Tsars, instead promoting the spectacular rise of science under communism. 'Up to the twentieth century, there was really no physics in Russia,' wrote the President of the Soviet Academy of Sciences in 1933. As we'll see, this was not true. Peter the Great supported some of the most important astronomical observations made during the early eighteenth century, whilst Russian physicists played a key role in the development of the radio in the nineteenth century. Some later Soviet historians did try and highlight earlier Russian scientific achievements.

But at least in the early decades of the twentieth century, it was much more important to emphasize the revolutionary advances made under communism rather than anything achieved under the old regime.[10]

Things played out slightly differently in Asia and the Middle East, although ultimately with similar consequences. The Cold War was a period of decolonization, in which many countries finally gained independence from European colonial powers. Political leaders in places like India and Egypt desperately wanted to forge a new sense of national identity. Many looked to the ancient past. They celebrated the achievements of medieval and ancient scientific thinkers, ignoring much of what had happened during the period of colonialism. It was in fact in the 1950s that the very idea of an Islamic or Hindu 'golden age' started to become popular – not just in Europe, as it had been in the nineteenth century, but also in the Middle East and Asia. Indian and Egyptian historians seized on the idea of a glorious scientific past, one waiting to be rediscovered. In doing so, they unwittingly reinforced the very myth being peddled by European and American historians. Modern science was Western, ancient science was Eastern, or so people were told.[11]

The Cold War is over, but the history of science is still stuck in the past. From popular history to academic textbooks, the idea that modern science was invented in Europe remains one of the most widespread myths in modern history. Yet there is very little evidence to support it. In this book, I provide a new history of modern science, one that is both better supported by the available evidence and more suited to the times in which we live. I show how the development of modern science fundamentally relied on the exchange of ideas between different cultures across the world. That was true in the fifteenth century, just as it is true today.

From Aztec palaces and Ottoman astronomical observatories to Indian laboratories and Chinese universities, this book follows the history of modern science across the globe. However, it is important to remember that this is not an encyclopaedia. I have not tried to cover every country in the world, nor every scientific discovery. Such an approach would be foolhardy, and not particularly enjoyable to read. Rather, the aim of this book is to show how global history shaped modern science. For that reason, I have picked four key periods of world historical change, linking each of these to some of the most important developments in the history of science. By placing the history of science at the heart of world history, this book also uncovers a new perspective on the making of the modern world – from the history of empire to the history of capitalism, if we want to understand modern history, we need to pay attention to the global history of science.

Finally, I want to emphasize that I see science as very much a human activity. Modern science was undoubtedly shaped by wider world events, but it was nonetheless made through the efforts of real people. These were individuals who, whilst living in a very different time and place, were not fundamentally different from you or me. They had families and relationships. They struggled with their emotions and health. And each of them wanted more than anything else to better understand the universe in which we live. Throughout this book, I have tried to give a sense of that more human side of science: an Ottoman astronomer captured by pirates in the Mediterranean; an enslaved African collecting medicinal herbs on a plantation in South America; a Chinese physicist fleeing the Japanese assault on Beijing; and a Mexican geneticist collecting blood samples from Olympic athletes. Each of these individuals, although largely forgotten today, made important contributions to the development of modern science. This is their story – the scientists who have been written out of history.

8. Genetic States

Masao Tsuzuki had heard that things were bad, but nothing could prepare him for the scene of devastation that he encountered on arriving in the ruined city of Hiroshima. Disfigured faces, bodies lying under the rubble, and children vomiting blood – it must have been difficult to fathom how a single explosion could have caused so much suffering. Tsuzuki, a professor at the Imperial University of Tokyo, was one of the first scientists to enter Hiroshima after the dropping of the atomic bomb on 6 August 1945. Over the following days, he examined survivors and conducted autopsies, building up a detailed picture of the medical effects of the blast. 'The burn action was so violent and severe that the entire thickness of the skin was burned,' he reported. Tsuzuki also noted how many survivors seemed to be suffering from what he called 'atomic bomb radiation sickness'. Those who were not killed by the explosion nonetheless developed disturbing symptoms, including vomiting, blood loss, and fever. The most severely affected patients typically died within a week.[1]

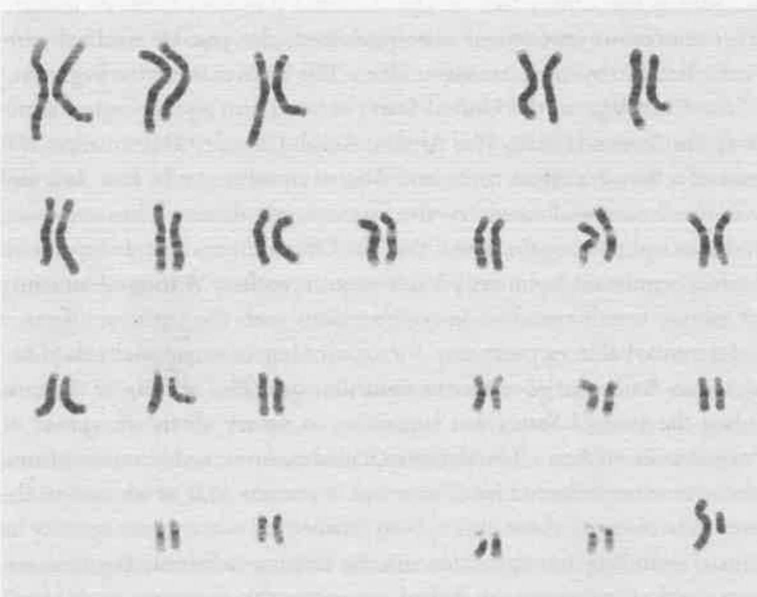
In the immediate aftermath of the explosion, Tsuzuki understandably concentrated on the most direct and observable effects of the blast. However, attention soon turned towards the long-term consequences of the use of nuclear weapons. A year later, Tsuzuki noted that scientists did not fully understand how exposure to radiation might affect 'the coming foetus, children, and descendants' of atomic bomb survivors. Since the 1920s, it had been known that radiation could cause genetic mutations. However, no one had really considered what this meant for the future of humanity, not until August 1945. Could these mutations be passed on to future generations? Was it safe for those exposed to atomic radiation to have children? There was a need for 'hereditary studies', argued Tsuzuki. These concerns were in fact shared by many scientists, not just in Japan, but also in the United States. 'If they could foresee the results 1,000 years from now . . . they might consider themselves more fortunate if the bombs had killed them,' argued the

American geneticist Hermann Joseph Muller, who went on to win the 1946 Nobel Prize in Physiology or Medicine for his earlier discovery of the genetic effects of radiation. 'There have been planted hundreds of thousands of minute time-bombs in the survivors' germ cells,' warned Muller, referring to the risk that damaging genetic mutations might be passed on to the next generation.[2]

Given widespread public concern, both at home and abroad, the United States government decided it needed to do something. In November 1946, President Harry Truman authorized the creation of the Atomic Bomb Casualty Commission. By this point, Japan had surrendered, and the country was under American occupation. Organized by the National Academy of Sciences, the Atomic Bomb Casualty Commission was tasked with tracking both the short- and long-term health outcomes of atomic bomb survivors, known in Japanese as the *hibakusha* (literally, 'exposed one'). Much of this work concerned the genetic impact of the blasts. The 'unique possibility for demonstrating genetic effects caused by atomic radiation should not be lost', argued the National Academy of Sciences. The study was led by an American geneticist named James Neel, who was assisted by a number of Japanese scientists, doctors, and midwives. In fact, well over 90 per cent of the staff employed by the Atomic Bomb Casualty Commission were Japanese. Tsuzuki was quickly recruited, as he was one of the few scientists to have entered Hiroshima in the weeks following the explosion. He had also conducted some experiments on the biological effects of radiation prior to the Second World War, so understood better than most what the genetic consequences of the use of nuclear weapons was likely to be.[3]

The initial work of the Atomic Bomb Casualty Commission, conducted by Neel and Tsuzuki in collaboration with a Japanese doctor named Saburo Kitamura, focused on tracking the birth outcomes of survivors. Together, Tsuzuki and Kitamura would travel around Hiroshima, interviewing pregnant women and examining newborn babies for any signs of abnormalities. Early reports seemed to suggest that spontaneous abortion was more common in cases where the father had been exposed to a high dose of radiation, but that the actual children born to atomic bomb survivors were not obviously affected in terms of major birth defects. This was consistent with the idea that the most damaging genetic mutations probably caused the death of the embryo well before it had a chance to grow. And so, although it was not possible to demonstrate a conclusive link between radiation exposure and reproductive health, Neel nonetheless concluded that genetic mutations must have occurred in the bodies of survivors.[4]

Alongside birth outcomes, the commission also began studying the effects of radiation at the level of the chromosome. Masuo Kodani, a Japanese American geneticist who had been interned in the United States during the war, played a leading role in this work. After completing a PhD at the University of California, Berkeley, Kodani moved to Japan – in part because his Japanese wife had been declared an illegal immigrant by the American government – and began working for the commission in 1948. The focus of Kodani's research was on the number of chromosomes found in the cells of atomic bomb survivors. By this point, it was possible to identify individual chromosomes – which are the carriers of genetic information, made up of strands of DNA – under



36. A typical set of human male chromosomes as observed under the microscope following staining. There are twenty-three pairs, forty-six in total.

the microscope. Kodani would take cell samples from patients, often from autopsies, stain them, and then carefully count the number of chromosomes he could see.[5]

In 1957, he published an important article documenting the existence of an additional chromosome in the testes of a number of male survivors of the atomic bombs. Whereas humans typically have 46 chromosomes – a fact that had only been confirmed the previous year by the Indonesian geneticist Joe Hin Tjio – Kodani found cases of atomic bomb survivors with either 47 or 48 chromosomes. Given that the presence of an additional chromosome can cause certain medical conditions, such as Down's syndrome and Klinefelter syndrome, and that these conditions can often be passed on to children, this was an incredibly significant discovery.[6]

The Atomic Bomb Casualty Commission was one of the largest scientific projects funded by the United States government in the immediate post-war period. At its height, the project employed over 1,000 staff and accounted for almost half of the National Research Council budget. This enormous investment was motivated, not just by medical concerns, but also by international politics. The 1940s marked the beginning of the Cold War, as the United States entered into an ideological battle with the Soviet Union. The Atomic Bomb Casualty Commission was part of a broader effort to extend American influence in East Asia and win the 'hearts and minds' of the Japanese population. This was going to be an uphill struggle, given that the United States had dropped two atomic bombs on Japan only a few months earlier. 'A long-term study of atomic bomb casualties in collaboration with the Japanese affords a most remarkable opportunity for cultivating international relations,' noted an American government report in 1947. This was just at the time when the United States was beginning to worry about the spread of communism in Asia – North Korea had already turned to communism, and was soon followed by China and Vietnam. And as we saw in the previous chapter, there was a long history of communist activity in Japan, including amongst scientists. By helping to rebuild Japanese science, the United States hoped to steer the country away from communism. It also hoped to allay fears about the continued testing of atomic weapons, something that was made much more difficult when a group of Japanese fishermen was inadvertently exposed to radioactive fallout following the detonation of an American hydrogen bomb on Bikini Atoll in March 1954.[7]

Throughout the 1950s, there continued to be major scientific disagreement over the effects of atomic radiation, particularly over the dose required to induce genetic mutations in humans. Some scientists believed that there was a minimum threshold dose, below which no genetic mutations could occur, and that it was therefore safe for humans to be exposed to relatively high doses of radiation, as might be encountered by workers in a nuclear power plant or those living close to nuclear weapons test sites. Others argued that this was wrong, and that even the smallest possible dose of radiation had the potential to induce a damaging genetic mutation. However, by the middle of the 1960s – thanks in part to the work of Japanese geneticists like Masuo Kodani – most scientists agreed that there was no threshold: exposure to radiation, no matter how small the dose, always had the potential to damage the genome.[8]

This, however, did not mark the end of the atomic age, but rather the start of it. Despite the knowledge of the damaging effects of radiation, governments around the world continued to invest in all kinds of nuclear technologies, particularly those related to energy and defence. This in turn created further demand for biological research into both the uses and effects of atomic radiation. The Atomic Bomb Casualty Commission, as we'll see, was just one of a number of institutions which brought together biological and nuclear science. At the international level, this work was supported by the United Nations, which throughout the 1950s and 1960s organized a series of conferences on the 'peaceful uses of atomic energy'. Every few years, scientists from around the world congregated in Geneva to discuss their research. Topics included the treatment of cancer using radiotherapy as well as the use of radiation to create new high-yield varieties of staple crops. 'I honestly believe that we are on the threshold of a new era in the study of . . . genetics,' wrote James Neel in 1957, echoing a widely held sentiment that the development of nuclear technologies, including atomic weapons, had brought about an unparalleled advance in the biological sciences.[9]

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It is tempting to think that the history of modern genetics, based on molecular biology, began with the discovery of the structure of DNA. This is how the story is often told. Whilst the existence of DNA had been known since the late nineteenth century, it was only in 1953 that Francis Crick and James Watson, working together at the University of Cambridge, finally identified the famous 'double helix' structure of the molecule. Crick and Watson achieved this by examining X-ray photographs of DNA taken by Maurice Wilkins and Rosalind Franklin at King's College, London. This was a major breakthrough, one that helped scientists better understand how genetic inheritance works. Since the early twentieth century, scientists had known that chromosomes, which are made up of long strands of DNA, carry genetic information. Identifying the structure of DNA was therefore the first step in understanding how genes transmit biological characteristics. In fact, soon after Crick's and Watson's discovery, scientists proved that DNA codes for another molecule, called RNA, which in turn codes for proteins – the basic building blocks of life. In 1958, Crick referred to this process, in which DNA codes for RNA which then codes for proteins, as the 'Central Dogma' of modern molecular biology. Together, these discoveries eventually led to the development of new genetic technologies, such as gene editing and genome sequencing.[10]

It is true that the discovery of the structure of DNA was an important moment in the history of modern genetics. However, by focusing exclusively on this single discovery, we miss out on many other significant advances that were made in the biological sciences during the second half of the twentieth century. The emphasis on Crick and Watson also diverts attention away from scientists working in places outside of Europe and the United States, many of whom also played an important role in the development of the modern biological sciences. With this in mind, I want to suggest an alternative way of thinking about the history of modern genetics. Rather than starting in 1953 with the discovery of the structure of DNA in Cambridge, I think that we should instead start in 1945 with the dropping of the atomic bombs on Hiroshima and Nagasaki. This event marked the start of the Cold War. It also marked the beginning of the development of modern genetics. We've already seen how Japanese scientists working for the Atomic Bomb Casualty Commission did much of the early research into the genetic effects of radiation in humans. We've also seen how American investment in this research programme was motivated by Cold War fears over the spread of communism in Asia. In order to understand the history of modern genetics, we therefore need to look to the global conflict which defined the second half of the twentieth century – that is, the Cold War.[11]

Modern genetics was central to the process of state formation during the Cold War, not just in Europe and the United States, but right across Asia, the Middle East, and Latin America. This again is something that is often missed when focusing solely on the discovery of the structure of DNA. After all, most governments were not particularly interested in the structure of DNA – whether it was a double helix or not had no particular bearing on the future of the state. However, governments around the world were interested in the practical benefits offered by recent advances in genetics, particularly when it came to human health and food security.

For many states, the most immediate concern following the Second World War was how to feed the nation. The second half of the twentieth century was a period of massive population growth, with the world population increasing from a little over two billion in 1945 to five billion in 1990. This led to fears of what was referred to as the 'population bomb' – another allusion to the atomic age – in which millions of people might starve to death if the world's food supply did not dramatically increase. By the early 1960s, it was estimated that 80 per cent of the world's population suffered from malnutrition. Most governments recognized that the legitimacy of the state depended upon its ability to provide food for the population. This was particularly the case in Asia and Latin America, where many states had recently either gained independence or gone through a political revolution. With this in mind, governments around the world invested in plant genetics, hoping that it might be possible to engineer new high-yield varieties of crops such as rice and wheat. Much of this work was supported by the Rockefeller Foundation, which helped establish seed banks in countries ranging from Indonesia to Nigeria.[12]

Research in plant genetics was also encouraged by the United States government, which believed that the spread of world hunger would fuel the spread of communism. 'Communism makes attractive promises to underfed peoples,' wrote one prominent American geneticist in the early 1950s. The failure of states to provide enough food for the population was 'a threat to the peace of the world as well as our national security', warned the United States Agency of International Development, which had been set up in 1961 in order to provide scientific and technical assistance to various 'Third World' governments. By the end of the 1960s, there was talk of a 'Green Revolution', in which advances in plant genetics, chemical fertilizers, and irrigation techniques would solve the problem of world hunger. As the term suggests, this was imagined as an antidote to the 'Red Revolution' of the Soviet Union.[13]

Alongside plant genetics, governments invested in the developing area of human genetics. As we've already seen, there was widespread concern over the biological effects of atomic radiation following the bombing of Hiroshima and Nagasaki. These concerns only increased as more and more states developed nuclear weapons and constructed nuclear power stations. The relationship between atomic radiation and human genetics therefore became a national security issue for many governments, an important part of planning the response to any future nuclear war. At the same time, many states believed that by promoting the medical benefits of nuclear research – in both diagnosis and treatment – they could persuade a reluctant public of the advantages of living in an atomic age. Again, this idea was promoted by new international organizations, such as the World Health Organization (established in 1948) and the International Atomic Energy Agency (established in 1957), both of which provided funding for scientists from around the world to conduct research into the medical uses and effects of radiation.

More broadly, governments from Latin America to East Asia believed that modern genetics might bring about dramatic improvements in human health, particularly through a better understanding of inherited diseases. There was also an interest in the use of modern genetics to answer questions concerning national and ethnic identity, another major concern during a period of state formation and mass migration. Today, we know that race is not a meaningful biological category. Indeed, as early as 1950 the United Nations had issued a statement describing race as a 'social myth' rather than a 'biological fact'. Nonetheless, throughout the Cold War, governments around the world organized countless genetic surveys, hoping to distinguish different ethnic groups, such as 'Turks' and 'Arabs', by their genetic make-up, even if this ultimately proved impossible.[14]

As all this suggests, the development of modern genetics was inseparable from Cold War politics. However, whilst many historians have recognized the Cold War as a significant period for the development of modern science, they have tended to focus on scientific advances made in the United States, Europe, and the Soviet Union. In this chapter, I take a different approach, following the history of modern genetics as it developed across Latin America, Asia, and the Middle East. These, after all, were the regions in which the United States and Soviet Union battled for influence, hoping to shape the development, not only of science and technology, but also of world politics. Ultimately, in order to properly understand the history of science during the Cold War, we once again need to think in terms of global history. We begin with a Mexican geneticist on his way to the market.[15]

I. Mutations in Mexico

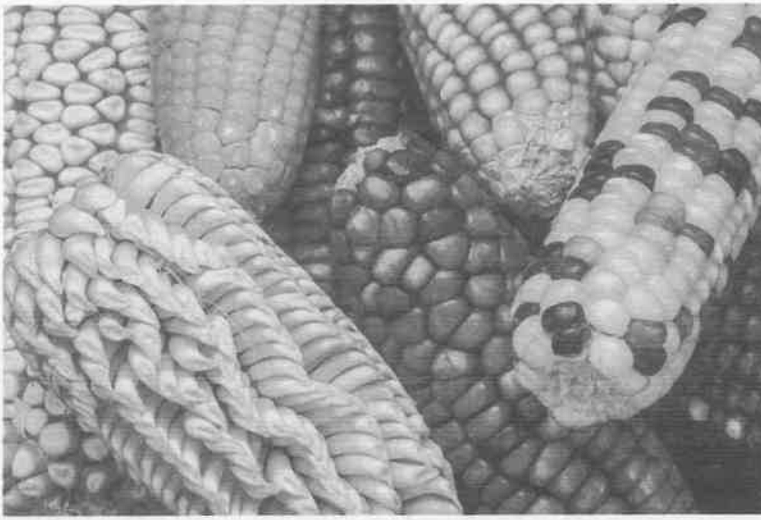
Efraím Hernández Xolocotzi had been driving for hours. It was an uncomfortable journey, rattling along in his old jeep through the Mexican countryside, but finally he arrived at his destination – a tiny market town in the southern state of Tabasco. Pulling up by the roadside, Hernández hopped out of his vehicle, and began chatting with people in the market. This was a relatively remote part of Mexico, and the locals didn't speak Spanish. Thankfully, Hernández was familiar with the Indigenous language of the region – one of the many dialects of Mayan – and was able to communicate without too much difficulty. He explained that he was looking to buy some maize, and the farmers in the market pointed him towards a stall piled high with cobs of corn. Hernández was delighted. He went over to the stall, examining each of the cobs closely, and then agreed to purchase the whole lot. The farmers must have wondered why he needed so much maize. Still, they didn't worry too much, as he paid a good price. Hernández then headed back to his jeep with the bags of corn, started the engine, and continued on his journey, winding his way towards the Yucatán Peninsula.[16]

Maize had been cultivated in Mexico for thousands of years, long before the arrival of Europeans in the sixteenth century. However, in the middle of the twentieth century, it became the focus of a major scientific investigation, one that formed the basis of the Green Revolution. Hernández was one of a number of geneticists employed to study maize by the Mexican Agricultural Program, which was established in 1943. It was located within the Mexican Ministry of Agriculture, but primarily funded by the Rockefeller Foundation, an American philanthropic organization. As we saw in the previous chapter, the Rockefeller Foundation played a major role in funding international science in the twentieth century. Alongside physics, the Rockefeller Foundation also invested in biology, particularly when there was an obvious practical application, as with plant genetics. In Mexico, the plan was to use the latest techniques of modern genetics in order to improve the yields of staple crops, such as wheat and maize.[17]

The Rockefeller Foundation certainly wanted to improve the lives of Mexican people. However, as with all philanthropy, there was an element of politics to this too. During the middle decades of the twentieth century, the United States grew increasingly concerned about the spread of communism, not just in Europe and Asia, but also closer to home. Following the Mexican Revolution of 1910–20, in which various armed groups fought for control following the overthrow of the president, Mexico seemed to be sliding towards radical socialism. Throughout the 1930s, the Mexican government redistributed large areas of farmland to impoverished peasants, and in 1938 the government appropriated a number of American-owned oil fields. These kinds of land seizures and collective ownership looked a lot like what was going on in the Soviet Union, and by the early 1940s, the American government was worried about the prospect of a communist state on its own border. The director of the Rockefeller Foundation shared these concerns, describing Mexico as 'tainted with Bolshevistic doctrines'. The Mexican Agricultural Program therefore served a number of overlapping political and scientific objectives. Chief amongst them was the notion that stopping the spread of hunger would help stop the spread of communism. By improving the yields of staple crops such as maize, the Rockefeller Foundation hoped to steer Mexico away from socialist politics. 'Hunger is a powerful enemy of peace,' wrote Paul Mangelsdorf, one of the American geneticists who worked for the Mexican Agricultural Program.[18]

Histories of the Green Revolution tend to focus on the contributions of American geneticists like Mangelsdorf. However, the Mexican Agricultural Program also employed a number of Mexican scientists who are today often forgotten. Hernández was one of those scientists. Born in 1913, he came from a humble background. His father was a peasant, possibly of Indigenous descent, and his mother was a teacher. Hernández knew the land well, and learned various Indigenous dialects as a boy, working in the fields with his father. However, Hernández moved around quite a bit, as his father looked for work and tried to stay out of trouble amidst ongoing conflict. In 1923, in the aftermath of the Mexican Revolution, ten-year-old Hernández emigrated with his mother to the United States. He studied at a local school in New Orleans, and later New York, before winning a scholarship to study biology at Cornell University, graduating in 1938. This was a great achievement, especially given that, much like today, Mexicans in the United States suffered from systematic racial discrimination, particularly when it came to education. After graduating from Cornell, Hernández was selected by the Rockefeller Foundation to undertake postgraduate study in genetics at Harvard University, spending two years learning the latest scientific techniques, before returning to Mexico in 1949. He was then hired as an 'Associate Geneticist' by the Mexican Agricultural Program, one of eighteen Mexican scientists who worked on the project.[19]

For two years, Hernández travelled across Latin America, sometimes by jeep, other times by train or boat. He reached as far south as Peru, and even crossed the Gulf of Mexico to collect specimens in Cuba. The son of an Indigenous farmer, Hernández knew more than anyone about the incredible variety of maize found in the region. 'The geographic distribution . . . was known only to E. Hernández Xolocotzi,' recalled one of the American scientists who worked for the programme. Hernández's fluency in a number of Indigenous dialects made tracking down different varieties of maize a lot easier. 'To collect the genetic variation of maize in a given community, one has to be persistent and to use a great deal of tact in dealing with the farmers,' explained Hernández. Even then, he sometimes struggled to convince people to sell him rare specimens, particularly the red varieties of corn used in certain rituals.



37. Different varieties of maize collected by geneticists in Latin America and the United States.

'I could not persuade the indigenous Hulchol population to sell me samples of their ceremonial maize varieties,' noted Hernández after returning empty-handed from a remote region of northwest Mexico. Nonetheless, after two years of intensive work, Hernández and his team had amassed a collection of over 2,000 different varieties of maize from across the Americas.[20]

Up to this point, the work undertaken by the Mexican Agricultural Program was not so different from the kind of natural history we saw in the eighteenth and nineteenth centuries. Hernández was collecting these different varieties in order to categorize them, with the ultimate aim of identifying those which might be crossed in order to increase yields. What was different, however, was the use of recent advances in genetics to guide this research. This was all explained in a book published by the Mexican Agricultural Program titled *Races of Maize in Mexico* (1952). Hernández was one of the co-authors, along with the American geneticists Edwin Wellhausen, Louis Roberts, and Paul Mangelsdorf. In *Races of Maize*, the team explained that the aim of the project was to combine an analysis of the 'vegetable characters of plants' with a study of 'genetic and cytological factors', meaning the examination of individual cells under the microscope. And so, as well as measuring the size of the leaves, tassels, and kernels of each specimen, the team also deployed the latest genetic techniques. One of the methods used by the programme was called Giemsa staining, which had been invented in the early twentieth century by the German chemist Gustav Giemsa. This staining technique made it possible to identify individual chromosomes, as well as distinctive bands of concentrated DNA, under the microscope, and so categorize different varieties of maize on this basis. Hernández himself was familiar with this technique, as it was the sort of thing he would have learned as part of his course on plant genetics at Harvard University in the 1940s.[21]

Through a combination of traditional natural history and modern genetics, the scientists built up a detailed picture of the 'extraordinary diversity of corn' in the Americas. Much of this work confirmed what Hernández had initially suspected, based on his existing knowledge of Mexican agriculture – that over the past 8,000 years the size of the corncob had increased through the hybridization of different varieties. More recent varieties, particularly those that had been bred after the Spanish conquest in the sixteenth century, tended to have larger cobs, whereas more ancient varieties, identified through archaeological remains, tended to have smaller cobs. The geneticists also found distinctive patterns of banding, referred to as 'chromosome knots', when examining the cells of more recent varieties under the microscope, which again seemed to confirm the long-term pattern of development. This genetic analysis then formed the basis of a major effort to increase food production in Mexico over the following decades. Different varieties of maize were selected according to their genetic characteristics. These hybrid varieties, which tended to have increased yields, were then sold to farmers for cultivation. By the late 1960s, improved varieties of maize made up 20 per cent of the annual crop.[22]

The Mexican Agricultural Program did not solve every problem, and not everyone supported its efforts to introduce improved varieties of maize. Food shortages continued in Mexico throughout the 1950s and 1960s, as did land seizures. At the same time, many Mexican scientists, including Hernández, worried that the Rockefeller Foundation was placing too much emphasis on industrial farming at the expense of smallholders and peasants. After all, the hybrid varieties produced by the programme were expensive to purchase. Mexican farmers were also encouraged to use more chemical fertilizers, which these varieties responded well to, despite the fact that overuse could cause long-term ecological damage. There was a related concern that a focus on improved varieties might end up destroying the very genetic diversity on which the Green Revolution depended. Some Mexican scientists even suggested that they would be better off seeking assistance from the Soviet Union, which promoted alternative 'socialist' farming methods, rather than the United States with its more industrial approach. Nonetheless, whatever people thought of it, the Mexican Agricultural Program marked an important moment in the history of modern genetics. The Green Revolution soon extended across Latin America, with the Rockefeller Foundation establishing similar programmes in Brazil and Columbia. As we'll see later in this chapter, the Mexican Agricultural Program in fact provided a model for many governments around the world, including those in Asia and the Middle East.[23]

Alongside work on plant genetics, Mexican scientists also made a number of important contributions to the development of human genetics. This was in part due to the efforts of the Rockefeller Foundation, which funded not only the Mexican Agricultural Program, but also a new Institute for Biomedical Research at the National Autonomous University of Mexico. The Mexican government itself also began investing more and more money in the biomedical sciences during this period. Much of the research in human genetics was undertaken by a team working for the Genetics and Radiobiology Program of the National Commission of Nuclear Energy. Just as we saw in Japan, the development of human genetics in Mexico was closely associated with the growth of nuclear science. Mexico in fact sits on substantial uranium deposits, located in the south of the country, which was one of the many reasons that the United States was so concerned about the future of its neighbour during the Cold War. However, unlike the United States, the Mexican government did not seek to develop nuclear weapons, and instead focused on the use of atomic energy for medical and scientific purposes.[24]

Established in 1960, the Genetics and Radiobiology Program was directed by a Mexican scientist named Alfonso León de Garay. Born in Puebla in 1920, de Garay studied medicine at a local university, before moving to Mexico City in 1947 to practise as a neurologist. It was during this period that the Mexican government started to look for ways to make use of the country's uranium deposits, establishing the National Commission of Nuclear Energy in 1953. De Garay himself became interested in radiobiology (the use of radiation to diagnose and treat medical conditions), as well as the long-term effects of radiation on the human body. In 1957, he was offered a fellowship to support postgraduate study in Europe by the International Atomic Energy Agency. De Garay chose to study at the Galton Laboratory at University College, London, spending three years there learning the latest techniques of genetic science. When de Garay returned to Mexico, he convinced the National Commission of Nuclear Energy to set up the Genetics and Radiobiology Program.[25]

De Garay quickly went about recruiting a team of promising young researchers to work with him. These included Rodolfo Félix Estrada, a graduate of the National Autonomous University who had initially worked as a geneticist for the Mexican Agricultural Program, as well as María Cristina Cortina Durán, who had studied at the National Autonomous University before completing a PhD at the University of Paris in the early 1960s. (Cortina Durán was also one of the first women to be employed by the Genetics and Radiobiology Program.) Together, the team conducted important research into the genetic effects of atomic radiation. Félix Estrada spent most days exposing fruit flies to radiation, and then seeing how long they survived afterwards in order to calculate the effect of different dosages. De Garay and Cortina Durán conducted similar experiments on human tissue, exposing cultured cells to radiation before examining them under the microscope. Through a series of very precise measurements, de Garay demonstrated that atomic radiation had the potential to shorten the length of human chromosomes, and so induce mutations. Cortina Durán focused on the relationship between radiation and cancer, helping to confirm earlier reports that exposure to radiation could induce a specific mutation on chromosome 22 which causes leukaemia. All this research fed into a series of major studies published throughout the 1960s by the United Nations Scientific Committee on the Effects of Atomic Radiation, of which de Garay was a leading member.[26]

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In 1968, the Genetics and Radiobiology Program began its most ambitious project yet. That October, Mexico City hosted the Summer Olympics, in which over 5,000 athletes from around the world competed. This turned out to be one of the most contentious sporting events of the twentieth century. Just ten days before the opening ceremony, armed police opened fire on a crowd of protestors, in what became known as the Tlatelolco massacre. The crowd had been protesting against the Mexican government, which was widely considered antidemocratic and regularly resorted to police violence in order to maintain power. Political tensions continued throughout the games. South Africa was banned from taking part at the last minute, as other athletes threatened to pull out in protest against the Apartheid regime. And most famously, the African American sprinters Tommie Smith and John Carlos both wore a black glove and raised a fist on the podium following the men's 200 metres, a silent protest against racial injustice in the United States.

Amidst all this ongoing controversy, de Garay convinced the Mexican government to fund a major genetic study of Olympic athletes. The idea was to showcase the best of Mexican science on the world stage. The project would 'benefit all humanity by providing a better understanding of human excellence', explained de Garay. He even claimed that such research might prove useful in the 'early identification and selection of potential athletic types'. With the support of both national and international sporting committees, the scientists at the Genetics and Radiobiology Program set up a temporary laboratory in the Olympic Village, collecting blood samples from 1,256 athletes representing ninety-two different countries. These blood samples then underwent various kinds of genetic tests, including for sickle-cell disease as well as G6PD deficiency (a metabolic condition which causes the breakdown of red blood cells).[27]

This was also the first Summer Olympics in which all female athletes underwent genetic testing for sex. This was done by checking blood samples for the presence or absence of a Y chromosome, which is typically only found in men. (Transgender athletes were excluded from the Olympics until 2004, often on the basis of this kind of genetic testing.) Alongside this, the team of Mexican scientists took bodily measurements and photographs of each of the athletes, building up a detailed picture of what de Garay called 'their genetic and anthropological characteristics'. Those tested included some of the most famous athletes at the time, such as the Czechoslovak gymnast Věra Čáslavská, who turned away during the medal ceremonies in protest against the recent Soviet invasion of her home country, as well as John Carlos himself, who was even named in the final report published by de Garay.[28]

If all this sounds suspiciously like eugenics, that's because in many ways it was. After all, de Garay had studied at the Galton Laboratory in London, which was named after Francis Galton, the nineteenth-century founder of the eugenics movement. Galton infamously argued that human populations should be 'improved' through selective breeding. In the final report, de Garay cited Galton approvingly, as well as a more recent book published by the British Eugenics Society titled *Genetic and Environmental Factors in Human Ability* (1966). Today, many scientists like to think that eugenics simply disappeared after the Second World War, as it became associated with the atrocities committed by the Nazis during the Holocaust. Unfortunately, this is not the case. Cold War tensions reinforced concerns about the 'fitness' of competing human populations, leading many scientists to try and identify specific genes that might code for more or less desirable traits. There was even talk in the 1960s of a 'new eugenics', based on the latest techniques of molecular biology. It all turned out to be a false promise. De Garay himself admitted that 'there has been no good correlation found between any specific genes and any specific athletic achievement'. Nonetheless, the presence of widespread genetic testing at the 1968 Summer Olympics is an important reminder of the continued influence of eugenics during the second half of the twentieth century – a damaging legacy that the scientific world is still struggling to grapple with.[29]

By the early 1970s, Mexico was firmly established as a leading international centre for the study of genetics. This is a story which began with the Green Revolution. The hope was that by solving 'the problem of food', geneticists could divert Mexico away from socialism. The Mexican Agricultural Program, funded by the Rockefeller Foundation, also provided an opportunity for a new generation of Mexican scientists to undertake advanced training in genetics. A similar trend followed across Latin America, with leading scientists in Argentina and Brazil also training in the United States before returning home to set up new genetics laboratories. There was even a Latin American Society of Genetics, established in 1969, to help foster scientific links across the region. During the same period, Latin American governments invested in the field of human genetics. Mexican scientists often walked a fine line between genetics and eugenics. Such concerns about health and identity were not confined to Mexico. Throughout the Cold War, states around the world believed that genetics might unlock the key to a happier and healthier population. In the following section, we explore how similar concerns over food security and human health shaped the development of genetics in postcolonial India.[30]

II. Indian Genetics after Independence

Mankombu Sambasivan Swaminathan never forgot the photographs of starving children, emaciated bodies lying by the roadside. Between 1943 and 1944, three million Indians died in what became known as the Great Bengal Famine. Initially, the British colonial government tried to keep the news from getting out. But in August 1943, a newspaper in Calcutta printed a harrowing image of a Bengali girl stooped over the dead bodies of two young children. This photograph, along with continued reports of British mismanagement of the crisis, galvanized the anticolonial movement in India. Many recognized that the famine was not simply the result of a poor harvest or drought. Rather, the British had seized food supplies in order to support troops during the Second World War, leaving millions of Indians to starve. This was part of a long history of colonial mismanagement, dating back to the eighteenth century, which had caused multiple waves of famine.

Swaminathan lived in the Madras Presidency in the southeast of India. But he was nonetheless shocked and angered by the British government's response to the famine, particularly after seeing photographs of starving children in a local newspaper. The famine was a 'man-made problem', he declared. Swaminathan was in fact already committed to the cause of Indian independence. His father was a keen follower of Mohandas Gandhi, and the family all wore homespun cloth in support of the *swadeshi* movement to boycott British goods. Swaminathan also organized a student strike as part of Gandhi's Quit India campaign in

1942, walking out of class at the University of Travancore, where he was studying zoology. The Great Bengal Famine really just confirmed what Swaminathan had always believed. That the British only looked after themselves. Indians would not prosper until they were free from colonial rule.[31]

As we learned in the previous chapter, many Indian scientists in this period saw their work as part of the fight against colonialism. This was just as true of biology as it was of physics. Born in the small temple town of Kumbakonam in 1925, Swaminathan went on to become one of the world's leading plant geneticists, helping to bring the Green Revolution to India. His interest in plant genetics was directly motivated by his interest in Indian politics. Initially, Swaminathan had wanted to become a zoologist, but after hearing about the Great Bengal Famine in 1943, he decided to switch subjects and undertake a postgraduate degree in agricultural science. He hoped that by better understanding the genetics of staple crops such as rice and wheat, independent India could avoid the kind of devastating famines that were all too common under British rule. 'Man-made problems have to have man-made solutions,' he argued. In the summer of 1947, Swaminathan graduated with an MSc from the University of Madras. That same summer, on 15 August, India finally gained its independence from Britain. This marked the end of nearly 200 years of colonial rule, and Swaminathan celebrated in the street with his friends and family. Still, the festivities couldn't go on for too long. Swaminathan, like many Indian scientists, now turned to the practical task of building a new nation.[32]

Shortly after graduating, he joined the Indian Agricultural Research Institute in Delhi. Working alongside a team of committed Indian geneticists, Swaminathan began to tackle the problem of how to feed a nation of over 300 million people. Unsurprisingly, this was a major priority for the Indian government in the years immediately following independence. After all, anticolonial nationalists had spent the last few decades criticizing the British for failing to supply enough food. It was therefore essential for the legitimacy of the Indian state to avoid another famine. In fact, this research was considered so important that in 1948 the Prime Minister, Jawaharlal Nehru, personally visited the Indian Agricultural Research Institute in order to better understand the work being done there. Nehru himself had great faith in the power of modern science to support the new nation, particularly when it came to combating famine. 'Poverty has ceased to be inevitable now because of science,' he declared.[33]

Swaminathan soon realized that, in order to feed the nation, he would need to undertake further training in plant genetics. With this in mind, he travelled to Britain in 1950 and began studying for a PhD at the University of Cambridge. The focus of his research was on a phenomenon known as 'polyploidy', which is when a plant has double the usual number of chromosomes. This was a topic with a direct practical application, as plants with polyploidy often have higher yields. Swaminathan spent two years examining the cells of different plants under the microscope, carefully counting the number of chromosomes. He would then cross-reference this against the characteristics of each variety, particularly the yield, building up a detailed picture of the effects of polyploidy. In 1952, Swaminathan graduated from Cambridge, one of the first of a new generation of Indian scientists, no longer a colonial subject, but rather a citizen of an independent state. Swaminathan then spent a year doing postdoctoral work at the University of Wisconsin in the United States. He was even offered a job there. However, Swaminathan never forgot why he had become a scientist. 'I asked myself, why did I study genetics? It was to produce enough food in India. So I came back,' he later explained.[34]

It was around this time that he first learned about the work being done by the Mexican Agricultural Program. Excited by the potential of the Green Revolution, Swaminathan wrote to Norman Borlaug, one of the American geneticists working in Mexico, asking for assistance. This was part of a long and fruitful scientific exchange between India and Mexico, one that continues to this day. In March 1963, Borlaug visited the Indian Agricultural Research Institute in Delhi, bringing with him some samples of improved varieties of Mexican wheat in his suitcase. 'What Mexico did, your country can also do, except that yours should do it in half the time,' Borlaug told the Indian scientists in Delhi. Encouraged by Borlaug's enthusiasm, Swaminathan and his team began experimenting with these new varieties, planting seeds in test beds at the Indian Agricultural Research Institute. The Rockefeller Foundation also provided funding to allow a team of Indian geneticists to visit Mexico and learn more about the work being done by the Mexican

Agricultural Program. The results were very promising. Swaminathan found that by crossing the varieties of wheat used in Mexico with existing Indian varieties, he could produce new hybrids with increased yields that were also suitable for the local soil and climate.[35]

There was, however, a problem. These new hybrid varieties of wheat tended to produce a red-coloured flour. In Mexico, no one really minded. But in India, consumers preferred their flour to be much lighter, particularly for making traditional breads such as chapatis. This simple difference in colour threatened to derail the whole programme. That was until an Indian geneticist named Dilbagh Singh Athwal began a series of experiments using X-rays. Athwal, who had studied in Australia at the University of Sydney in the 1950s, knew that it was possible to induce genetic mutations by exposing plants to radiation. Perhaps, he thought, it might be possible to change the colour of wheat in this way? After a bit of trial and error, Athwal finally succeeded in inducing the mutation he hoped for – a variety of high-yield wheat that produced a light golden flour. With this problem solved, the Indian government began scaling up the agricultural programme in the late 1960s. By 1968, wheat production in India had increased by over 40 per cent. And by 1971, India was finally producing enough food to stop wheat imports from abroad. As elsewhere, the Green Revolution caused a fair amount of controversy in India. Smaller farmers were pushed out of the market, whilst the introduction of high-yield varieties went hand in hand with the overuse of chemical fertilizers, causing ecological damage. But for India's political leaders, if not its farmers, this was a price worth paying for food security.[36]

Much as we saw in Mexico, the development of modern genetics in India was closely associated with concerns over the supply of food. The Indian Agricultural Research Institute, originally founded in 1911 by the colonial government, soon emerged as a leading centre for the study of plant genetics in independent India. Scientists working there made a number of important breakthroughs, particularly in developing hybrid varieties of wheat suitable for the South Asian market. This work was only made possible thanks to a massive increase in science funding following independence. Between 1948 and 1958, the national science budget in India increased by close to a factor of ten. This reflected a conviction, promoted in particular by the Prime Minister, Jawaharlal Nehru, that India needed to invest in modern science and technology in order to escape from the problems of the past. Without the 'spirit of science', India was 'doomed to decay', Nehru warned. With this in mind, the Indian government initiated a series of 'Five-Year Plans' with the aim of building up scientific capacity. This initiative was directly inspired by the Soviet Union, which had run a series of Five-Year Plans since the late 1920s. Nehru himself was not a communist, but he was nonetheless sympathetic towards socialism, and believed that India had as much to learn from the Soviet Union as it did from the United States. In fact, during the 1950s a number of Indian geneticists were sent to Moscow, as well as Beijing, in order to learn about the agricultural science being done in communist states.[37]

The First Five-Year Plan of 1951 to 1956 saw the creation of a number of new scientific institutions. Amongst these was the Atomic Energy Establishment, set up in 1954 on the outskirts of Bombay. Following independence, the Indian government invested significantly in atomic research. The hope was that nuclear power might provide a secure source of energy for the new nation, and thus reduce reliance on imports of petroleum and gas. At the same time, the Indian government secretly initiated a nuclear weapons programme, conducting its first successful test in May 1974. Just as we've seen elsewhere, the development of atomic science in India went alongside the development of modern genetics. In 1958, Nehru himself ordered the Atomic Energy Establishment to undertake a study of 'the genetic effects of these explosions on the present and future generations'. This eventually led to the creation of a dedicated Molecular Biology Unit within the Atomic Energy Establishment.[38]

The new Molecular Biology Unit was directed by an outstanding Indian geneticist named Obaid Siddiqi. Born in 1932 in the northern state of Uttar Pradesh, Siddiqi came close to leaving India as a young man. In 1947, the British partitioned the Indian subcontinent into Muslim-majority Pakistan and Hindu-majority India. This resulted in one of the largest migration events in modern history, in which over fourteen million people moved from one country to the other. Religious violence broke out across the subcontinent, and hundreds of thousands of people lost their lives. Siddiqi was a Muslim and much of his extended family moved to Pakistan. It was a close call, but in the end Siddiqi decided to stay in India in order to complete his education. He enrolled at Aligarh Muslim University in Uttar Pradesh, and began studying for a degree in biology. During his time there, Siddiqi became involved in radical politics. In 1949, whilst still at university, he was arrested and held in a local prison along with a group of communist activists. Siddiqi later recalled being beaten by the guards. In the end, after two years, he was released without charge.[39]

Given his experience in prison, Siddiqi might well have been tempted to relocate to Pakistan. However, like many Indian Muslims, he ultimately considered India as his home, and saw no reason why he should move to a foreign country. Siddiqi was in fact rather patriotic. Through his scientific work, he hoped to contribute to the development of the new nation. And so, after graduating from Aligarh Muslim University in 1951, Siddiqi joined the Indian Agricultural Research Institute in Delhi. He was planning on dedicating his life to plant genetics. That was until 1954, when a freak hail storm destroyed the entire crop that Siddiqi had been working on. With his experiment ruined, he started to reflect on what he really wanted to do with his scientific career. He had just read about the discovery of the structure of DNA, which was announced in April 1953. Excited by this recent breakthrough, Siddiqi decided to retrain. In 1958, he moved to Scotland and began a PhD in molecular biology at the University of Glasgow.[40]

After receiving his PhD in 1961, Siddiqi was offered a position as a researcher at the University of Pennsylvania. By this time, it was becoming increasingly common for Indian scientists to undertake postdoctoral work in the United States. The American government was keen to support Indian scientific development, again in the hope of stemming the spread of communism in Asia. For their part, many Indian scientists saw the United States as an attractive alternative to Britain, which after all was a former colonial power. Siddiqi thrived amongst the American scientific community. He even got to meet his scientific hero, the American biologist James Watson, one of the co-authors of the original 1953 paper on the structure of DNA. It was also in the United States that Siddiqi made his first major breakthrough. Working with the American geneticist Alan Garen at the University of Pennsylvania, Siddiqi discovered a natural mechanism through which organisms are sometimes protected against certain genetic mutations. In some cases, a second mutation, known as a 'suppressor' mutation, cancels out the effect of an earlier more damaging one. Siddiqi and Garen worked on bacteria, but suppressor mutations occur in all organisms. Their findings therefore had broader implications for the study of human health, allowing scientists to pinpoint the effects of particular genetic mutations.[41]

By the early 1960s, Obaid Siddiqi was looking to return to India. However, at this time there were no laboratories in the country that were suitable for conducting cutting-edge research in molecular biology. With this in mind, he wrote to the director of the Atomic Energy Establishment in Bombay, a nuclear physicist named Homi Bhabha. 'I feel that in India, both from the point of view of facilities and the intellectual environment, the laboratories of the physical sciences would be more suitable places for developing molecular biology than the traditional biological institutions,' explained Siddiqi. The timing was just right. At Nehru's request, Bhabha had recently set up the Molecular Biology Unit within the Atomic Energy Establishment. In the summer of 1962, Bhabha invited Siddiqi to return to India to direct the new laboratory, which was soon relocated to the nearby Tata Institute of Fundamental Research. 'I am very interested personally in supporting the work in India in molecular biology and genetics,' wrote Bhabha, who at the time was helping to develop India's nuclear energy programme.[42]

Working in Bombay throughout the 1970s, Siddiqi made a series of major scientific breakthroughs. Much of this work was in the growing field of neurogenetics. During the Cold War, scientists worried about how genetic mutations, such as those caused by atomic radiation and chemical warfare, might impact on the function of the nervous system. This was a particularly pressing issue in the early 1970s, as the United States had recently deployed a devastating chemical weapon codenamed 'Agent Orange' in the Vietnam War. The chemical, sprayed from American helicopters across Vietnam, was used to destroy foliage and thus reduce cover for enemy soldiers. However, Agent Orange was later proved to cause cancer in humans alongside chronic inflammation of the skin. There was also a concern over the increased use of chemical fertilizers and pesticides following the Green Revolution. Some of these were also known to induce genetic mutations. In fact, Agent Orange itself was originally developed as a chemical herbicide.

Siddiqi began studying the effects of chemically induced mutations on the nervous system. Like many geneticists in this period, he chose to work on the fruit fly. These are easy to breed and have a small number of chromosomes, making genetic analysis more straightforward. In his laboratory in Bombay, he started exposing fruit fly larvae to a dangerous chemical called ethyl methane-sulphonate, or EMS. He also began exchanging letters with Seymour Benzer, an American geneticist based at the California Institute of Technology, where Siddiqi had spent a year as a visiting professor in 1968. Working together, Siddiqi and Benzer showed that it was possible to chemically induce a genetic mutation which causes paralysis in the fruit fly. The genes identified by Siddiqi and Benzer turned out to regulate the conduction of electrical signals within the nerves of the fly, hence the paralysis. This was an incredibly important discovery, one that opened up a whole new field of research. Up to this point, the fruit fly had mainly been used to study the genetics of relatively simple characteristics, such as the colour of the eye. Now, scientists began to study much more complex characteristics, such as the way genes regulate the development of the nervous system.[43]

Alongside his work with American geneticists, Obaid Siddiqi also conducted a number of important experiments in collaboration with an Indian geneticist named Veronica Rodrigues. Born in 1953, Rodrigues was one of a new cohort of Indian women to train in the sciences following independence. As we saw in the previous chapter, a small number of Indian women did enter the world of science in the early decades of the twentieth century. However, they faced significant barriers, not least the sexist attitudes of their male colleagues. Problems of sexual discrimination did not simply disappear following independence in 1947. Even by 1975, women still made up less than 25 per cent of those studying science at university in India. Nonetheless, thanks to the efforts of campaign groups such as the Indian Women Scientists' Association, this picture began to improve. Gradually, more and more Indian women were able to pursue a career in science. Some, like Rodrigues, went on to transform an entire field.[44]

Rodrigues is also another good example of how the wider world of international politics shaped the development of science during the Cold War. She had in fact spent the first twenty years of her life outside of India. Born in Kenya, she was the daughter of Goan immigrants who had travelled to East Africa in search of work. Rodrigues's parents most likely migrated to Kenya during the early decades of the twentieth century, when the British Empire recruited hundreds of thousands of Indian labourers to work in East Africa. The family was relatively poor, and Rodrigues's early years were tough. Thankfully, her mother and father managed to scrape together just enough money to send Rodrigues to a local school in Nairobi. It was here that she first developed a love of science. In 1971, Rodrigues went on to study at the University of East Africa in Uganda. However, shortly after arriving in the capital city of Kampala, Rodrigues was forced to flee. This was the year that Idi Amin launched a military coup in Uganda. Hundreds of thousands of people were killed in the violence that followed. Amongst other ethnic groups, Amin targeted the Asian population in Uganda. In August 1972, all Indians were ordered to leave the country. Rodrigues, however, didn't give up on her dream of studying science at university. Instead of returning to Nairobi, she decided to travel to Ireland, enrolling for a degree in biology at Trinity College, Dublin.[45]

Rodrigues graduated in 1976. By this time, she was technically stateless. Her student visa in Ireland had expired, and Rodrigues couldn't return to Uganda or Kenya. Britain had also recently tightened its immigration laws in order to prevent those from former colonies settling in the country. With nowhere else to go, Rodrigues started to think about moving to India. She wrote to the Tata Institute of Fundamental Research in Bombay, asking if there might be a place for her on the PhD programme there. Impressed by her determination to pursue a career in science, Siddiqi agreed to take Rodrigues on as a student in the Molecular Biology Unit. She arrived in Bombay at the end of 1976, aged twenty-three. This was the very first time that Rodrigues had ever set foot in India.[46]

Rodrigues's major breakthrough came in 1978, whilst she was still a PhD student. Through a series of careful experiments, she was able to isolate the particular genetic mutations that affect the sense of taste and smell in fruit flies. Like Siddiqi, Rodrigues used chemicals to induce genetic mutations in the flies. She then tested to see whether the flies had a preference for or against certain substances, such as sugar or quinine. Once she had done this, Rodrigues undertook a minute study of the anatomy of the mutant flies. This was the key bit of the research. Rodrigues was ultimately able to show that particular genes controlled for the development of certain sensors on the fly antennae. She was even able to map these genes to a particular region on one of the chromosomes. This was a foundational moment in the history of neurogenetics. Rodrigues proved that it was possible to trace the effect of a genetic mutation all the way through the nervous system, right down to the level of being able to detect a certain taste or smell.[47]

When India gained independence in 1947 it marked an important moment, not just in the political history of the nation, but also in the history of science. The Prime Minister of India, Jawaharlal Nehru, had himself studied Natural Sciences at the University of Cambridge, and was passionate about the possibility of science to transform the new nation. Through a series of Five-Year Plans, modelled on those of the Soviet Union, the Indian government began to build up scientific capacity, establishing new laboratories and institutions. These would be 'temples of science built for the service of our motherland', declared Nehru in 1954. The focus of much of this early scientific work was on solving the problem of hunger. By the early 1980s, India had emerged as an important research hub in the region, with scientists from Bangladesh, Sri Lanka, Burma, Vietnam, and Thailand all travelling to study plant genetics at the Indian Agricultural Research Institute.[48]

Decolonization fundamentally shaped the development of modern science in twentieth-century India. Obaid Siddiqi, an Indian Muslim, narrowly escaped the violence that followed the Partition of India in 1947. Veronica Rodrigues too lived through the end of empire. Her life represents a period in the history of science that I think we urgently need to remember today. This is a history of how the end of empire transformed promising young scientists into stateless migrants. But it is also a history of how those same scientists seized the opportunity of independence to forge a new path. In the following section, we explore another side to the history of science during the Cold War. Across the border, scientists in China were grappling with one of the most significant political events of the twentieth century – the rise of the Chinese Communist Party.[49]

III. Communist Genetics under Chairman Mao

Li Jingzhun had been planning his escape for months. Finally, in February 1950, he decided it was no longer safe to stay in China. Accompanied by his wife and four-year-old daughter, Li boarded a train from Beijing. It was around Chinese New Year, so he hoped that the authorities would not notice that he was gone before it was too late. Over the following weeks, Li and his family travelled south, before finally reaching Canton. Then, in the dead of night, they crossed over the border into Hong Kong, which at this time was still a British colony. Li's daughter was so exhausted that he had to carry her on his shoulders for the final part of the journey. And when Li arrived in Hong Kong, he collapsed, overwhelmed with tiredness and emotion. He was finally free. Free from political persecution. And free to carry out his scientific research in peace.[50]

One of the leading geneticists of the twentieth century, Li found himself an enemy of the state when the Chinese Communist Party came to power in 1949. Prior to the outbreak of the Second World War, Li had completed a PhD in plant genetics at Cornell University in the United States. He was one of the new generation of Chinese scientists that we met in the previous chapter, those who trained abroad in the first few decades of the twentieth century. However, when Li returned to China in the early 1940s, he found that the country had descended into civil war. Over the following years, the Chinese Communist Party, led by Mao Zedong, secured much of the mainland, whilst the Nationalist Party retreated to the island of Taiwan. On 1 October 1949, Mao declared the foundation of the People's Republic of China. The world's most populous country was now the world's largest communist state.[51]

At the time, Li was teaching genetics at Beijing Agricultural University. He soon learned that he was no longer welcome. At the end of October, the new dean of the university, a Chinese Communist Party official, called all the staff to a meeting. Li and the others were told that they needed to stop teaching Mendelian genetics. (This was the most widely accepted genetic theory of the time, in which characteristics are passed on exclusively through genetic material contained within the chromosomes.) Instead, the scientists at Beijing Agricultural University were ordered to teach an alternative genetic theory promoted by a Soviet scientist named Trofim Lysenko. This new theory was apparently 'a great achievement of the conscious, thorough application of Marxism and Leninism to the biological sciences'. Li was horrified. Lysenko was infamous. At a meeting of the Leningrad Academy of Agricultural Sciences in August 1948, Lysenko had given a speech denouncing the work of European and American geneticists. According to Lysenko, Mendelian genetics was completely incompatible with Marxism. It was an 'idealist doctrine', he claimed. The concept of the 'gene' was an abstraction from 'the real regularities of animate nature'. Instead, Lysenko tried to resurrect the old idea of the inheritance of acquired characteristics, which he believed was much more in keeping with Marxist philosophy, with its focus on materialism and collective action. Anyone who disagreed would be sent to the Gulag.[52]

Throughout the 1950s, Lysenko's theory, which turned out to be completely false, spread throughout China. The official Chinese Communist Party newspaper, the *People's Daily*, told readers that Lysenkoism represented 'a fundamental revolution in biology' and that 'the old genetics . . . must be thoroughly reformed'. Similarly, another newspaper proudly announced that 'the reactionary theories of heredity propounded by Mendel . . . have already been deleted from the biology textbooks'. During the same period, Soviet scientists were invited to lecture at Chinese universities, whilst Russian textbooks were translated into Chinese. A cinema in Beijing even screened a Soviet propaganda film, dubbed in Chinese, which explained the basics of Lysenko's theory. This was all part of Mao's attempt to forge an alliance with the Soviet Union during the early 1950s. China needed to 'learn from the advanced experience of the Soviet Union', declared Mao. This would help accelerate Chinese scientific development as well as 'strengthen our solidarity with the Soviet Union . . . [and] with all the socialist countries'.[53]

Li chose to leave China rather than be forced to teach the 'new genetics' promoted by the Chinese Communist Party. Shortly after escaping to Hong Kong, he wrote a brief letter describing his experiences. It was printed in the *Journal of Heredity*, the official publication of the American Genetic Association, under the title 'Genetics Dies in China'. This was the first time that the international scientific community had heard about the spread of Lysenkoism in China. Beijing Agricultural University had been 'completely taken over by the Communists . . . the courses on Mendelian genetics were suspended immediately', reported Li. He also described the strict ideological conformity imposed by the Chinese Communist Party, explaining that 'one must declare his allegiance to the Lysenko theory or leave. The latter has been my choice.' Li then ended the letter with an appeal for help. 'If I may be of any service to any of the American universities or institutions that you know of, I should be only too glad to offer them,' he wrote. The following year, Li was appointed as a professor at the University of Pittsburgh, where he remained for the rest of his career, conducting pioneering work on the use of new statistical methods in population genetics. He never returned to China.[54]

Li Jingzhun was just one of a number of scientists who fled China following the rise of Chairman Mao in 1949. The persecution he suffered is another reminder of how ideological conflict shaped the development of twentieth-century science, particularly during the Cold War. Throughout the 1950s, the United States government took great pride in helping scientists from around the world escape political repression. Li's experience was an example of the need to 'uphold scientific freedom and to challenge totalitarianism', argued one prominent American geneticist.[55]

It is important to remember, however, that this is only one side of the story. True, scientists in China faced exceptionally challenging conditions. Many were removed from their posts, never to be seen again. And even those that did follow the party line found themselves cut off from the wider world, with limited access to laboratory equipment and international scientific journals. Still, we should not assume that, simply because they were working in a communist state, Chinese scientists in this period were unable to do any worthwhile research. Such a view simply reinforces a Cold War narrative which portrayed China as a backward nation, opposed to modernization. This narrative also does a disservice to the many Chinese scientists who, despite the extraordinary circumstances, managed to make a number of important contributions to the development of modern science. Ultimately, in order to properly understand the history of science in twentieth-century China, we need to get the balance right. We need to acknowledge the oppressive nature of the communist regime, particularly under Chairman Mao. But we also need to recognize the achievements of Chinese scientists, rather than simply discounting them.[56]

Contrary to popular belief, Mao himself was not opposed to modern science. In fact, like many socialist leaders around the world, Mao believed that science would flourish under communism. 'We can assuredly build a socialist state with modern industry, modern agriculture, and modern science,' declared Mao in 1957. He repeated this claim a few years later, arguing that 'scientific experiment' was one of the 'three great revolutionary movements for building a mighty socialist country'. With this in mind, the Chinese government invested a significant amount of money in the development of new scientific institutions, tripling the national science budget during the First Five-Year Plan of 1953–7. In 1959, Mao even authorized the creation of a new Institute of Genetics, affiliated with the Chinese Academy of Sciences in Beijing. And in 1967, China conducted its first successful nuclear weapons test, astounding many American policymakers who had assumed that the country was simply incapable of producing any kind of advanced technology.[57]

During the same period, the Chinese Communist Party moved away from its commitment to Lysenkoism. This was in part due to the changing geopolitical situation. In 1956, Mao began to break with the Soviet Union, which he believed was insufficiently committed to the cause of world revolution. That same year, Mao gave an influential speech in which he recognized the need for greater intellectual diversity, particularly when it came to science. 'Let a hundred flowers bloom, and a hundred schools of thought contend,' he declared. This prompted a group of Chinese scientists to organize a major conference on the future of genetics. During the opening session, a Chinese Communist Party official clearly signalled that Lysenkoism was no longer state policy. 'Our Party does not want to interfere in the debate on genetics like the Soviet Party,' he explained. The official even put a Marxist spin on the recent discovery of the structure of DNA, pointing out that this proved that the concept of the gene had a material basis. (At the core of Marxist philosophy was the idea that everything, even scientific concepts like the 'gene', was a product of the material conditions of life. As Marx put it, 'it is not the consciousness of men that determines their existence, but their social existence that determines their consciousness'.) The official then concluded with a reference to Mao's speech, stating that in science, as elsewhere, the policy of the Chinese Communist Party was to 'let a hundred flowers bloom'.[58]

Much as we've seen elsewhere, renewed interest in modern genetics in China was largely motivated by concerns over the supply of food. During the Second World War, China had suffered a major famine, in which over two million people died. This was then followed by the Great Chinese Famine of 1959–61. Over the course of three years, well over fifteen million people died in what turned out to be one of the worst famines in human history. The famine was caused by a number of different factors, but chief amongst them was the Chinese Communist Party's policy of redirecting rural farmers towards the production of iron and steel rather than food. This was then exacerbated by the adoption of Lysenkoism, as Chinese agricultural scientists spent much of the 1950s wasting their time on futile experiments. Naturally, Mao was unwilling to admit responsibility. Still, the Chinese Communist Party recognized that it could not afford a repeat of such a disaster, investing significantly in the development of agricultural science and modern genetics from the 1960s onwards.[59]

Yuan Longping was haunted by memories of the Great Chinese Famine. He later recalled seeing bodies lying by the roadside and children eating soil in a desperate attempt to survive. It was this grim experience that motivated Yuan to search for a new way to increase crop yields in China. Today, he is remembered for having developed the first varieties of hybrid rice, an important breakthrough that many scientists in Europe and the United States thought was impossible. Born in 1930 in Beijing, Yuan represents the other side of the history of genetics in China. Unlike most of the previous generation of Chinese scientists, Yuan was not educated in the United States. Instead, he studied plant genetics at Southwestern Agricultural University in the early 1950s, one of the new institutions established by the Chinese Communist Party.

Yuan was studying at a time when Lysenkoism still dominated the teaching of genetics in China. He was even required to learn Russian whilst at university. However, one of Yuan's lecturers secretly introduced him to Mendelian genetics, sharing an old Chinese translation of a popular American textbook with him. This was a risky thing to be involved in, and the lecturer was later removed from his post, never to be seen again. Yuan soon learned to keep his head down, although he kept reading about Mendel, hiding his copy of the textbook by wrapping it up in a recent edition of the *People's Daily*.[60]

After graduating in 1953, Yuan was assigned to work at the Anjiang Agricultural School, located in an old Buddhist temple in the far west of Hunan Province. Even in this remote part of China, Lysenkoism influenced how geneticists conducted their research. Yuan was asked to conduct bizarre experiments, grafting a tomato plant onto a sweet potato, in the hope of producing a new hybrid. Needless to say, the experiments failed. A few years later, the Great Chinese Famine reached Hunan. Yuan witnessed the devastation first hand. 'I saw five people fall down dying, on the roadside, at the ridge of the fields or under a bridge,' he later recollected. Following the great famine of 1959–61, Yuan was finally able to start teaching Mendelian genetics at the Anjiang Agricultural School. As mentioned earlier, by this time China had split from the Soviet Union, and so it was once again safe to criticize Lysenkoism. Nonetheless, Yuan was still expected to follow a socialist model of scientific research. The Chinese Communist Party promoted the idea of 'mass science', in which 'old peasants' and 'educated youths' would learn from one another. 'To a large extent, inventions come not from experts or scholars but from the working people,' explained the *People's Daily*. University-educated scientists like Yuan were therefore expected to spend time in the fields, learning from rural farmers. Chairman Mao referred to this as the 'rural scientific experiment movement'.[61]

Yuan therefore spent much of his time in the surrounding fields, speaking with farmers and instructing peasants in the basics of Mendelian genetics. This, as it turned out, proved rather useful. In the summer of 1964, whilst walking through the local paddy fields, Yuan came across an unusual variety of rice plant, with strangely shaped flowers. Intrigued, he took the specimen back to the Anjiang Agricultural

School. Flowers naturally have both male and female reproductive organs. The male organs, known as the anthers, produce the pollen, and the female organs, known as the carpels, receive the pollen. Examining the strange specimen of rice plant under the microscope, Yuan quickly noticed that the anthers were all shrivelled up and not producing any pollen. This suggested that the plant was what is known as a 'male sterile'.[62]

Yuan immediately recognized the importance of what he had discovered. Rice is a naturally self-pollinating plant. Scientists had therefore assumed that it was practically impossible to breed hybrid rice, as the plant would always pollinate itself before there was a chance to cross it with a different variety. This is one of the reasons why geneticists in the United States and Mexico had focused their efforts on maize, which cross-pollinates naturally. Yuan, however, suddenly realized that it might be possible to breed hybrid rice after all. In the fields of Hunan, he had discovered a rice plant that, simply because of a random genetic mutation, was unable to pollinate itself. Crucially, the female reproductive organs of the plant were still intact and capable of being pollinated by another rice plant. In theory, it would therefore be feasible to select a different variety of rice and cross it with this male sterile specimen, thus creating what many thought was impossible – an improved hybrid variety of rice.[63]

In 1966, Yuan reported his discovery in the *Chinese Science Bulletin*, the main periodical published by the Chinese Academy of Sciences in Beijing. This marked the beginning of a major programme to breed hybrid rice in China. In many ways, this was an example of Mao's 'mass science' in action. Yuan had made his discovery whilst working alongside peasant farmers in rural China. And in order to scale up the programme, he needed to train those same peasant farmers to identify and collect more examples of the male sterile rice plant. Over the following years, Yuan and his team collected over 14,000 specimens, of which just five turned out to be suitable for cultivation. This was genetic science, but not as we often think of it. There was no high-tech laboratory, no X-rays, and no chemicals. Instead, Yuan brought genetics back into the field.[64]

Despite his apparent commitment to socialist science, Yuan was not immune from political persecution. One day in 1969 he arrived at work to find a handmade poster pasted to the wall. It read, 'Down with Yuan Longping, active counter-revolutionary!' This was at the height of a movement known as the Cultural Revolution in which Chairman Mao led a campaign against what he saw as the remaining elements of bourgeois society. Intellectuals in particular were targeted, as well as those who came from more middle-class backgrounds. Students at universities across China were encouraged to identify potential 'counter-revolutionaries' and report them to the authorities. Yuan's university education, as well as his interest in European and American genetics, marked him out. A few weeks later, the head of the Anjiang Agricultural School ordered Yuan to resign from his post. He was told that he had been reassigned to work in a nearby coalmine.[65]

During the Cultural Revolution, thousands of Chinese scientists were 'sent down' to work in similar labour camps. Many were never seen again. Yuan, however, was one of the lucky ones. After two months of backbreaking work, he was suddenly released and told to return to the Anjiang Agricultural School. It was his science that had saved him. An official working in the State Science and Technology Commission had read Yuan's article in the *Chinese Science Bulletin* and recognized its importance for the future of agriculture in China. The official then wrote a telegram to the authorities in Anjiang, ordering Yuan's release. With the approval of the Chinese Communist Party, Yuan was finally able to continue his research in peace. It took a bit of trial and error, crossing different varieties, but in 1973, Yuan successfully developed the world's first hybrid rice plant that could be used in agricultural production, something that many scientists had previously thought was impossible.[66]

In many ways, the development of modern genetics in the People's Republic of China was exceptional. During the early 1950s, the Chinese Communist Party promoted the discredited theories of the Soviet biologist Trofim Lysenko, causing a number of leading geneticists to flee the country. Even after the Chinese Communist Party rejected Lysenkoism, genetics still proved a source of deep ideological conflict. The geneticist Yuan Longping, who otherwise acted as a model socialist scientist, only narrowly escaped the ideological purges of the Cultural Revolution. All this was certainly extraordinary, matched only by the experience of the Soviet Union. Yet in many other ways, the history of modern genetics in China followed a very similar pattern to that which we've seen elsewhere. Rather than regarding China as an aberration, we should therefore try and understand how it fits into a broader history of Cold War science.

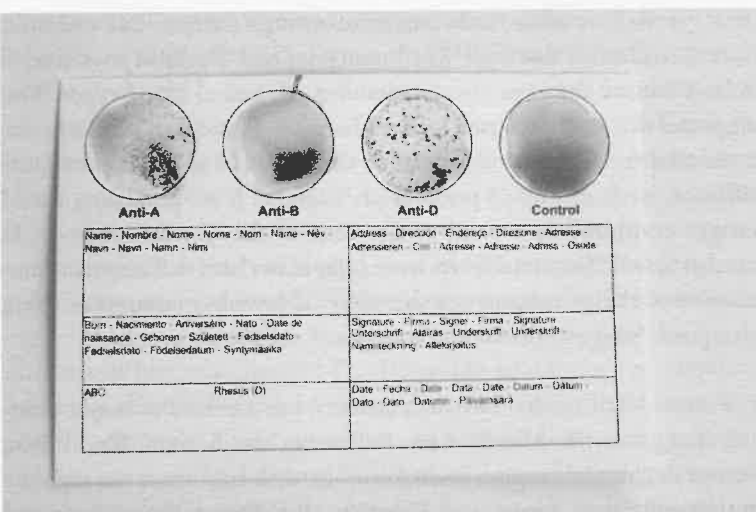
In China, just like in Mexico and India, the development of modern genetics was closely tied to the practical demands of the state, particularly the demand for increased food production. Somewhat ironically, then, the Green Revolution – which the United States promoted as part of its fight against communism – ultimately found one of its biggest supporters in none other than Chairman Mao. Throughout the 1960s, Mao endorsed what he called 'scientific farming'. His hope was that the development of improved varieties of staple crops, along with the use of chemical fertilizers and pesticides, would help modernize Chinese agriculture and feed the nation. It seemed to work. Today, the most recent version of Yuan's hybrid rice is grown, not only in China, but also in India, Vietnam, and the Philippines, helping to feed hundreds of millions of people across Asia.[67]

IV. Genetics and the State of Israel

Every morning, Joseph Gurevitch would get in his car and drive down to one of the immigration camps on the outskirts of Jerusalem. Once there, he would begin his medical rounds – examining patients, administering vaccinations, and taking blood samples. Between 1949 and 1951, over 600,000 Jewish immigrants arrived in Israel. The vast majority passed through one of the camps set up by the government following the foundation of the State of Israel in 1948. Many of the immigrants came from Europe, often survivors of the Holocaust. Others came from Jewish communities in the Middle East, Africa, and Asia. All travelled to Israel in the hope of starting a new life, free from antisemitism, in what had long been promised as 'a national home for the Jewish people'. Gurevitch was one of the hundreds of doctors employed to both examine and care for the newly arrived immigrants. Born to an Orthodox Jewish family in Germany at the end of the nineteenth century, he studied medicine in Czechoslovakia following the First World War, before migrating to

Mandatory Palestine in the early 1920s. By the time of the foundation of the State of Israel, Gurevitch was working as a physician at the Hadassah Hospital in Jerusalem. And it was during this period that he started to become interested in 'the genetics of the Jewish people'.[68]

Walking around the immigration camps, Gurevitch was struck by the physical diversity of the different Jewish populations arriving in Israel. Yemeni Jews, for example, looked very different from Ashkenazi Jews, who in turn looked different from Persian Jews. Yet according to the Torah, all these different Jewish groups shared a common ancestry, dating back some 3,000 years. Gurevitch started to wonder whether it might be possible to trace this ancestry using the latest techniques of modern science. With this in mind, he began collecting thousands of blood samples from Jewish immigrants in the camps around Jerusalem, storing them in the blood bank at the Hadassah Hospital. Each of the blood samples was carefully labelled in order to identify the specific ethnic group from which it had been taken, before being tested to determine the blood type – either A, B, AB, or O – of the individual in question. Once all this was complete, Gurevitch began comparing the ratios of the different blood types found amongst various Jewish communities.[69]



38. A test kit for identifying the ABO and rhesus factor blood groups. Blood tests were widely used by population geneticists in the twentieth century.

The ABO blood group system had been discovered around 1900, and so Gurevitch would have first learned about it during his medical training back in Europe. During the 1920s and 1930s, a number of other blood group systems were also discovered, such as the rhesus system and the MN system, each of which plays a different role in human health. For example, the ABO system helps regulate the coagulation of the blood. That is why it is so important to receive the correct blood type in a transfusion, as mixing the wrong types causes the blood to coagulate. During the First World War, states around the world began setting up blood banks in order to provide the right blood for transfusions, particularly for soldiers injured in combat. These blood banks, whilst primarily intended for use in medical care, also provided a new opportunity for genetic research. For the first time, geneticists had access to large collections of blood samples which could easily be cross-referenced against individual patient records. Like many other scientists in this period, Gurevitch believed that blood tests might provide the key to tracing the genetic history of humankind.[70]

Throughout the 1950s, Gurevitch published a series of articles on Jewish genetics. By comparing the frequencies of different blood types, he tried to show what united the separate Jewish communities arriving in Israel, as well as what made particular groups distinct. For example, Gurevitch claimed that both 'Kurdistani Jews' and 'Baghdad Jews' tended to have around the same frequencies of A, B, and O blood types. This suggested that they possessed a shared heritage. However, Gurevitch also noted that the relative frequencies of the M and N antigens were quite different, with around 40 per cent of 'Baghdad Jews' possessing the M antigen compared to around 30 per cent of the 'Kurdistani Jews'. In another article, Gurevitch even went as far as to claim that a certain combination of rhesus antigens was shared by 'all Jewish communities'. This, he argued, 'suggests the common origin of the Jewish people'.[71]

The second half of the twentieth century was a period of major political change in the Middle East. Following the Second World War, European colonial empires were forced to withdraw from the region – the British from Egypt and Palestine, the French from Syria and Lebanon. This led to the creation of a number of new states, including the State of Israel in 1948. In Israel, as elsewhere, modern science was widely understood to be essential for the success of the new nation. 'Israel is a small country, lacking material wealth and poor in natural resources. The importance of scientific research for its development cannot be overstressed,' argued the President of the Hebrew University of Jerusalem in 1960. This view was shared by many political leaders, including the first prime minister of Israel, David Ben-Gurion, who authorized the creation of a number of new scientific institutions, such as the Institute for Biomedical Research, established in 1952. The Israeli government also increased funding for existing scientific institutions, many of which dated from the period of the British Mandate for Palestine, such as the Hebrew University of Jerusalem.[72]

State investment in modern science was in fact common across the Middle East in this period. Following the Egyptian Revolution of 1952, Gamal Abdel Nasser approved the creation of the Egyptian National Research Centre, whilst in Turkey, the government established the Scientific and Technological Research Council shortly after the 1960 military coup. Both the Egyptian and Turkish governments also invested in genetic research, often in the hope of improving agriculture and human health. Egyptian and Turkish doctors, like their Israeli counterparts, were similarly interested in the genetic make-up of Middle Eastern populations. They too wrestled with questions of national identity. The Republic of Turkey tried to distinguish Turks from other ethnic groups, such as Arabs and Jews, who had long lived in the lands formerly occupied by the Ottoman Empire before its collapse in 1922. Similarly, the Egyptian government under Nasser promoted the idea of a shared Arab identity as the basis of regional cooperation following decolonization, hence the investment in genetic studies of the population.[73]

We've already seen how, during the Cold War, modern science – and genetics in particular – could be turned to a variety of different political uses. This was certainly true in Israel, especially when it came to the question of national identity. The Israeli Declaration of Independence explicitly identified 'the land of Israel' as 'the birthplace of the Jewish people', whilst the 1950 Law of Return declared that 'every Jew has a right to come to this country'. The question of who was and was not Jewish therefore became a key political issue in the middle decades of the twentieth century. Joseph Gurevitch was just one amongst a number of Israeli doctors who believed that modern genetics might provide a way to tackle this problem. During the same period, Israeli political leaders also discussed whether there needed to be some kind of 'regulation of immigration', perhaps even selection based on medical criteria. Indeed, the 1950 Law of Return actually included a clause which allowed the Israeli government to reject anyone who might 'endanger public health'. That was in part why the government set up the immigration camps, in order to medically assess new arrivals, as well as administer vaccinations and antimalarials. These two concerns – over national identity and public health – played a key role in shaping the development of modern genetics in the Middle East.[74]

In September 1961, the Hebrew University of Jerusalem hosted a major international conference on population genetics. Those attending included the American geneticist James Neel, who as we saw earlier worked as part of the Atomic Bomb Casualty Commission in Japan, as well as the British geneticist Arthur Mourant, who had recently published an influential book titled *The Distribution of the Human Blood Groups* (1954). Others travelled from India, Brazil, and Turkey in order to share their latest work on the origins of different human populations. There were, however, no representatives from neighbouring Arab states, despite the fact that scientists in these countries were also working on similar problems in population genetics at this time. For example, Munib Shahid, a Lebanese doctor based at the American University of Beirut, had recently published a series of articles on the prevalence of sickle cell anaemia in the Arab population, whilst Karima Ibrahim, an Egyptian doctor based at the State Serum Institute in Cairo, had actually co-authored an article with Mourant on 'The Blood Groups of the People of Egypt'. However, given the recent Arab–Israeli War of 1948 and the Suez Crisis of 1956, in which Israeli troops occupied the Sinai Peninsula, it is perhaps unsurprising that neither Shahid nor Ibrahim attended the conference in Jerusalem.[75]

The conference had been organized by an Israeli geneticist named Elisabeth Goldschmidt. Like many other Jewish scientists in this period, Goldschmidt was a refugee from Nazi Germany. Born to a Jewish family in 1912, Goldschmidt began studying medicine at Frankfurt University in the early 1930s, but was forced to flee following the rise of the Nazi Party. After escaping to Britain, Goldschmidt enrolled at the University of London, studying zoology and graduating in 1936. She then emigrated to Mandatory Palestine and began a PhD on the genetics of the mosquito at the Hebrew University of Jerusalem. Following a year in the United States, Goldschmidt returned to Israel in 1951, helping to set up the first dedicated genetics course at the Hebrew University. Goldschmidt also established the Genetics Society of Israel in 1958, serving as its first president.[76]

The other major figure behind the 1961 conference was an Israeli doctor named Chaim Sheba. Much like Goldschmidt, Sheba grew up in Europe during a period of rising antisemitism. Born in Austria–Hungary in 1908, he attended a series of local Jewish schools before studying medicine in Vienna in the early 1930s. Sheba then emigrated to Mandatory Palestine in 1933, deciding it was best to leave Austria given the recent electoral success of the Nazi Party in neighbouring Germany. By the early 1950s, he was working at the Tel-Hashomer Hospital, located just outside of Tel Aviv. Like Gurevitch, Sheba spent much of his time in the nearby immigration camps, collecting blood samples and tending to patients. And it was during this time that he too started to become interested in 'the genetic differentiation among the Jewish groups of Israel'.[77]

By the early 1960s, Israel was widely recognized as an important site for the study of population genetics. 'Israel, with its diverse population, drawn from so many parts of the world and so many different environments presents a unique laboratory for the geneticist,' announced the rector of the Hebrew University of Jerusalem during the opening address of the 1961 conference. And whilst the papers presented covered a wide variety of subjects, the majority focused on the relationship between population genetics and disease. Goldschmidt, for example, presented her recent research on the prevalence of Tay–Sachs disease – an inherited condition affecting the nervous system – in Ashkenazi Jews, whilst Sheba discussed his work on the prevalence of G6PD deficiency – a kind of metabolic disorder – in different Jewish groups.[78]

To be clear, this kind of research was not unique to Israel, but was in fact common across the world throughout the Cold War. Other scientists at the meeting presented their work on different regions and ethnic groups. A Japanese geneticist described his recent study of the 'differences between Caucasians and Japanese', whilst a Brazilian geneticist presented his research on mutations amongst those he referred to as 'Whites' and 'non-Whites'. As might be expected, the Israeli participants made sure to clearly distinguish their research from the kind of eugenics practised by the Nazis. Throughout the 1960s, Goldschmidt in particular campaigned vigorously against the continued influence of eugenics in modern science, reminding the international community that 'pseudo-genetic argumentation served as a pretext to the extermination of millions'. Another scientist at the conference also urged participants to remember that 'population genetics is a field in whose name great outrages have been committed'.[79]

The Cold War was a period in which scientific understandings of race and identity underwent a significant shift. Prior to the Second World War, most scientists understood race as a straightforward biological fact. However, in the aftermath of the Holocaust, this view came under increasing attack. 'For all practical social purposes, "race" is not so much a biological phenomenon as a social myth,' argued the United Nations in its influential 'Statement on Race', published in 1950. Rather than seeing race as a fixed biological concept, geneticists started thinking about it as something in constant flux. The focus of modern population genetics was not therefore on identifying fixed racial groups, but rather tracing the migration and mixing of different communities over time. This was one of the reasons why blood groups proved such a popular topic of research. 'A study of blood groups show[s] a heterogeneity in the proudest nations and support[s] the view that the races of the present day are but temporary integrations,' explained the British geneticist Arthur Mourant. Within any given ethnic group, there was in fact a great deal of genetic diversity. 'We must disavow any mystic notion of blood as a racial factor,' he concluded.[80]

This view of race, however, was much easier to maintain in principle rather than in practice. During a period in which many new states were in the process of formation, the political demand for a strong sense of national identity often took precedence. We've already seen how, shortly after the formation of the State of Israel in 1948, Joseph Gurevitch claimed to have identified the 'common origin of the Jewish people' through his study of ABO blood groups. Sheba made a similar claim, arguing that the prevalence of G6PD deficiency – which was known to be genetically inherited – could be used to trace the 'ethnic origin' of different Jewish groups. Others were more sceptical. Goldschmidt, for example, denied that Tay–Sachs disease was a good marker of Jewish identity, whilst Mourant argued that 'the genetical constitution of modern Jewish communities shows a wide range of variation'. In the end, most scientists tried to find a balance, arguing that whilst there was no single 'Jewish gene', it was nonetheless possible to trace the migration of different Jewish groups through their genetic history.[81]

At the same time as Chaim Sheba and Arthur Mourant were discussing the genetic history of humankind, another group was exploring the origins of agriculture. Historians had long believed that the earliest farming communities, dating to around 10,000 years ago, were located in the region between Palestine and Persia, an area commonly referred to as the 'Fertile Crescent'. In the early 1960s, a team of scientists at the Hebrew University of Jerusalem began testing this hypothesis. They were led by a plant geneticist named Daniel Zohary. Born in Jerusalem in 1926, Zohary was the son of an eminent botanist who had emigrated to Mandatory Palestine from Austria following the First World War. As a young boy, he would accompany his father on botanical field trips, particularly around the Sea of Galilee, learning the basics of plant taxonomy. In 1946, Zohary entered the Hebrew University of Jerusalem, studying botany in the hope of following in his father's footsteps. His degree, however, was interrupted by the outbreak of the Arab–Israeli War in 1948. The original campus of the Hebrew University of Jerusalem, located on Mount Scopus, had to be evacuated, as it was overrun by Jordanian troops. Zohary himself managed to escape, and went on to serve in the war, but one of his best friends was killed. Once the fighting was over, Zohary returned to complete his degree at the new university campus, located at Givat Ram.[82]

At this point, Zohary's scientific knowledge was not so different from his father's. That all changed following a visit to the United States in the early 1950s. Between 1952 and 1956, Zohary studied for a PhD in genetics at the University of California, Berkeley. It was here that he learned the techniques that would later prove so useful in identifying the origins of domesticated crops. Zohary would spend his days examining plant chromosomes under the microscope, staining them and comparing banding patterns. It was also in California that Zohary met his lifelong friend and collaborator, an American geneticist named Jack Harlan, who later worked for the United States Department of

Agriculture. Together, Zohary and Harlan hoped 'to discover when, where, and under what circumstances [the] early domestication of cereals came about'. However, Zohary quickly realized that, if he really wanted to grapple with this problem, he would need to return to the 'Fertile Crescent' itself. And so, after completing his PhD, Zohary moved back to Israel, taking up a position in the Department of Genetics at the Hebrew University of Jerusalem in 1956.[83]

Zohary's approach to the history of agriculture had a lot in common with the work conducted by the Mexican Agricultural Program that we encountered earlier. Zohary first went out collecting different varieties of wild plants, particularly those he thought might be related to staple crops such as wheat and barley. This was actually easier said than done, particularly as the region covered by the 'Fertile Crescent' extended well beyond Israeli territory. Zohary had to call in some favours, writing to Harlan in the United States as well as to botanists in Britain, Iran, and the Soviet Union, requesting that they send samples from local seed banks. This work was made easier thanks to the recent establishment of a major regional seed bank, supported by the United Nations Food and Agricultural Organization, located in Izmir, western Turkey. Having amassed a vast collection, Zohary then began comparing the different varieties of wild plants. In the 1950s, he focused on what he called 'chromosome analysis', which meant staining plant chromosomes and comparing them under the microscope, a technique he had learned in California. However, following a series of technological breakthroughs in the 1970s, Zohary was also able to analyse actual sequences of DNA, extracted directly from the plants he wanted to compare. It was then possible to accurately calculate the 'genetic distances' between different plants, determining which were close relations and which were distant cousins. 'The impact of these new molecular techniques is just starting to be felt in solving [the] problems of the origin of cultivated plants,' noted Zohary.[84]

After nearly three decades of intensive research, Zohary published his major work, titled *Domestication of Plants in the Old World* (1988). In this book, which was co-authored with the German archaeologist Maria Hopf, Zohary confirmed that staple crops such as wheat and barley were indeed first domesticated in the ancient Middle East, around 10,000 years ago. Crucially, he was also able to identify the wild ancestors of many contemporary crops, demonstrating their exact 'genetic relationship' to one another. This was a considerable intellectual achievement, but there was also a practical side to Zohary's work. The discovery of 'the original wild ancestors of cultivated cereals . . . opens a possibility for their utilization as genetic material for further crop improvement', noted one of Zohary's colleagues at the Hebrew University of Jerusalem. This was a simple idea, but it turned out to be very effective. By crossing existing varieties of wheat and barley with their wild ancestors, agricultural scientists were able to significantly increase crop yields. Zohary himself recognized the implications of his research, helping to develop, not only improved varieties of wheat and barley, but also vegetables and fruit. This was all part of a major drive towards achieving self-sufficiency in food production in Israel, something that was all the more pressing given the sharp increase in population that followed the arrival of hundreds of thousands of Jewish immigrants from the late 1940s onwards.[85]

During the second half of the twentieth century, scientists presented the Middle East as at the 'crossroads' of human history. Whether it was the migration of different ethnic groups, or the origins of agriculture, the lands around Palestine were widely understood to be the location of some of the most important events of the past 10,000 years. In this section, we've seen how Israeli scientists deployed the latest advances in modern genetics in order to better understand this history. Much as we've seen elsewhere, the development of modern genetics in Israel was closely tied to the process of state formation. Scientific interest in Jewish genetics was motivated by concerns over unrestricted immigration, whilst research into the deep history of agriculture was part of a broader programme to increase food production.[86]

Israeli scientists, many of whom were refugees from Nazi Germany, or survivors of the Holocaust, also played an important role in fighting antisemitism in science. Elisabeth Goldschmidt, the founder of the Genetics Society of Israel, did much to combat the continued influence of eugenics in post-war population genetics. At the same time, however, other Israeli scientists believed that modern genetics might provide a way to trace the ethnic origins of different Jewish communities. This somewhat contradictory approach to human genetics was not unique to Israel, but was in fact characteristic of the post-war period. In Turkey, geneticists used blood samples to distinguish between 'Arabs' and 'Turks', whilst in Iran, the same technique was used to trace the origins of the Zoroastrian population. Similar studies were conducted across Asia and the Americas. Officially, the scientific community rejected the concept of race as a meaningful biological category. Yet this often proved difficult to balance with the political demand for a strong sense of national identity, both in the Middle East and elsewhere. Today, we are still living with the legacies of this unresolved tension between genetics, race, and nationalism.[87]

V. Conclusion

On 26 June 2000, President Bill Clinton held a press conference in the East Room of the White House. He was joined by the German, French, and Japanese ambassadors to the United States, as well as the British Prime Minister, Tony Blair, via video-link. With the world's press watching, Clinton began his speech. 'We are here to celebrate the completion of the first survey of the entire human genome,' he announced. He then went on to explain how 'more than 1,000 researchers across six nations have revealed nearly all three billion letters of our miraculous genetic code'. Ten years earlier, the United States had launched the Human Genome Project. It cost $3 billion, but by the summer of 2000, scientists had finally completed the draft sequence of the entire human genome. The hope was that a map of the human genome would help scientists better understand the cause of diseases, such as cancer and Parkinson's. Medicine could then be personalized right down to the level of the individual, with those more at risk due to genetic factors identified before they developed symptoms. And although the project was led by the United States, it was a truly international effort, with geneticists working in Britain, France, Germany, Japan, and China all contributing to the sequencing. Different teams in different countries were assigned particular sections of the human genome, such as a particular chromosome. The results were then combined to give the complete genetic sequence.[88]

For many, including Clinton, the Human Genome Project was a symbol of the end of the Cold War. The project had launched just as the

Soviet Union was beginning to collapse, and the researchers involved spanned continents, even including scientists working in China, which since the death of Chairman Mao in 1976 had started to liberalize its economy and develop diplomatic relations with the United States. The Human Genome Project, Clinton claimed, would 'be directed towards making life better for all citizens of the world'. This view was shared by Blair, who spoke of a 'global community . . . now working across national frontiers to safeguard our shared values and put this remarkable scientific achievement at the service of all mankind'.[89]

As we've seen in this chapter, the development of modern genetics was fundamentally shaped by Cold War politics, particularly the process of state formation. It is therefore tempting to think of the Human Genome Project as a moment of transition, in which the era of Cold War rivalry gave way to a new era of globalization. That is certainly how both Bill Clinton and Tony Blair, perhaps the two politicians most associated with the wave of globalization that followed the collapse of the Soviet Union, understood the Human Genome Project. The idea that 'in genetic terms, all human beings, regardless of race, are more than 99.9 percent the same' proved exceptionally appealing to those looking to promote a vision of 'shared humanity'. The Human Genome Project was imagined as part of a future without racial discrimination.[90]

It would be a mistake, however, to finish the story here. The end of the Cold War was not the end of history, and the expansion of globalization during the 1990s did not bring about a more harmonious world. The Human Genome Project certainly did not put an end to racism. As we are now all too aware, globalization – in science, as in society more generally – in fact led to even greater fragmentation, dividing people more than ever and reinforcing existing inequalities. Even the promise of personalized medicine largely failed to materialize, whilst scientists continue to debate the ethics of gene editing.

All this was reflected in the field of genetics as it developed throughout the 2000s. Almost as soon as the Human Genome Project was complete, scientists and political leaders began to challenge the idea that a single reference genome could stand in for the whole of humanity. After all, the vast majority of the genetic material sequenced by the Human Genome Project came from a single male donor – almost certainly white – living in Buffalo, New York. With this in mind, states around the world began setting up their own national genome projects. These included the Iranian Human Genome Project (launched in 2000), the Indian Genome Variation Consortium (launched in 2003), the Turkey Genome Project (launched in 2010), the Genome Russia Project (launched in 2015), and the Han Chinese Genome Initiative (launched in 2017). All these projects had the effect of promoting ethnic nationalism, in which nations were once again seen in racial terms. This was most obviously the case with the Chinese example, which focused exclusively on the Han majority ethnic group, ignoring the genetic and ethnic diversity of the wider Chinese population. The Cold War might have been over, but genetics was just as much a tool of state formation in the 2000s as it was during the 1950s.[91]

At the same time, governments began to target minority ethnic groups, which came to be blamed for all kinds of social and political problems. The Genome Russia Project, for example, explicitly distinguished between what it called 'Ethnical Russian Groups' and 'Ethnical Non-Russian Groups'. The latter included a number of ethnic minorities which the government considered a threat to national security, such as the Chechens, who had fought against Russian troops in Chechnya throughout the 1990s in a bid for independence. The United States government made similar use of genetic testing to target minority ethnic groups. At the beginning of 2020, the Department of Homeland Security started collecting DNA samples from migrants crossing the US–Mexico border, with the results fed back into a massive criminal database. The use of genetics as a tool of state surveillance also became increasingly common in China throughout the 2000s. In 2016, the Chinese government began collecting DNA samples from the Uyghur minority ethnic group, most of whom are Muslim. This was all part of a broader effort to track and subdue the Uyghur population, culminating in the forced removal of over one million Uyghurs to detention camps across Xinjiang in northwest China. Today, the 'shared humanity' promised by modern genetics seems further away than ever.[92]

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Epilogue: The Future of Science

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