

GENETIC GENEALOGY CHEAT SHEET

BY BLAINE BETTINGER AND THE EDITORS OF FAMILY TREE MAGAZINE



Your Two Family Trees

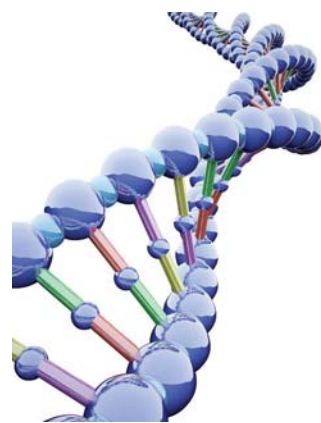


GENEALOGICAL FAMILY TREE		GENETIC FAMILY TREE
your ancestry according to recorded history	WHAT IT IS	all the people whose DNA you inherited
every ancestor who had a child who had a child who had a child, and so on, ultimately leading to you	WHO'S IN IT	only those ancestors who contributed to your DNA, including your parents and grandparents; the further back you go, the less likely it is that a given ancestor is represented in your DNA
using paper records such as birth and death certificates, censuses and newspapers	HOW YOU EXPLORE IT	through DNA testing combined with knowledge of genealogical family tree from traditional research
to the end of paper records, often in the 1600s to early 1800s, depending on the family and location	HOW FAR BACK IT GOES	DNA tests can reveal information about your "deep ancestry"—not specific ancestors, but the location or tribe of your ancient forebears

Genetic Inheritance

Your autosomal DNA represents the bulk of your genetic makeup. It comes from all over your family tree. Due to recombination at conception, the amount of DNA from a given ancestor is halved with each generation. Below, see approximately how much autosomal DNA you inherited from each ancestor through great-great-grandparents. There's no test—yet—that tells you which part of your autosomal DNA came from which ancestor

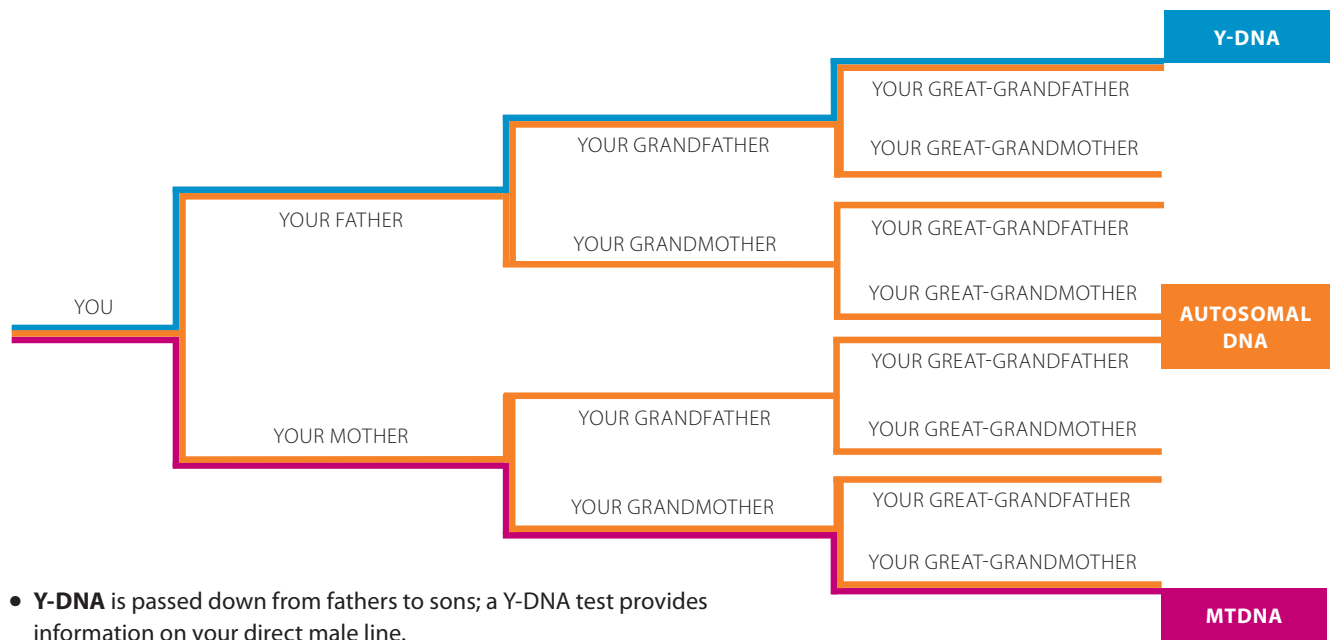
GENERATION		PERCENTAGE OF YOUR DNA
great-great-grandparents		6.25%
great-grandparents		12.5%
grandparents		25%
parents		50%



ARE ALL MY ANCESTORS IN MY DNA?

No. Beyond about your third-grandparents, it's unlikely that you have enough DNA from any one ancestor for that person to be represented in your genome.

TYPES OF DNA TESTS



- **Y-DNA** is passed down from fathers to sons; a Y-DNA test provides information on your direct male line.
- **mitochondrial (mt) DNA** is passed from mothers to their children; an mtDNA test provides information on your direct female line.
- **autosomal DNA** is inherited from both parents; half from the mother and half from the father. An autosomal test provides information on your ancestors within about the past five generations.

TYPES OF GENETIC GENEALOGY TESTS					
TEST	Autosomal	Ethnic	Mitochondrial	X-DNA	Y-DNA
WHAT IT DOES	Analyzes the 22 pairs of non-sex chromosomes. Tells you about both sides of your family. Can confirm if you're related to a living person and estimate a relationship. Both individuals must provide a DNA sample.	Examines DNA markers to determine genetic heritage among anthropological groups. Compares your DNA markers to those typical of certain ethnicities, and regions. Some companies specialize in specific backgrounds, such as African or British.	Best for learning about ancient maternal-line ancestry. Can confirm a maternal relationship but not when the common ancestor lived. Results apply only to female ancestors in your maternal line. Results assign a haplogroup.	Analyzes the X chromosome, of which men have one copy (inherited from the mother) and women have two copies (one from the father, one from the mother). Some autosomal DNA tests also examine the X chromosome.	Determines whether families with the same last name are related and about when the common ancestor lived. Results relate only to male ancestors in your direct paternal line. Y-DNA tests also can determine a haplogroup.
WHO CAN TAKE IT	men and women	men and women	men and women	men and women	men (a woman can test her father, brother, or another known male-line relative)
WHICH COMPANIES OFFER IT	<ul style="list-style-type: none"> • 23andMe • AncestryDNA • Family Tree DNA (Family Finder test) • Living DNA • MyHeritage DNA 	<ul style="list-style-type: none"> • 23andMe* • AfricanAncestry • AncestryDNA* • BritainsDNA • Family Tree DNA* (Family Finder test) • Genographic Project • Living DNA* • MyHeritage DNA* 	<ul style="list-style-type: none"> • 23andMe • BritainsDNA • Family Tree DNA • Genebase • Genographic Project • Oxford Ancestors 	<ul style="list-style-type: none"> • 23andMe* • Family Tree DNA* (Family Finder test) 	<ul style="list-style-type: none"> • 23andMe • BritainsDNA • Family Tree DNA • Full Genomes • Genebase • Genographic Project • Oxford Ancestors

* part of autosomal DNA test

DECODING DNA TEST RESULTS

Y-DNA

	1 Markers						
	DYS455	DYS454	DYS447	DYS437	DYS448	DYS449	2
Person A	11	11	20	15	19	29	4
Person B	11	11	25	15	19	31	

1 Markers represent the specific genetic markers of the Y-chromosome that you tested. The more markers tested, the higher “resolution” the test. Y-DNA tests go up to 111 markers. You’ll need to compare your values to others’ values for the same markers.

2 The meanings of the numbers and letters identifying your DNA markers are:

- D: DNA
- Y: Y chromosome
- S: a unique segment
- 455: a number assigned to this unique segment

3 These numbers represent the value, or how many times the marker repeats. For example, a value of 11 at DYS455 means that the DNA from the Y chromosome on segment 455 repeats 11 times.

4 The chart above shows two people’s results. Differences between their marker values are called “genetic distance.” The smaller the genetic distance, the closer the relationship. On a 37-marker test, genetic distance must be less than about 6 to indicate a recent relationship. On a 25-marker test, 2 or less indicates a recent relationship. On higher-resolution tests, a bigger genetic distance can still indicate a recent relationship.

HOW TO CALCULATE Y-DNA GENETIC DISTANCE

STEP 1 Note differences in the marker values between two sets of results.

STEP 2 Subtract the lower values from the higher values at each varying marker.

STEP 3 Add up the differences. The total is the genetic distance.

Example

Above, persons A and B show different values at two markers:

- DYS447: $25 - 20 = 5$
- DYS449: $31 - 29 = 2$

The genetic distance is $5 + 2 = 7$. This high genetic distance indicates these two men aren’t recently related on their paternal line.

mtDNA

1 An mtDNA test will tell you which haplogroup you belong to. You could think of your haplogroup as your ancient ancestral tribe or clan.

2 mtDNA results are compared to a standard called the revised Cambridge Reference Sequence (rCRS). Differences from the rCRS are called mutations.

3 mtDNA results come as a list of mutations. A full sequence test looks at the two parts of mtDNA:

- hypervariable region (HVR), subdivided into HVR1 and HVR2. The HVR has a relatively high mutation rate
- coding region

4 Mutations can include changes, insertions or deletions of nucleotides. This example shows: **A** a change at position 246 from a T to a G, and **B** insertions at positions 309 and 315.

HAPLOGROUP H1

3	HVR1 Differences from rCRS	HVR2 Differences from rCRS	2	Coding Region Differences from rCRS
	A16051G	T246G	4 A	C4763A
	T16519C	A263G		C5309G
		309.1C	4 B	
		315.1C		

The more differences between you and an mtDNA match, the more distant your most recent common ancestor (MRCA). If you ...

- match on HVR1: there’s a 50 percent chance your MRCA lived in the last 52 generations
- match on HVR1 and HVR2: 50 percent chance your MRCA lived within the last 28 generations
- match on the full sequence: 50 percent chance an MRCA lived within the last five generations

Autosomal DNA

1 Autosomal DNA tests estimate your ethnicity by comparing your DNA to reference populations of people with roots in a particular location for many generations. If part of your DNA matches a reference population, it's a hint that you may have ancestors in that place. The key word is *estimate*: Variations can occur because testing companies use different algorithms and reference populations.

2 Depending on your testing company, your estimate might show broad ethnic categories (African, Native American) and/or sub-regions such as Northern, Southern and Eastern European here.

3 You'll get an "Unknown" percentage if the company can't determine an estimated location for part of your DNA.

4 This estimate shows a person with a mixed ethnicity—DNA from several different regions, including Africa, Europe and the Americas.

5 The total doesn't always come to 100 percent. You might get a total of 99 or 98 percent due to rounding.

SAMPLE ETHNIC ORIGINS ESTIMATE

1 Ethnicity	4 Percentage Estimate
African	3%
2 North Africa	3%
Sub-Saharan Africa	0%
Asian	0%
European	91%
Northern European	45%
Southern European	23%
Eastern European	23%
Native American	5%
3 Unknown	1%
Total	100% 5

SAMPLE AUTOSOMAL DNA MATCH LIST

1 Name	2 Estimated relationship	3 Shared cM	3 Longest cM	4 Surnames
George Sanderson	second cousin	201.5	40.8	Lucas, Bailey, Block, Marshall
Thomas Johns	third cousin	43.44	35.79	Donnelly, Rose, Guillion, Block
Helene Block	fourth cousin	35.66	20.81	Blankman, Zubia, Ramirez, Hall
Stephen Smith	fourth cousin	29.78	16.80	Whipple, Florey, Dillman, Jones
Jonah Arkin	distant cousin	27.83	12.25	Block, Wayne, Baker, Gray

1 Your testing company will compare your autosomal DNA to others in its customer database and report the people who have DNA that matches yours (determined by factors such as length of shared DNA segments and total amount of shared DNA).

2 The testing company estimates your relationship to each match. The more and longer segments of DNA you share, the closer the likelihood of relationship. Keep in mind that a given relationship can share varying amounts of DNA.

3 Create a chart like this one to organize your closest matches. You'll also see the lengths of your shared autosomal DNA segments, measured in centimorgans (cM). The average cM shared chart at isogg.org/wiki/Autosomal_DNA_statistics shows you possible relationships.

4 List surnames that appear in the family trees of your genetic cousins. Compare them to your own ancestral surnames. You can begin to guess which family line or ancestors might be related to this person through.

HOW TO FIND YOUR MRCA BY TRIANGULATING AUTOSOMAL DNA MATCHES

STEP 1 Identify a close match, preferably a fourth cousin or closer.

STEP 2 Find a third person who matches you both by using the Shared Matches (also called In Common With) tool. If you don't find a third match, keep checking back. More people are getting tested all the time.

STEP 3 Search through all three of your family trees for a common ancestor, or at least common surnames and birth places.

STEP 4 Identified the most recent ancestor you all share? Congratulations! If not, use the names and places as clues, doing traditional genealogy research to pinpoint the common ancestor.

DNA ANALYSIS TOOLS

Tool	Cost	Function/Features
David Pike's Utilities < www.math.mun.ca/~dapike/FF23utils >	free	<ul style="list-style-type: none"> comprehensive suite of tools for analyzing raw autosomal data from 23andMe, AncestryDNA and Family Tree DNA search for shared DNA in two files
DNAGedcom < www.dnagedcom.com >	free	<ul style="list-style-type: none"> suite of tools for 23andMe, AncestryDNA and Family Tree DNA autosomal customers download matches, shared segments and other data into a handy spreadsheet for further analysis
DNALand < dna.land >	free	<ul style="list-style-type: none"> suite of tools for raw autosomal data from 23andMe, AncestryDNA and Family Tree DNA learn about genetic and health-related traits associated with your genome do admixture analysis find genetic matches your anonymized data are used for medical research
DNAPainter < dnainter.com >	free	<ul style="list-style-type: none"> chromosome mapping tool color-codes your DNA by the ancestor it's inherited from uses segment data from 23andme, Family Tree DNA, GEDmatch or MyHeritage
GEDmatch < gedmatch.com >	free; advanced tools available for a fee	<ul style="list-style-type: none"> suite of tools for 23andMe, AncestryDNA and Family Tree DNA raw autosomal data compare your DNA to everyone else's or to a specific individual in the database perform numerous admixture analyses phase your DNA (determine which parent contributed each allele)
GENOtation < genotation.stanford.edu >	free	<ul style="list-style-type: none"> collection of tools for analyzing 23andMe raw data using only a web browser (i.e., raw data is not uploaded) admixture analysis health information
Promethease < promethease.com/ondemand >	\$12-\$16	<ul style="list-style-type: none"> analyze your 23andMe, Family Tree DNA, or AncestryDNA raw data and build a report based on SNPedia reports contain information about health and ancestry as well as several other options
Segment Mapper < kittymunson.com/dna/SegmentMapper.php >	free	<ul style="list-style-type: none"> clever and powerful "mapping" tool to show specific DNA segments in a graphic chromosome-style chart

TIP: A NEGATIVE CAN BE A POSITIVE

Even negative DNA test results can be revealing. Knowing you *don't* match another person saves you from wasted effort pursuing the wrong family line. Negative results may also spur you to consider a research path you wouldn't have pursued otherwise.



TIP: MANAGE YOUR EXPECTATIONS

Before testing your DNA, make sure you understand the limitations and benefits of each type of test. Taking the most helpful test for your research needs will save you time and money.

GENETIC GENEALOGY GLOSSARY

TERM	DEFINITION
admixture	ancestry that originates from more than one ethnic group or region
allele result	one of multiple alternative forms of a single gene occupying a locus on a chromosome
autosomal DNA (atDNA)	all your DNA except what's on the X and Y chromosomes and your mtDNA
centimorgan (cM)	an approximate measurement of distance along a chromosome
chromosome	a singular piece of DNA, recognizable as a double-helix molecule containing lots of genes
confidence level	a measure of the likelihood you share a recent ancestor with a match, based on the amount and location of shared DNA between you and your match
deoxyribonucleic acid (DNA)	a molecule encoding genetic information
genealogical cousins	people who share an ancestor in your genealogical family tree, but do not necessarily share your DNA
genetic cousins	people, such as first cousins, who share detectable amounts of DNA from a common ancestor
genetic distance	a calculation of the differences or mutations between two Y-DNA or mtDNA samples
genome	a person's complete set of genetic material
haplogroup	an identification of the genetic group your ancient ancestors (10,000 to 60,000 years ago) belonged to
haplotype	collectively, the marker values on your Y-DNA or mtDNA test results
hypervariable region (HVR)	sections of mtDNA (such as HV1 and HV2) most commonly tested by an mtDNA test

TERM	DEFINITION
locus	the location of a gene, SNP or DNA sequence on a chromosome
mitochondrial DNA (mtDNA)	a small circular piece of DNA that mothers pass on to their children
MRCA (most recent common ancestor)	the most recent ancestor two individuals both descend from
mutation	changes in DNA that can help reveal how long ago an MRCA lived when two people have closely matching marker values
nonpaternity event	a circumstance such as illegitimacy or adoption, which would cause an ancestor's biological father to be different from his or her documented father
phasing	the process of determining which parent contributed which genes, most often applied to autosomal or X-DNA testing
recombination	the process by which chromosomes cross and switch genetic material during meiosis
SNP (single nucleotide polymorphism)	mutations in autosomal DNA that can indicate where your ancient ancestors came from
STR (short tandem repeat)	a type of DNA marker used to determine relationships between individuals
surname DNA project	a genetic genealogy project using Y-DNA testing to trace relationships among males with the same or a similar surname
triangulation	analyzing a matching DNA segment among three people to determine which ancestor those people have in common, allowing them to determine a specific relationship
X-DNA	genetic material on the X chromosome; men have one X chromosome and women have two
Y-DNA	a chromosome that fathers pass to their sons; men have one Y chromosome and women have none

Q Will a DNA test tell me who my ancestors are?

A No. Your DNA test results won't give you names of ancestors. In order to effectively use genetic genealogy, you'll need to combine DNA testing with traditional research methods.

Q Can a DNA test tell me how I'm related to a match?

A Not exactly. An autosomal DNA test can determine whether you have DNA in common with another person, and estimate your relationship based on how much DNA you share. The estimate will be broad, such as "close family" or "second to fourth cousins." By researching your family tree and your matches' family trees, you can learn how you're related.

A Y-DNA test can determine whether you're related to a match through male lines, and estimate how far back the shared ancestor lived. A mitochondrial (mt) DNA test can determine whether you share DNA with someone along maternal lines, but it isn't good at telling how closely you're related.

Q Do I have to get blood drawn for a genealogy DNA test?

A No. Your genealogy DNA test will involve spitting into a tube or swabbing the inside of your cheek.

Q Do I need my deceased ancestor's DNA for comparison?

A No. Genetic genealogy works because your ancestors passed on genes to you. For example, a man inherits Y-DNA from his father, who inherited it from his father, and so on. You can make discoveries about your family by comparing your genetic makeup with other relatives' DNA and family research.

Q I'm a woman. How can I use Y-DNA testing if my father is deceased?

A In this case, you can get a sample from another known relative who has the same Y-DNA as your dad. He must be related through male lines: Your brother, your father's brother

or your father's brother's sons are the most likely candidates. If you don't have those relatives, go further up your tree to identify living sources of that DNA, such as your father's first cousins through his paternal grandfather.

Q What's a nonpaternity event?

A It's a circumstance in which a person's documented father isn't his or her biological father, such as illegitimacy, adoption or even a genealogical research mistake. Genetic genealogy test results suggest a nonpaternity event when two people who should match, don't.

Q Is genetic genealogy 99.9 percent accurate, like paternity tests?

A Although your DNA doesn't lie, genetic genealogy test results are different from other types of DNA tests. Genetic genealogy involves more interpretation. Ethnicity analyses, for example, can suggest but can't prove that you have ancestry from a certain area of the world. Results from older Y-DNA tests that covered few markers sometimes created "false positive" matches—if more markers had been tested, mutations at those markers

would have shown the people weren't actually closely related. A DNA test may reveal surprising information, such as an unexpected ethnicity or a nonpaternity event.

Q Can I look for DNA matches at other testing companies?

A Yes. Your testing company will automatically alert you to DNA matches in its own customer database. You can then download your raw DNA data for upload to other testing companies that accept such uploads (check Family Tree DNA, Living DNA and MyHeritage DNA). You also can upload your raw DNA data to third-party tools such as GEDmatch (see DNA Analysis Tools in this guide) to compare and analyze your results outside your testing company.

Q What is triangulation?

A In autosomal DNA testing, triangulation is the process of analyzing three people who all match one another to determine the source of their common DNA. Start with two matches at a close cousin level. Then find another person whom both cousins match, and look for common names and birth places in all three trees.

DNA Testing and your privacy

When you sign up with a DNA testing company website, you can choose how much personal information to include in your profile. Some sites let you opt out of appearing on others' match lists, which also means you won't get matches. You'll get the most genealogical benefit by linking your DNA account to your public family tree. If you prefer, you can create a "skeleton tree" with only names, dates and places.

Genetic genealogy testing companies' terms of service govern how your results can be used. You and any relatives you ask to test should read these before testing. Some companies, for example, provide anonymized DNA data for scientific research (and may allow you to opt out). To date, no major testing service sells customers' personal data to third parties.

It's also possible today for law enforcement to use public DNA databases like GEDmatch to identify suspects in crimes. If you have any privacy concerns about DNA testing, consider carefully whether to test (or consider removing your profile from DNA websites).

Genetic Genealogy Timeline

1989	First known use of the term <i>genetic genealogy</i> , in the <i>Dallas Morning News</i>
2000	FamilyTreeDNA offers first consumer genetic genealogy tests, processing 300 samples the first year
2002	Sorensen Molecular Genealogy Foundation (SMGF) is formed
2003	Completion of Human Genome Project
2004	First International Conference on Genetic Genealogy in Houston; SMGF posts a Y-DNA database online with 5,000 samples and pedigree charts
2005	National Geographic Project launches to trace human origins and migration
2006	International Society of Genetic Genealogy forms; annual US sales of genetic genealogy tests estimated at \$60 million
2007	Ancestry.com absorbs Relative Genetics and offers DNA tests
2009	23andMe offers autosomal tests for genealogy research, priced for mass market
2012	Ancestry launches autosomal testing
2014	AncestryDNA retires Y-DNA and mtDNA tests, focusing exclusively on autosomal testing
2016	MyHeritage launches MyHeritage DNA testing service
2017	Living DNA launches to the US market

GENETIC GENEALOGY TESTING COMPANIES*

23andme <www.23andme.com>	DNA Consulting <dnaconsultants.com>	MyHeritage DNA <myheritage.com/dna>
African Ancestry <africanancestry.com>	Family Tree DNA <familytreedna.com>	National Geographic Genographic Project <genographic.nationalgeographic.com>
AfricanDNA <www.africandna.com>	Full Genomes <www.fullgenomes.com>	Oxford Ancestors <oxfordancestors.com>
AncestryDNA <ancestry.com/dna>	Genebase <www.genebase.com>	
BritainsDNA <www.britainsdna.com>	LivingDNA <www.livingdna.com>	

*Find an extensive, updated list of testing companies at <www.isogg.org/wiki/List_of_DNA_testing_companies>.

RESOURCES

WEBSITES

- AncestryDNA Matching Facebook group** <www.facebook.com/groups/407494112747727>
- DNAeXplained genetic genealogy blog** <dna-explained.com>
- DNA Newbie Facebook Group** <www.facebook.com/groups/dnaneewbie>
- Family Tree DNA Surname Projects** <familytreedna.com/projects.aspx>
- Family Tree University: genetic genealogy classes** <www.familytreemagazine.com/store/university>
- The Genetic Genealogist blog** <www.thegeneticgenealogist.com>
- International Society of Genetic Genealogy** <www.isogg.org>
- Journal of Genetic Genealogy** <www.jogg.info>
- Kitty Cooper's Blog: Musings on Genealogy, Genetics and Gardening** <blog.kittycooper.com>
- The Legal Genealogist blog** <www.legalgenealogist.com>
- Online Journal of Genetics and Genealogy** <jgg-online.blogspot.com>

Your Genetic Genealogist blog
<www.yourgeneticgenealogist.com>

BOOKS

- Abraham's Children: Race, Identity and the DNA of the Chosen** by Jon Entine (Grand Central Publishing)
- The Adoptee's Guide to DNA Testing** by Tamar Weinberg (Family Tree Books)
- Deep Ancestry: Inside The Genographic Project** by Spencer Wells (National Geographic)
- DNA and Tradition: The Genetic Link to the Ancient Hebrews** by Yaakov Kleiman (Devora Publishing)
- Family History in the Genes: Trace Your DNA and Grow Your Family Tree** by Chris Pomery (The [UK] National Archives)
- The Family Tree Guide to DNA Testing and Genetic Genealogy** by Blaine Bettinger (Family Tree Books)
- Saxons, Vikings, and Celts: The Genetic Roots of Britain and Ireland** by Bryan Sykes (W.W. Norton & Co.)
- The Seven Daughters of Eve** by Bryan Sykes (W.W. Norton & Co.)