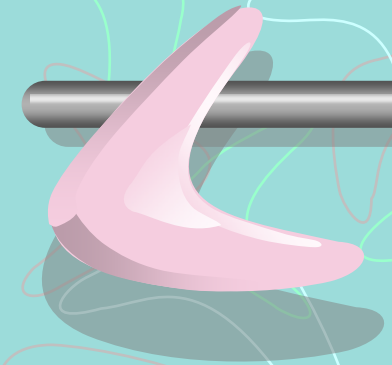
DNA as a Biometric Identifier



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DNA, a biometric?

DNA differs from standard biometrics in several ways:

- **DNA requires a tangible physical sample as opposed to an impression, image, or recording.**
- **DNA matching is not done in real-time, and currently not all stages of comparison are automated.**
- **DNA matching does not employ templates or feature extraction, but rather represents the comparison of actual samples.**

Why DNA?

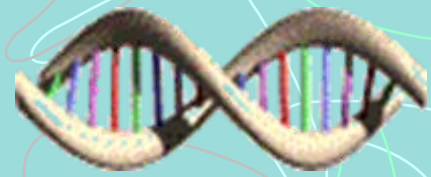
- DNA is unique to every individual on the planet
  - Only identical twins share the same DNA
- It can be easily obtained from a variety of sources
- It is readily used in forensics to match crime scene evidence to individuals
- It does not change during the life!

DNA Sources

- Paper or plastic cup
- Glass
- Ear wax
- Fingernail clippings
- Socks
- Urine
- Licked stamps
- Cheek swabs
- Sweaty t-shirts
- Hair with roots
- Hair without roots

- Dried blood
- Whole blood
- Chewed gum
- Dental floss
- Cigarette butts
- Used tissue
- Dried skin
- Used razor
- Other biological specimens

DNA Basics

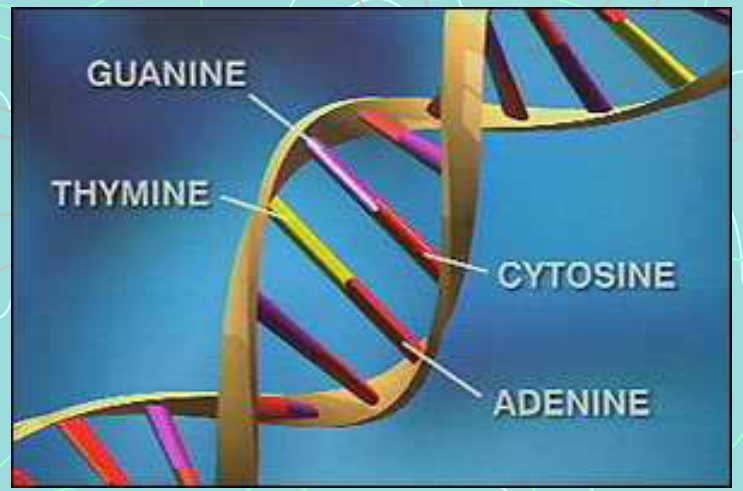


Think back to high school biology!

- Double-stranded helical molecule resembling a twisted ladder
- Sugar and phosphate backbone and nucleic acid interior
- Found in the nucleus of all cells (there is also DNA in the mitochondria of cells)
- Bundled into chromosomes
- Chromosomes replicate each time a cell divides

DNA Basic (con't)

- Only 4 nucleic acids (nucleotides) comprise the genetic code of DNA
  - (A)denine
  - (C)ytosine
  - (T)hymine
  - (G)uanine
- Base Pairing! A-T and G-C
- 3 billion such the pairs in DNA



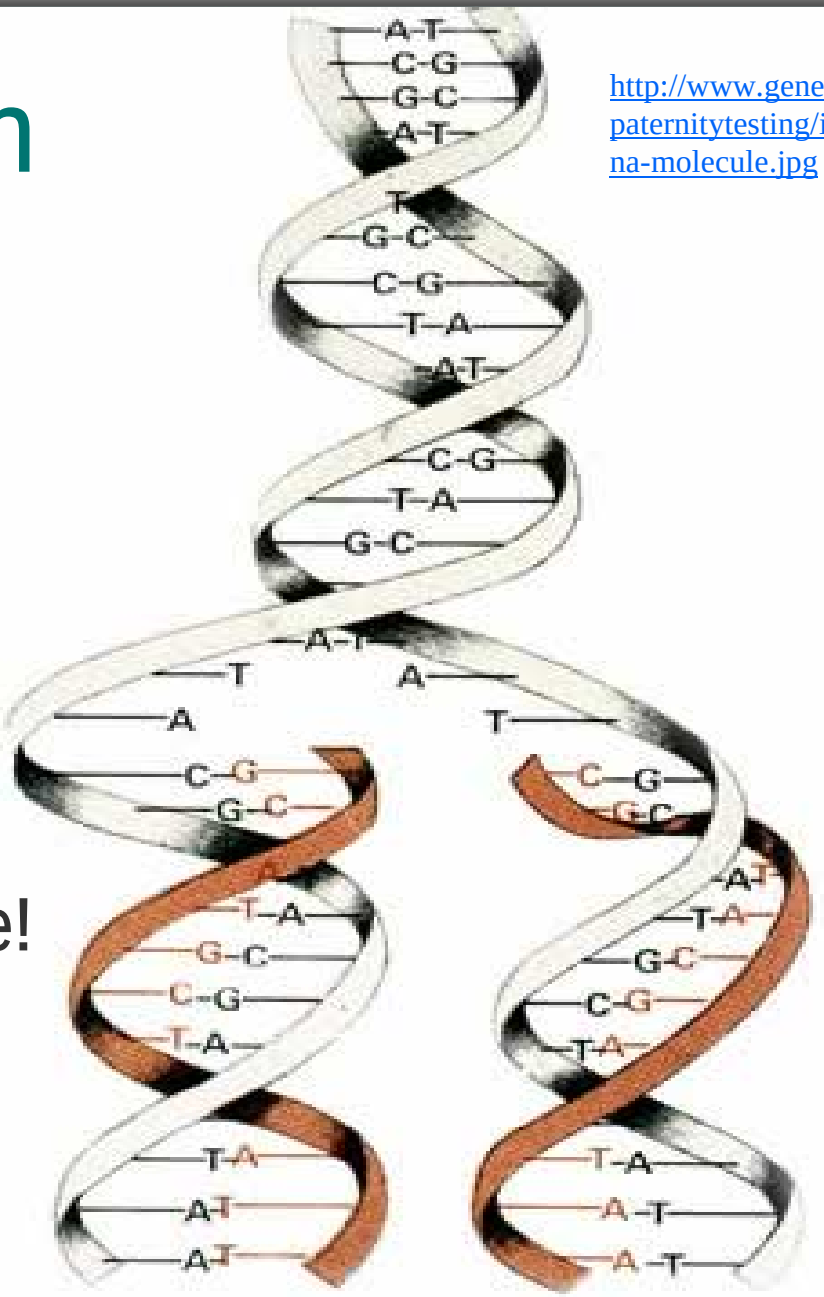
A T A G G C T A T T T C A

T A T C C G A T A A A G T

http://www.don-lindsay-archive.org/creation/dna.jpg

DNA Replication

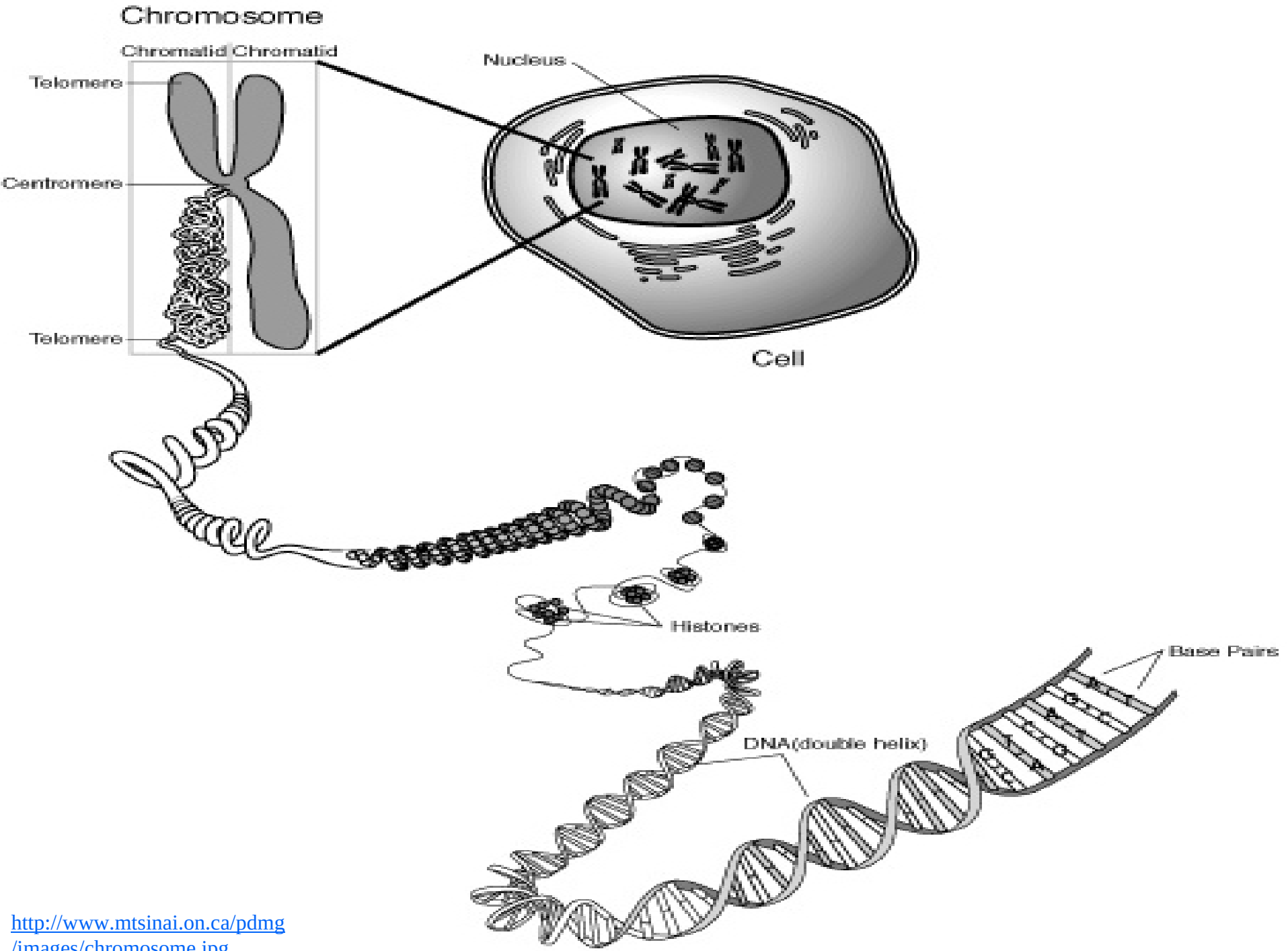
During replication, the two DNA strands separate, or denature, and a new complementary strand is constructed using the exposed bases as a template!



http://www.genelex.com/paternitytesting/images/dna-molecule.jpg

Human DNA

- Humans have 23 homologous (“pairs of”) chromosomes resulting in 46 total
  - One set of 23 from each parent is passed on to offspring.
  - 99.7% of human DNA is shared.
  - 0.3% (~ 1 million nucleotides) is variable!
  - This variability is inherited and is therefore unique to each individual.
  - These variable regions, called Short Tandem Repeats (or STRs), can be examined to distinguish one person from another.



http://www.mtsinai.on.ca/pdmg/images/chromosome.jpg

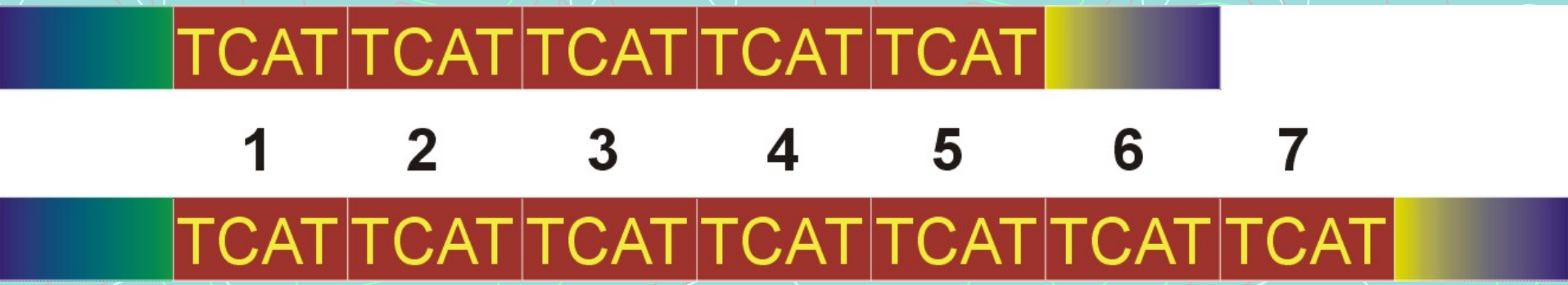
STRs (Short Tandem Repeats)

- In order to distinguish one person from another using DNA, you need highly variable segments of DNA.
- In the early 1980s, several highly variable regions were discovered that could be used to tell individuals apart!
- Today, there are 13 such regions that are used in DNA profiling.

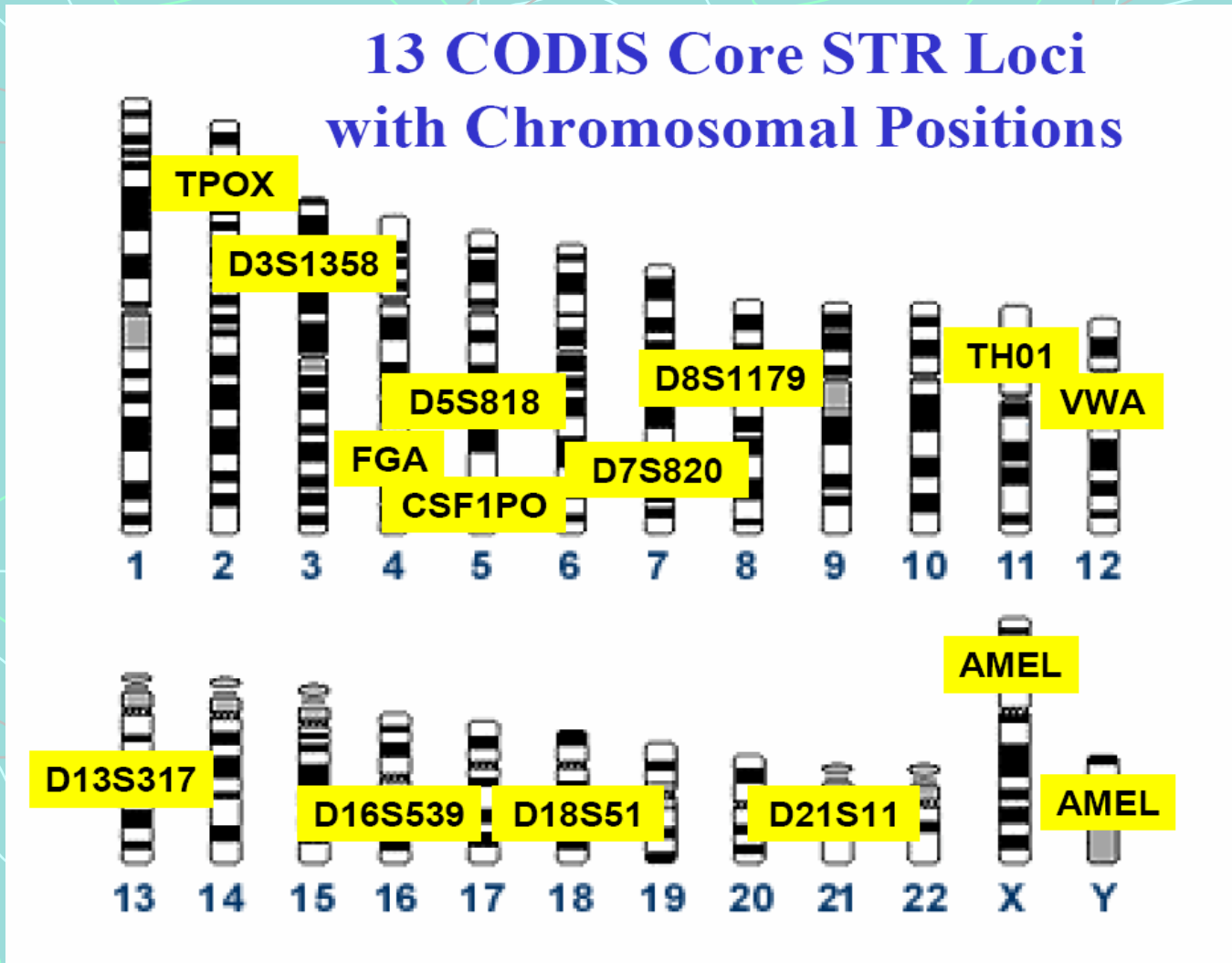
How do STRs work?

- At each of the 13 regions (or loci), there is a repeated sequence that is variable in length between individuals.
  - ACCT repeated at one locus, or TTTC repeated at another
- The number of repeats at each location can be measured during DNA sequencing.
- Each number of repeats has statistics associated with it that can be compared to the population.
- The Product Rule can be used to multiply the statistics for all 13 regions, yielding a highly individualizing result.
- Most DNA profiles give odds of sharing a profile with another person on earth as about one in a trillion!

Example STR result for a single locus



http://www.rechtsmedizin.uni-mainz.de/Remedneu/molgen/Repeat.jpg


13 CODIS Core STR Loci
with Chromosomal Positions
TPOX
D3S1358
D5S818
FGA
CSF1PO
D7S820
D8S1179
TH01
VWA
1 2 3 4 5 6 7 8 9 10 11 12
D13S317
D16S539
D18S51
D21S11
AMEL
AMEL
13 14 15 16 17 18 19 20 21 22 X Y

Cracking the DNA code!

3 Important Steps:

- Extract (obtain and isolate DNA from sample)
- Amplify (create multiple copies of the “target sequences”)
- Sequence (obtain unique code of nucleic acid bases from the DNA sample)

Contamination at any of these steps will result in test failure!!!

DNA Extraction

Main Methods of Extraction:

- Organic
- Chelex™
- FTA™ paper (or similar)
- Alkaline

DNA Extraction Methods

- Organic
  - Uses a phenol, chloroform, and several centrifuge steps to separate DNA from cellular debris.
  - Time: 2-3 hours
- Chelex™
  - Uses a boiling step and iminodiacetic beads to bind DNA.
  - Quick, but also not very clean and prone to degradation
  - Time: less than one hour

DNA Extraction Methods (con't)

- FTA™ paper
  - Sample placed directly on paper, allowed to dry, and is washed several times.
  - Paper can then proceed directly to amplification reaction.
  - Time: less than an hour
- Alkaline
  - Sample is dissolved in a strong base such as sodium hydroxide and the DNA is removed via filtering
  - Time: several hours

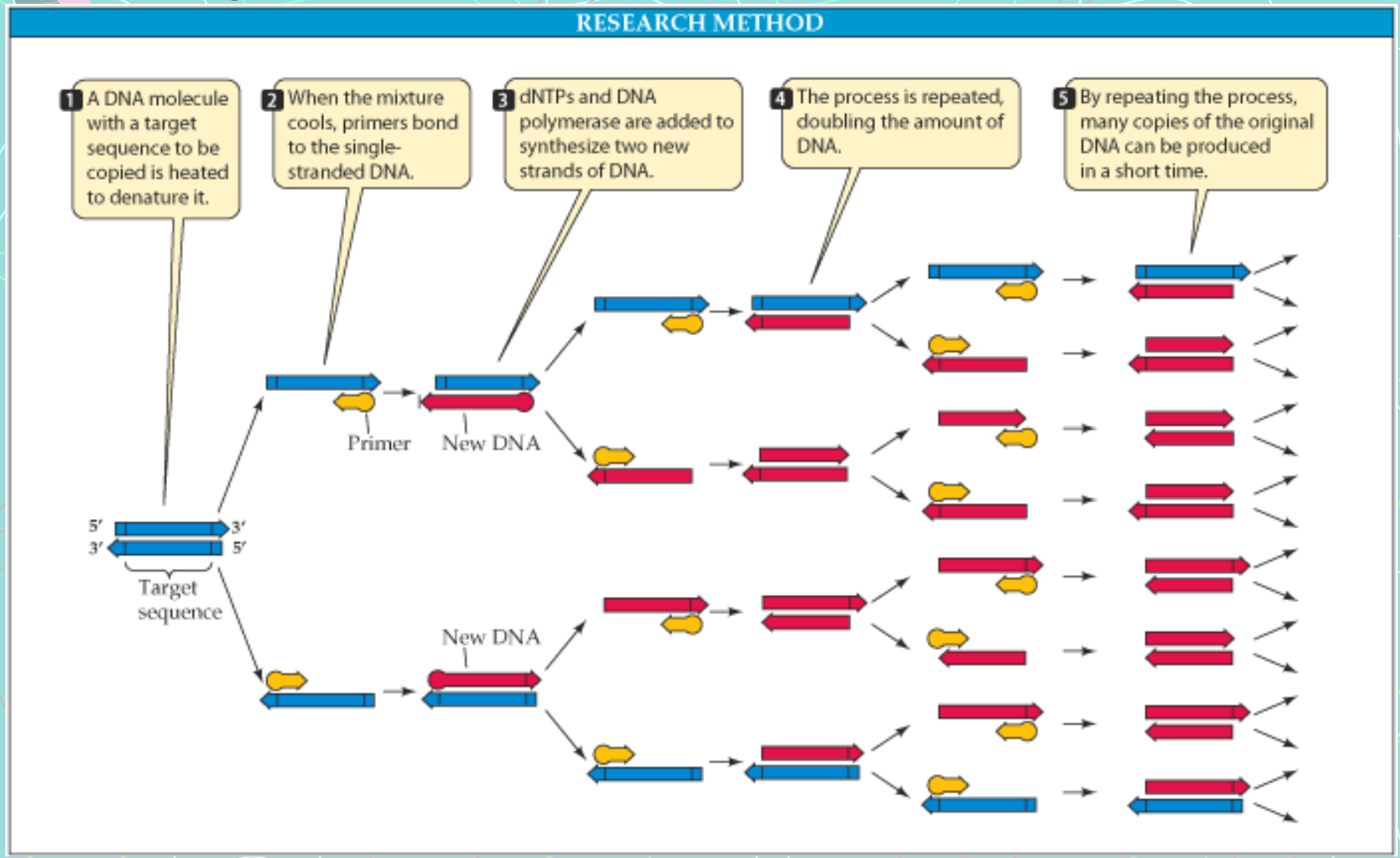
DNA Amplification

- After DNA is isolated from a biological sample, the number of copies must be increased
- DNA must be amplified before proper sequencing can be carried out to ensure enough is present for the reaction

Polymerase Chain Reaction (PCR)

- PCR is an enzymatic amplification of DNA.
- PCR exponentially increases the initial copy number of DNA.
- The reaction requires extracted DNA, primers, a polymerase (the enzyme), free-floating nucleotide bases, and buffer.
- These ingredients, along with a series of temperature increases and decreases, allows for rapid, accurate replication of DNA.
- TIME: 2-3 hours for 32 cycles

Polymerase Chain Reaction



http://bcs.whfreeman.com/thelifewire/content/chp11/f11020.gif

DNA Sequencing

- DNA sequencing is the step that generates a DNA profile.
- Amplified DNA is loaded into the genetic analyzer (sequencer) with fluorescently labeled A, T, C, and Gs attached to the DNA
- An electric current is applied to the system and the DNA migrates past a laser—the bases that pass by the laser are recorded, one at a time, until the entire sequence is recorded.
- Once the data are analyzed, a unique DNA profile can be visualized
- TIME: ~30 minutes per sample

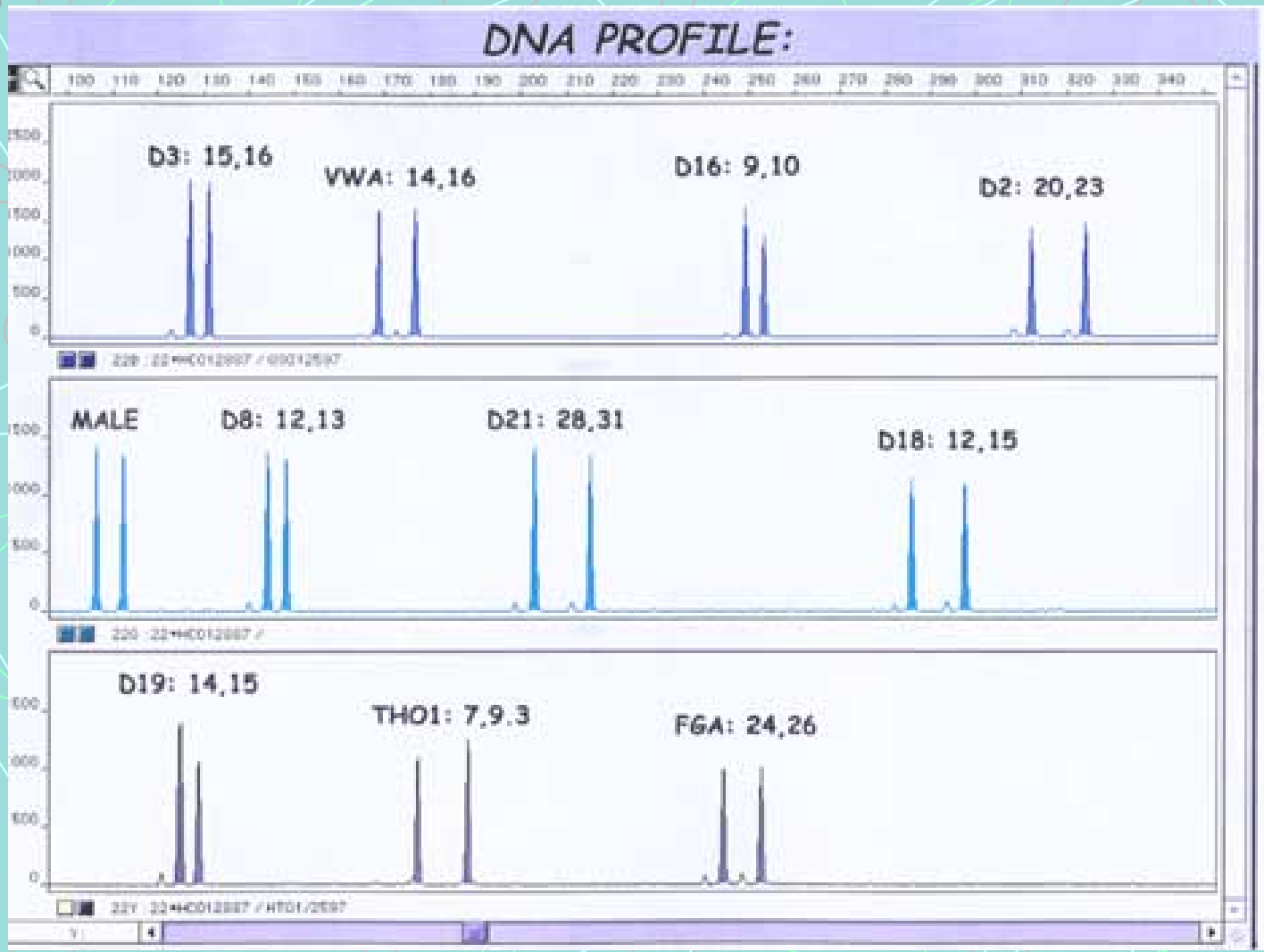
Common Genetic Analyzers

ABI 310

http://www.appliedbiosystems.com/catalog/myab/StoreCatalog/products/CategoryDetails.jsp?hierarchyID=102&category1st=a50&category2nd=a51&category3rd=111903

Hitachi FMBIO II

http://www.helixxtec.com/Hitachi/fmbio.htm



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DNA Profiling Timeline

- Obtaining a sample such as a swab of cheek cells (buccal swab): ~10 seconds
- Extracting DNA: 30minutes – 3 hours
- Amplifying DNA: 2 – 3 hours
- Sequencing DNA: 30 min – 1 hour

Total: minimum of approximately 3 hours

This is unacceptable for biometric use! What can be done??

Advances in DNA Technology

- Extracting DNA
  - New commercial products are available that allow for the rapid collection and extraction of DNA
  - The Bode Technologies Buccal DNA Collector functions similarly to FTA™ paper
  - A scraping of cheek cells can be collected and transferred directly to the PCR reaction tube for amplification, greatly reducing extraction time

TIME: less than 30 seconds

Advances in DNA Technology

- Amplifying DNA
  - Products in the research stage can amplify DNA in minutes rather than hours!
  - The new devices rapidly change temperature, allowing DNA to be copied at a much quicker rate
  - MATCI (Miniature Analytical Thermal Cycling Instrument) is a portable PCR unit that can perform 32 cycles in about 21 minutes!
  - On-chip PCR utilizes glass microchips with sample chambers to perform PCR

TIME: approximately 20 minutes

MATCI device

http://aafs.micronexx.com/PDF/JOFS/JFSCH8315X3/JFSCH8315X3.pdf

Advances in DNA Technology

- Sequencing DNA
  - High-throughput DNA analysis is commercially available with products like the ABI 3730xl.
  - Microchip sequencers in the research phase have small channels etched in them that perform the DNA separation and laser detection.
  - The small distance (~2cm) the DNA travels (opposed to 35cm in standard machines) allows results in as little as 30 seconds
  - High-throughput microchips have also been shown to provide results up to 5 times faster than current machines (Paegel et al.)

ABI 3730xl

http://www.appliedbiosystems.com/catalog/myab/StoreCatalog/products/CategoryDetails.jsp?hierarchyID=102&category1st=a50&category2nd=a51&category3rd=111907

Nanochip™ Microchip

http://www.kpl.gov.tr/image/dnachip11.jpg

Advances in DNA Technology

- New research in microchip technology is aiming to combine DNA amplification and sequencing!
- Adding DNA extraction to the continuous flow microchip is also in the works
- Combining all three steps to obtain a DNA profile is the DNA profiling method of the future, and the one that is most applicable to biometrics

Timeline with new technology

- Obtaining a sample such as a swab of cheek cells (buccal swab): 10 seconds
- Extracting DNA: ~10 seconds
- Amplifying DNA: ~20 minutes
- Sequencing DNA: 30 seconds – 5 minutes

Total: Less than 30 minutes!

Matching DNA Profiles

- CODIS
  - The CODIS System currently in place by the FBI is similar to AFIS
  - Convicted offenders' DNA profiles are loaded into the system to catch repeat offenders and those that commit crimes across state lines
  - Simple matching is the algorithm used to compare profiles
  - A database such as CODIS would be ideal for a biometric DNA database

To Summarize…

- DNA is highly individualizing and has great potential as a biometric identifier
- The nature of DNA and the state of current technology prevents DNA from being an efficient biometric
- New technology and current research have greatly reduced the time required to generate a DNA profile
- Despite the current advances, DNA profiling as a means of biometric identification still falls short of current demand