Halacha meets DNA fingerprinting

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The genetic code is stored within the sequences of nitrogenous bases (i.e., adenine, thymine, cytosine, and guanine) on DNA of nuclear chromosomes and on mitochondrial DNA. Except for isolated mutations, an individual's DNA remains constant throughout life and forms that person's unique genetic code, controlling biochemical reactions, growth, and development. About 99.9% of the human DNA sequences are similar in every person, with only a very small amount of DNA differing from individual to individual. These relatively minor differences serve as genetic markers and are of sufficient quantity to allow forensic scientists to distinguish one person from another person. Genetic markers, the DNA sequences used to identify (i.e., to mark) a specific location on a chromosome, include single nucleotide polymorphisms (SNPs) and copy number variants (CNVs). A SNP is a single base pair that differs among individuals. For a SNP to be a genetic marker it must be present in at least 1% of the population, thereby excluding those genetic variants that are too rare for general usefulness in genetic analyses. There are millions of SNPs in the human genome. Consecutive SNPs on the same DNA sequence of a chromosome are correlated, as each arose in history as a single point mutation which then was transmitted, surrounded by earlier SNPs, to descendants. Such a cluster of SNPs, when located near enough to each other on a chromosome, are transmitted as a unit (or, a haplotype). CNVs are tandemly repeated DNA sequences, present in different numbers of copies in different individuals. CNVs can range in size from one a kilobase, a thousand base pairs, to a megabase, a million base pairs. CNVs vary in number from person to person. A genetic marker is identified by a probe, usually a short fragment of DNA that is a few or a few dozen nucleotides in length. Both the genetic marker and the probe are made single-stranded, with the genetic marker detected by pairing (termed, hybridization) between the complementary base sequences on the genetic marker and on the probe [1, 2].

The technique of DNA fingerprinting is as follows. DNA is obtained either from blood, a root hair follicle, a buccal swab, or (in cases of rape) semen. Once isolated and purified, the DNA is cut with restriction enzymes, thereby generating thousands of DNA fragments which are placed into wells of an agarose gel for electrophoresis. An electrical field is applied and the DNA fragments (which carry a negative charge) migrate towards the positive electrode, with the smaller sized fragments moving faster than the larger sized fragments. This process is termed DNA gel electrophoresis. The double-stranded DNA fragments, now separated according to their sizes, are transferred from the gel (which can easily break) to a nitrocellulose or nylon filter; the double-stranded DNA fragments then are denatured to single-stranded DNA fragments. This transfer process is termed Southern blotting. Specific DNA sequences are identified by their interactions with radioactive single-stranded DNA probes. Those DNA probes that are complementary to sequences in specific DNA fragments hybridize on the filter; the excess, nonhybridized probes are washed away. The filter is exposed to X-ray film and those fragments of DNA that have bound the probes appear as dark bands on the film. The developed film, called an autoradiogram, shows the pattern of a DNA profile. To eliminate the chance of mistaken identity, forensic scientists use several different probes. Although more than one individual might have a particular DNA fragment, it becomes less likely that multiple individuals will have several sequences in common. The multiplication rule is applied, in which the chance of two independent events happening simultaneously is their product [1, 2]. For example, suppose that the chance of having fragment #1 is 5%, of fragment #2 is 10%, of fragment #3 is 5%, and of fragment #4 is 10%. The chance of having fragments #1 through #4 is 0.05 x 0.1 x 0.05 x 0.1 = 0.000025 (0.0025% or 1 in 40,000). In actuality, many more probes are used, so that the likelihood that the DNA profile of one individual would be an exact match to that of someone else is so remote that it is virtually nil. As a DNA fingerprint pattern could only fit one person out of myriads of people, a specific DNA fingerprint pattern falls under the halachic category of umdenah demuchach, or a totally obvious and logical assumption which is so overwhelmingly apparent that we accept it as fact [3]. Rav Zalman Nechemia Goldberg, halachic authority and Chief Justice of the Rabbinical Court in Jerusalem, noted that the chance of error regarding DNA evidence ranges from a billion to one to a quintillion to one, putting it in the category of a siman muvhok for victim identification [4].

DNA fingerprinting is applied in identifying humans, animals, and plants.

(a) Humans. Identification of cadavers and human remains and fragments, after natural catastrophes, military actions, and terrorist attacks, is essential for the completion and certification of legal documents, such as death certificates and wills, and for the distribution of benefits and insurance claims. Victim identification is also important regarding the remarriage of the surviving spouse. According to halacha, a Jewish woman who is presumed to be a widow cannot remarry unless she has definitive proof of the death of her "missing" husband. Without such proof, should she remarry, this latter association would be considered adultery and any child from that relationship would be designated as a mamzer, a person born to certain relationships forbidden by halacha. Mere presumption of the death of her husband is insufficient in halacha to allow the woman, now termed an agunah (or, chained woman), to remarry. Also, in halacha, a man is not permitted to be simultaneously married to two sisters. To allow a presumed widower to marry the sister of his decreased wife, mere presumption of the death of his wife is insufficient [5]. DNA fingerprinting,

performed on the DNA removed from a disfigured cadaver or from human remains, may provide the evidence needed to change the presumption of death to the certainty of death, since "currently the chance of error in a properly administered DNA test is greater than 10 billion to one" [6].

In Israel in the 1990s, Muslim terrorists carried out numerous suicidal bombings in crowded public places, including on buses and in a pizza store, creating a forensic nightmare in identification of human remains and fragments. Halacha requires immediate burial, as such, victim identification and reconstruction of the human remains into a complete body for burial needed to be accomplished as soon as possible. In instances of suicidal bombings, body parts were scattered throughout the area, making reconstruction of the body a complicated process. DNA fingerprinting was applied to the identification of these human remains, thereby allowing for the piecing together of the body fragments into a complete human body. Victim identification was carried out by the Division of Identification and Forensic Science of the Israel National Police Headquarters in Jerusalem, which developed laboratory protocols whereby the extraction of DNA from cadaveric fragments was accomplished in one hour, followed by DNA amplification by the polymerase chain reaction (PCR) method, and subsequent DNA typing within 2 hours, thereby yielding results in 2 to 3 hours. DNA technology, coupled with visual recognition, fingerprint analyses, and dental data, allowed for identification of 86% of the cadavers within 24 hours [7].

Forensic science technology, which included the usage of DNA fingerprinting, was employed to identify the human remains after the September 11, 2001 Muslim terrorist attacks on the Twin Towers, World Trade Center in Manhattan. As with the suicidal bombings in Israel, many of the bodies of the victims were never recovered intact, leaving married women in doubt of their marital status, both as a widow and as an agunah. Rav Yonah Reiss, RIETS, then recently assigned the director of the Beth Din of America, assumed the main role in assisting these presumed widows. A working relationship was established between the Beth Din of America and the NYC Medical Examiner's Office, the unit charged with identifying body fragments. Rav Reiss and his colleagues developed expertise in DNA analyses and concluded that DNA fingerprinting was a powerful tool in victim identification [8]. The NYC Medical Examiner's Office tested the DNA from body parts found near the World Trade Center and compared them with the DNA from personal belongings of the missing people, which were brought in by relatives. The laboratories tested 13 different genetic markers in each DNA sample that was received. The odds of a DNA sample belonging to someone else other than to the matching sample was less than one in a trillion, or fewer than all the people who have ever lived. Such data were sufficient for the dayanim of the Beth Din, Rav Gedalia Dov Schwartz and Rav Mordechai Willig, to permit these presumed widows to remarry, and thereby to leave the category of agunot. Whereas DNA evidence was considered sufficient for victim identification regarding 9/11, some American and Israeli rabbinical courts prefer to couple DNA evidence with other data (e.g., dental records) [8, 9].

The Medical Examiner's Office is located on First Avenue and East 26th Street, near the NYU Medical Center and relatively close to Stern College for Women. In an empty lot adjacent to the East River were a dozen refrigerated trucks, loaded with body parts of the victims of the 9/11 attack. Jewish volunteers, including many undergraduates from SCW, came to take part in the around-the-clock recitations of Tehillim. Shifts were established and this shmira watch ran without stop for 24 hr/day, seven days/week, from September 11, 2001 until April 30, 2002 [10]. "But on Shabbat, when the volunteers - who came from as far as New Jersey and Pennsylvania - couldn't take trains or taxis to reach the site, students from Yeshiva University's Stern College for Women, which was within walking distance of the morgue at 30th Street and First Avenue, managed the vigil" [11].

In addition to using DNA fingerprinting in victim identification, DNA fingerprinting has other important uses in the court system, most often to establish paternity in custody and child support litigation. Parentage testing cases are numerically the largest users of DNA testing. Most paternity testing is done for financial reasons, i.e., to establish legal responsibility and provide for financial support [1]. DNA fingerprinting has the potential to ascertain the potential mamzeirut status of an offspring, i.e., that the husband was not the biological father of the child. Rav Ovadia Yosef regarded DNA evidence of parentage as inadmissible proof in beit din. Also, Rav Yosef Shalom Eliashiv avoided using DNA evidence to reveal the identity of a mamzer, although he apparently believed that DNA evidence was admissible in beit din [12]. Rav Shmuel Ha'Levi Wosner and Rav Nissim Karlitz, poskim of Bnei Brak, ruled that DNA fingerprinting analyses do not constitute evidence for mamzeirut status, but do have relevance for allowing an agunah to remarry [6]. The approach of the rabbinical courts, apparently, is that there is no obligation to be proactive to reveal the mamzeirut status of an individual.

No technique is 100% perfect and, apparently, there is at least one instance in which DNA fingerprinting may provide misleading data. Consider the case of Lydia Fairchild, a pregnant mother of three who applied for public assistance. DNA analyses for paternity tests unexpectedly showed that she was not the biological mother of her three children. Taken to court and accused of fraud, the court appointed a witness to be present at the birth of her fourth child. DNA analyses of Fairchild's blood, skin, hair, and saliva did not match with that of her newborn. The initial thought was that, perhaps, she was a surrogate mother. Her attorneys requested additional DNA analyses. DNA taken from her cervix, however, did match the DNA of her four children. Lydia Fairchild was a tetragametic chimera, formed in utero by the fusion of two zygotes or of early stage embryos (which should have developed into fraternal twins), containing two genetically distinct cell lines. Thus, Lydia was two females in one, with each cell line forming distinct organs of her body. The cell line that eventually produced her ovaries and, apparently, other organs of her reproductive tract was a genetic match to her four children. The other cell line, which apparently formed her blood, hair, skin, and salivary glands, upon DNA analyses did not match the DNA of her children [13]. Such cases of tetragametic chimeras are rare and, as they can be handled successfully by forensic DNA laboratories, should not be an impediment for halachic issues of victim identification.

(b) Animals. The same technology used to fingerprint human beings

is applicable to identifying animals. As cattle were disappearing from Israeli farms, Bactochem, an Israeli company, developed a database of cattle DNA to be used to identify each animal in case of theft. The database provided sufficient evidence to build a court case against the thieves, who were mainly Bedouins. An outgrowth of this DNA technology is being considered for kashrus issues. A cattle processor would send meat samples from each slaughtered animal to Bactochem, who would then generate a DNA fingerprint profile for that specific animal. The DNA profile would be encoded on a barcode, attached to each package of meat that the processor produced for that animal. If the meat was further cut or repackaged at a supermarket or at a warehouse, a copy of the barcode would be attached to each package. When a customer wanted information about the meat picked from the store refrigerator, a photo of the barcode would be uploaded on a smartphone developed by Bactochem. Data about this particular cow would be at the fingertips of the customer [14]. Rav Moshe Tendler, RIETS and Biology Department, Yeshiva College, suggested that DNA fingerprinting could be applied to spot check fish to ensure that they are of a kosher variety. This potentially could be used in place of sending kosher supervisors to foreign countries, thereby saving unnecessary monetary expenses [15]. DNA fingerprinting could also alleviate the concern of whether dolphins were inadvertently processed along with tuna fish.

Around 2010 it was becoming more and more apparent that parasitic marine worms, or nematodes, were noted in the flesh of wild salmon, thus triggering concern that consumption of such fish impacted on hilchos toloyim. Soon after, worms were noted in canned sardines. This halachic issue is most complicated and ignited much debate among rabbinic authorities; attention will focus only on the aspect of this debate that is relevant to DNA fingerprinting. Parasitic worms associated with fish are not a new halachic issue, as the Talmud (Chullin 67b) noted cases of fish infested with worms. An interesting conversation was recorded between Ravina and his mother. Apparently, Ravina observed worms in the fish being prepared by his mother. Repulsed by the worms, he requested that his mother mix the worms with the fish and then he would consume it. A factor in the permissibility of consuming fish infested with parasitic worms is the location of the worms. The Shulcan Aruch (Yoreh Deah 84:16) notes that worms identified in the internal organs (e.g., stomach and intestines) of a fish are prohibited to consume, whereas worms found within the flesh or between the skin and the flesh are permitted for consumption.

The marine parasitic worm noted in the flesh of salmon was, Anisakis, a nematode with an interesting and complex life cycle. Adult worms mate within the stomach of a host mammal (e.g., dolphin, seal, whale, etc.) and produce unembryonated eggs which are excreted from the host's intestines into the aquatic environment. The eggs settle to the ocean floor, embryonate, and develop into free-swimming larvae. These larvae are ingested by crustaceans (such as, krill, a type of shrimp), and mature within their host. The crustacean is then consumed by a predator fish, which, in turn, is consumed by larger fish, such as salmon, remaining viable in the latter's digestive tract. Upon death of the host fish, the larvae migrate from the intestines and penetrate and then encyst within muscle tissue. These encysted Anisakis ignited the issue of hilchos toloyim regarding their occurrence in salmon, halibut, sea bass, scrod, and sardines. The life cycle of this worm is continued within the mammalian host (which, possibly could include a human being who had eaten sushi). Within the mammal, the encysted larvae emerge as adult worms, mate, and produce eggs, which are released with the excreta of the mammal into the marine environment [16, 17].

Initially, when evaluating the life history of Anisakis, there was some confusion as to whether the worm noted in the digestive tract was capable of boring through the intestines of the host fish to encyst within its musculature. Perhaps, the encysted worm within the flesh was not the same worm identified in the intestines. Rav J. David Bleich [17] suggested that DNA fingerprinting of the free larva and of the encysted larva would solve this dilemma. Subsequently, parasitic worms were noted to be contaminating canned sardines. "The presence of worms portends of improper handling during which intestinal contents have been allowed to co-mingle with sardine meat … in a manner that would compromise kosher certification. Fish can harbor nematode life history stages in musculature and elsewhere besides the intestinal lumen; the difference in tissue location is predicated on the nematode species in question and its life cycle." The OU commissioned Dr. Mark Siddall, a parasitologist at the American Museum of Natural History, to perform DNA analyses of worms observed in canned sardines. The research clearly showed that the worms in the canned sardines were species of Anisakis and were the type noted in muscle tissue, thereby permitting the sardines for consumption [18, 19].

(c) Plants. DNA fingerprinting analyses on botanical species have focused on the esrog (Citrus medica), as there were concerns of its purity, particularly, whether it was grafted to a lemon tree. Grafting of a tree branch from one species to that of another species is forbidden. The Mishnah listed forbidden grafts among fruit trees (Kilayim 1:4), without reference to an esrog which can be grafted only to a lemon tree. This lack of recognition in the Talmud of grafting an esrog branch to a lemon tree was because in the era of the Talmud, the lemon tree was not, as yet, indigenous, to the Middle East. Lemon trees were introduced into the Middle East from the 7th century and onwards [7]. Thereby explaining the lack of Talmudic literature on an esrog-lemon hybrid.

Today, however, there are concerns of a hybrid esrog-lemon. Nicolosi et al. [20] obtained esrogim with differing phenotypes, from different environments, and conducted DNA fingerprint analyses on them. The esrogim included those from Israel (5 varieties), Italy (2 varieties), Morocco (2 seedless varieties), and Yemen (3 varieties of extremely large fruits). The results showed no introgression of lemon or other citrus genomes into the genomes of the esrogim that were analyzed. However, Rav Yechiel Stern [21] consulted with botanical experts and concluded that even the kosher esrogim have some genetic traces of the lemon genome. However, cross pollination, not grafting, was the cause of concern. Apparently, bees transporting pollen from stamens of flowers from lemon trees cross-pollinated pistils of flowers on esrogim trees. However, no scientific data were presented. In addition, it is difficult to understand why only traces of lemon genome were noted in these esrogim. If the lemon genome was introduced by cross pollination to an esrog, then 50% of the resultant fruit would be esrog DNA and 50% would be lemon DNA.

This brief discussion focused on DNA fingerprinting. However, other advances in DNA technology have provided the means to improve the quality of life. For example, most Orthodox Jewish young adults understand the need for DNA analyses in pre-marital genetic screening for genetic diseases. Tay-Sachs disease, primarily because of Dor Yeshorim's genetic screening program, has been eradicated among Orthodox Jewry. DNA technology also plays a key role in assisted reproductive technology regarding preimplantation genetic diagnoses (PGD) of preembryos for genetic diseases, as well as for gender selection. Although rabbinical authorities frown upon preembryo gender selection for frivolous reasons, an interesting case was reported in which it was permitted. The potential father was a kohen who did not produce sperm. The couple received rabbinic permission to use donor sperm and to use PGD to specifically select female preembryos for implantation. Producing a female, rather than a male, child would eliminate the question of the kohen status of the child, which would arise when the boy is called for an aliyah to the Torah [15]. Recently, the complete genetic sequence of Ashkenazi Jews was deciphered. These data will serve to better understand genetic diseases and as a vehicle for developing personalized medicines [22]. Beyond the scope of this article are the halachic issues raised by creating genetically-engineered foods, both plant and animal [23-26].

This increased knowledge has provided human beings to partner with HaShem in perfecting the world, as noted in Bereshis (1:28), humanity is required "to fill the world and conquer it."

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