RESOURCES / LITERATURE CONCERNING the X CHROMOSOME:

SNPs, STRs, HAPLOBLOCKS & ANCESTRY

By

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Companies which test 500 Kb or more autosomal and X chromosome SNPs

1) 23andMe: http://www.23andme.com

2) DeCODEme: http://www.decodeme.com

Companies which test X – STRs (short tandem repeats)

Family Tree DNA: http://www.familytreedna.com

World Families X Forum – XDNA (location where all interested readers may wish to consider registering as this is the focal point of X research for genetic genealogists)

http://www.worldfamilies.net/forum/index.php?board=2222.0

Those wishing to explore the X to learn about what it has to offer in the way of ancestral informative features my wish (need) to start at different places. Those who believe that they have a sufficient background in biology that they feel comfortable jumping directly to the X can skip over the next section.

Starting with General Reading on Genetics and the Human Genome

If perchance much of the terminology and the concepts in this area of study are a little "fuzzy", or in need of a refresher, it would be a good idea to read some of the general works on human genetics. Here is one I found particularly helpful, more will be added as time goes by:

The human genome: A user's guide (Hawley and Mori) - 1999:

http://www.amazon.com/Human-Genome-Users-Guide/dp/B000XZBI6W/ref=sr_1_4?ie=UTF8&s=books&qid=1230485583&sr=8-4

The human genome: A user's guide (Richards and Hawley – second edition to above) - 2004:

http://www.amazon.com/Human-Genome-Elsevier-Science-Society/dp/0123334624/ref=sr_1_1?ie=UTF8&s=books&qid=1230485583&sr=8-1

When you are ready for the next step (this one is not for the faint of heart) there is:

Human evolutionary genetics: Origins, peoples & disease (Jobling et al., 2003):

http://www.amazon.com/Human-Evolutionary-Genetics-Origins-Peoples/dp/0815341857/ref=sr_1_1?ie=UTF8&s=books&qid=1230486065&sr=1-1

Starting with an Introduction to the X

Animated overview from SMRF:

http://www.smgf.org/education/animations/x_chromosome.jspx

Overview of the X chromosome from Wiki:

http://en.wikipedia.org/wiki/X_chromosome

National Library of Medicine's information page on the X:

http://ghr.nlm.nih.gov/chromosome=X

Unlocking the genealogical secrets of the X chromosome (Blaine Bettinger's summary of the subject and accompanying fan chart showing the Fibonacci inheritance pattern):

http://www.thegeneticgenealogist.com/2008/12/21/unlocking-the-genealogical-secrets-of-the-x-chromosome/

Follow up to Blaine's posting which includes fan charts showing percentage contribution from each ancestor and their respective genealogical number:

http://www.thegeneticgenealogist.com/2009/01/12/more-x-chromosome-charts/

X chromosome inheritance charts (Jim Turner's pedigree charts with notation of percentage contribution from each potential ancestor) + Analysis of size of blocks comparing each of the people in Ben Moscia's database below:

http://freepages.genealogy.rootsweb.ancestry.com/~hulseberg/DNA/xinheritance.html

The growing family tree: The power of DNA in reconstructing family relationships (SMGF publications – put the X in context with autosomes, the Y and mtDNA to sort out ancestral relationships. They also include a demo of the Fibonacci Sequence):

http://www.smgf.org/resources/papers/biot04-smgf.pdf

Welcome to ChrX-STR.org (forensic applications etc. of the X including good background information):

http://www.chrx-str.org/

Book – "The X in Sex: How the X Chromosome Controls our Lives" by David Bainbridge:

http://www.amazon.com/X-Sex-Chromosome-Controls-Lives/dp/0674016211/ref=pd_ys_iyr_img

The first X-haploblock phylogenetic presentation? (Anders Palsen's important posting on Rootsweb):

http://archiver.rootsweb.ancestry.com/th/read/GENEALOGY-DNA/2008-09/1220813306

Ann Turner's article on pedigrees and the X chromosome:

http://www.jogg.info/42/files/turner.pdf

Ann Turner's analysis of compare me feature at decodeme:

http://dnacousins.vizachero.com/deCODEme_Compare_Genomes.doc

Haploblock sharing among family members: Autosomes and the X chromosome as shown in the Decodeme demo:

http://davidkfaux.org/Decodeme_Family_Sharing.pdf

Haploblock sharing amongh family members: Autosomes and the X chromosome as shown in the 23andme demo of the "Mendel Family":

To see the visuals here if you have a 23andme account you will have to go to "Settings" and click on "Show the Mendel Family". If you don't have an account you will need to go to http://www.23andme.com and set up a trial account which gives access to the Mendel Family when you click on "Family Inheritance".

Structural and Functional Components of the X Chromosome

The DNA Sequence of the Human X Chromosome:

http://www.nature.com/nature/journal/v434/n7031/pdf/nature03440.pdf

Human X Chromosome: Project Overview (special edition of *Nature*):

http://www.sanger.ac.uk/HGP/ChrX/

Crossing over – exchanging on the X (with animation):

http://www.accessexcellence.org/RC/AB/BC/Genetic_Recombination.php

Probability of recombination and the concept of centriMorgan (Ann Turner's posting to Rootsweb):

http://archiver.rootsweb.ancestry.com/th/read/GENEALOGY-DNA/2008-05/1209827037

Animation – Linkage disequilibrium and haploblock mapping:

http://www.ics.uci.edu/~dechter/courses/ics-295/spring-2007/class12-LD.pdf

Recombination hotspots:

http://biology.plosjournals.org/archive/1545-7885/2/6/pdf/10.1371_journal.pbio.0020190-L.pdf

Physical and genetic mapping of the human X chromosome centromere: Repression of recombination:

http://genome.cshlp.org/content/8/2/100.full.pdf

X chromosome map at 75-kb resolution, revealing extremes of recombination and GC content:

http://genome.cshlp.org/content/7/3/210.full.pdf+html

Heritable skewed X-chromosome inactivation leads to haemophilia A expression in heterozygous females (Renalut et al., 2007):

http://www.nature.com/ejhg/journal/v15/n6/pdf/5201799a.pdf

SNPs and Linkage Disequilibrium (tendency for SNPs to "travel together"):

http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1866708&blobtype=pdf

Series of articles on the X chromosome in *Nature*:

http://www.nature.com/nature/supplements/collections/humangenome/chromosomes/x.html

The structure of haplotype blocks in the human genome:

http://www.sciencemag.org/cgi/reprint/296/5576/2225.pdf

Genotyping and functional SNP localization:

http://www.jlr.org/cgi/reprint/48/2/434.pdf

DNA sequence variation in a non-coding region of low recombination on the human X chromosome:

http://bioportal.weizmann.ac.il/course/evogen/HumanVariation/Kaessmann_NG_1999.pdf

Haplotype diversity and SNP frequency dependence in the description of genetic variation (Stumpf, 2004):

http://www.nature.com/ejhg/journal/v12/n6/pdf/5201179a.pdf

Analysis of the number of nucleotide bases that could be conserved intact over a 300 to 500 year period (two articles from Blaine Bettinger's blog – be sure to click on the links to the original papers). Although these papers focus on colon cancer and the autosomes, the pedigree and other information would pertain directly to the X chromosome:

1) http://www.thegeneticgenealogist.com/2008/04/21/tracing-a-500-year-old-founder-mutation-using-genetic-genealogy/
2) http://www.thegeneticgenealogist.com/2008/01/03/a-single-colon-cancer-gene-traced-to-1630-the-future-of-genetic-genealogy/

Study of regions of extended homozygosticty:

http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=2343471&blobtype=pdf

Recombination rate estimation in the presence of hotspots (Auton & McVean, 2007):

http://genome.cshlp.org/content/17/8/1219.full.pdf+html

Dosage compensation in mammals: fine-tuned the expression of the X chromosome (Heard & Disteche, 2006):

http://genesdev.cshlp.org/content/20/14/1848.full.pdf+html

Heritable skewed X-chromosome inactivation leads to heamophillia A expression in heterozygous females (Renault et al., 2007):

http://www.nature.com/ejhg/journal/v15/n6/pdf/5201799a.pdf

Chromosome staining, the mapping of G and R bands**:**

http://www.pnas.org/content/99/2/797.full.pdf+html

Databases Currently being Researched by Genetic Genealogists

The X chromosome Project: World Families (participants X data from 23andme and decodeme is uploaded here so comparisons can be made)**:**

http://www.worldfamilies.net/geo/xdna

Ben Moscia's database of X chromosome raw data from 23andme (NB Also see Jim Turner's website above for a comparison of haploblocks between these individuals):

http://cid-bb940b89da5692bf.skydrive.live.com/self.aspx/.Public/X-23andme.xls

DNA-Fingerprint X-Match (for X STR markers)**:**

http://www.dna-fingerprint.com/modules.php?op=modload&name=xmatch

Databases and Tools for the Advanced User

X-STR.org database (similar to Y-STR database and designed for forensic users, but very limited in its capabilities at this point):

http://www.chrx-str.org/

International HapMap Project: Database downloads, browser, etc:

http://www.hapmap.org/index.html.en

Download HapMap phased data (meaning diploid nucleotide output separated to each chromosome) from 4 Continental groups:

http://ftp.hapmap.org/phasing/2006-07_phaseII/

ALFRED:

http://www.alfred.med.nlm.nih.gov/SNP/

SNP @ ETHNOS: A catalogue of human SNPs and genes that contain human ethnic variation:

http://variome.kobic.re.kr/SNPatETHNIC/

NCBI X chromosome map BUILD:

http://www.ncbi.nlm.nih.gov/projects/mapview/maps.cgi?taxid=9606&chr=X

Recombination and hotspot database:

http://ftp.hapmap.org/recombination/2008-03_rel22_B36/rates/

Different phasing programs to cluster haplotypes:

http://www.cell.com/AJHG/retrieve/pii/S000292970763701X

Haploblock – SNP haplotype block software – Haplotyping SNPs – Linkage disequilibrium mapping:

http://bioinfo.cs.technion.ac.il/haploblock/

Study of X haplotypes and the use of phasing software to infer the haplotypes of females:

http://www.biomedcentral.com/content/pdf/1471-2156-6-S1-S77.pdf

Anders Palsen's PLINK analysis of the HGDP-CEPH panel data showing matching haploblocks for 1049 individuals (a Zip file that opens into Excel):

http://www.davidkfaux.org/X-Segment-FauxV2.zip

PLINK users website:

http://pngu.mgh.harvard.edu/~purcell/plink/res.shtml

PLINK: A toolset for whole-genome association and population-based linkage analyses (Purcell et al., 2007):

http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1950838&blobtype=pdf

Human Population Studies – X-STRs and Alu Insertions

DXS10079, DXS10074 and DXS10075: new alleles and SNP occurrence (Hering et al., 2007) – Article relating to the STR markers tested by FTDNA:

http://www.excli.de/vol6/Hering06-07proof.pdf

A novel polymorphic Alu insertion embedded in a LINE 1 retrotransposon in the human X chromosome (DXS225): identification and world population study (Pereira et al., 2006):

http://www.funpecrp.com.br/gmr/year2006/vol1-5/gmr0209_full_text.htm

The X chromosome Alu insertions as a tool for human population genetics: data from European and African human groups (Athanasiadis et al., 2007):

http://www.nature.com/ejhg/journal/v15/n5/pdf/5201797a.pdf

Human Population Studies - SNPs

The X chromosome in population genetics:

http://www.broad.mit.edu/~sfs/nrg_Xchrom.pdf

Study of migration as assessed by X haploblocks:

http://www.biomedcentral.com/content/pdf/1471-2156-9-76.pdf

Admixed individuals and haplotype blocks:

http://genome.cshlp.org/content/18/4/676.full.pdf+html

Reconstructing Genetic Ancestry Blocks in Admixed Individuals:

http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B8JDD-4R30166-2&_user=10&_coverDate=07%2F31%2F2006&_alid=844209488&_rdoc=6&_fmt=high&_orig=search&_cdi=43612&_sort=d&_docanchor=&view=c&_ct=15&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=0cb38c0a85e7fb8ba41bd55311ac4911

X-chromosome as a marker for population history: Linkage disequilibrium and haplotype study in Eurasian populations (Laan et al., 2005):

http://email.eva.mpg.de/~paabo/pdf1/Laan_XChromosome_EJHG_2005.pdf

Worldwide human relationships inferred from genome-wide patterns of variation (Li et al., 2008) – e.g., closest genetic links between Native Americans and Asians – chromosome X and autosomes + Supplemental materials:

http://www.sciencemag.org/cgi/reprint/319/5866/1100.pdf

http://www.sciencemag.org/cgi/data/319/5866/1100/DC1/1

Linkage disequilibrium patterns vary substantially among populations (Sawyer et al., 2005):

http://info.med.yale.edu/genetics/kkidd/441.pdf

Haplotype blocks, linkage disequilibrium and ancient ancestry:

http://www.genetics.org/cgi/reprint/170/4/1849

Significant variation in haplotype block structure but conservation in tagSNP patterns among global populations (Gu et al., 2007):

http://info.med.yale.edu/genetics/kkidd/453.pdf

Resources available from the Kidd lab:

http://info.med.yale.edu/genetics/kkidd/contents.html

Archaic Asian ancestry on the X chromosome:

http://mbe.oxfordjournals.org/cgi/reprint/22/2/189

Divergent haplotypes and human history as revealed in a a worldwide survey of X-linked DNA sequence variation (Shimada et al., 2007):

http://mbe.oxfordjournals.org/cgi/reprint/24/3/687

Accelerated genetic drift on chromosome X in the human dispersal out of Africa:

https://secure.nature.com/ng/journal/vaop/ncurrent/pdf/ng.303.pdf

On the number of New World founders: A population genetic portrait of the peopling of the Americas (Hey, 2005):

http://biology.plosjournals.org/archive/1545-885/3/6/pdf/10.1371_journal.pbio.0030193-S.pdf

Sex-biased evolutionary forces shape genomic patterns of human diversity:

http://www.plosgenetics.org/article/info%3Adoi%2F10.1371%2Fjournal.pgen.1000202

Study of regions of extended homozygosity provides a powerful method to explore haplotype structure in human populations:

http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=2343471&blobtype=pdf

Selected Articles: Autosomal SNP Testing and Population Structure (Ancestry)

World:

Inferring human colonization history using a copying model (Hellenthal et al., 2008):

http://www.plosgenetics.org/article/info:doi%2F10.1371%2Fjournal.pgen.1000078

PCA-correlated SNPs for structure identification in worldwide human populations**:**

http://www.plosgenetics.org/article/info:doi/10.1371/journal.pgen.0030160

Europe:

Analysis and application of European genetic substructure using 300 K SNP information (Tian et al., 2008):

http://www.plosgenetics.org/article/info:doi/10.1371/journal.pgen.0040004

Investigation of the fine structure of European populations with applications to disease association studies (Heath et al., 2008):

http://www.nature.com/ejhg/journal/v16/n12/abs/ejhg2008210a.html

European population substructure: Clustering of northern and southern populations:

http://www.plosgenetics.org/article/info:doi%2F10.1371%2Fjournal.pgen.0020143

East Asia:

Use of autosomal loci for clustering individuals and populations of East Asian origin:

http://info.med.yale.edu/genetics/kkidd/442.pdf

Analysis of East Asia genetic substructure using genome-wide SNP arrays (Tian et al., 2008):

http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0003862

Native American:

Genetic variation and population structure in Native Americans (Wang et al., 2007)**:**

http://www.plosgenetics.org/article/info:doi/10.1371/journal.pgen.0030185

Some of the key information from the above resources is summarized here:

http://davidkfaux.org/X_Facts.pdf

Note that a great deal of important research on X chromosome haploblocks is being completed by genetic genealogists and reported to GENEALOGY-DNA-LIST and Dna-Forums and most recently World Families. The above list is preliminary, and will require a better description categorizing of each resource in order to offer greater utility to this list of resources.

The above compilation includes articles that directly address the X chromosome, and others which although focusing on the autosomes clearly apply to the X.

The author's use of some of the above resources to analyze one of his X haploblocks, possibly reflecting minority Native American (Lower Mohawk) ancestry, can be found here – starting first with the autosomes:

http://davidkfaux.org/Autosomal_NA_Analysis.html

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Please send suggestions for material to include here to fauxdk [at] gmail.com.
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