Alec John Jeffreys (1950–)

Alec John Jeffreys created a process called DNA fingerprinting in the UK during the twentieth century. For DNA fingerprinting, technicians identify a person as the source of a biological sample by comparing the genetic information contained in the person's DNA to the DNA contained in the sample. Jeffreys developed the technique in the 1980s while at the University of Leicester in Leicester, UK. Jeffreys´s technique had immediate applications. In forensic science, DNA fingerprinting enabled police to identify suspects of crimes based on their genetic identities. Previous biologic techniques enabled only the exclusion of possible suspects, not the identification of individuals. Jeffreys's technique also enabled technicians to identify the father of a child in paternity testing.

Jeffreys was born in Oxford, England, in 1950 to Joan Jefferys and Sidney Victor Jeffreys. His mother worked as a designer, while his father was an engineer in the automotive industry. As a child, Jeffreys attended Luton Grammar School in Bedfordshire, England, for his primary education. Jeffreys later said that his scientific-minded father instilled a sense of wonder and curiosity in him that would drive his study of science. When his father bought him a chemistry set at age eight, Jeffreys accidentally splashed sulfuric acid on his chin leaving a life-long scar. Jeffreys matriculated to Luten Sixth Form College in Bedfordshire for college preparatory studies, roughly the equivalent of high school in the United States, and renowned for its diverse population and for promoting leadership skills. Jeffreys later credited his principal at Luton for starting him on his path to the University of Oxford, saying that without his advice, Jeffreys never would have believed he´d a chance of studying there.

Upon graduation from Luton in 1968, Jeffreys entered the Merton College at the University of Oxford in Oxford, England. In 1971, he married Susan Miles, whom he´d met during his time at Luton. He graduated in 1972 with an undergraduate degree in biochemistry. Jeffreys remained at Oxford and completed his doctoral degree researching mitochondria in mammalian cells in 1975. Jeffreys and Miles had their first daughter in 1979 and their second in 1983.

After completing his PhD, Jeffreys accepted a post-doctoral research fellowship with the European Molecular Biology Organization that took him to the University of Amsterdam in Amsterdam, Netherlands. Initially, he planned to research cellular organization in yeast cells under the tutelage of Piet Borst, a mitochondria expert. However, fellow researcher Richard Flavell soon recruited Jeffreys to join a project attempting to detect and clone a single copy of a mammalian gene, specifically the beta-globin gene in rabbits. The beta-globin gene in mammals produces the hemoglobin protein that carries oxygen in the blood, and even though the project to clone the gene was unsuccessful, Jeffreys developed a technique for detecting the globin gene.

The technique used enzymes, called restriction enzymes or restriction endonucleases, which cut double-stranded DNA into fragments whenever a specific short sequence of DNA bases occurred on the strands. The DNA fragments, when placed on an agarose gel, separate by molecular weight or size by applying an electric field to the anti-convective agarose gel, called gel electrophoresis. After separation, researchers transfer the fragments to nitrocellulose filter paper by blotting. To detect the fragments, researchers hybridize them with a complementary DNA strand or probe labeled with radioactive phosphate. Researchers then use X-ray film to develop the nitrocellulose paper. The X-ray film shows the fragments that contain the complementary DNA or probe. These fragments order themselves into a kind of physical map of restriction endonuclease cleavage sites around the beta-globin gene in the rabbit genome. The technique enabled Jeffreys and Flavell to create their first map, or record of the DNA sequence, of a mammalian gene, which they published in 1977.

While mapping the rabbit globin gene, Jeffreys noted that regions of unexpressed DNA, later called introns, came between DNA regions, later called exons, that code for the amino acid sequences

that produce the proteins. Jeffreys and Flavell published their findings in 1977. Some groups, such as the Royal Netherlands Academy of Arts and Sciences, later credited Jeffreys with the discovery of introns. However, Phillip Sharp at the Massachusetts Institute of Technology in Cambridge, Massachusetts, and Richard J. Roberts from the University of Sheffield in Sheffield, England, shared the 1993 Nobel Prize in Physiology or Medicine for independently discovering the intron in 1977, the same year Jeffreys and Flavell published their work.

Later in 1977, Jeffreys accepted a position as a lecturer at the University of Leicester at Leicester, UK. At Leicester, he continued studying genes by analyzing structural variations in genes and their effects on inheritance. Jeffreys noted that restriction endonuclease fragments varied across individuals in the DNA sequences that came from the individuals´ shared ancestors, sequences called homologous DNA. He developed a technique to detect variations in individuals by comparing the fragments of DNA. He used fragments called restriction fragment length polymorphisms (RFLPs), to detect different patterns of the globin genes from unrelated individuals. He expanded upon his technique and published his results in 1979.

To create RFLPs, Jeffreys isolated a specific sequence of the nucleic acid bases from a strand of DNA, and he used the sequence as a probe. The nucleic acid bases are guanine (G), adenine (A), cytosine (C), and thymine (T). He attached a restriction enzyme such as RcoRI, which cleaves double stranded DNA between the G and A of the GAATTC sequence and between the A and G of the complement sequence CTTAAG, to each end of the probe. Jeffreys selected a specific sequence of DNA as the target for the probe in his experiments. He incubated the probe with the restriction endonucleases attached with the test DNA. In the case of RFLPs, after the probe and test DNA align during gel electrophoresis, the enzyme restrictors on each side of the probe located the complementary sequence of the test DNA. The enzymes then excised the targeted sequence from the strand of test DNA. When Jeffreys separated both the probe and the attached test DNA to the probe's complementary strand of DNA, he used gel electrophoresis to show that the two sequences matched.

In the 1970s, nucleic acid technology enabled researchers to study of a variety of genes in many organisms, including humans. Jeffreys compared the hemoglobin gene and neighboring sequences of humans with those of several other primates. In 1981, he published two articles about the variations in restriction sites between these species, and about the evolution of nuclear DNA in primates and humans. His team investigated gene arrangements, and sequence divergences within and between species, including old and new world monkeys and humans. The team investigated the evolution of DNA sequences that didn´t code for proteins.

Jeffreys later said that his work with RFLPs began to frustrate him. He said that he found the RFLPs inefficient and difficult to work with, and he turned his attention back to the globin gene. After receiving an unexpected gift of seal meat from the British Antarctic Survey, stationed in Cambridge, UK, Jeffreys found that seal muscles expressed high levels of myoglobin, the protein that binds iron and carries oxygen in muscle cells. The high levels of myoglobin made it easier for him to locate the myoglobin gene, which produces the myoglobin protein found in the muscle tissue of vertebrates. Jeffreys noted that the seal DNA he examined had remarkably long introns, and he published his results in 1983.

Jeffreys then used the seal myoglobin gene to locate the human myoglobin gene through the technique of cross-hybridization. The cross-hybridization technique relies on the tendency of one strand of DNA to bind to similar complementary strand of DNA even if the two strands are not a perfect match. Once he had identified the human gene, Jeffreys described the specific sequence of A, T, G, and C in the DNA strand of the gene, a process called sequencing or mapping the gene. The myoglobin gene produced a specific type of fragment, called a tandem repeat, that contained a sequence that repeated a different number of times in different individuals. The variation in the number of repeats led Jeffreys to develop a process of identification by comparing the number of repeats in an individual´s DNA with the number of repeats in a DNA sample.

Jeffreys later said that his eureka moment came on the morning of 10 September 1984 in his lab in Leicester. Jeffreys placed fragments of DNA with varying numbers of repeating sequences into wells at one end of a gel electrophoresis container, and he connected the positive and negative

charges to either end of the container and applied an electric current across the gel. The DNA fragments moved through the gel, toward the positively charged pole, at differing speeds based on the molecular weight or size of the fragment. Jeffrey experimented with this process, using samples taken from a lab assistant and her family and took an X-ray of the gel.

The X-rays produced a chart-like picture in which the various fragment lengths appeared as what Jeffreys called a smudgy, blurry mess of dark marks at various places along the length of the X-ray image. When he compared the three X-ray images from related individuals, he could clearly see a similar pattern, which identified the genetic pattern in related individuals. Jeffreys had stumbled upon a method to identify related individuals based upon the features of their DNA. He published two more papers in 1985 based on this research. First, he wrote ”Hypervariable ‘Minisatellite’ Regions in Human DNA”. The second paper was ”Individual Specific ‘Fingerprints» of Human DNA.” In a retrospective radio interview, Jeffreys said that the discovery changed his life forever.

Soon after Jeffreys published on his DNA fingerprinting technique in 1985, lawyers contacted him to help resolve an immigration matter for a family from Ghana living in the UK. The family´s youngest son visited Ghana and upon his return to the UK, customs officials suspected that the individual was actually another person trying to enter the UK under the son´s identity. After reading about DNA fingerprinting in the newspaper, a lawyer for the family asked Jeffreys for help.

In a 2007 interview, Jeffreys recalled being initially reluctant to help for two reasons. First, his technique could only point to the existence of a familial relationship between two people, but it was unable to identify the nature of that relationship. This limitation meant that he could show only if there was or was not a familial connection between the Ghanaian family and the suspected imposter, but it could not determine if he was in fact their son. Second, the boy´s father was unavailable. Because each individual inherits half of their genes from the maternal line and half of their genes from the paternal line, Jeffreys´ technique could only show where the suspected imposter´s genes matched, or did not match, the mother´s genes. Without having a sample of the father´s genes, Jeffrey couldn’t say definitively that the boy was the mother´s offspring.

Jeffreys eventually took the case and used his DNA fingerprinting technique to review the similarity in DNA between the suspected imposter and the mother. To increase the odds of positive identification, Jeffreys reconstructed the father´s DNA from three of his other children. Next, Jeffreys showed that all of the boy´s genes were inherited from either the maternal or the paternal lines. When Jeffreys compared the son´s DNA fingerprint to the mother´s fingerprint and the father´s reconstructed fingerprint, each of the smudges created by son´s DNA fragment on an X-ray image was in the same place as a smudge on an X-ray image for either his mother´s or for his father´s DNA fingerprint. Jeffreys concluded that the suspected imposter was in fact the son he´d claimed to be.

Jeffreys success in the immigration case received a lot of publicity. Police forces become interested in DNA fingerprinting, and in 1986, they asked Jeffreys to help solve a crime. In 1983, authorities had discovered the body of fifteen-year old Lynda Mann on a little used footpath near the village of Enderby, UK. She had been beaten, raped, and strangled. Using the best methods available at the time, police determined the suspect's blood group profile matched approximately ten per cent of the male population.

Three years later, authorities had found the body of another fifteen-year old girl, Dawn Ashworth, raped and strangled not far from the scene of the Mann murder. Richard Buckland, a local teen with developmental disabilities, confessed to the murder of Dawn Ashworth. However, he denied involvement with the Mann murder. Jeffreys tested the biological evidence recovered from both victims and concluded the same person committed both crimes. However, the test also showed neither sample came from Buckland. Buckland became the first person exonerated by Jeffreys DNA fingerprinting technique. The technique subsequently was used to convict the actual perpetrator of the crime, Colin Pitchfork, who had concealed his identity.

After his successes in the immigration case and the murder case, Jeffreys further developed his DNA fingerprinting technique. In 1990, Jeffreys examined a DNA sample taken from skeletal remains found in Sao Paulo, Brazil. Some suspected that the remains belonged to Joseph Mengele, a Nazi physician who had conducted experiments on Jewish prisoners during World War II. After comparing

the DNA fingerprints from the remains with those of Mengele"s first wife, Irene Schönbein, and of their son, Rolf Mengele, Jeffreys concluded that the remains belonged to Joseph Mengele. Though he helped close a forty-year-old investigation, Jeffreys said in an interview that he began to feel that the science of DNA fingerprinting had already reached its full potential.

Though Jeffreys increasingly studied other topics related to DNA and genetics, he received awards for his DNA fingerprinting technique. The Royal Society awarded him the Davy Medal in 1987 and named him the Wolfson Research Professor for the Royal Society in 1991. In 1994, Jeffreys received Knighthood, and in 2004 and the Royal Medal for introducing DNA analysis into forensic science. The Royal Society awarded him the Copley Medal for outstanding achievement in any branch of science in 2014. He remained at the University of Leicester into the early decades of the twenty-first century.

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