Naming the Dead – Forensic Identification

Secrets of the Sequence Video Series on the Life Sciences • Grades 9 – 12

Teaching materials developed by VCU Life Sciences.

Virginia Commonwealth University

Classroom Tested Lesson

Video Description

"Secrets of the Sequence," Show 103, Episode 1
"Naming the Dead" – approximately 10:00 minutes viewing time

Genetic science is bringing closure to Bosnian families still missing loved ones after the country's devastating war. Forensic detectives are using the latest DNA analysis techniques to identify bodies and help solve the mystery of what happened to thousands of victims.

Ward Television
Producer: Susan Ladika
Associate Producer: Julie James
Featuring: Gordon Bacon, Chief of Staff, International Commission on Missing Persons; Ed Huffine, DNA Program Director, ICMP; Rijad Konjhodzic, DNA Lab Coordinator, ICMP; John Crews, Deputy DNA Program Director, ICMP
Lesson Author; Reviewers: Susan Walton; Cathie Alder, Catherine Dahl, Dick Rezba, and Selvi Sriranganathan
Trial Testing Teachers: Lynn Visone, Beth Richert

National and State Science Standards of Learning

National Science Standards Connection

Content Standard C: Life Science
As a result of their activities in grades 9 through 12, all students should develop an understanding of:

- molecular basis of heredity.

Content Standard F: Science in Personal and Social Perspectives
As a result of their activities in grades 9-12, all students should develop an understanding of:

- science and technology in local, national and global challenges.

Content Standard E: Science & Technology
As a result of their activities in grades 9-12, all students should understand:

- abilities of technological design and
- understandings about science and technology.

Selected State Science Standards of Learning Connections

Use http://www.eduhound.com (click on "Standards by State") or a search engine to access additional state science standards.

Virginia

BIO.4

The student will investigate and understand relationships between cell structure and function. Key concepts include:

a) characteristics of prokaryotic and eukaryotic cells.

BIO.6

The students will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include:

h) use, limitations and misuse of genetic information;

i) exploration of the impact of DNA technologies.

Texas

Biology (4) Science concepts.

The student knows that cells are the basic structures of all living things and have specialized parts that perform specific functions, and that viruses are different from cells and have different properties and functions. The student is expected to: (A) identify the parts of prokaryotic and eukaryotic cells.

Biology (6) Science concepts.

The student knows the structures and functions of nucleic acids in the mechanisms of genetics. The student is expected to: (A) describe components of deoxyribonucleic acid (DNA), and illustrate how information for specifying the traits of an organism is carried in the DNA.

Overview

It is now common practice to use nuclear DNA analysis for forensic identification. Technological advances, including automation, have improved the accuracy and speed with which such determinations have been made. But there is another source of DNA that can be used for forensic purposes – the mitochondria.

Mitochondria are the cellular organelles that are responsible for the release of energy from food and changing the energy into adenosine triphosphate, or ATP, the chemical energy used for cellular reactions. The current theory for the origin of mitochondria is that they were once prokaryotic cells that developed a symbiosis with eukaryotic cells. The mitochondria entered the eukaryotic cells, receiving a protected environment and returned a supply of energy. The DNA of the prokaryotic cells was a circular structure. This circular DNA structure is still found in the mitochondria of eukaryotic cells and is known as mtDNA.

While mtDNA contains only a small amount of DNA, it can still be a very useful tool for analysis. Each cell has multiple mitochondria and each mitochondria carries several copies of mtDNA. Cells that use a great deal of energy will have more mitochondria – up to 2500 for a muscle cell. Cells that use less energy may have as few as 500 mitochondria. Either way, each cell provides a great deal of mtDNA for analysis.

Mitochondrial DNA is inherited only from the mother, which allows analysis to establish a specific maternal lineage. Both egg and sperm contain mitochondria, but most of the sperm's mitochondria are near the flagella, which is lost as the sperm enters the egg.

Thus, mtDNA can only be used to connect an individual to his or her mother and any related individuals (the missing individual's siblings, maternal aunts and uncles, etc). If the missing individual is a woman, her children's mtDNA can also be used to identify her. However, if the missing individual has no maternal relatives (and in the case of a missing woman, no children) available to supply DNA, mtDNA would not be able to identify him or her. Another technique may be used in this instance for a missing man who has a living father, son, or other paternal relative. This technique looks at the male Y chromosome for Y-STR (short tandem repeat) markers and Y-SNP (single nucleotide polymorphism) testing. Both Y chromosome and mtDNA analysis are also used to study worldwide migration of the human population.

The following quote from the inventor of the first test in 1984 to use mtDNA for forensic identification is truly appropriate for the Srebrenician families, for whom perseverance is a key factor leading to the identification of loved ones.
"I think there are two keys to being creatively productive. One is not being daunted by one's fear of failure. The second is sheer perseverance." Dr. Mary-Claire King

Testing: A sample related multiple choice item from State Standardized Exams

Cell Organelles and Functions

Kingdom	Metabolism	Control	Covering	Food Production
Fungi	mitochondria	nucleus	cell wall	none
Animalia	mitochondria	nucleus	cell membrane	none
Plantae	mitochondria	nucleus	cell wall	chloroplasts
Protista	mitochondria	nucleus	cell membrane	some with chloroplasts
Monera	ribosomes	DNA strand	cell wall	none

Which of these statements is supported by the data shown in the table?

A Most kingdoms are made up of prokaryotic cells.
B All cells have nuclei for control of cell functions.
C Eukaryotic cells vary in covering and in food production.
D Each of the kingdoms has different organelles for metabolism.

Source: Standards of Learning End of Course Test, Biology, Virginia Department of Education, 2001
Answer: C

Before Viewing

1. Briefly review the structure and function of the mitochondrion.

2. Introduce or review as necessary:
   - DNA and artifacts/samples
   - mtDNA (from mothers, found in energy producing units of cell) and nuclear DNA (unique to individual…1/2 from father, 1/2 from mother.) mtDNA more plentiful, and lasts longer
   - DNA fingerprints
   - DNA variations to determine parentage/identification

3. Ask students to respond to the following questions.
   - Remember how you felt on the day of Sept. 11, 2001, the day of the attack on the World Trade Center. How important do you think it was to the families of the victims to have the remains identified?
     Responses will vary; many students would want to have the remains identified and returned to the families.)

- What are examples of forensic artifacts (items that are used or worn by humans) that identification personnel asked for from the families of the victims of 9/11 in order to obtain DNA samples for identification of bodies?
- Where do you think DNA resides in these artifacts?
- Where do scientists find DNA? Does DNA die or completely disappear at the death of the individual?

4. Optional History Review:
   Discuss the conflict in Bosnia in the 1990's. Most students will know very little about this conflict. It will help to review the basic historical facts of the conflict before viewing the video. Students should know that over the years the region has seen various levels of ethnic conflict and cleansing. Consider assigning the research as preparation for this class. Another option is collaboration – ask your students' history teachers to complete a lesson about Bosnia before you do this lesson. See *Srebrenica* in the Additional Resources section of this lesson plan.

   A good history of the region can be found at http://www.kakarigi.net/manu/briefhis.htm (A Brief History of Bosnia-Herzegovina by Andras Riedlmayer, Harvard University). Several Web sites on the conflict are referenced at http://www.its.caltech.edu/~bosnia/doc/history.html.

   Some questions to ask could include the following:

   - What is ethnic cleansing?
   - Is ethnicity expressed or shown in our DNA?
   - What techniques could be used to identify the remains of a victim of a disaster or conflict?
     clothing and other personal effects, dental records, features found on the bones, DNA

During Viewing

1. START the video.

2. PAUSE the video (4:00 minutes into the video) after the narrator says, "Once the remains are located, they are transported to morgues."

   Ask the following questions:
   - "What happened at Srebrenica?"
     Over 7,000 Muslim men and boys were taken and killed.
   - "What conditions make identifying the remains especially difficult?"
     Mass graves contained numerous victims, graves were sometimes moved, and victims were often mutilated; due to the passage of time much decomposition has occurred)
   - "What are dental records? Why are they unique?"
     Dental records are data collected during dental examination. Tooth arrangement and dental work are unique (or nearly so) for each individual. Additionally, teeth are resistant to fire and decay, so dental records allow for positive identification of damaged remains.

3. RESUME the video.

4. PAUSE the video (6:30 minutes into the video) after the computer explanation of "About DNA" including mitochondrial DNA.

   Show students a map of mitochondrial DNA (see Appendix A). This is just to allow students to appreciate the similarities and differences between nuclear and mitochondrial DNA.

Ask the following questions:

- "How does the complexity of mtDNA compare to nuclear DNA?"
  mtDNA is much less complex than nuclear DNA.

- What other uses might mtDNA have other than for identification analysis?"
  anthropologists are using mtDNA to study human migration and population variations. Also, there are several human diseases associated with mutations of mtDNA.)

Note: One of the trial test teachers noted that these questions were a bit advanced for her class – use your best judgment.

6. RESUME video and play to the end.

After Viewing

1. Summarize the techniques used to identify victims of war crimes in Bosnia.
   - *Bone samples from victims and blood samples from survivors are used.*
   - *The samples are tested for nuclear and mtDNA.*
   - *At least two blood donors are needed to identify each person.*
   - *If more than one family member is missing, mtDNA cannot differentiate between them.*
   - *It also cannot be used if there are no surviving females in the family.*
   - *In these cases, analysis of the DNA from the male Y chromosome can be used.*

2. Ask: "Can you think of other situations in which these techniques can be used to identify remains?"
   These techniques can be used to identify victims of disasters such as airline crashes and floods, victims of war crimes in other countries, identifying remains of unknown soldiers, verifying remains in historical gravesites.

3. Mitochondrial DNA testing has been used to verify the remains of Jesse James. An article is at http://journalsip.astm.org/PDF/JOFS/JFS4610173/JFS4610173.pdf. Recently Y chromosome testing has been used to explore the relationship between Thomas Jefferson and Sally Hemmings. Resources are available at the Monticello Web site, http://www.monticello.org/plantation/hemingscontro/hemings_resource.html. You may wish to have students visit these two Web sites.

4. Conduct the Student Activity: DNA and Solving Cases of Human Rights Violations

5. Alternatively, you may wish to substitute a Web-based activity on the Russian Romanov royal family. The teacher's guide can be found at: http://www.dnai.org/teacherguide/pdf/ts_romanovs.pdf The Web-based activity is found at http://www.dnai.org/d/index.html

Teacher Notes for the Student Activity: DNA and Solving Cases of Human Rights Violations

Materials

- Copies of the article "The Fire Within: The Unfolding Story of Human Mitochondrial DNA" (see Appendix B)
- Student Handout with mtDNA sequences and pedigree

Procedure

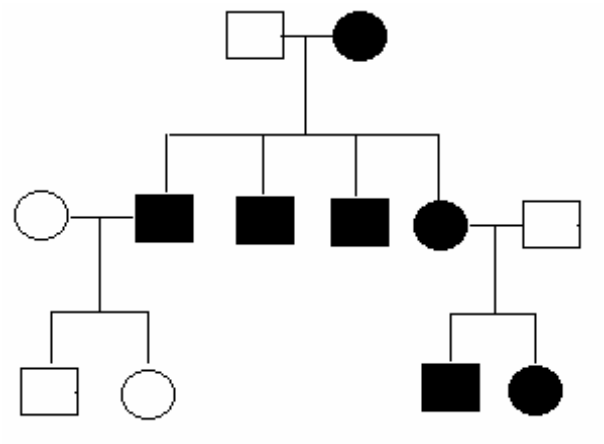
1. Distribute copies of the article to students.
2. Have students read the article and note any information about mtDNA that is new to them.
3. After reading, focus on the section of the article that explains Dr. Mary-Claire King's work in Argentina. Ask: "How can mtDNA research help solve cases of human rights violations?"
4. Distribute the Student Handout with the sample mtDNA segments and pedigree. The sequences are part of an actual mtDNA study in which remains were identified.
5. In the activity students are asked to identify which sequences could belong to the victim's mother, father or a sibling of the victim.
6. Using their knowledge that mtDNA is only passed to offspring through the maternal lineage, students are asked to fill in the pedigree indicating which of the victim's relatives would share the same mtDNA.

Answer Key to questions on Student Handout:

Question 1

Sequences 1 and 3 represent maternal and sibling sequences. They are identical to each other and are identical to the sample sequence. Sequence 2 is the paternal sequence, but because no mtDNA is inherited from the father it does not resemble the victim's sequence.

Question 2



After completing these activities, you may wish to discuss/review the following with the students:

- How would you explain how mtDNA is used to identify victims?
- Where have these techniques been used before?
- How might this technology be used in the future?

Student Handout: DNA and Solving Cases of Human Rights Violations

The mtDNA sequences below represent a bone sample from a victim, a maternal sequence, a paternal sequence and a sibling sequence. Identify the segments that came from the mother and a sibling. Keep in mind that mitochondria come exclusively from the egg and not the sperm; an individual inherits 100% of his/her mtDNA from the mother and none from the father.

DNA sequence from bone sample:

…ACATCGACTGCAACTCCAAAGCCACCCCTCACCCACTAGGATACCAACAAACCTACTCACCC…

1…ACATCGACTGCAACTCCAAAGCCACCCCTCACCCACTAGGATACCAACAAACCTACTCACCC…

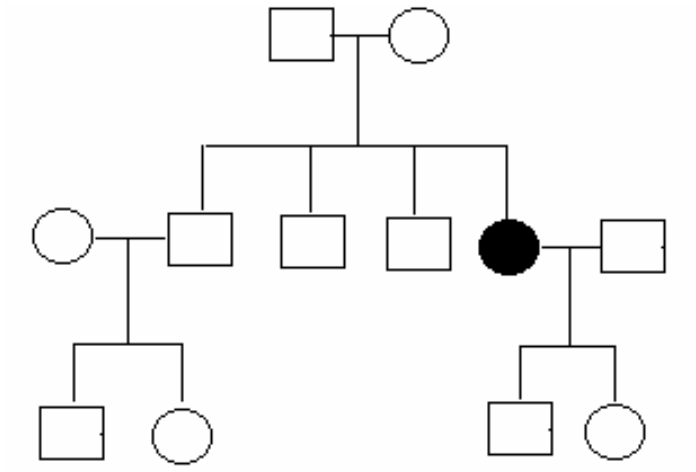
2…ACATCGACTGCAACTCCAAAACCACCCCTCGCCCACTAGGATACCAACAAACCTACCTACCC…

3…ACATCGACTGCAACTCCAAAGCCACCCCTCACCCACTAGGATACCAACAAACCTACTCACCC…

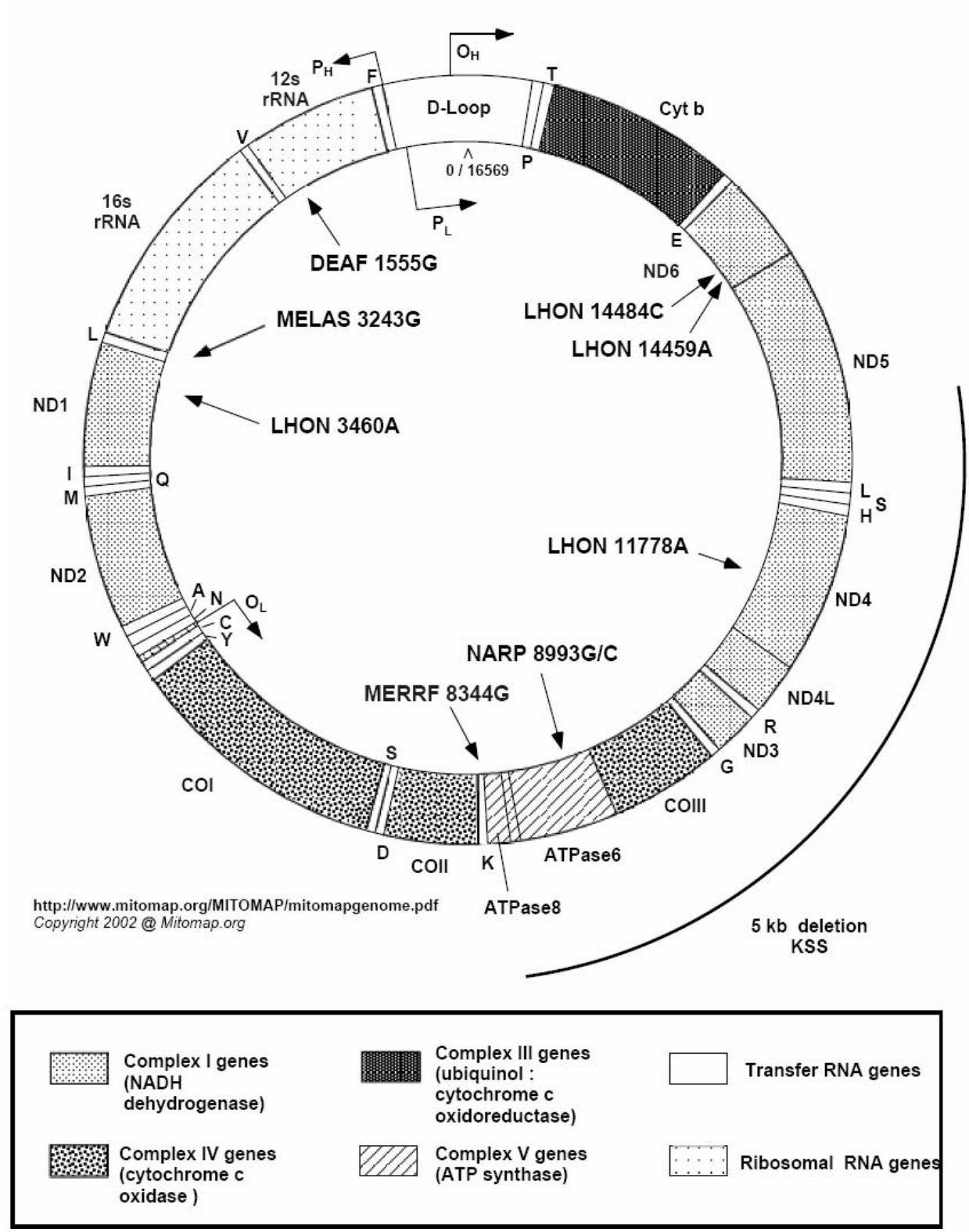
Fill in the following information:

- Which of the above sequences could be the mother? How do you know?
- Which of the above sequences could be the sibling? How do you know?
- Which of the above sequences could be the father? How do you know?

1. Fill in the symbols on the pedigree for all individuals who would have the same mtDNA sequence as the victim. The symbol for the victim is already filled in.



APPENDIX A A Map of Mitochondrial DNA



Appendix B
The Fire Within: The Unfolding Story of Human Mitochondrial DNA by Kenneth R. Miller

Nearly every cell of the human body contains scores of mitochondria, tiny organelles that play a key role in releasing cellular energy. Every student of biology learns (some more willingly than others) that mitochondria are home to a complex series of biochemical pathways, including the Krebs cycle and the electron transport chain (see pp. 123-131 in Biology by Miller & Levine). Mitochondria have always been interesting, ever since they were first recognized as important subcellular organelles by Altmann in 1890. He called them "bioblasts," and suggested that they might be tiny independent organisms within eukaryotic cells. He was wrong about that, but not quite as wrong as biologists once believed.

When sugars are broken down to release energy, most first enter a pathway in the cytoplasm known as glycolysis which produces a modest amount of adenosine triphosphate ATP. The end product of that pathway, pyruvate, enters the mitochondrion and then proceeds into the Krebs cycle. The reactions of the cycle systematically strip high-energy electrons away from the intermediates of the cycle, and these electrons enter the electron transport pathway, which is bound to the inner mitochondrial membrane. The oxygen we breathe serves as the final electron acceptor of the chain. As Peter Mitchell showed, this electron flow produces a proton gradient across the membrane which, like the pressure of water against a dam, can be used to generate energy. The proton "pressure" across the inner mitochondrial membrane produces not electricity but chemical energy in the form of ATP.

If any part of a human cell truly contains what the ancients called "the fire of life," it's the mitochondrion. Interrupt, even for a moment, the flow of electrons to oxygen, and that fire will go out. Indeed, some of the most lethal poisons, including the cyanides, act by blocking mitochondrial electron transport, and that is precisely why they are so deadly. There are a host of connections between the pathways in these tiny organelles and the larger organism, many of which I've shared with my students over the years. However, until very recently, one of those stories was nothing but a minor footnote. It's a footnote no more, and that's why it's the subject of this article: Mitochondria have DNA.

In the early 1960s a number of experiments showed that mitochondria could not be produced by cells de novo, but instead always arose from the division of preexisting mitochondria. In other words, they were self-replicating. By the end of the decade it was clear that mitochondria had their own DNA, and some researchers began to speculate that they might indeed be the semi-independent creatures that Altmann had wondered about. Led by Lynn Margulis (now of the University of Massachusetts), a number of researchers suggested that today's mitochondria are the descendants of ancient prokaryotes that took up residence within eukaryotic cells, and provided them with important biochemical benefits, notably the ability to oxidize food compounds and produce ATP (Biology p. 349). This is an intriguing idea that continues to influence thinking about the evolution of the eukaryotic cell.

How big is mitochondrial DNA? Well, it's not big at all. In fact, human mitochondria DNA (one of the smallest known) is only 16,569 base pairs in length, less than 1/300,000th of the total length of DNA molecules in the nucleus of a human cell. We now know the complete DNA sequence of human mitochondrial DNA. It codes for ribosomal RNAs and transfer RNAs used in the mitochondrion, and contains only 13 recognizable genes that code for polypeptides. It's not a very impressive piece of DNA, although it is efficient Ñ nearly every part of the molecule is transcribed, and there is precious little unused space between the genes. What are those 13 genes? Each codes for a different polypeptide that makes up part of the electron transport chain in the inner mitochondrial membrane. It looks as though the location of these genes inside the mitochondrion makes it easier for their gene products, including some nearly insoluble polypeptides, to be inserted into the inner mitochondrial membrane.

This is interesting enough, but it's hardly the stuff of medical mystery or international intrigue. At least that's the way things were. They may never be the same.

A few years ago, Doug Wallace, a researcher at Emory University in Atlanta, was puzzled by an unusual inherited

disorder known as Leber's Hereditary Optic Neuropathy ("Leber's" for short). Leber's results in a rapid loss of vision that usually begins in adolescence and can result in total blindness due to degeneration of the optic nerve. Leber's runs in families, so it had long been suspected as a genetic disorder, but there were two puzzling aspects to the disorder. First, the disorder was highly variable, causing complete blindness in some people and only minor loss of vision in others. Second, and most puzzling, was the fact that only women seemed to be able to pass the disorder along to their children. The children of men with Leber's never inherited the disorder, but the children of women with Leber's very often did. This did not mean that Leber's was sex-linked. Remember that sex-linked genes, although they are expressed more frequently in men, may be inherited from either parent, since they are carried on the X-chromosome. These two characteristics -- variable effect and maternal inheritance -- seemed to violate Mendel's principles of genetics. Wallace, and everyone else who had worked on Leber's, was puzzled.

What could account for this strange pattern of inheritance? Wallace was familiar with work on human mitochondrial DNA, and he wondered whether there was a chance that Leber's might be due to a mitochondrial gene. Using restriction enzymes to analyze fragments of mitochondrial DNA, he discovered that Leber's patients had a point mutation -- a single DNA base change – in their mtDNA that normal patients did not. Of what possible consequence could this single altered base be? Well, as it turns out, the base change changed a single codon in the gene for a protein in the electron transport pathway. When the slightly altered mRNA from this gene is translated, a single amino acid in the protein is changed. The protein still works, still transfers electrons, but it's just a bit less efficient.

This reduced efficiency of electron transport, which slightly lowers the rate at which ATP can be made, is at the heart of Leber's. In a connection still being worked out, Wallace and his coworkers theorize that the tiny defect becomes critical only in cells with very high demands for ATP. Such cells include the neurons of the optic nerve. Late in adolescence, a few of the cells in the nerve cannot keep up with ATP demand, weaken, and die. This increases the load on the remaining nerve cells until an increasing number of them malfunction, resulting in total blindness, first in one and often in the other. As interesting as this was, the most interesting part of the story may be how the mitochondrial connection fits in with Leber's non-Mendelian inheritance.

When sperm and egg fuse to form a diploid zygote, the new individual gets half of its nuclear genetic information, 23 chromosomes, from each parent. That 50/50 split is the basis of Mendelian inheritance. However, due to the sheer size of the egg cell, all (or nearly all) of the mitochondria in the embryo come from the mother. In other words, mitochondrial inheritance is maternal, and that's why Leber's is passed only from mother to child. What about the variability of Leber's? Well, if a particular allele is located, say, on chromosome #7, since we carry two copies of chromosome #7, one carries 0, 1, or 2 copies of the allele. Those are the only possibilities, barring a major chromosomal rearrangement. This is not the case for mitochondria. An egg cell contains more than 1,000 mitochondria, each with its own DNA "mini-chromosome." This means that several mitochondrial genotypes may exist side-by-side in the egg. Furthermore, because mitochondria are not carefully separated by the mitotic spindle (as chromosomes are), a mixture mitochondria are randomly split between two daughter cells during mitosis.

Wallace suspected that this meant that Leber's variability might simply be due to the percentage of defective mitochondria carried by an individual. Sure enough, his clinical studies revealed that individuals suffering from Leber's-induced blindness carried more than 70% defective mitochondria, while those with milder forms had no more than 30%. Apparently, the presence of a large number of "healthy" mitochondria can compensate for the loss of respiratory efficiency in those carrying the Leber's base change as long as there are enough of them around.

The Leber's story is not unique. In the last few years at least 6 genetic disorders have been traced to mitochondrial DNA, and there is no doubt that more will be discovered. To date, the discovery of the causes of these disorders has not resulted in treatments, but there are many possibilities to investigate. It's not at all improbable to speculate that in the near future individuals who carry the Leber's defect may wish to have their egg cells undergo an injection of "healthy" mitochondria to ensure that their children will not suffer premature blindness. Other therapies are possible, too, all made possible by the recognition that within there is a second, tiny genome in these remarkable organelles. The mitochondrial story provides a superb example of the links between molecular biology, genetics, neurobiology, and medicine. It also opens a new way to study inheritance, which has already had application in some surprising areas. And that's the next part of the story.

It is unfortunately true that the 20th century has been home not only to a series of flourishing democracies, but also to a number of brutal and repressive dictatorships around the world. We can be thankful that many of these regimes have fallen in the past few years, but in many cases they have left behind some appalling human wreckage after many years in power. One case in point is found in Argentina, where a new democracy is struggling with the legacy of a long-standing military dictatorship. The military's techniques for staying in power included the routine kidnapping, torture, and murder of political opponents. An estimated 12,000 people were killed during this reign of terror. In most cases, the victims were simply snatched from the streets and vanished from view. More than 200 children were either kidnapped along with their parents, or born to them in captivity. Now that democracy has been restored to Argentina, the families of the disappeared have begun a frenzied search to find out what happened to their loved ones.

In many cases there are no records to help them, and the only evidence of the disappeared are mass graves containing hundreds of bodies. The families of the disappeared are eager to identify the remains of their relatives, of course, but they are particularly eager to find their disappeared grandchildren. Many of these children were literally stolen from their parents, and sold on an active black market for babies.

As you may know, it is possible to identify individuals by means of unique sequences in their DNA. Because such sequences are inherited, they can also be used to establish family relationships. At first, molecular biologists tried to use such techniques to identify the children of the disappeared and to match them with their grandparents. However, after a few successes, they ran into a problem. In most cases the closest living relatives of the disappeared are their grandmothers. Unfortunately, a given DNA sequence has only a 50% chance of being passed from parent to child, so that all 4 grandparents would have to be checked for a match to the DNA sequence of a particular child. Where one or two of the four grandparents were missing or deceased, definitive identification was often impossible. Could there be a better way? Perhaps a DNA sequence that was always passed from mother to child?

No doubt, you already have the answer. So did Mary-Claire King, a molecular geneticist from Berkeley. Realizing that DNA sequences in mitochondria were passed directly from mother to child, she searched mitochondrial DNA until she found a 600-base pair region in which the variability from one individual to another was so great that they could be used to link mother and child unambiguously. Because mtDNA is passed directly from grandmother to mother to child it serves as a perfect recognition marker to establish identity. Supported by private foundations and the new Argentine government, Dr. King organized a systematic study of mtDNA from the grandmothers, and has now begun to use this data to identify the children of the disappeared. Mary-Claire King's work has won her international recognition and acclaim, as well as the thanks of scores of families who now have a chance to identify their missing children.

The fact that the tiny mitochondrial genome, unlike the much larger nuclear genome, is directly transmitted through the maternal line, makes it an ideal piece DNA with which to trace family lineage's. Small families, and large ones, too. The last few years have seen an extraordinary number of studies on the relationships of human population groups throughout the world. These studies have approached important questions, not the least of which is how long ago the great native populations of Africa, Europe, and Asia diverged from each other. The genetic markers used for these studies, naturally enough, are mitochondrial DNA.

It's already clear that mtDNA has become a powerful too for analyzing relationships in humans and other animals, and that the influence of mitochondrial genetics on human health can be substantial. These tiny organelles within our cells may indeed be the remnants of ancient strangers, as Lynn Margulis has suggested, and the fire of life which they represent has only just begun to fire human curiosity about their miniature world.

Additional Resources

Because Web sites frequently change, some of these resources may no longer be available. Use a search engine and related key words to locate new Web sites.

Forensics
DNA Forensics
http://www.ornl.gov/TechResources/Human_Genome/elsi/forensics.html

Use of DNA in Identification
http://www.accessexcellence.org/AB/BA/Use_of_DNA_Identification.html

Forensic Use of Mitochondrial DNA – helpful in understanding pedigree exercise (see Student Activity)
http://www.people.virginia.edu/~rjh9u/mitodnaforensic.html

Mitochondrial DNA

Mitochondrial DNA Analysis at the FBI Laboratory
http://www.fbi.gov/hq/lab/fsc/backissu/july1999/dnatext.htm#Back%20to%20text,%20Figure%201

MITOMAPA human mitochondrial genome database
http://www.mitomap.org/

Genetic Origins: The Mitochondrial Control Center
http://www.geneticorigins.org/geneticorigins/mito/mitoframeset.htm

Holland, M.M. et al, Mitochondrial DNA Sequence Analysis of Human Skeletal Remains:
Identification of Remains from the Vietnam War
http://www.bodetech.com/documents/44.pdf

Y Chromosome Testing

Y-Chromosome STRs
http://www.cstl.nist.gov/biotech/strbase/y_strs.htm

Y-Chromosome Links
http://john.hynes.net/y.html

The Y Chromosome in the Study of Human Evolution, Migration and Prehistory
http://www.ucl.ac.uk/tcga/ScienceSpectra-pages/SciSpect-14-98.html

Srebrenica

Bosnia mass grave reveals secrets
http://www.cnn.com/2002/WORLD/europe/07/23/bosnia.grave/index.html

The Scientist “Identifying Those Remember”
http://www.the-scientist.com/yr2002/jun/profile_020610.html

Mary-Claire King

King’s Science also Serves Human Rights
http://www.washington.edu/alumni/columns/sept96/king2.html

Mary-Claire King, Inventor of the Week
http://web.mit.edu/invent/iow/king.html

Genomic Revolution
http://www.ornl.gov/sci/techresources/Human_Genome/education/education.shtmL
This Web site of the government-funded Human Genome Project has links about genomics, the history of the project, and more.

Secrets of the Sequence Videos and Lessons
This video and 49 others with their accompanying lessons are available *at no charge* from www.vcu.edu/lifesci/sosq