FAMILY LOCKET GENEALOGISTS

Research Like a Pro *with* DNA

A Genealogist's Guide to Finding and Confirming Ancestors with DNA Evidence

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FOREWORD BY PAUL WOODBURY

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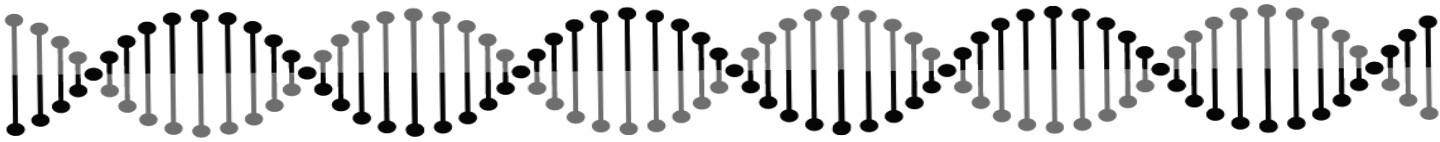

Take a DNA Test

Robin Wirthlin

One of the great discoveries of the nineteenth and twentieth centuries was DNA—deoxyribonucleic acid.[1] DNA consists of a sugar molecule called deoxyribose, a phosphoric acid, and four nitrogen-containing bases called adenine, thymine, guanine, and cytosine. We simplify this by referring only to the four bases using a string of letters, A, T, G, and C. Combinations of these four bases make up the DNA genetic code in each of the cells in our bodies. Over the past 150+ years, human DNA has been described, isolated, and studied. Significant advances in technology and scientific breakthroughs now enable DNA to be used as a genealogical research and discovery tool.[2]

DNA is a biological connection to our ancestors; we inherited our DNA from our parents, who inherited it from their parents, and they inherited DNA from their parents, etc., back through time. We live in an exciting era! Now we can use DNA as evidence to determine and discern family relationships, discover more about our ancestors, and extend our family lines.

1. Ral Dahm, "Friedrich Miescher and the Discovery of DNA," *Developmental Biology* 278 (15 February 2005): 274–88; image copy, *ScienceDirect* (https://www.sciencedirect.com/science/article/pii/S0012160604008231). See also J. D. Watson, F.H.C. Crick, "Molecular Structure of Nucleic Acids: A Structure for Deoxyribose Nucleic Acid," *Nature* 171, (1953): 737–738; image copy, *Nature* (https://doi.org/10.1038/171737a0).

2. Ugo A. Perego, et al, "The Science of Molecular Genealogy," *National Genealogical Society Quarterly* 93, (December 2005): 245–59.

Ancestors we seek to identify and confirm do not need to be alive today to test their DNA. We glimpse into the past as we examine our DNA results compared to the DNA results of others who are alive or who have recently passed on. We do not know precisely what happened in the past, but we can use DNA test results in conjunction with genealogical records to confirm or refute family relationships and help us overcome "brick walls" or dead-ends in our family trees. We don't need the DNA from the bodies of specific ancestors to confirm relationships. We just need to compare our DNA to the DNA of other descendants of one of our ancestors to make the connection.

Humans have different types of DNA: nuclear and mitochondrial. The nucleus of most human cells contains nuclear DNA. Nuclear DNA includes 23 pairs of chromosomes, numbered 1–22, and are called autosomal DNA, and the remaining pair are the sex chromosomes, X and Y. One copy of each chromosome numbered 1–22 is inherited from your mother, and one copy of each chromosome 1–22 is inherited from your father. Females have two X chromosomes, and males have one X and one Y chromosome.

All people have mitochondrial DNA, which is found in the many mitochondria in each human cell. Each type of DNA is tested by one or more direct-to-consumer DNA testing companies. The type of DNA you choose to test may depend on the research objective you are seeking to achieve.

Which Kind of DNA Test Should I Take?

Many people wonder, "Which DNA test should I take?" The answer depends on what information you are seeking. The following information will help you choose the type of DNA test that is best for you and learn which companies will help you get the most for your money. The International Society of Genetic Genealogy Wiki (ISOGG Wiki) has excellent ideas on this as well. [3]

Autosomal DNA (atDNA)

The most widely promoted DNA tests on the market today are autosomal DNA (atDNA) tests. These tests focus on the autosomes, which are the 22 chromosome pairs. X chromosome

3. "Autosomal DNA testing comparison chart," rev. 18:10, 9 January 2021, *International Society of Genetic Genealogy (ISOGG) Wiki*, (https://isogg.org/wiki/Autosomal_DNA_testing_comparison_chart).

DNA (X-DNA) is also examined in some commercial autosomal DNA tests and has its own unique inheritance pattern.

Most human DNA is the same. There are millions of locations in the human genetic code that are identical from person to person. Direct-to-consumer DNA tests look at approximately 700,000 locations in a person's atDNA, where the DNA code is more likely to vary. The variations are called single nucleotide polymorphisms, or SNPs for short. The nucleotides listed in your raw DNA data are represented by a string of letters, G, A, T, and C. The output from the raw DNA data shows the letter code variations.

When you submit your DNA kit to a testing company, the testing company compares your test results with other test results that are already in their database. A DNA match list is generated from the people that share DNA with you, and the amount of DNA they share with you is listed in centimorgans (cM). A centimorgan is a unit measurement of the likelihood that DNA will recombine.[4] "Recombination [is an] event occurring during meiosis—the formation of sperm and egg cells. One chromosome from the mother and the other from the father break and trade segments with one another."[5]

The number of cM listed with a person on your DNA match list can be compared to a range of cM found in known family relationships. *In general, the higher the number, the closer the relationship.* You do not inherit autosomal DNA from every one of your ancestors on all of your ancestral lines because there is a random element to DNA recombination. Practically speaking, this also means that there is a limit to how far back we can infer genetic relationships. With today's technology, this is approximately 6–8 generations back from you. If you are interested in learning more about your family members, ancestors, or ethnicity, take an autosomal DNA test. And if you have parents, aunts, uncles, grandparents, great-aunts, great-uncles or great-grandparents, etc., still living, seriously consider asking them to take a DNA test too!

Five leading testing companies focus on atDNA. Remember that each company is free to decide how to store and interpret your test results. Periodically, each company offers sales on DNA tests. See the company comparison chart in table 1.1.

AncestryDNA, and 23andMe, do not allow raw data transfers of DNA test results from other companies to be uploaded into their databases. Family Tree DNA, MyHeritage, and Living DNA do allow test results to be transferred from another company. If you think you will want to have your DNA results in more than one company database, it is best to test with AncestryDNA and 23andMe first.

4. "CentiMorgan," rev. 22:50, 14 December 2020, *ISOGG Wiki* (https://isogg.org/wiki/CentiMorgan).

5. "Recombination," rev. 11:59, 14 April 2019, *ISOGG Wiki* (https://isogg.org/wiki/Recombination).

Table 1.1. DNA testing company comparison

Company	Transfer From	Transfer To	Autosomal	Y-DNA	Mitochondrial DNA	Sample
AncestryDNA	yes	no	yes	no	no	saliva
Family Tree DNA	yes	yes	yes	yes, multiple test levels	yes, multiple test levels	swab
23andMe	yes	no	yes	Haplogroup given	Haplogroup given	saliva
MyHeritage	yes	yes	yes	no	no	swab
Living DNA	yes	yes	yes	Haplogroup given	Haplogroup given	swab

Raw data results from those two companies may be downloaded to your computer and then uploaded to Family Tree DNA, MyHeritage, and Living DNA for free, where additional analysis tools can be unlocked for a small fee.

When you open your raw DNA data file, you will see a string of letters that report nucleotides at the tested locations in your DNA. DNA information is meaningful in family history research *only* when it is compared with other DNA test-takers, family relationships, and genealogical records. When DNA and family history records are used together, you can learn a great deal about yourself and your family.

Why would you want to have your atDNA test results in multiple DNA companies' databases? *It's all about making connections*. Some companies have databases that are predominantly filled with test results from people who come from certain parts of the world or specific ethnicities. You may find a match with a long-lost cousin who may know more about your ancestors than you currently do, but they may have only had their DNA test done by one company—and it's only in that company's database. The following list in alphabetical order will help you see the value of having your DNA in multiple companies' databases. Additional considerations on which DNA company to test with could include database size, available tools, strengths of ethnicity estimates, number of trees attached to match results, the response rate of matches, collaboration options, etc. The ISOGG Wiki

has an extensive comparison chart that lists the major DNA testing companies' features that you can examine in great detail.[6]

- **23andMe** has a reputation for having the best ethnicity estimates. The website also includes a unique ethnicity chromosome browser that indicates sections of your DNA inherited from people with specific ethnic backgrounds. Additionally, 23andMe provides tools to help you see what segments of DNA you share with your relatives.
- **AncestryDNA** has the most family trees associated with DNA matches and the most test results in its database—over 20 million.[7]
- **Family Tree DNA** is best known for having useful analysis tools to compare and understand your DNA data and storing DNA samples for up to 25 years. We can only imagine the significant technological breakthroughs in DNA that will happen in the future. It may be helpful to have your DNA stored so it can be utilized again for new applications.
- **MyHeritage DNA** has a significant European customer base contributing to its database. It offers analysis tools, including an in-house AutoCluster feature that gathers your DNA matches into groups that share DNA with you and with each other.
- **Living DNA** features ethnicity estimates that break down to the sub-regional level in the British Isles, which may help you focus on geographical regions where you can look for genealogical records that may list your ancestors.

Figure 1.1 illustrates the autosomal DNA inheritance pattern. Autosomal DNA is passed from the ancestral couple at the top of the chart to their children, who pass it on to their children, etc.

Y-chromosomal DNA (Y-DNA)

When Y-DNA information in genealogical research, the hope is to learn how two or more male test-takers are related via a common ancestor. It could also help extend the paternal line, give clues for extending a paternal line, distinguish between similarly named

6. "Autosomal DNA testing comparison chart," rev. 18:10, 9 January 2021, *ISOGG Wiki*.

7. "Our Story," *Ancestry* (https://www.ancestry.com/corporate/about-ancestry/company-facts).

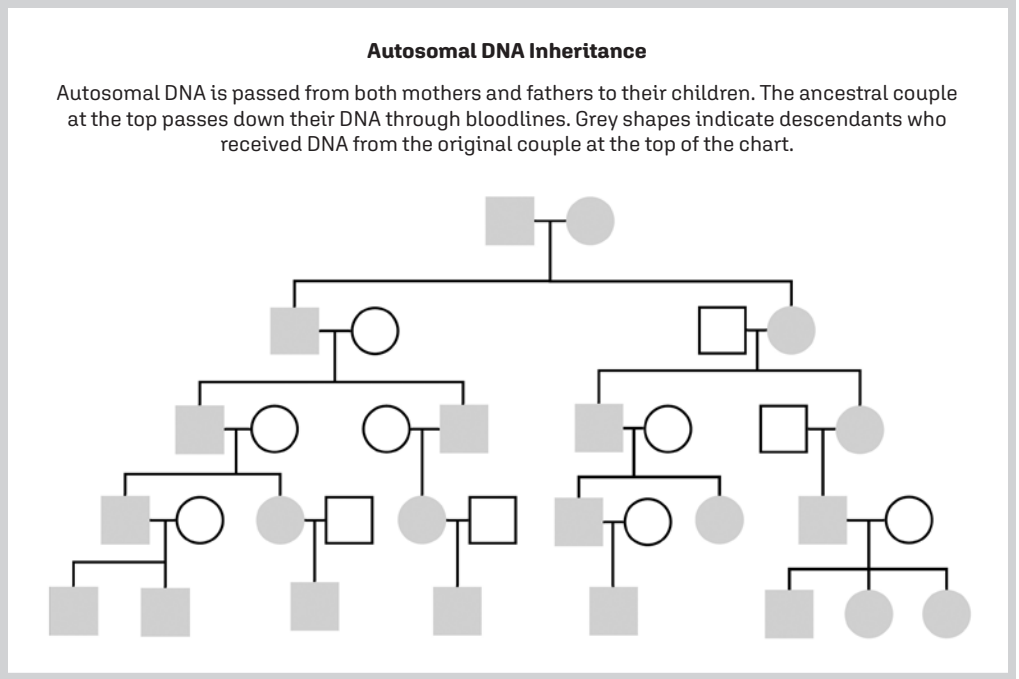

Figure 1.1. Inheritance pattern for autosomal DNA. Created by Robin Wirthlin.

individuals, or evaluate candidates to be a direct paternal ancestor through targeted testing.

A man inherits a Y-chromosome from his father. He inherited a Y-chromosome from his father, which was inherited from his father, and so on, directly along the patrilineal line. If you are a male interested in learning more about your paternal line, or your father's, father's, father's, etc., lineage, take a Y-DNA test. If you are a female, you can ask a male who is descended directly from your father, grandfather, or great-grandfather to take a Y-DNA test.

If you are researching another male ancestor not in your patrilineal line, consider asking a direct paternal descendant of that ancestor to take a Y-DNA test to get more genetic information. This approach is called target testing. The haplogroup and associated surnames reported will provide information and clues about possible ethnicity or family origins. The DNA match list may provide opportunities to connect to other living matches, who may have additional knowledge about the ancestral line.

The Y chromosome is passed down mostly unchanged for many generations, which provides genealogical value in Y-DNA tests. In some cultures, a surname passes from

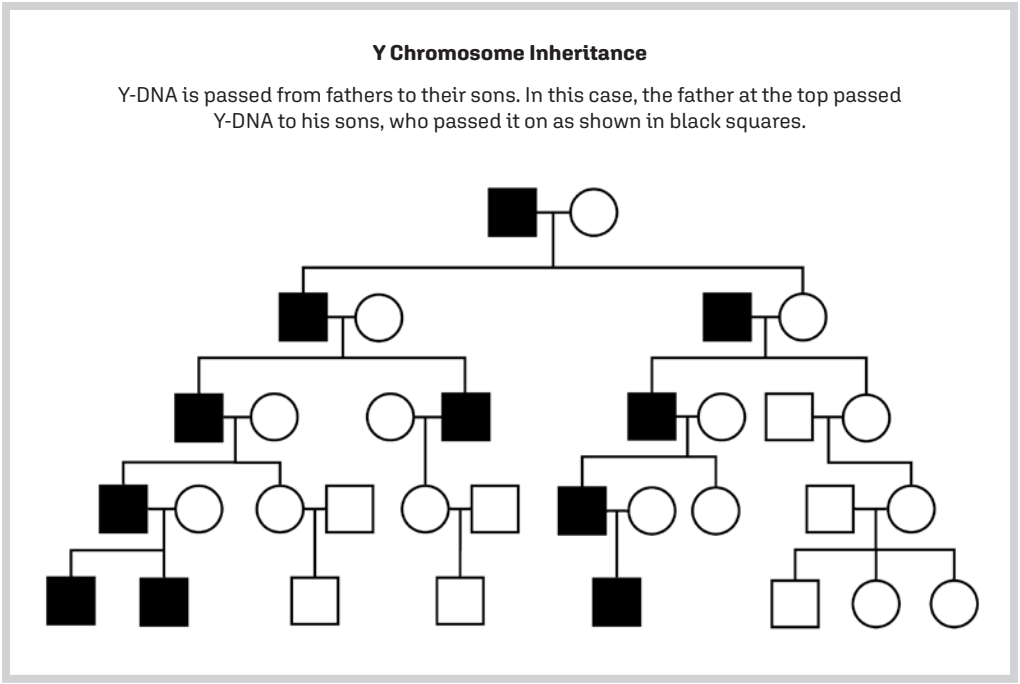

Figure 1.2. Inheritance pattern for Y- DNA. Created by Robin Wirthlin.

fathers to their children. If a man from one of those cultures takes a Y-DNA test, it may indicate the surname used for generations. It may also show if there has been a misattributed parentage event sometime in the previous generations. Many surname projects are available online where Y-DNA test results can be posted and compared. Members of the projects seek to identify the origin of the surname or how closely people with the same surname are related. This type of test may be beneficial for males seeking to identify unknown fathers.

The DNA inheritance chart in figure 1.2 illustrates how Y-DNA is passed on from father to son through the generations. The black squares show the men who inherit Y-DNA from their paternal line, starting with the ancestral couple at the top of the chart.

In a Y-DNA test, short tandem repeats (STRs) are examined. STRs are regions of DNA where a small motif (typically 2–5 bases in length) is repeated several times in a consecutive sequence in the genetic code. Occasionally when DNA is replicated before being passed on to the next generation, mutations occur. These regions might experience a deletion or addition of the motif causing variation in the general population regarding how many times a particular motif is repeated. DNA locations with STRs tested are called

markers. In your Y-DNA results, you will see the tested marker's name and the number of repeats of a motif at that location on the Y-chromosome.

For example, DYS522 is a marker that has four nucleotides that repeat themselves between 8 and 17 times in the pattern [GATA][GATA][GATA][GATA] . . .[8] The genetic distance reported generally indicates how closely individual test takers are related to each other—but it does not mean the number of generations between test takers. It refers to the number of stepwise mutations differentiating the two Y-chromosome haplotypes. The lower the genetic distance (GD), the closer the people are related. There is always a chance that a mutation will occur during the descent from father to son, especially in fast-mutating markers. Some fathers and sons will have a GD of 1 at a particular marker because the mutation happened in their generation. See chapter six for more discussion of fast-mutating or fast-moving markers.

Family Tree DNA offers Y-DNA tests, whose name indicates the number of STR markers that are examined. At first, a 12-marker test was available, then later, 25, 37, 67, and 111 marker tests were added, and finally, the Big-Y-700 test (which looks at STRs and SNPs). Currently, the Y-37, Y-111, and Big Y-700 tests are offered. The higher the number of markers tested, the more refined the results will be.

23andMe, Living DNA, and others examine Y-DNA SNP markers in their tests though not all report them. The more markers, the higher the test's resolution, and the matches you receive will be closer in a genealogical timeframe. If you are a male, 23andMe and LivingDNA tests estimate your Y-DNA haplogroup based on the markers they test on the Y-chromosome, which may help with unknown parentage research. However, the only information given is the haplogroup without the specific number of repeats at the markers tested, which is not detailed enough to achieve genealogical proof.

Mitochondrial DNA (mtDNA)

Both men and women inherit mitochondrial DNA from their mothers, but only women can pass it on to their children. 23andMe and Living DNA report mtDNA haplogroup estimates. mtDNA tests, offered by FamilyTree DNA, are genealogically useful and can provide distinctive DNA clues and a set of markers used to create a match list. If you are looking

8. U.S. Department of Commerce, National Institute of Standards and Technology, "Summary List of Y Chromosome STR Loci and Available Fact Sheets," *STRBase (SRD-130)* (https://strbase.nist.gov/ystr_fact.htm). See also, John M. Butler et al., "Addressing Y-Chromosome Short Tandem Repeat Allele Nomenclature," *Journal of Genetic Genealogy* 4 (Fall 2008): 125–148; e-journal, (https://jogg.info/pages/42/files/butler.pdf).

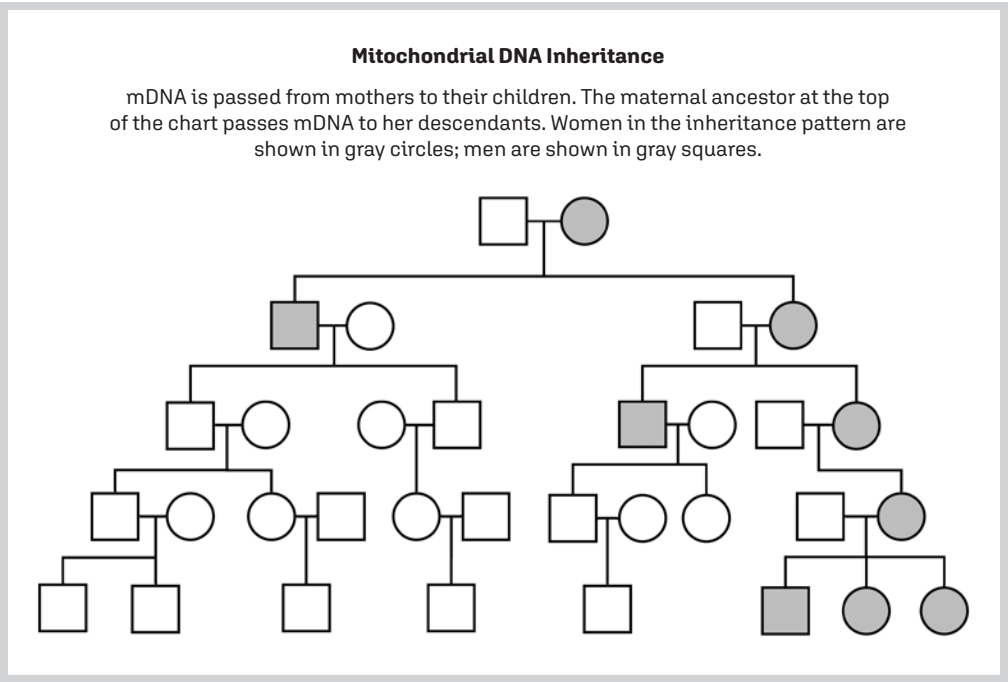

Figure 1.3. Inheritance pattern for mitochondrial DNA. Created by Robin Wirthlin.

for information about your mother's, mother's, mother's genealogical line, take a mitochondrial DNA test. The results report a mitochondrial haplogroup. People with the same mtDNA haplogroup share a common matrilineal ancestor. See figure 1.3 for an illustration of mtDNA inheritance from mothers to their children.

mtDNA mutates very slowly, and the female ancestor that two DNA matches share may have lived dozens, hundreds, or thousands of years ago. An mtDNA test can show that two individuals are related along the direct maternal line. If they are exact matches at the full mitochondrial sequence level, they may be related within a genealogical timeframe. This result is ideal for testing hypothesized relationships. Imagine the hypothesis that Elizabeth was the daughter of Irinda. We can test a direct maternal descendant of Elizabeth and a direct maternal relative of Irinda, and that should tell us if our hypothesis is correct. Still, the defining feature is NOT just a shared haplogroup—instead, it is a shared mtDNA sequence with few (if any) differences. People can belong to the same haplogroup and still have differences between them.

X-chromosomal DNA (X-DNA)

Both men and women have X-chromosomes. Women inherit one X-chromosome from their fathers that was passed on unrecombined. This X-chromosome, in-turn, was inherited from the father's mother. They also inherit an X-chromosome from their mothers—this X- chromosome may be recombined from the X that the mother received from her father and her mother or inherited unrecombined. Men inherit an X-chromosome from their mothers, which may be recombined from the mother's father and mother or inherited unrecombined.

X-DNA has a unique inheritance pattern illustrated in fan charts in figures 1.4 and 1.5. The charts illuminate specific ancestors from whom a whole X-chromosome or X-DNA segments *might be* inherited. It is entirely possible not to inherit X-DNA from some of these ancestors. The X-DNA inheritance pattern is different for males and females. Males are shown in dark gray, and females are shown in light gray. Choose either the male or female inheritance chart for the DNA tester.[9]

For maximum effectiveness, use X-DNA results in conjunction with atDNA results in your research. X-DNA can help you discern if a DNA match is related to your maternal or paternal side only if you are male. If you are female, an X-DNA match could be either maternal or paternal. X-DNA can guide your research and help you focus on the ancestral lines from which it was inherited, which ultimately saves time in your research.

As you can see in the inheritance charts, if you have an X-DNA match and you don't know how they fit into your family tree, you can immediately exclude half or more of your ancestral lines from consideration. Suppose you don't share X-DNA with a match; it doesn't mean that you are not related along a particular ancestral line. Still, if you share a significant portion of X-DNA (at least 10-20 cM) with a DNA match, it indicates that you and the match are related along an X-DNA inheritance path.

X-DNA testing is included in the Illumina OmniExpress and Global Screening Array chips that 23andMe, AncestryDNA, Family Tree DNA, Living DNA, and MyHeritage use.[10] Your raw DNA from each of these companies will report X-DNA results, sometimes listed

9. To see more X-DNA inheritance charts, see Blaine Bettinger, "More X-Chromosome Charts," 12 January 2009, *The Genetic Genealogist* (https://thegeneticgenealogist.com/2009/01/12/more-x-chromosome-charts/). Also, Debbie Parker Wayne, "X-DNA Inheritance Charts," Deb's Delvings Blog, posted 25 October 2013 (http://debsdelvings.blogspot.com/2013/10/x-dna-inheritance-charts.html). Also, Debbie Parker Wayne, "Quick Reference Links," *Deb's Delvings Blog* (http://debbiewayne.com/pubs.php#quickref), X-DNA section.

10. "X-chromosome testing," rev. 17:31, 23 November 2020, *ISOGG Wiki* (https://isogg.org/wiki/X-chromosome_testing).

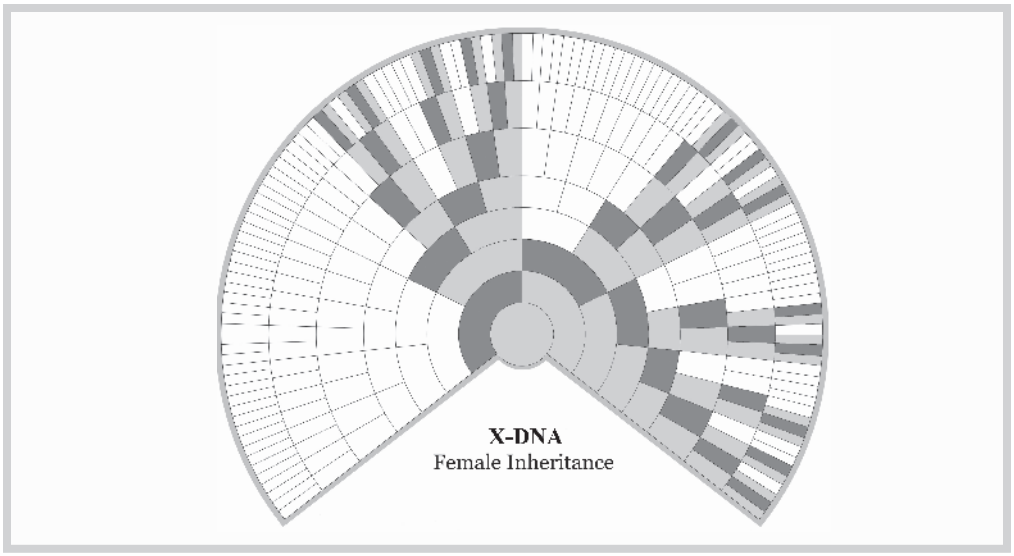

Figure 1.4. X-DNA female inheritance chart, annotated. Courtesy of Blaine Bettinger, "Unlocking the Genealogical Secrets of the X Chromosome," 21 December 2008, The Genetic Genealogist (https://thegeneticgenealogist.com/2008/12/21/unlocking-the-genealogical-secrets-of-the-x-chromosome/).

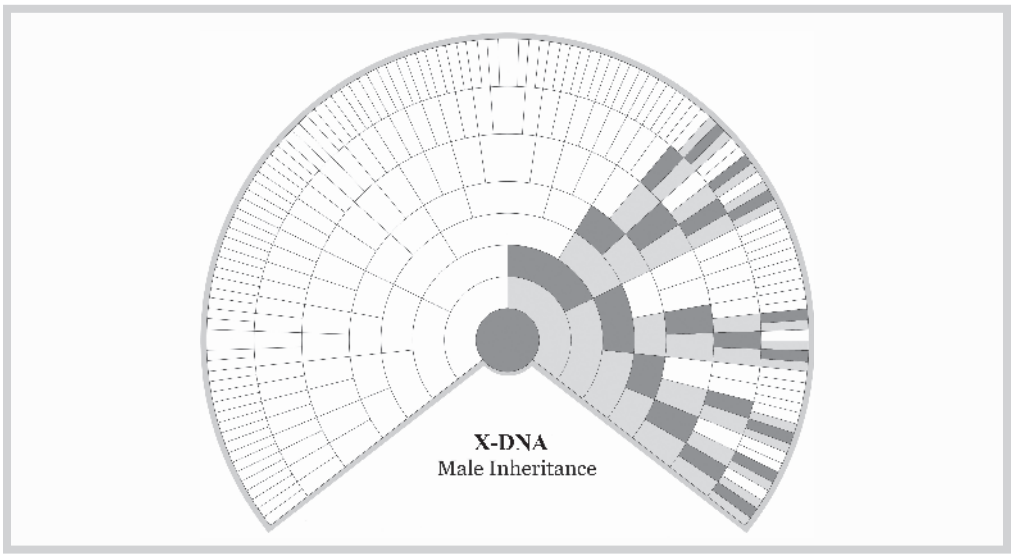

Figure 1.5. X-DNA male inheritance chart, annotated. Courtesy of Blaine Bettinger, "Unlocking the Genealogical Secrets of the X Chromosome," 21 December 2008, The Genetic Genealogist (https://thegeneticgenealogist.com/2008/12/21/unlocking-the-genealogical-secrets-of-the-x-chromosome/).

under chromosome 23, but only 23andMe and Family Tree DNA show the results on a chromosome browser. Additionally, Family Tree DNA tells you on the DNA match page if both you and a DNA match share X-DNA. Be cautious with this information as not all X matches listed share enough X-DNA to be considered pertinent.

Informed Consent

As you take DNA tests yourself and encourage others to test, it is crucial to contemplate genetic testing's long-term implications. Consider the possibility of uncovering unknown information, such as previously unknown relatives, or learning that some family connections are not biological. An informed consent agreement will help you and your family members become aware of DNA testing's positive and possible negative outcomes.

The DNA tester needs to know about these possibilities before agreeing to take a DNA test. If you will be overseeing the DNA test results and working with them in family history research, it is essential to have the tester give permission and learn about the risks involved in DNA testing. Ask the tester to sign an informed consent agreement. This agreement can be sent via email or given in person.

It is also essential to thoroughly review the DNA testing companies' privacy policies. Carefully consider the security of your genetic data. Only utilize companies with which you feel comfortable.

DNA Testing Strategy

With your new understanding of the kinds of DNA tests that exist and the importance of knowing the implications of genetic testing, you are ready to address the question, "What next steps do I take?" The following strategies outline the least expensive testing plan that will deliver the most information quickly. If you already have a specific objective in mind for using DNA evidence in your research, you may want to make a targeted testing plan first, as discussed in chapter six. These options may not be available in all countries.

For Yourself

1. Take an AncestryDNA test.
2. Consider taking a 23andMe DNA test.

3. Transfer the results to other companies to maximize the number of relatives on your DNA match lists.

    a. Download your raw DNA data. For instructions, see "Downloading AncestryDNA® Raw Data"[11] or search for "Download Your Raw Data" on 23andme.com.[12]
    b. Transfer your raw DNA data from AncestryDNA or 23andMe to Family Tree DNA (FTDNA) and unlock the analysis tools for a small fee. Click on "Upload DNA Data" at the top left of the Family Tree DNA website, then choose Autosomal DNA in the drop-down menu for instructions.[13] Another source of instructions is an article called "Autosomal Transfers" found in the Family Tree DNA Learning Center.[14]
    c. Transfer your raw DNA data to MyHeritage and unlock the analysis tools for a relatively small fee. See "Upload DNA data"[15] for instructions.
    d. Consider transferring your raw DNA data to GEDmatch—a 3rd party website. Carefully read the terms and conditions of GEDmatch, which is a public website. *Only transfer your raw DNA data if you agree with the terms and conditions.* After creating an account, on the right side of the main page is a section called "Upload your DNA files:" After clicking on, "Generic Uploads (23andme, FTDNA, AncestryDNA, most others)" detailed instructions are available about how to upload your raw DNA data.[16]

4. Take a Living DNA test or upload raw DNA data from another testing company. See "Upload your DNA for FREE and discover more"[17] for instructions.
5. Take a Y-DNA test at Family Tree DNA if you are a male. Or, if you are a female, ask a male relative to test.
6. Take a mitochondrial DNA test at Family Tree DNA.

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11. "Downloading AncestryDNA Raw Data," *Ancestry* (https://support.ancestry.com/s/article/Downloading-AncestryDNA-Raw-Data).

12. "Download Raw Data," *23andMe* (https://you.23andme.com/tools/data/download/).

13. Join the world's most comprehensive DNA database!" *Family Tree DNA* (https://www.familytreedna.com/autosomal-transfer).

14. "Autosomal Transfers," *Family Tree DNA Learning Center* (https://learn.familytreedna.com/imports/transfer-autosomal-ancestry/family-tree-dna-family-finder-transfer-program/).

15. "Upload DNA data," *MyHeritage DNA* (https://www.myheritage.com/dna/upload).

16. "GEDmatch raw DNA upload utility," *GEDmatch* (https://www.gedmatch.com/v_upload1N.phpnf).

17. "Upload your DNA for FREE and discover more," *Living DNA* (https://livingdna.com/free-dna-upload).

For others

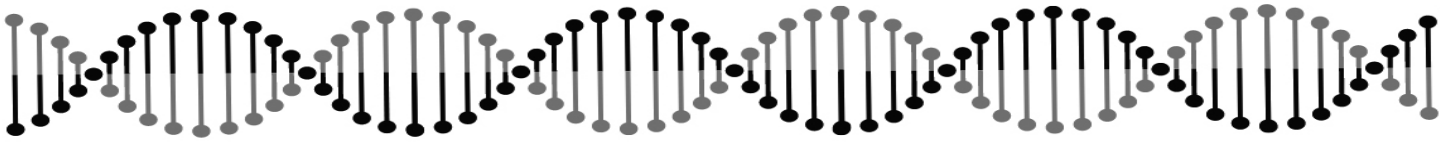
1. Test the oldest people in your family first, especially those who are generationally closer to shared ancestors.
    a. Parents, grandparents, great-aunts, great-uncles, aunts, uncles, and cousins of parents or grandparents.
2. Test your siblings if *both* parents are not available to DNA test. If both parents have DNA tested, your siblings will not add any more DNA information relevant to your genealogy research. If only one parent is available to take a DNA test, it will be beneficial to your research to ask your siblings to test. The specific segments of DNA inherited by your siblings are different than what you inherited. Each parent randomly gives half of their DNA to each child, so the DNA passed on from their ancestors is unique.
3. Test first cousins, second cousins, or more distant cousins. These relatives inherited some different segments of DNA from your ancestors than you did.

If you test older adults, consider testing directly with FTDNA in addition to AncestryDNA or 23andMe since FTDNA will store the DNA samples for up to 25 years.

Your Task

Take a DNA test and upload the raw data to other DNA websites that accept uploads, following the DNA testing strategy previously outlined. Explore the website of each DNA testing company you chose to use and familiarize yourself with the features in preparation for the next steps in the *Research Like a Pro with DNA* method. The learning center or forums on the DNA company websites answer questions and explain how to best use their tools to work with your DNA test results.

CHAPTER 2



Assess Your DNA Matches and Analyze Your Pedigree

Diana Elder

What did you do when your DNA test results finally arrived? Did you first check your ethnicity results? Did you feel validated to discover the estimated countries of origin? Clicking on your DNA match page, thousands of results likely overwhelmed you. Perhaps you recognized a few close relatives but puzzled over the many unknown cousins appearing on page after page.

As a genealogist, you can use DNA as evidence to discover, confirm, or reject family relationships, but where do you start? Setting up a system to assess your DNA matches will give you control over your test results and help you better understand how to use them to achieve your research goals. Assessing a DNA match includes analyzing the amount of shared DNA against the relationship found in the family tree. For example, does a second cousin share the appropriate amount of DNA? In this chapter, we will discuss each of the following steps needed for this initial assessment.

1. Assess your family tree.
2. Set up a system to track your DNA matches.
3. Cluster your DNA matches into genetic networks.
4. Check the amount of shared DNA.
5. Calculate possible relationships with the Shared cM Project Tool.
6. Contact DNA Matches.

Your Genealogical Family Tree versus Your Genetic Family Tree

When you first began your genealogy journey, how did you start? You probably began to build a family tree, identifying parents and grandparents, then moved back in time. Depending on the family knowledge, localities, and time frame, you may have been able to fill out many generations of your tree, or you may have hit a brick wall ancestor. Beyond that brick wall are several missing branches of your genealogical tree.

Why does this matter? When working with DNA results, how easily you can identify a DNA match will depend on your own tree's fullness. Your goal should be to verify or refute each generation of your family tree and eventually assign each DNA match to a common ancestor or ancestral couple. If you have missing ancestors on your genealogical tree, it will be challenging to determine how you connect with many of your DNA matches. The good news is that you can confirm or reject known relationships by working with your DNA test results. Those results can also provide clues to any unknown ancestors.

For example, my maternal family tree is relatively complete—reaching back to England and Denmark. See figure 2.1. These well-researched ancestral lines make it easier to determine a common ancestral couple for my maternal DNA matches.

On the other hand, my paternal family tree is missing many ancestors. See figure 2.2. I have several unknown ancestors. Because my paternal lines originate in the southern United States, where intermarriage among families was common, determining the common ancestral couple of my paternal DNA matches becomes more complicated.

When you and a DNA match share more than one common ancestor or ancestral couple, that could be a sign of pedigree collapse, a different scenario than endogamy (where intermarriage has occurred among a small group for many generations). Either of these situations can make the DNA analysis more complicated and should be taken into consideration when analyzing your DNA matches.

Your genetic family tree will look different from your genealogical family tree because of DNA inheritance's random nature. You received 50% of your DNA from each of your parents, about 25% from each of your grandparents, and about 12.5% from each of your great grandparents. Figure 2.3 will give you an idea of how much DNA you could share with your close relatives.

With each subsequent generation, the amount of DNA you are likely to inherit from an ancestor is cut in half. Because of DNA inheritance's randomness, some ancestors did not provide you with any DNA and won't be on your genetic family tree. They still make up your genealogical family tree, but you won't have any DNA matches to their descendants.

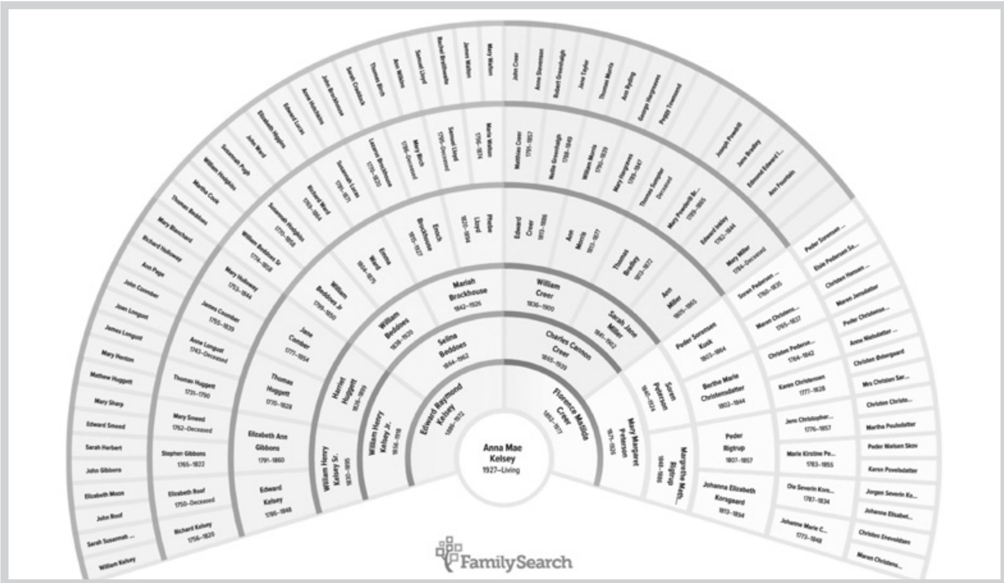


Figure 2.1. Fan Chart for Anna Mae Kelsey.
FamilySearch, https://www.familysearch.org/tree/pedigree/fanchart/LFZX-V49

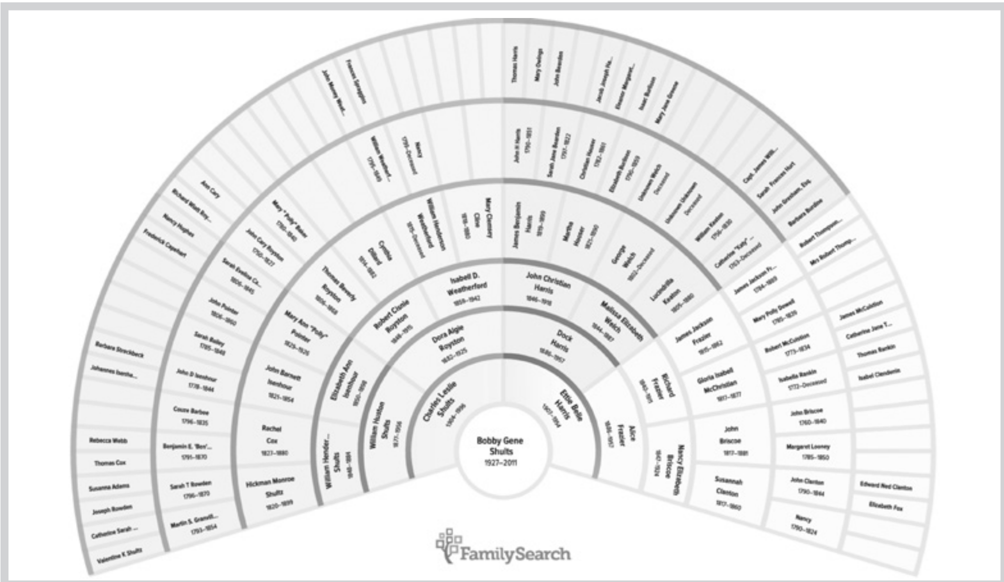


Figure 2.2. Fan Chart for Bobby Gene Shults.
FamilySearch, https://www.familysearch.org/tree/pedigree/fanchart/KWZM-TKN

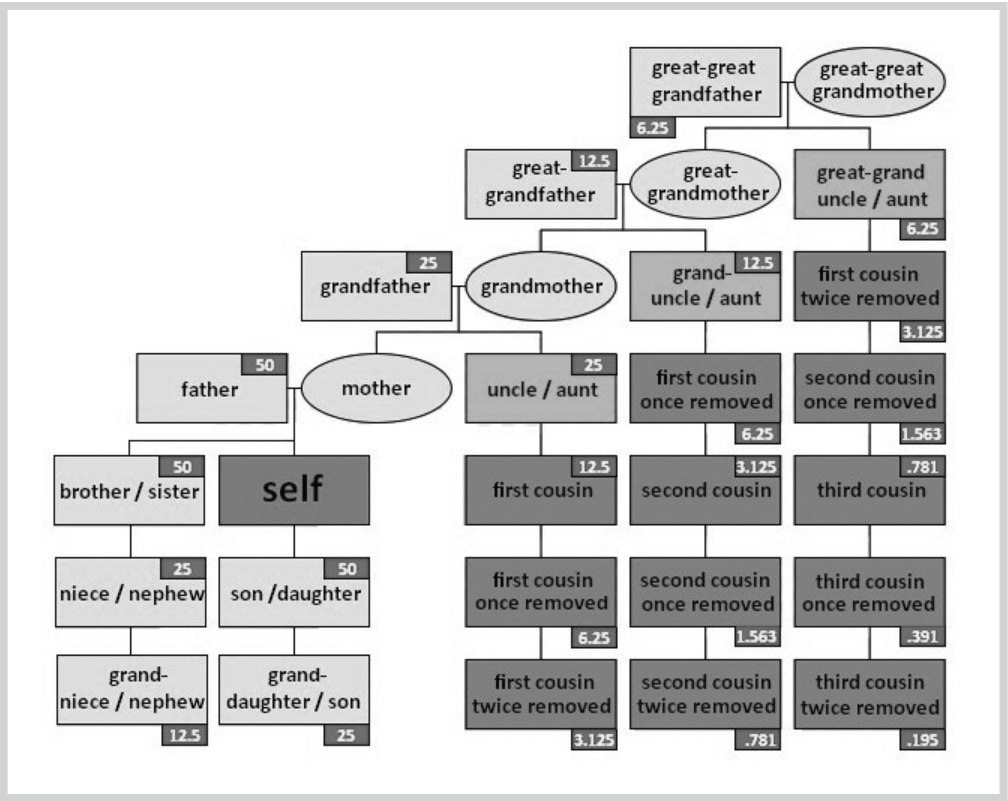


Figure 2.3. Cousin tree showing genetic kinship.
Wikimedia Commons, https://commons.wikimedia.org/wiki/File:Cousin_tree_(with_genetic_kinship).png.

Whether your genealogical family tree is full, partially full, or missing significant branches, DNA analysis has the power to help you understand your genetic relationships to your relatives. Because autosomal DNA tests yield the most DNA matches, the following steps will be most beneficial for tracking those matches. The testing company databases are large, and you can often have success by "fishing" in each pond of autosomal DNA matches.

If you've taken a Y-DNA or a mitochondrial DNA test, you can also use these steps to evaluate and track your DNA matches. Your match list will typically be smaller because of those tests' narrow focus, but you will still want to work on identifying the matches and possible connections to you. Because these databases are smaller, targeted testing will often yield the best results. Depending on your matches, Autosomal DNA, in conjunction

with Y-DNA or mitochondrial DNA (if pertinent to the research question), could give you the most thorough information. See chapter six for more detail on targeted testing.

Tracking your DNA Matches

Before starting any research on your matches, choose a method to record the information you will discover. You'll likely have your DNA data on several testing websites, so you'll want to have a master notebook, document, or spreadsheet to record details about your DNA matches. If you figure out a connection or have a conversation through the company's messaging system, you won't want to lose track of your new knowledge because you didn't record it.

As you work with each match, you'll begin to discover your connection—either a shared ancestor, ancestral couple, or possible family line. A powerful tool for tracking this information is the Airtable DNA research log base (see chapter ten for ideas on setting this up). Airtable is part spreadsheet and part database—enabling you to link information between tables. DNA research is complicated, and Airtable streamlines data entry. The correspondence table within the DNA research log has columns for suggested details to record, such as the date messaged, the DNA matches' contact information, and the messages sent and received. For this chapter's purpose, the term "research log" will be used to refer to whatever record-keeping program you choose.

Each DNA testing company has a notes section to record details about a DNA match. As you fill in the research log, you can also create a note on the website. Because many people use a pseudonym instead of their actual name, it can be easy to forget a previously discovered connection.

I once spent a considerable amount of time corresponding with a DNA match who used a pseudonym not related to her actual name. We found we were second cousins and shared photos and stories. Unfortunately, I failed to put her information into the notes section of the testing company website and messaged her again after a few months. She replied, "This is your cousin, Mary." To keep this from recurring, I now track my DNA matches in my research log and use the DNA testing website note systems to identify the individual and our common ancestral couple.

Notes Protocol

Creating a protocol for the information to include in the notes can help you be consistent and thorough. Useful information includes the amount of DNA shared, the confirmed or possible relationship, the individual's real name once discovered, and the path back

to your shared ancestral couple. Add any other information as desired, such as the date messaged or possible family lines. As your DNA research advances, you may want to note if you've added the match to your chromosome map, family tree, or charting program.

For example, in working with my DNA matches, I wondered about P.H., who appeared in my match list. I sent a message through Ancestry's system with a list of my surnames and was fortunate to receive a response. My match identified herself as Patty and a descendant of my great-grandparents, William Huston Shults and Dora Algie Royston, through their daughter, Lola. I created the following note:

> 2C Pat > Lola Marjorine Jerden Johnson > Lola Shults Jerden > William Huston Shults & Dora Algie Royston, sharing 200 cM across 15 segments.

Using acronyms is an efficient method to note relationships. For example, the 2C in the note is short for second cousin. When charting DNA matches, space is limited, so a shortened description of the relationship is helpful. Once you have discovered the relationship, you could diagram the path in a diagramming program or your chosen family tree organizational system. See chapter three for details about visually organizing your matches.

Suppose you don't know your relationship to the DNA match or the full path back to a suspected ancestral couple. In that case, you can use question marks to indicate a hypothesis rather than a confirmed relationship. You can also use the shared matching system on the DNA company websites to determine a possible common ancestral couple and record that in the notes. Here is another example of a note I created—this time with an unidentified match. Notice my use of the question mark to indicate what I don't know.

> 2C? E. W. > ? > ? > John C. Harris & Malissa Welch, shared matches with Harris/Welch cousins, sharing 224 cM across 13 segments.

Research Logs

As well as creating a note for a DNA match on the company website, you can create an entry in your research log. What is the best way to set up your research log? That will depend on your specific needs and your research project. Following are some suggestions for broad organization. See chapter 10 for specific details.

Master Research Log for Closest Matches

If you don't have a parent's test results in the database and you can't identify any of the close matches to help you determine maternal or paternal lines, you can keep all the DNA

matches in one research log and sort them out as you go. This is also a good practice for an adoptee project where maternal lines and paternal lines are unknown.

If your maternal and paternal lines intermarried, you would probably want to have just one research log for all your close matches. You will likely have two sets of common ancestors for some of your DNA matches, and it might be helpful to have all the matches in one research log.

Maternal or Paternal Research Log for Closest Matches

You can choose to have your research log divided into maternal and paternal DNA matches if you've tested a parent. This can help to sort out your closest matches from the beginning. If you have not tested a parent but have sorted DNA matches by paternal or maternal lines based on known relatives such as a first cousin or aunt, you could also use this option. Creating a research log for each grandparent, great-grandparent, etc., could be another way to organize your matches.

I have my DNA results and those of my mother on all the major testing company websites, making it easy to separate maternal and paternal matches. Any DNA match that does not also match my mother is on my paternal line. I chose to create a separate research log for my maternal line and one for my paternal line, which is quite different. My maternal ancestors emigrated from England and Denmark in the mid-1800s coming directly to Utah. My paternal ancestors emigrated in the 1600s and 1700s and eventually found their way to Texas through a southern migration. I have discovered only one overlap in the lines to date, so creating two separate research logs makes sense.

Research Log for an Objective

Suppose you have already identified your close matches and are working on a specific research objective. In that case, the research log can hold the correspondence and match details related only to that objective. The focus will be on a select group of DNA matches from each testing company database used.

Separate DNA Matches into Genetic Networks

After you've recorded the known DNA matches and relationships to you, an efficient next step is to create a genetic network or to separate your matches into groups that cluster around one of your ancestral lines. This will put some order to your DNA match list and aid you in your DNA research. When contacting an unknown DNA match, you can explain that you match on a specific family line.

Dividing your match list into family clusters will let you focus your research on discovering the most recent common ancestor or ancestral couple of that cluster. This knowledge will help you to find, confirm, or reject ancestors on your genetic family tree.

As you gain more information about how you connect to a DNA match, you can record it in the research log: "shared match with Smith relatives" or "in a cluster with the Jones family." You can also record this information in the notes section on each DNA testing company website.

You have two choices when separating your DNA matches into shared match clusters–doing the process manually or using an automatic tool. The following overview will give you an idea of what is available on each website. See chapter eight for an in-depth look at how to use the clustering tools.

Create Shared Match Clusters Manually

What are the advantages of creating shared match clusters manually? You might enjoy working with each match and discovering your shared ancestral lines. Each testing company website enables you to view people that share DNA with you and with your DNA match. Shared DNA match lists and in common with (ICW) lists can help you place a DNA Match in the correct family group. For example, a known first or second cousin would reveal whether a DNA match was on the paternal or maternal line.

Each testing company defines a shared match differently, using unique parameters and approaches to display the information. As you use the features available at each website, you can manually separate your matches into groups.

23andMe: "Relatives in Common"

23andMe uses the term "Relatives in Common" and allows you to see genetic relatives you have in common with a specific DNA match. The website creates a table of relatives in common by looking at your DNA relatives list and checking to see if any other relatives on your list share at least 5cM of identical DNA with your match.[1]

Ancestry: "Shared Matches"

Ancestry uses the term "Shared Matches" and only displays "high confidence" matches (4th cousins and closer to each of you).[2] This generally translates to anyone sharing more

1. "DNA Relatives in Common Report Feature," *23andMe* (https://customercare.23andme.com/hc/en-us/articles/221689668-DNA-Relatives-In-Common-Report-Feature).

2. "What are Shared Matches?" *Ancestry* (https://www.ancestry.com/cs/dna-help/matches/shared-matches).

than 20 cM of DNA with you and your DNA match. If you review the more distant matches in your list, you will be able to see those who share at least 20 cM of DNA with your closer genetic cousins, even if they share less with you.

When you click on one of your DNA matches, you will be redirected to the match page that shows more information about your DNA match. If both you and your match have trees that include the same individual, you might see a common ancestor named. You will also be able to compare ethnicity estimates.

Ancestry has the added feature of using colored dots to group people into genetic networks. You can work with the colored dots any way you choose but consider thinking through a system before beginning. A DNA match may have as many dots assigned to it as desired. An initial dot for maternal or paternal could be assigned; then other dots added as you discover more information. Pedigree charts often use blue and green for the paternal line and pink and yellow for the maternal lines. You could follow this practice in assigning the colors to your matches. For an excellent system, see Leah Larkin's article, "Quick Tip: Color Code Your Ancestry Tree."[3]

FamilyTree DNA: "In Common With"

Family Tree DNA defines a shared match when you, your DNA match, and the shared match have at least 20 cM in common. FamilyTree DNA provides two tools for shared matching—"In Common With" and "Matrix." These will help to discover a cluster of individuals who share DNA with you and with each other.

Additionally, if you have a family tree on the website, you can link a known maternal or paternal DNA match using the feature titled "Family Finder—Family Matching." This will phase your DNA test, assigning maternal or paternal icons to each DNA match so you can determine which line a match is on at a glance. See the website for complete instructions on using this feature, which will also be discussed in chapter three.[4]

MyHeritage: "Shared DNA Matches"

My Heritage's shared matching includes anyone sharing DNA with other matches down to 6 cM. MyHeritage provides a chromosome browser to view triangulated segments among shared matches. This capability makes this feature particularly powerful because it lets you identify whether the shared match group of three individuals all share a common

3. Leah Larkin, "Quick Tip: Color Code Your Ancestry Tree," *The DNA Geek* (https://thednageek.com/quick-tip-color-code-your-ancestry-tree/).

4. "Family Finder—Family Matching Feature," Learning Center, *FamilyTreeDNA* (https://learn.familytreedna.com/user-guide/family-finder-myftdna/ftdna-family-matching-system/).

segment. If not, that could signal that the three people are related in another way.

Living DNA: "Relatives"

Living DNA reports DNA matches under the term "relatives." When you click on a match, an "in common" list appears, sorted by relationship degree. Living DNA reports shared matches from 9 cM and up. In the future, additional features will be added: "shared map" and "shared DNA."

GEDmatch: "People who match both kits, or 1 of 2 kits"

GEDmatch is a third-party website where you can upload your raw DNA from the DNA testing websites. To cluster your matches, use the tool titled "People who match both kits, or 1 of 2 kits." Enter your kit number and that of a known cousin to find other people related to both of you.

Leeds Method

Dana Leeds created a manual clustering tool in 2018 using a spreadsheet, color coding, and the testing companies' shared matching tools.[5] Initially designed for unknown parentage cases, it also works well for doing an initial sort of your DNA matches. After the method became widespread, others created automated tools to shorten the time it takes to cluster your shared matches.

Create Genetic Networks Using an Automated Tool

If you'd rather not take the time to cluster your DNA matches manually, you can experiment with automated tools to create genetic networks of the DNA matches for analysis. Explore these tools in chapter eight. However you perform clustering, the process will help you make sense of your DNA matches before starting the DNA match analysis.

Analyzing DNA Matches

Can additional information be used for analyzing your shared matches? The amount of shared DNA is vital when it comes to the analysis of possible relationships. Let's look at how that works.

5. "The Leeds Method," *Dana Leeds* (https://www.danaleeds.com/the-leeds-method/).

Check the amount of shared DNA

Each testing company lists the amount of DNA you share with a match, reporting it in two ways:

- Centimorgans (cM) as shown at AncestryDNA and Family Tree DNA
- Percentages and centimorgans as shown at 23andMe and My Heritage

Generally, the more DNA you share with a match, the closer the relationship. As you work with your DNA matches, you may discover exceptions to this guideline if you share more than one ancestor with an individual. The testing company will give you an estimate of the relationship you could share with a DNA match. Still, there are usually multiple relationships that can be possible, given the percentage or number of centimorgans of shared DNA.

For example, AncestryDNA estimated a relationship of second to third cousin for my match, Patty. We share 200 cM across 15 segments and are actually second cousins. Don't be surprised if each testing company reports a slightly different amount of shared DNA with the same individual. Each company uses a unique algorithm and different thresholds to evaluate and report the shared DNA.

Calculate possible relationships with the Shared cM Project Tool

Blaine Bettinger created the crowd-sourced Shared cM Project by gathering information from over 60,000 people who reported the amount of DNA they shared with their known relatives. Jonny Perl then created the Shared cM tool and added it to his website, DNA Painter, and added Leah Larkin's probabilities.6 The collaboration has resulted in a valuable tool for analyzing the amount of DNA you share with a match.

After you've viewed the amount of shared DNA with a match and recorded it in your research log, you can use the Shared cM Project tool (https://dnapainter.com/tools/sharedcmv4) to see what possible familial relationships you might share with that match.

With this free tool, you can see the probabilities of various relationships you might have with your shared DNA match. Access the DNA Painter tool from the link above and enter the number of centimorgans or the percentages from data given by a DNA testing company. The tool will then calculate the probabilities of specific familial relationships based on the amount of shared DNA.

6. Jonny Perl, "Introducing the Updated Shared cM Tool," 27 March 2020, *DNA Painter* (https://dnapainter.com/blog/introducing-the-updated-shared-cm-tool/).

For instance, when I entered the 200cM that I share with my DNA match Patty into the tool, I saw many more possibilities than just second to third cousin. Included in the mix were possible relationships of half-second cousin, second cousin once removed, great-great-aunt, etc. The tool suggested over eighteen different relationships.

What if you don't know the relationship to a DNA match? What do you do with the many possibilities? First, don't get overwhelmed—some family tree information may narrow down your relationship. There is not enough information in the amount of DNA shared to determine the exact relationship without looking at known family relationships and family history.

When analyzing a possible relationship, another help is the histogram included for each relationship as part of the Shared cM Project at DNA Painter. See figure 2.4. The histogram allows you to see where the amount of cM you share with a DNA cousin falls in the mix.

Clicking on the 2C for my match with Patty, I saw that 943 people also reported a match of 200 cM as a second cousin. That lets me know that this relationship falls well within the expected range. What if I only shared 50 cM with my second cousin? Only 23 people reported that amount of DNA in a second cousin relationship. It is still possible but could be a cause for re-evaluating the relationship. For more about analyzing DNA matches, including Y-DNA, mtDNA, and X-DNA matches, see chapter six.

Contact DNA Matches

Because you will only recognize your closest DNA matches, you will need to contact more distant matches to see where they fit on the family tree. Using the DNA testing website messaging system or provided email address, you can write to a DNA match and ask them to help you determine the shared common ancestor. Robin shares this example:

> I had three women with whom I shared between 191–315 cM on my DNA match list. I could not figure out who they were from their family tree or lack of a family tree, and I had never heard their names before. I wrote to each of them with a version of the following:
>
> > *Hello! [The DNA company] says that we share ____cM of DNA. That puts us in the range of 2nd-3rd cousins. I would love to connect with you and figure out our common ancestor. I have family history information that*

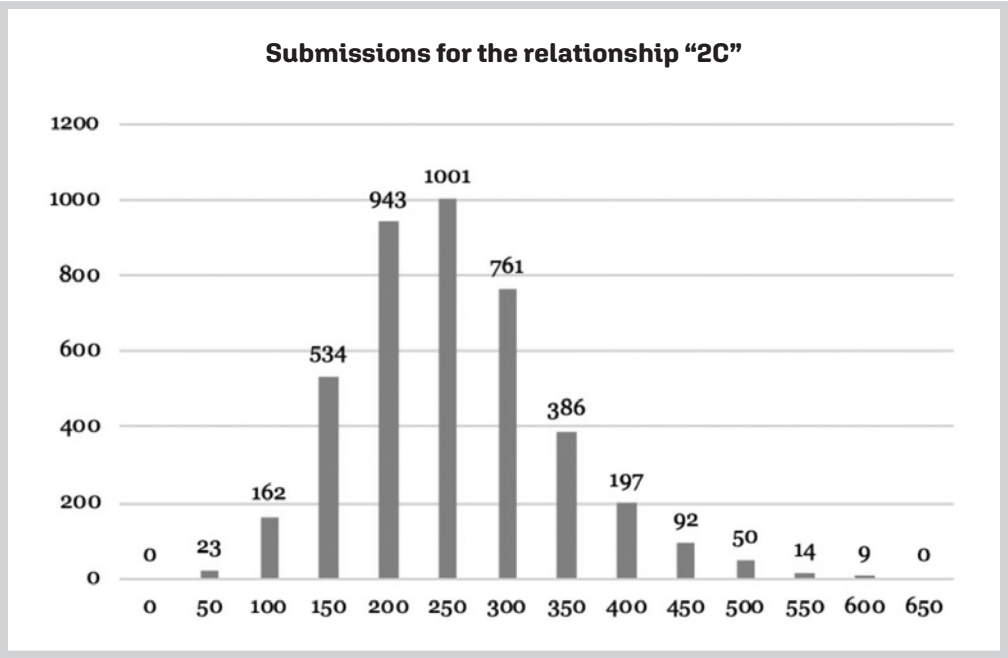


Figure 2.4. Histogram with submissions for the second cousin relationship.
Shared cM Project. Blaine T. Bettinger and Jonny Perl, "The Shared cM project 4.0 tool v4," DNA Painter (https://dnapainter.com/tools/sharedcmv4), licensed under CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/).

> *I would love to share with you. You can contact me through the [DNA company] messaging system or via email at [___@___.com]. I look forward to hearing from you!*

They each responded, and we figured out that our grandparents were siblings. Therefore, our common ancestors are our great-grandparents, which means that we are second cousins. That new information and connection have opened the door for sharing photos, stories, and knowledge about our ancestors."

Keep track of messages or emails sent to unknown DNA matches in your research log. See chapter 10 for ideas on how to set up this portion of your research log. If a match doesn't reply within a reasonable amount of time, you could try again. We never know what might be happening in a match's life that prevents them from communicating with you.

An easy way to help a DNA match see your connection is to include a link to your online family tree. If a match doesn't have an Ancestry subscription, they won't see more than a preview of your Ancestry tree so consider putting a tree in a public place like your website, WikiTree, or FamilySearch.

Some tips for messaging include the following:

- Use exciting message headers to capture their attention.
- Contact new matches as soon as possible as they are more likely to sign into the website to check their results.
- Write out a protocol for a message to reuse.
- Try to determine which family line you match on and include that in the message.
- Offer to share family information.
- Send a direct link to the common ancestor in your online family tree.

Conclusion

Once you receive your DNA test results, some simple steps will help you assess and analyze each match. As you learn more about each match, add that information to your research log.

1. Assess your family tree.
2. Set up a system to track your DNA matches.
3. Cluster your DNA matches into genetic clusters.
4. Check the amount of shared DNA.
5. Calculate possible relationships with the Shared cM Project Tool.
6. Contact DNA Matches.

As you practice, your confidence will grow, and you will learn to assess and analyze your DNA matches effectively.

Your Task

1. Assess your closest DNA matches on each DNA testing website. Use the notes feature to record your relationship following your notes protocol.
2. Start a research log. Choose to create one master log, a log for your maternal line and a log for your paternal line, or a log for a specific project/objective.
3. Record information in the research log for individuals you recognize.
4. Begin clustering your closer DNA matches into genetic clusters either manually or automatically. Add new information to your research log.
5. Analyze the amount of shared DNA with each match using the Shared cM Project tool. Add the information to your research log.
6. Send messages to any matches you don't recognize and track your correspondence.

Build your family tree with DNA & documentary evidence

Would you like to use DNA evidence in your genealogy research? Do you have thousands of cousin matches, but no idea what to do next? Perhaps you have found some evidence to support your theories, but are not confident in your conclusions.

Learn a step-by-step method to organize and use your DNA test results to find and confirm ancestors in your family tree. Diana Elder, AG, Nicole Dyer, and Robin Wirthlin share the method they use in their professional research to incorporate DNA with documentary evidence. Study the methodology in each chapter, then apply it in your own research by completing the associated task. You will group and evaluate your matches, diagram descent from common ancestors, plan next research steps, track correspondence and research in a log, and write a report incorporating DNA evidence. Work samples and templates are included.

Diana Elder AG® is a professional genealogist accredited in the Gulf South region of the United States. She serves as a Commissioner for The International Commission for the Accreditation of Professional Genealogists (ICAPGen). Diana first used Y-DNA in 2009 to connect her Texas Royston family to the descendants of John Royston, born 1610 of Virginia. Since then Diana has continued adding to her DNA knowledge and experience, completing the advanced DNA course, "A Practical Approach: Establishing Genealogical Proof with DNA" in 2018 and the "All-DNA Advanced Evidence Analysis Practicum" in 2020 (both through the Salt Lake Institute of Genealogy). Diana regularly uses DNA in her client work as well as her own family history research. Diana is the author of the bestselling book, *Research Like a Pro: A Genealogist's Guide* and the creator of the Research Like a Pro study group and e-Course. Diana and her daughter, Nicole Dyer are the hosts of the Research Like a Pro Genealogy Podcast and share research tips on their website, FamilyLocket.com.

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