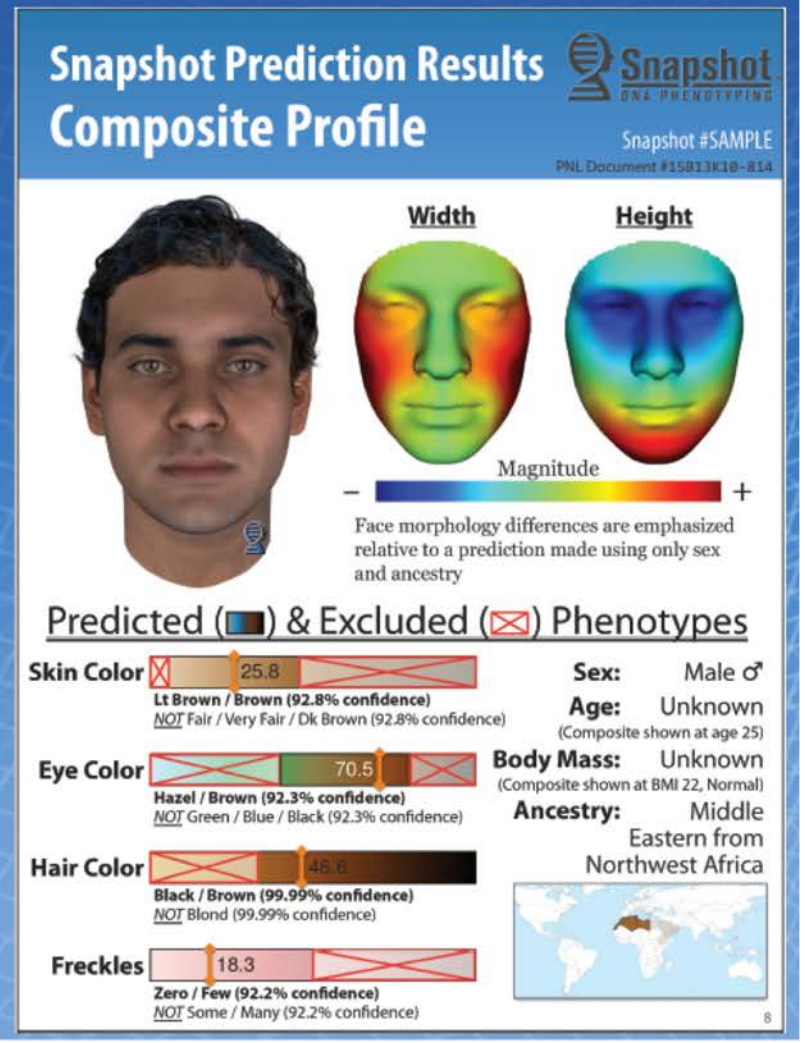
# Parabon® Snapshot® DNA Phenotyping for Sexual Assault Investigations

***Predict the Perpetrator's Ancestry and Physical Appearance from DNA***




Snapshot™
DNA PHENOTYPING

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# DNA Phenotyping

PARABON®

- DNA Phenotyping = predicting an unknown person's physical appearance traits from forensic DNA
- Gives investigators a new way to use DNA
  - Instead of simply a biometric, DNA serves as an objective *genetic witness*
- Phenotyping is ideal for focusing investigative resources in cold cases AND active cases:
  - Narrow a pool of suspects
  - Generate new leads
  - Help identify unknown remains

# Definitions: SNPs vs. STRs

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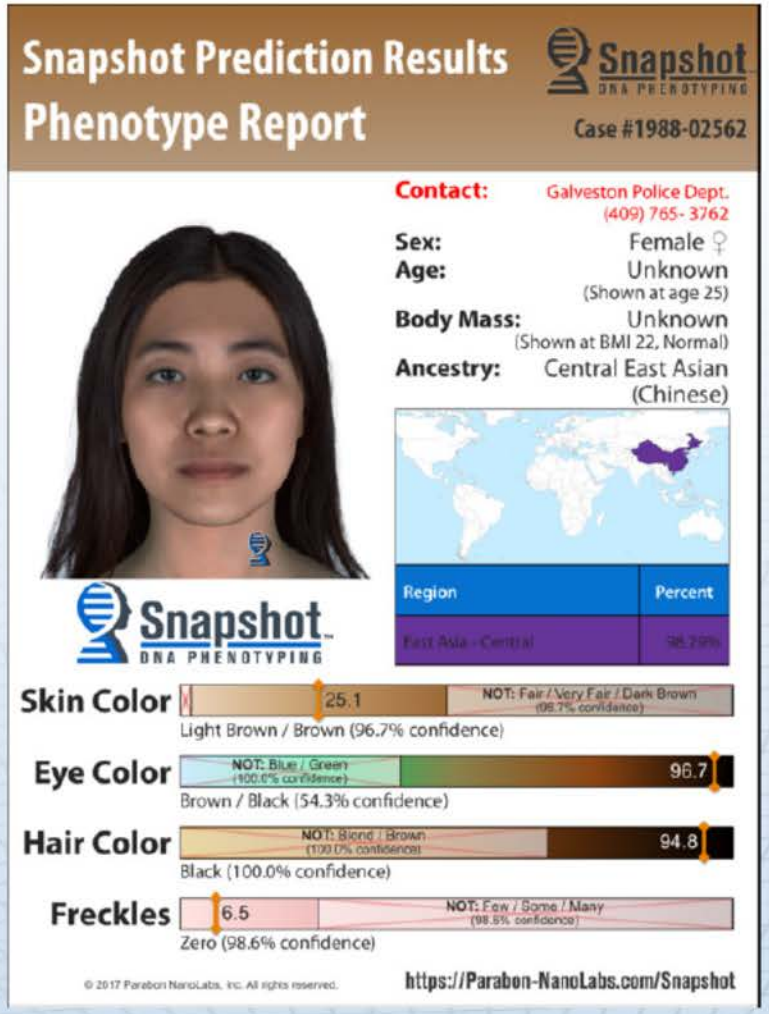
- DNA Phenotyping cannot use an STR profile, as it does not contain the required genetic information
- DNA Phenotyping uses SNPs

| DNA | Current "DNA Fingerprint" Short Tandem Repeats (**STRs**) | New "DNA Blueprint" Single Nucleotide Polymorphisms (**SNPs**) |
|---|---|---|
| | … TCAT **AATG AATG** TTAG … 2 Repeats | |
| | … TCAT **AATG AATG AATG AATG** TTAG … 4 Repeats | |
| | … TCAT **AATG AATG AATG** TTAG … 3 Repeats | |

# Parabon® Snapshot® DNA Phenotyping

PARABON®

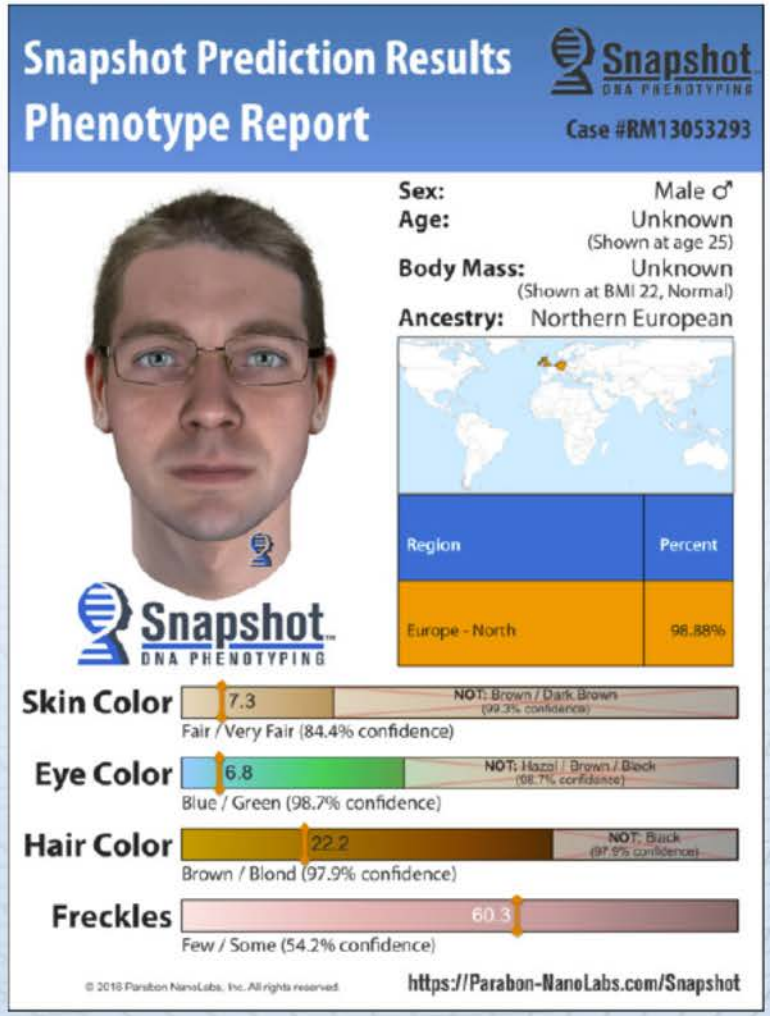
- Funded by the US DOD for anti-terrorism purposes
- Developed over 4 years with access to the DOD supercomputers
- Snapshot is sophisticated bioinformatics software that analyzes data from standard laboratory techniques
  - Microarray chips generate hundreds of thousands of SNP genotypes in a single assay



# Parabon® Snapshot® DNA Phenotyping

PARABON®

- Snapshot predicts:
  - ✓ Ancestry
  - ✓ Skin color
  - ✓ Eye color
  - ✓ Hair color
  - ✓ Freckling
  - ✓ Face morphology [shape]
- Provides confidence statements and reports phenotypes that can be excluded with very high confidence
- Produces a composite image of the subject's possible appearance



# Snapshot Use: Facial Composite

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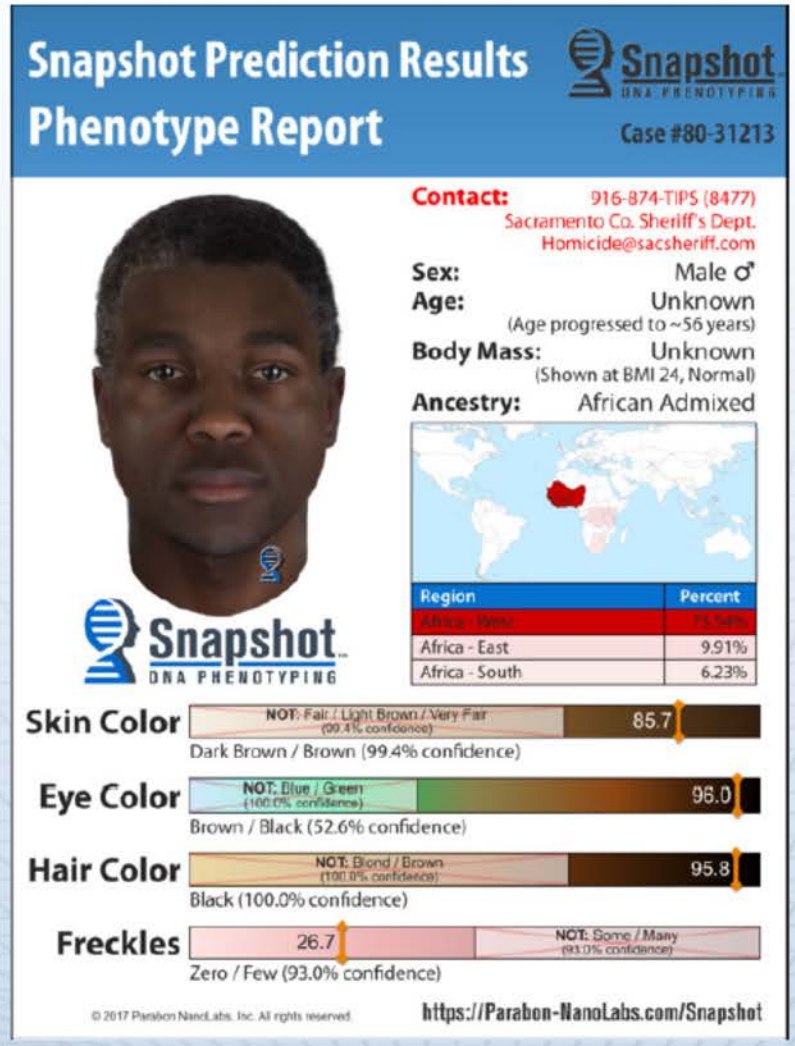
- Snapshot composites are generated at a default age of 25 years and body mass index (BMI) of 22
  - Age progressions can be performed by Parabon's certified forensic artist
  - Predictions can be combined with witness descriptions or other information
- Facial composite is an "illustration"
- Should not be used in facial recognition systems
- Illustration should always be distributed with associated phenotype charts and confidence measures

# Parabon® Snapshot™ DNA Phenotyping

PARABON®

- Information is used in the same manner as information obtained from an eyewitness account
- Once a suspect pool has been narrowed or new leads have been generated, then traditional investigation methods and STRs are used to determine the identity of the individual
- Information derived from Snapshot will not, in and of itself, lead to probable cause for an arrest or search warrant



# DNA Input

PARABON®

- Snapshot can be used with as little as **1 ng** of DNA from any forensic sample type
- Snapshot can handle 2 person mixtures as long as the person of interest is the major contributor
  - Must have minor contributor's single source reference sample if >10% mixture
  - Has successfully been used on many differential extraction samples
  - Can handle 3-person mixtures as long as the above requirements are met and the 3rd contributor is <10%

# Sample Report

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# Snapshot Prediction Results
# Skin Color

Snapshot

Snapshot #SAMPLE

PNL Document #15R13C28-R14

## Background

The skin color model is based on unrelated individuals from a range of ethnic backgrounds. Each subject's melanin index (M-index, a measure of the amount of light absorbed by skin, or skin darkness) was measured objectively using three separate measurements from a reflectance spectrophotometer on the forehead. Outlier values were discarded, and each subject's remaining measurements were averaged. Larger numbers mean darker skin color, with an overall range of 10.367 – 111.033.

The subject is predicted to have **M-index = 42.067**.

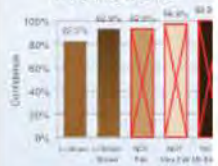
In the range of previously observed prediction values for M-index, this value falls at 25.8%.

This M-index value corresponds to a skin color value of **2.824**.

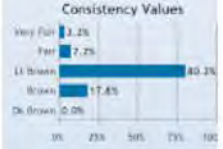
Based on these results, this subject likely self-describes as:

- Has **Light Brown** skin color with 82.2% confidence
- Has **Light Brown or Brown** skin color with 92.8% confidence
- Does not have **Fair** skin color with 92.8% confidence
- Does not have **Very Fair** skin color with 96.8% confidence
- Does not have **Dark Brown** skin color with 99.99% confidence

### Predictions



### Skin Index
Consistency Values




# Snapshot Prediction Results
# Hair Color

Snapshot

Snapshot #SAMPLE

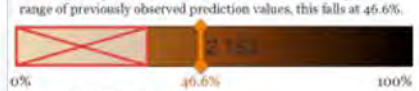
PNL Document #15R13C28-R14

## Background

The hair darkness model is based on unrelated individuals from a range of ethnic backgrounds. The categorical trait values are coded from lightest to darkest, such that Blond = 1, Brown = 2, Black = 3.

The hair redness model is also based on unrelated individuals. The binary trait values are coded as Red = 1 and Not Red = 0.

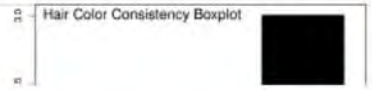
The subject is predicted to have **hair darkness = 2.163**. In the range of previously observed prediction values, this falls at 46.6%.



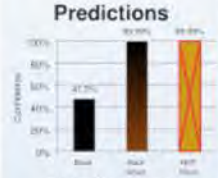

Based on these results, this subject:

- Has **Black** hair darkness with 47.5% confidence
- Has **Black or Brown** hair darkness with 99.99% confidence
- Does not have **Blond** hair darkness with 99.99% confidence

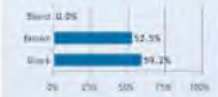
Consistency of this value with the three possible trait values for hair darkness is shown below.




### Predictions



### Hair Darkness
Consistency Values




### Hair Redness
Consistency Values

# Snapshot Prediction Results
# Eye Color

Snapshot

Snapshot #SAMPLE

## Background

The eye color model is based on unrelated individuals from a range of ethnic backgrounds. The categorical trait values are coded from lightest to darkest, such that:

| | |
|---|---|
| Blue | = 1 |
| Green | = 2 |
| Hazel | = 3 |
| Brown | = 4 |
| Black | = 5 |

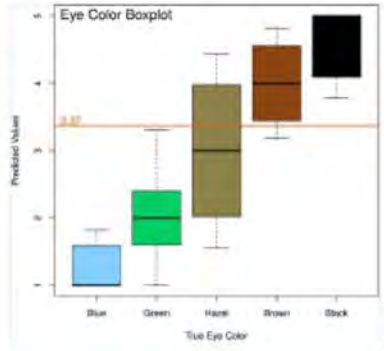
The subject is predicted to have **eye color = 3.370**.

In the range of previously observed prediction values for eye, this value falls at 70.5%.

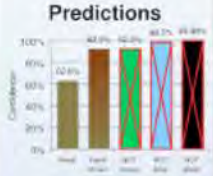
Based on these results, this subject:

- Has **Hazel** eye color with 62.9% confidence
- Has **Hazel or Brown** eye color with 92.3% confidence
- Does not have **Green** eye color with 92.3% confidence
- Does not have **Blue** eye color with 98.5% confidence
- Does not have **Black** eye color with 99.99% confidence

Consistency of this value with the five possible trait values for eye color is shown below.




### Predictions



### Eye Color
Consistency Values

# Snapshot Prediction Results
# Freckles

Snapshot

Snapshot #SAMPLE

PNL Document #15R13C28-R14

## Background

The freckles model is based on unrelated individuals from a range of ethnic backgrounds. The categorical trait values are coded from lightest to darkest, such that:

| | |
|---|---|
| Zero | = 1 |
| Few | = 2 |
| Some | = 3 |
| Many | = 4 |

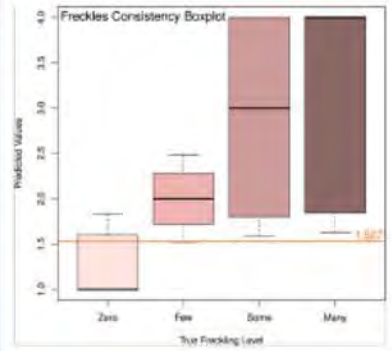
The subject is predicted to have **freckles = 1.527**.

In the range of previously observed prediction values for freckles, this value falls at 18.3%.

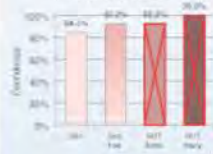
Based on these results, this subject:

- Has **Zero** freckles with 84.3% confidence
- Has **Zero or Few** freckles with 92.2% confidence
- Does not have **Some** freckles with 92.2% confidence
- Does not have **Many** freckles with 99.9% confidence

Consistency of this value with the four possible trait values for freckles is shown below.




### Predictions



### Freckles
Consistency Values

# Snapshot Prediction Results
# Genomic Ancestry

Snapshot

Snapshot #SAMPLE

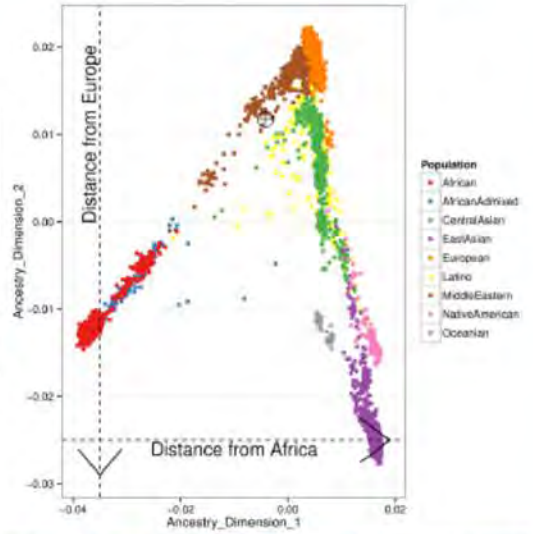
PNL Document #15813K10-814

The genome for this subject best matches Northwest African ancestry. The evidence supporting this conclusion follows.

Partitioning this genome according to its proportional membership in the seven continental regions yields:

| Region | Percent |
|---|---|
| Middle East | 91.87% |
| Africa | 8.08% |
| Americas | ** |
| Central Asia | ** |
| East Asia | ** |
| Europe | ** |
| Oceania | ** |

** - No significant ancestry from this population




On a global scale, this genome clusters with known Middle Eastern individuals (brown points on the top right plot).

This individual shows primarily Middle Eastern ancestry with a small amount of African ancestry. These proportions are also shown on the map to the right. This ancestry is common within the Northwest and Northeast African regions of the Middle East.

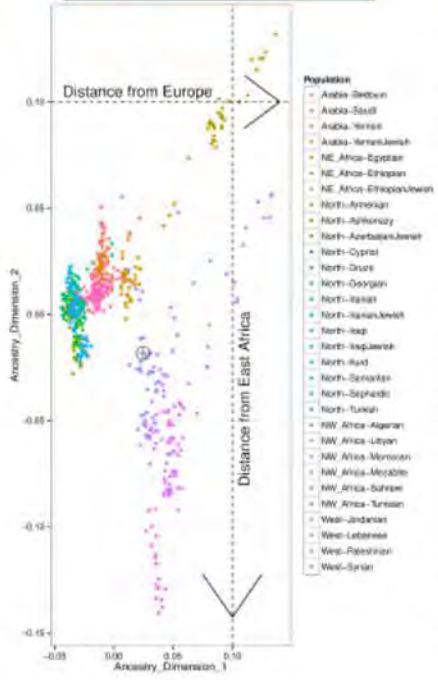
# Snapshot Prediction Results
# Genomic Ancestry

Snapshot

Snapshot #SAMPLE

PNL Document #15813K10-814

Partitioning analysis within the Middle East and Africa yields the following results:




| Region | Percent |
|---|---|
| Middle East - NW Africa | 60.32% |
| Middle East - Arabia | 18.51% |
| Middle East - NE Africa | 11.81% |
| Europe - South | 5.26% |

This individual primarily shows ancestry from Northwest Africa, with smaller contributions from Arabia, Northeast Africa, and South Europe. Although there was inferred to be some African ancestry on a global scale, no African regions show significant ancestry, indicating that this global ancestry can most likely be explained by the intermediate ancestry common to the Northwest Africa region due to its geography and history, rather than genuine admixture. In the Snapshot ancestry database, this pattern closely matches 22 individuals, 100% of whom are Northwest African, representing 10.3% of Northwest African subjects.

The principal component plot at the left shows only subjects from the Middle East. It can be loosely interpreted as generally showing increasing distance from Europe from left to right and increasing distance from East Africa from top to bottom. This subject (crosshairs) clusters with subjects from Northwest Africa (purple points).

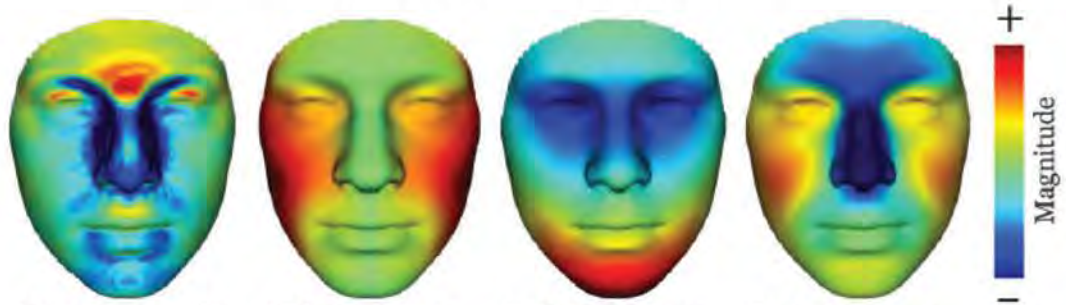
Northwest Africa includes subjects from the following populations: Algerian, Libyan, Moroccan, Mozabite (a Berber group living in Algeria), Sahrawi (Western Sahara), and Tunisian. Arabia includes Bedouin, Saudi, and Yemeni subjects. Northeast Africa includes subjects from Egypt and Ethiopia. South Europe contains subjects from the Greek, Italian, Sardinian, Swiss Italian, and Tuscan populations.

# Snapshot Prediction Results
# Face Morphology

Snapshot #SAMPLE
PNL Document #15813K10-814

Below is the predicted face for this subject from the front and from the side. This prediction was compared to the average predicted face for subjects with the same sex and ancestry. The heat maps show how the predicted face differs from this average face in area and X, Y, and Z displacement. In all heat maps, red indicates an increase in value of the prediction as compared to the average, and blue indicates a decrease. X displacement is relative to the center of the face — i.e., red means farther from the center — whereas Y displacement is relative to the bottom of the chin.

Predicted face for this subject




**Area**: Larger eyelids and mid-brow; smaller brows, nose, mouth, and chin

**X Displacement**: Wider temples, eyes, cheeks, and jaw

**Y Displacement**: Higher (shorter) chin; lower eyes, nose, and cheeks

**Z Displacement**: Less prominent nose & brow; protruding eyes & cheeks

Relative to a face predicted using only sex and ancestry

# Snapshot Prediction Results
# Composite Profile

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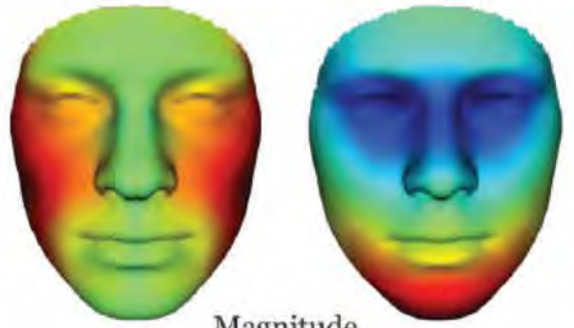
Snapshot #SAMPLE
PNL Document #15B13K10-814




Face morphology differences are emphasized relative to a prediction made using only sex and ancestry

## Predicted (■) & Excluded (☒) Phenotypes

**Skin Color** ☒ 25.8 ☒
**Lt Brown / Brown (92.8% confidence)**
*NOT* Fair / Very Fair / Dk Brown (92.8% confidence)

**Eye Color** ☒ 70.5 ☒
**Hazel / Brown (92.3% confidence)**
*NOT* Green / Blue / Black (92.3% confidence)

**Hair Color** ☒ 46.6
**Black / Brown (99.99% confidence)**
*NOT* Blond (99.99% confidence)

**Freckles** 18.3 ☒
**Zero / Few (92.2% confidence)**
*NOT* Some / Many (92.2% confidence)

**Sex:** Male ♂
**Age:** Unknown
(Composite shown at age 25)
**Body Mass:** Unknown
(Composite shown at BMI 22, Normal)
**Ancestry:** Middle Eastern from Northwest Africa

# Sample Report: Prediction vs. Actual

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**Prediction from DNA**

DNA donor self-reports as being from Algeria, which matches the Snapshot regional ancestry analysis
(regional analysis provided 3 slides back)

# Actual Case Examples

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# U.S. Cold Case Solved

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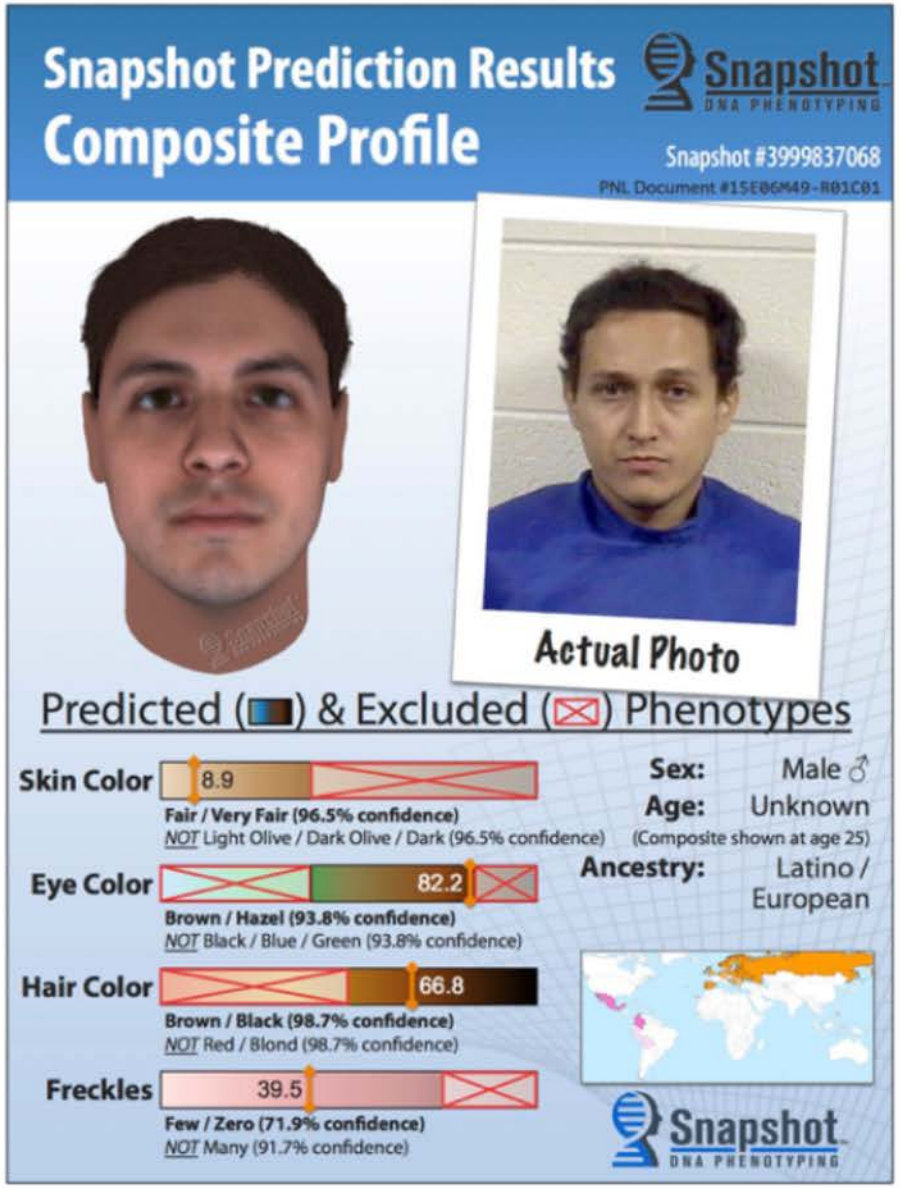



**2006 Double Homicide**
Rockingham County, NC

Use of Snapshot helped law enforcement identify the person responsible for double homicide. Case had been cold ~ 3 years

Snapshot indicated the person of interest had **one Latino parent and one European parent.**

Positive identification of the murderer was made within weeks after Snapshot was used.

# U.S. Cold Case Solved

PARABON®

**2009 Homicide**
Calcasieu Parish, LA

Before using Snapshot, **the victim's cell phone records had guided investigators to look for a male of Latino ancestry.**

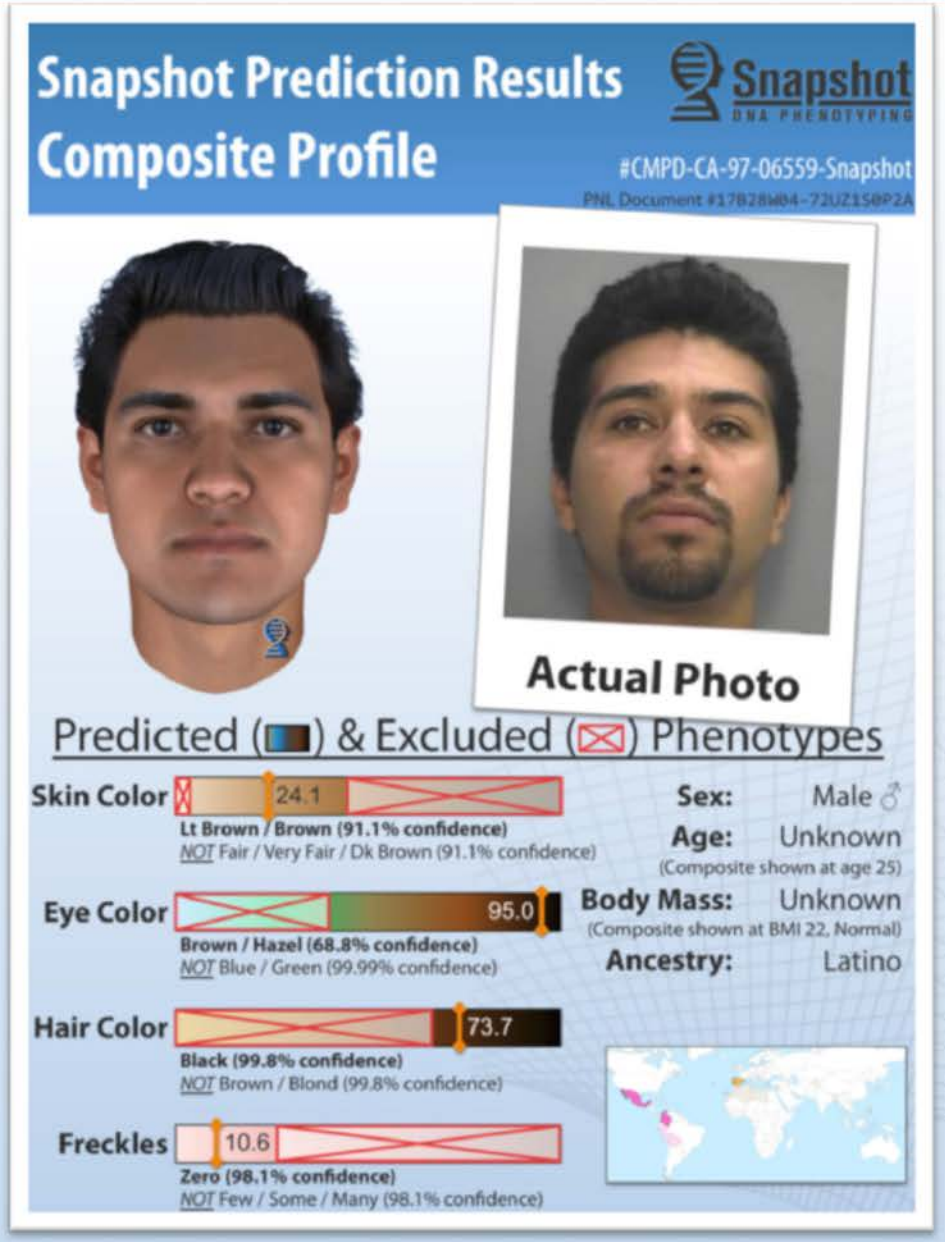
In 2015, Snapshot DNA Phenotyping was performed, predicting a European male with light eyes.

The case and the Snapshot prediction were featured in National Geographic Magazine.

Positive identification of the murderer was made following a tip generated from the Snapshot composite.

# U.S. Cold Case Solved

PARABON®




## 1997 Sexual Assault/Homicide

Costa Mesa, CA

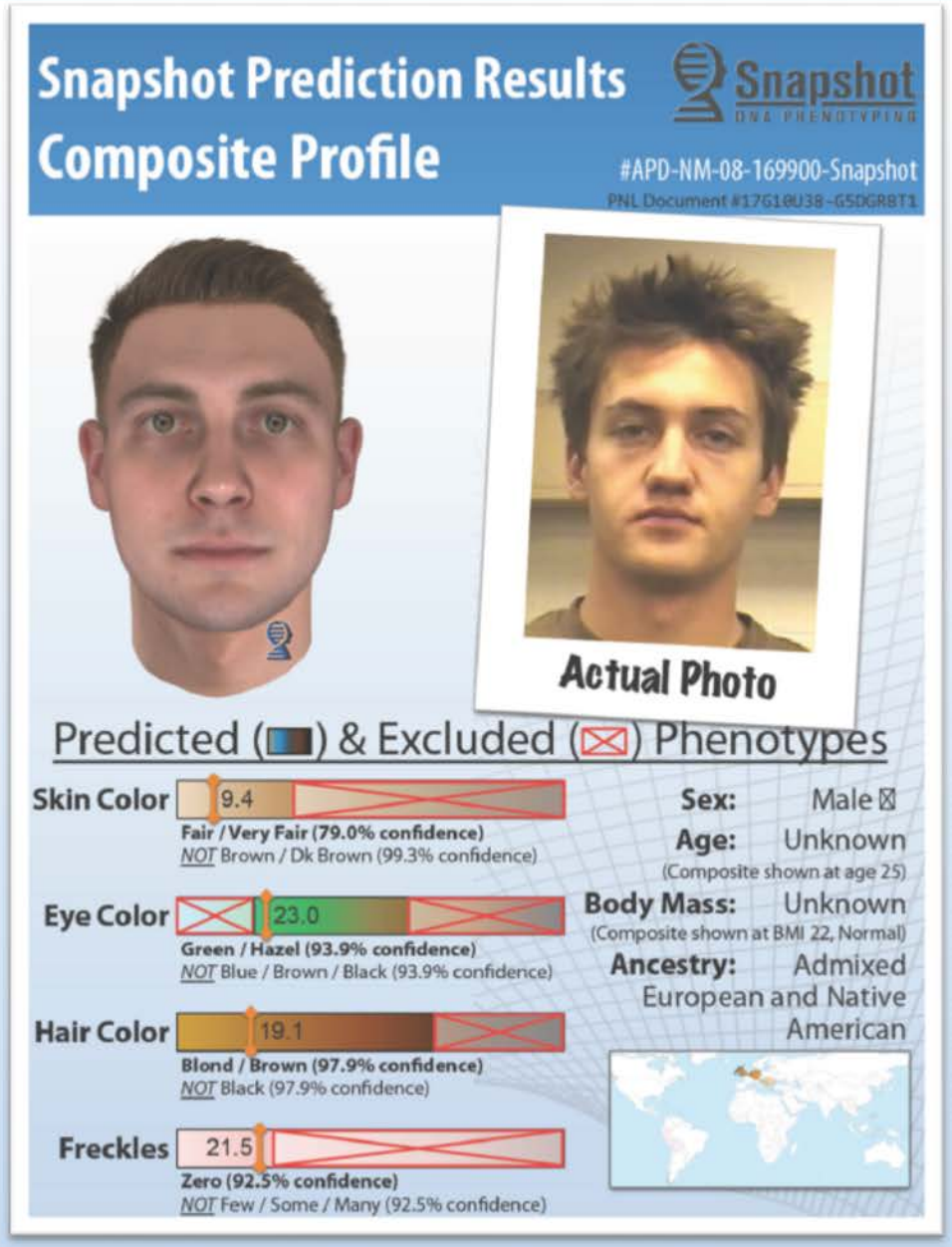
Prediction did not match any known subject, so agency decided to reexamine all case evidence. A fingerprint led detectives to a booking photo of an individual with a stunning resemblance to the Snapshot composite.

**Positive identification of the person-of-interest was made within weeks after Snapshot was used.**

Identity was confirmed through STR comparison with a known family member. Extradition from Mexico is being sought.

# U.S. Cold Case Solved

PARABON®




**2008 Cold Case Assault**
Albuquerque, NM

Teenaged female victim severely beaten with a shovel in her home in 2008.

In 2010, case was featured on ***America's Most Wanted***.

***"We had one person on the list with brown hair and green eyes, and his name was Justin Hansen. His resemblance to the Snapshot composite could not be ignored."***

-Detective Jodie Gonterman
Albuquerque Police Department

# U.S. Cold Case Solved

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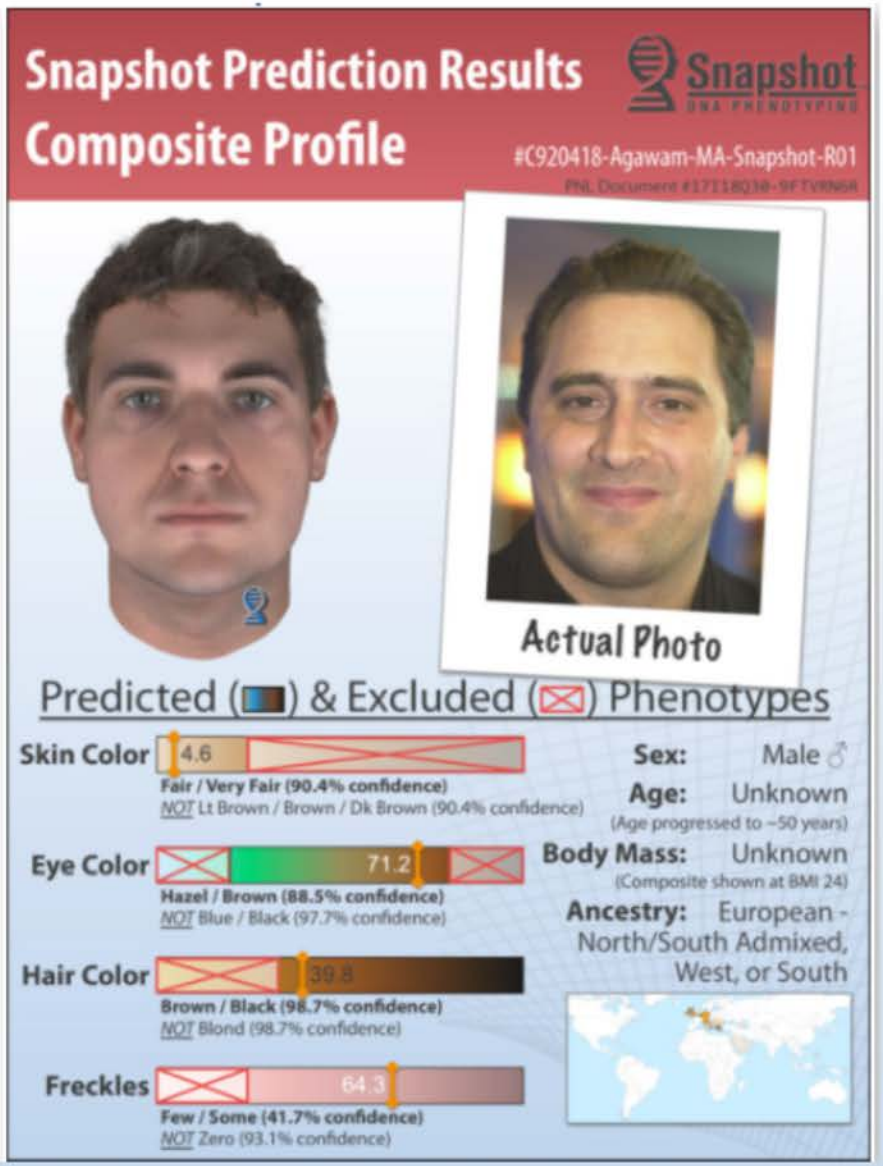



**1992 Sexual Assault/Homicide**
Agawam, MA

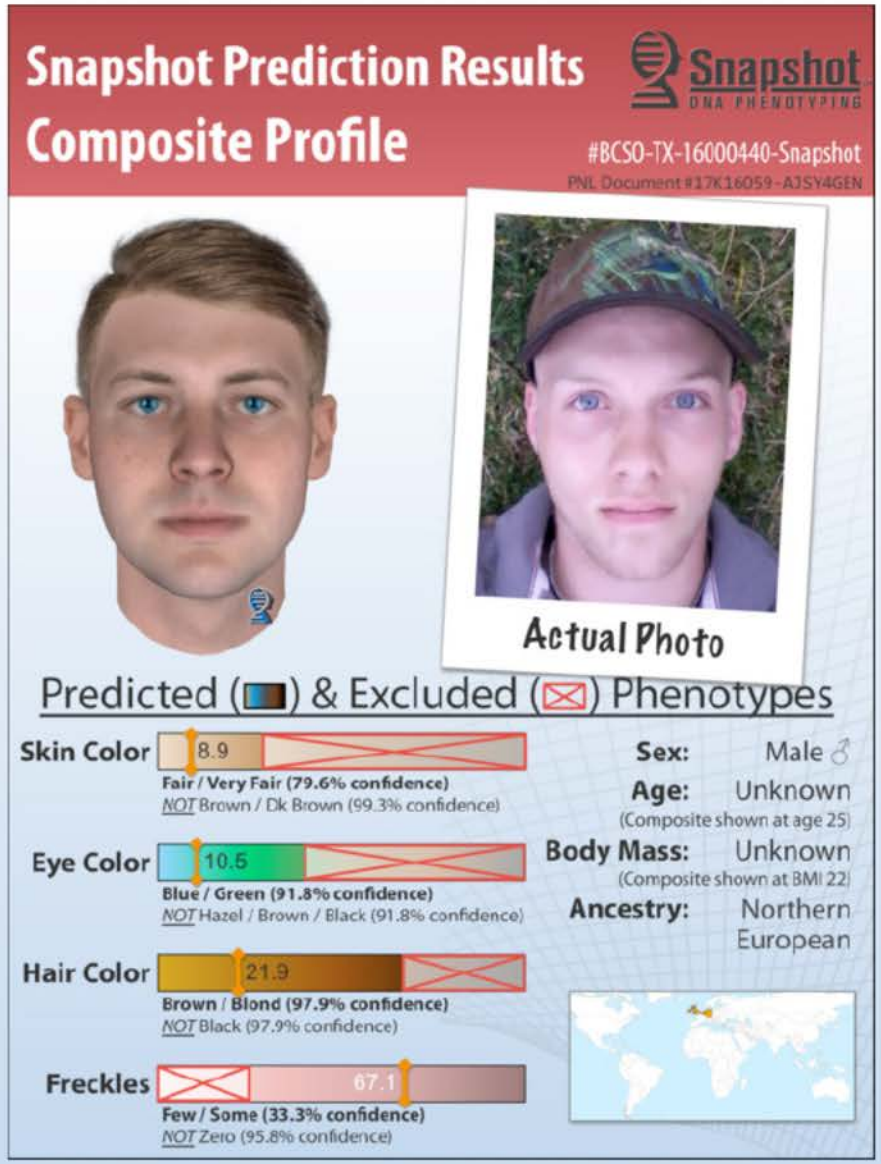
Abduction and homicide of an aspiring teacher, Lisa Ziegert, was solved after 25 years.

***"What the Parabon analysis allowed us to do was to narrow this investigation; it gave us criteria with which we could exclude and include people."***

-Anthony Gulluni
Hampden County MA District Attorney

# U.S. Cold Case Solved

PARABON®




**2016**
**Sexual Assault/Homicide**
Lake Brownwood, TX

Within hours of the Snapshot composite release to the public, the agency received numerous tips, one of which was Ryan Derek Riggs.

After evading police nearly a week, Riggs confessed before his church congregation.

***"Riggs was not even on our radar prior to the release of the Snapshot composite."***

-Sheriff Vance Hill
Brown County Sheriff's Office

# Extended Kinship Inference

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# Kinship Inference

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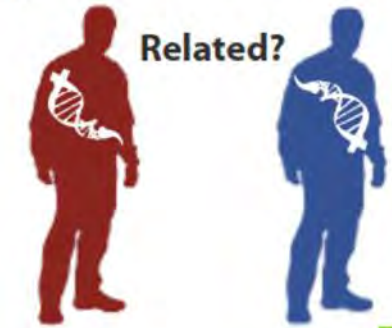
- Autosomal STRs can only detect very close relationships and even then have limited accuracy
- Mitochondrial and Y-chromosome haplotypes can indicate a shared lineage but cannot determine how distant the relationship is and have a limited range of references that can be tested
- Existing SNP methods cannot reliably distinguish among relationships beyond the 2nd degree

# Snapshot® Kinship Inference




Traditional Forensic DNA Kinship

- father
- mother
- brother / sister
- self / twin
- niece / nephew
- son / daughter
- grand-niece / nephew
- grand-son / daughter

Snapshot: Precise Inferences

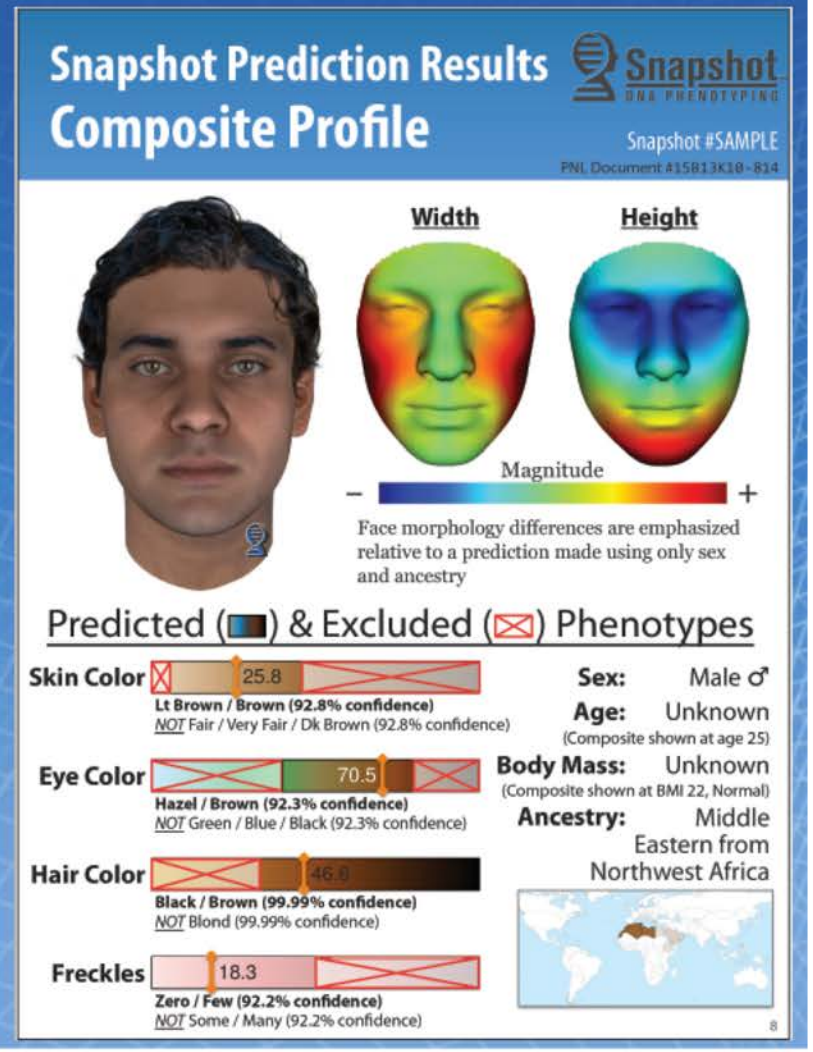
| | | | |
|---|---|---|---|
| Identical Twins | Relationship | 4th Degree Relatives | 7th Degree Relatives |
| Parent-Offspring | 2nd Degree Relatives | 5th Degree Relatives | 8th Degree Relatives |
| Full Siblings | 3rd Degree Relatives | 6th Degree Relatives | 9th Degree Relatives |

: Extended Inferences

| | | | | | |
|---|---|---|---|---|---|
| great-great-great-grandfather | great-great-great-grandmother | | | | |
| great-great-grandfather | great-great-grandmother | great-great-great-uncle / aunt | | | |
| great-grandfather | great-grandmother | great-great-uncle / aunt | first cousin thrice removed | | |
| grandfather | grandmother | great-uncle / aunt | first cousin twice removed | second cousin twice removed | |
| uncle / aunt | first cousin once removed | second cousin once removed | third cousin once removed | | |
| first cousin | second cousin | third cousin | fourth cousin | | |
| first cousin once removed | second cousin once removed | third cousin once removed | | | |
| first cousin twice removed | second cousin twice removed | third cousin twice removed | | | |

# The Parabon® Snapshot™ DNA Phenotyping Service

***Snapshot Predicts What People Look Like from DNA Found at a Crime Scene***




Snapshot™
DNA PHENOTYPING

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