Forensic DNA Analysis

or "*DNA for Dummies: An Introduction to Forensic DNA Analysis*"

Criminalist Harry Klann Jr.

- DNA Technical Leader

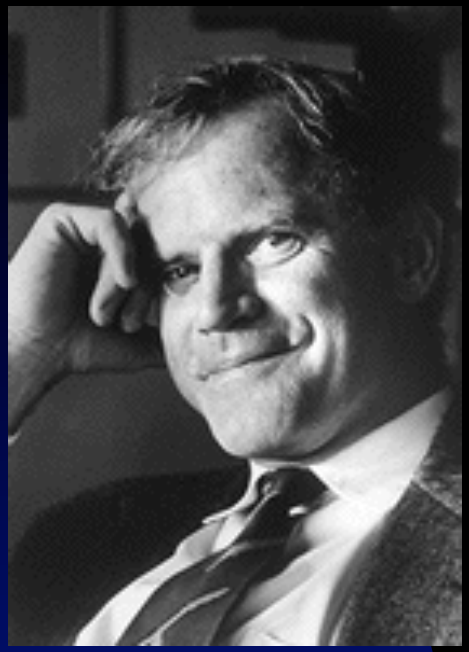
- Serology/DNA Unit

- LAPD Crime Lab

PowerPoint presentation by
Criminalist Carl Matthies

Objectives of Forensic DNA Testing

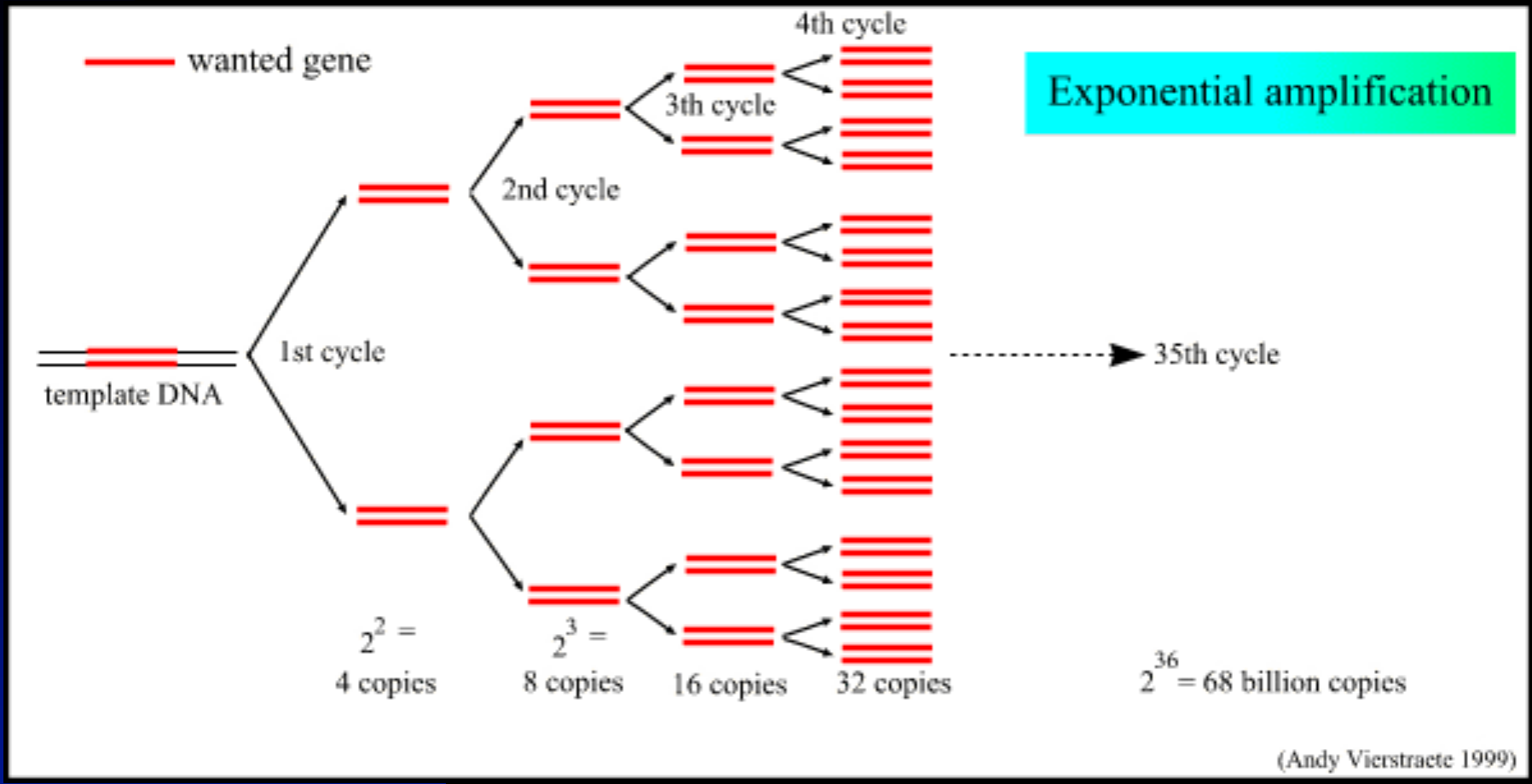
- To link an individual to a crime scene/criminal act
- To exonerate suspects
- To identify victims of mass disasters



Dr. Kary Mullis
Eccentric Genius
Nobel Laureate
Surfer

PCR

- Polymerase Chain Reaction = molecular Xeroxing
- Three temperature phases, carried out in a Thermal Cycler, replicate or “amplify” the desired DNA fragment(s)


wanted gene
Exponential amplification
4th cycle
3th cycle
2nd cycle
1st cycle
template DNA
35th cycle
2^2 =
4 copies
2^3 =
8 copies
16 copies
32 copies
2^{36} = 68 billion copies
(Andy Vierstraete 1999)

"PCR has transformed molecular biology through vastly extending the capacity to identify, manipulate and reproduce DNA. It makes abundant what was once scarce: the genetic material required for experimentation."

Paul Rabinow

PCR (cont'd)

- First forensic application is the DQα locus, later multi-plexed with *Polymarker* loci using dot-blot detection method
- Works with lower quantity (1-2ng), lower quality samples
- Power of discrimination goes from 10^2-10^6...not quite good enough for databasing

The Current Method of Choice: Autosomal Short Tandem Repeats (STRs)

- Non-coding, tetranucleotide sequences which vary greatly from person to person in the number of repeating units
- Requires 0.5-1.5ng of DNA to type 13 STR loci
- Power of discrimination ranges from 10^{14}-10^{23}. World population is 10^{9} so bring on the database!

10^{14} = 100 trillion

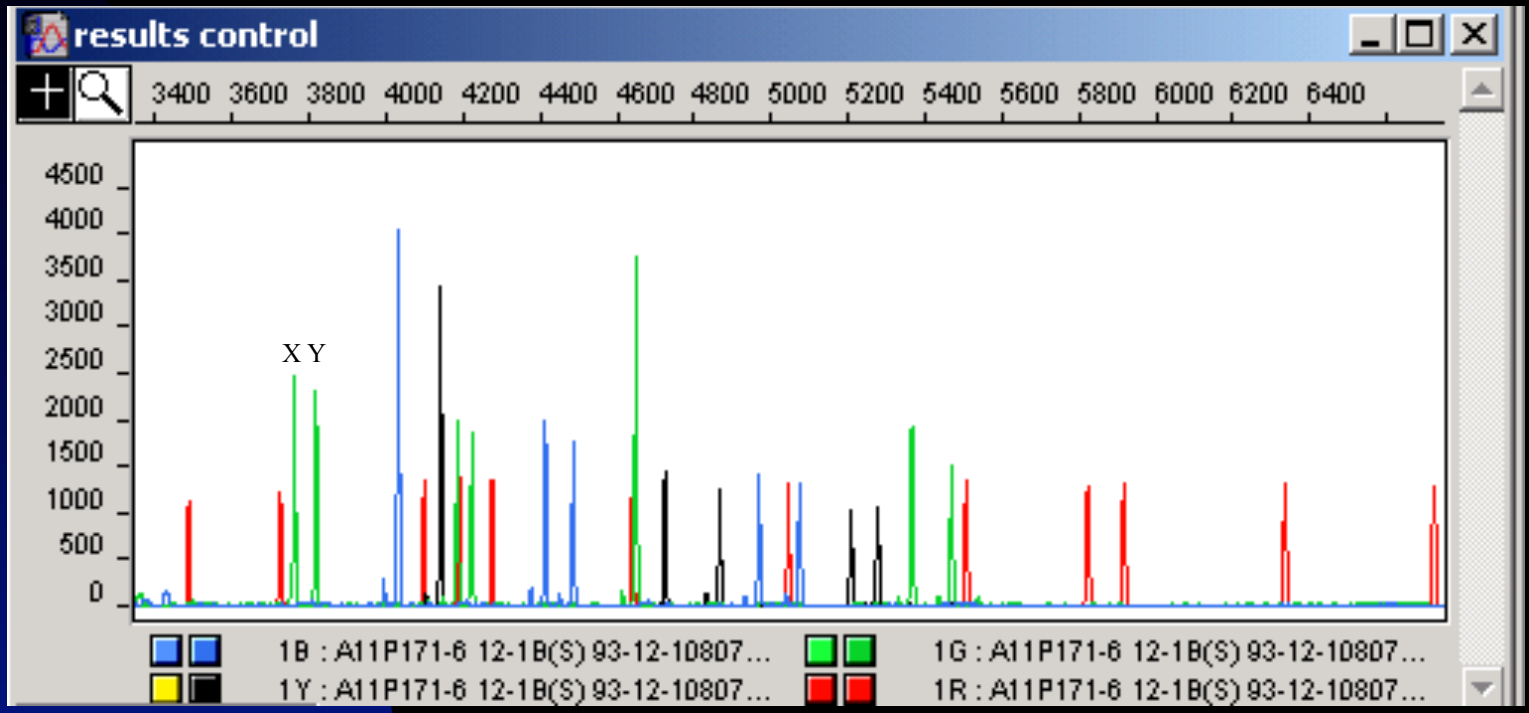
10^{23} = 100 sextillion

Applied Biosystems 310 Genetic Analyzer

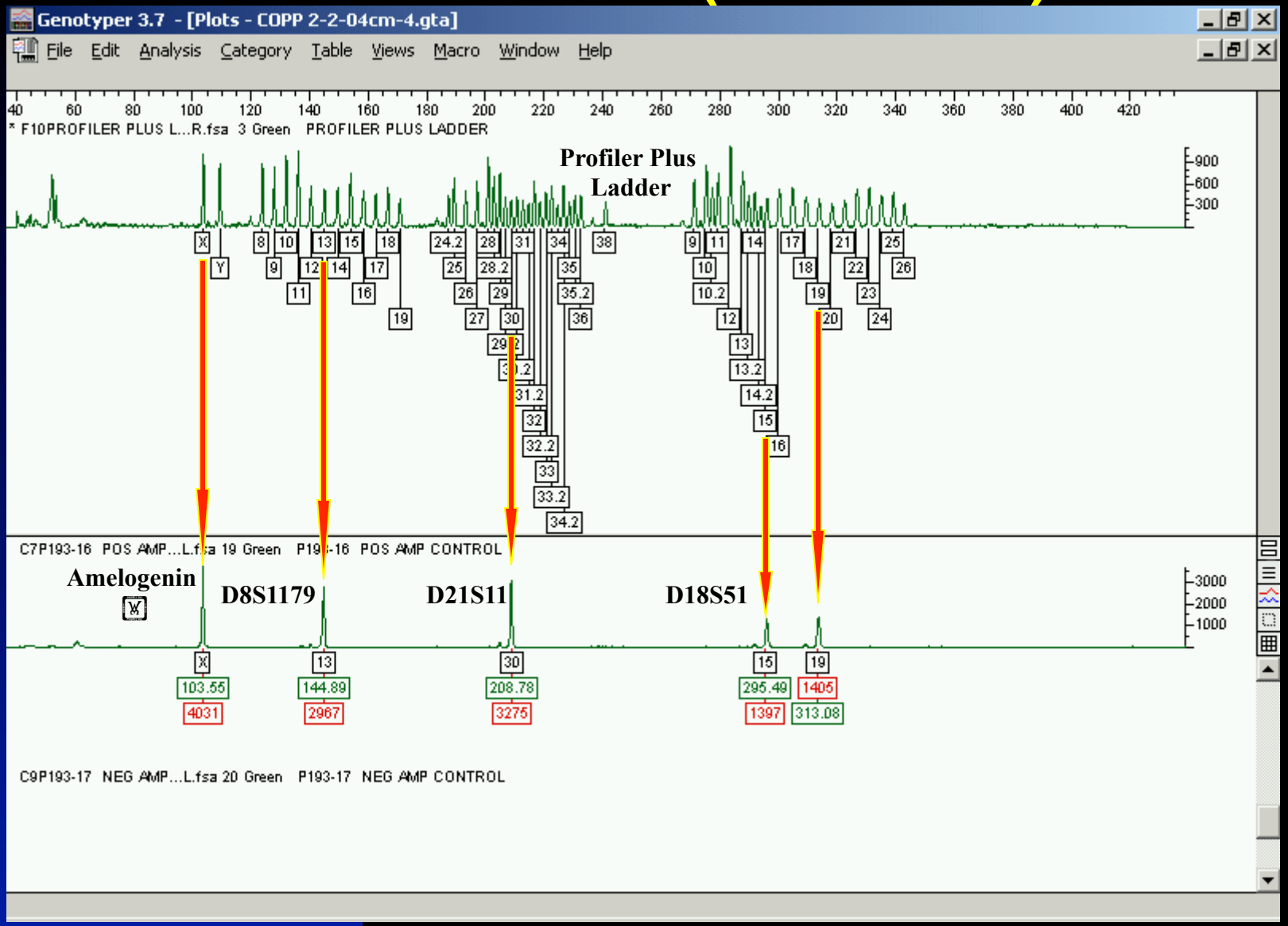
The Process In a Nutshell

Amplified DNA samples are injected into a capillary. Fluorescent tags on the DNA fragments are excited by a laser as they pass a window in the capillary, the fluorescence is recorded by a camera, and this signal is converted into a “peak” by the computer software.

STR data


results control
3400 3600 3800 4000 4200 4400 4600 4800 5000 5200 5400 5600 5800 6000 6200 6400
4500
4000
3500
3000
2500
2000
1500
1000
500
0
X Y
1B : A11P171-6 12-1B(S) 93-12-10807...
1G : A11P171-6 12-1B(S) 93-12-10807...
1Y : A11P171-6 12-1B(S) 93-12-10807...
1R : A11P171-6 12-1B(S) 93-12-10807...

STR data (cont'd)



STR data (cont'd)

STR TYPING SUMMARY SHEET													
Date: 9/24/1999			**DNA Analyst / Serial #:** MATTHIES V9780							**DR #:** 00-00-00001			
Item #	AMEL	D3S1358	vWA	FGA	D8S1179	D21S11	D18S51	D5S818	D13S317	D7S820	D16S539	THO1	TPOX
25(S)	X, Y	17	15, 17	23, 26	14, 15	26	12, 15	10	9, 13	8, 10	9, 10	8, 9	9, 10
	X, Y	17								8, 10			
25(E)	X	15, 17	16, 18	19, 26	15	28, 32.2	14, 16	8, 13	12	11	11, 12	7, 8	11
	X	15, 17								11			
VICTIM	X	15, 17	16, 18	19, 26	15	28, 32.2	14, 16	8, 13	12	11	11, 12	7, 8	11
	X	15, 17								11			
SUSPECT	X, Y	17	15, 17	23, 26	14, 15	26	12, 15	10	9, 13	8, 10	9, 10	8, 9	9, 10
	X, Y	17								8, 10			

"The DNA profile obtained from Item 25(S) matches the DNA profile of the suspect. The combination of genetic marker types exhibited by Item 25(S) and the suspect occurs in approximately one in one hundred quadrillion (10^{17}) individuals…"

How are these astronomical figures derived?

The product rule: combined probability of a series of independent events is determined by multiplying the probabilities of each event.

STR loci are inherited independently (unlinked)

Homozygous loci: p^2 (same allele inherited from mother and father)

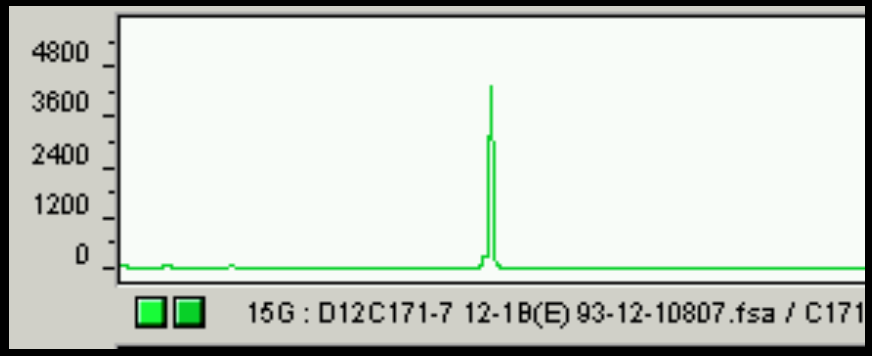
Heterozygous loci: 2pq (either allele could be inherited from either parent)

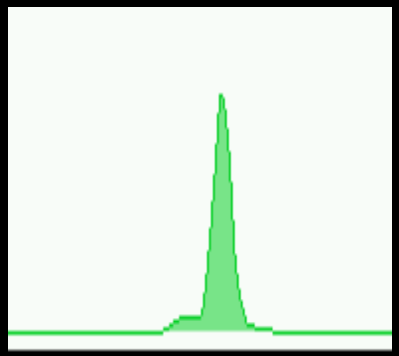
$$p(17)^2 \times 2p(15)q(17) \times 2p(23)q(26)\ldots.$$

$(.223)^2 \times 2(.083)(.25) \times 2(.14)(.02) = .000013$, which is equivalent to a probability of one in 76,000 using just 3 of the 13 loci!

STR Artifacts

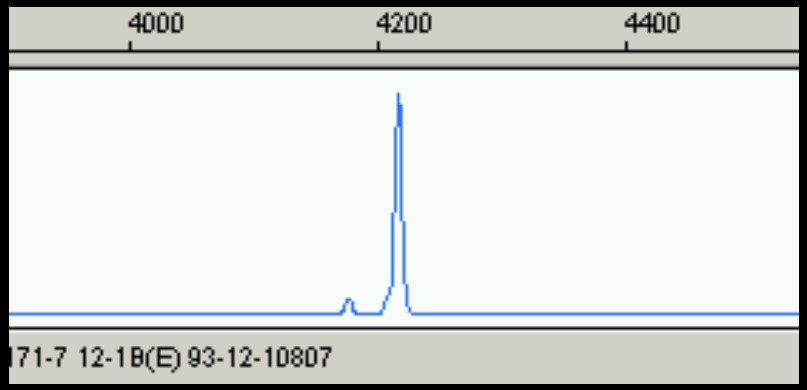
-A ("minus A"): Incomplete addition of nucleotide 'A' by DNA polymerase; results in a peak that is one base pair smaller than allele peak.

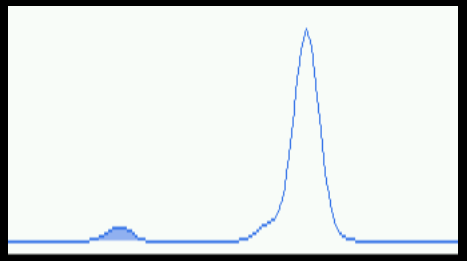




STR Artifacts

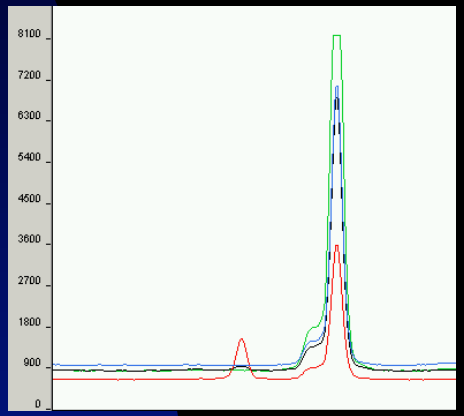
Stutter: Slippage of DNA polymerase; results in a peak that is four base pairs (one repeat unit) smaller than allele peak.

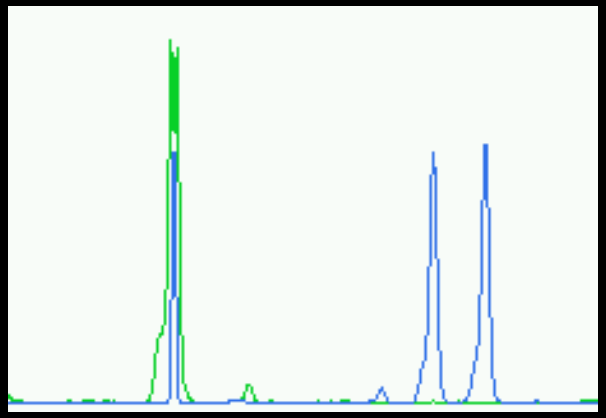




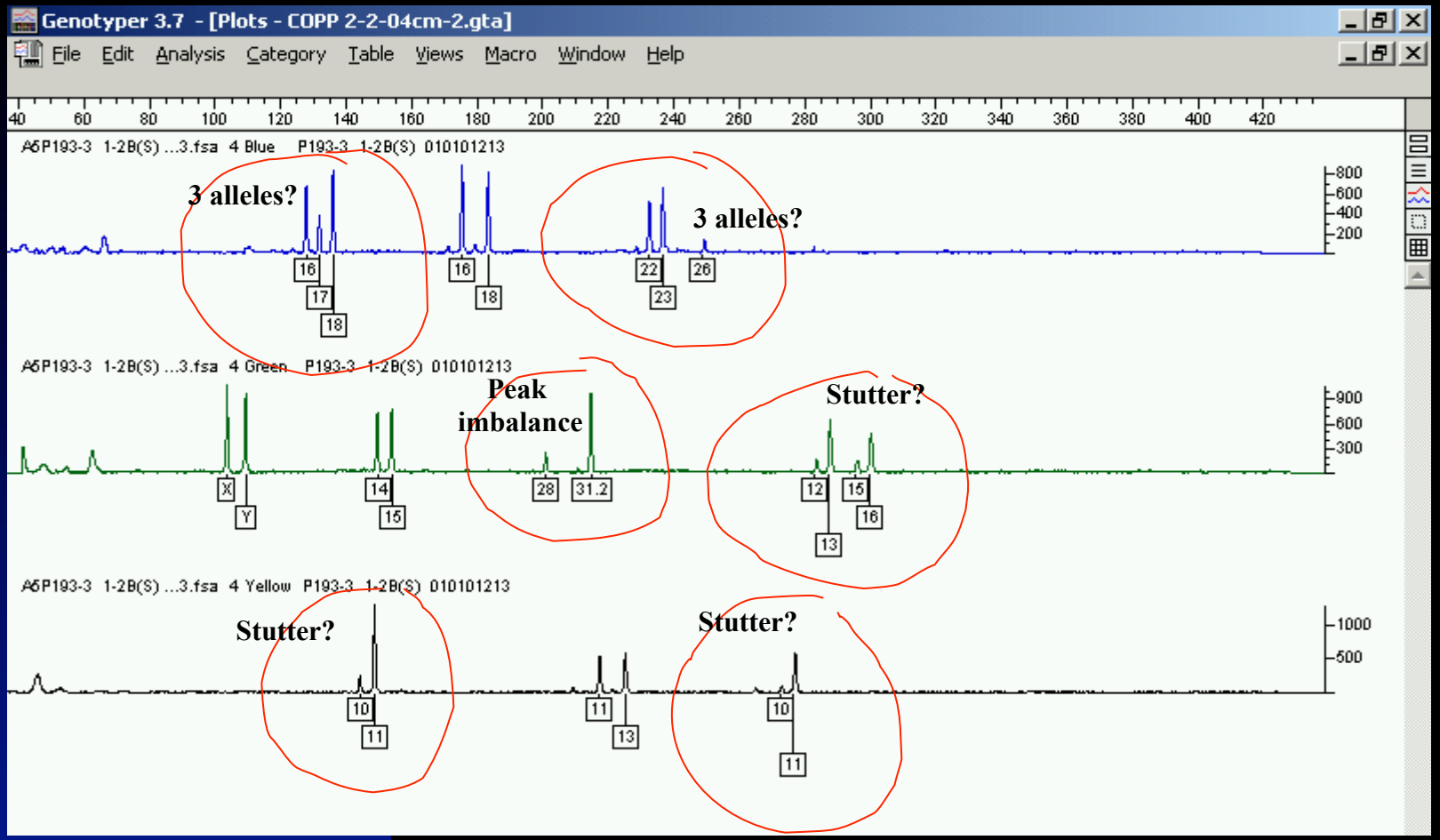
STR Artifacts

Pull-up: Incomplete filtration of spectral overlap in fluorescent detection system.



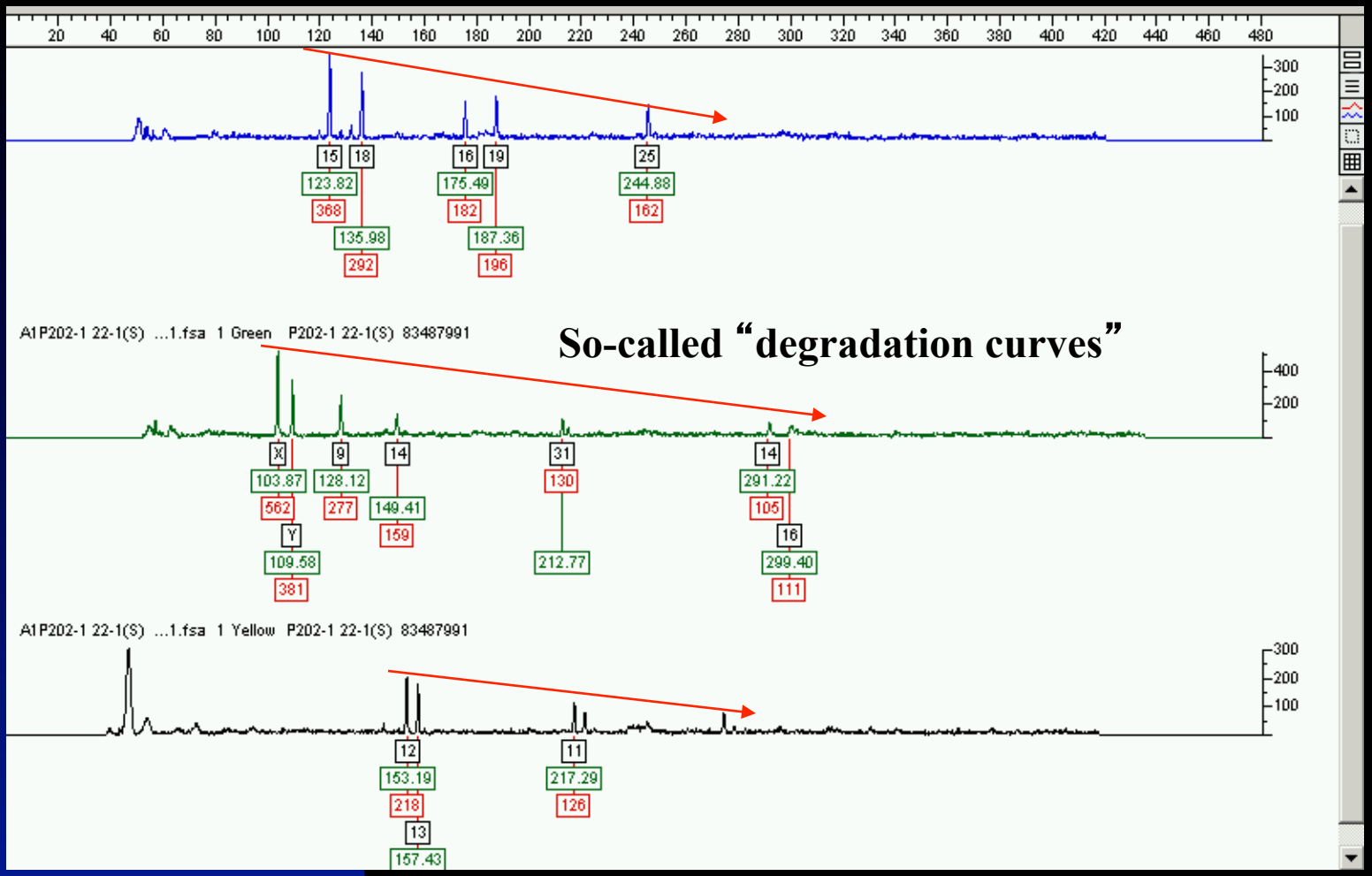


DNA Mixtures

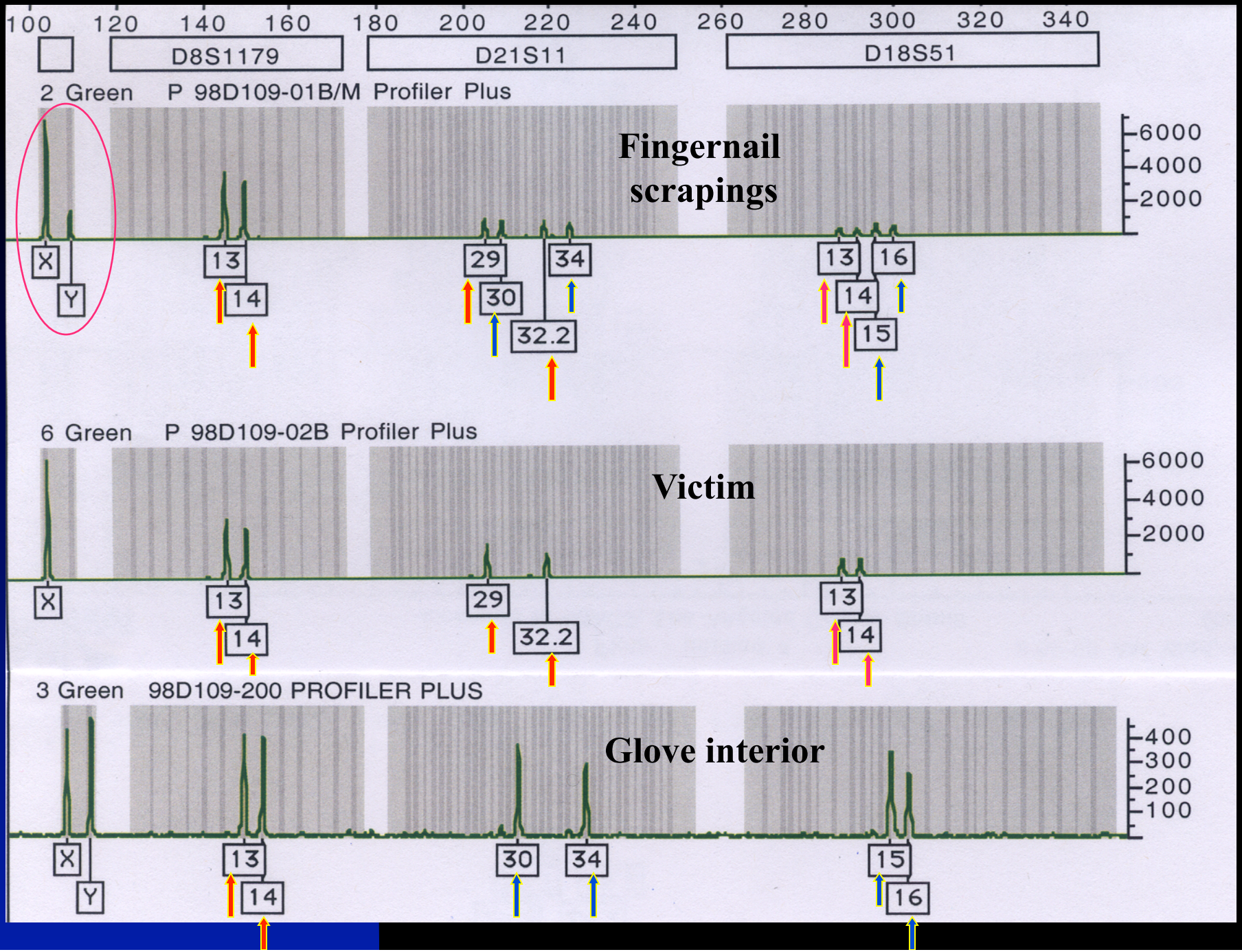


When more than one source of DNA is detected in a sample, assignment of genotypes becomes more difficult.

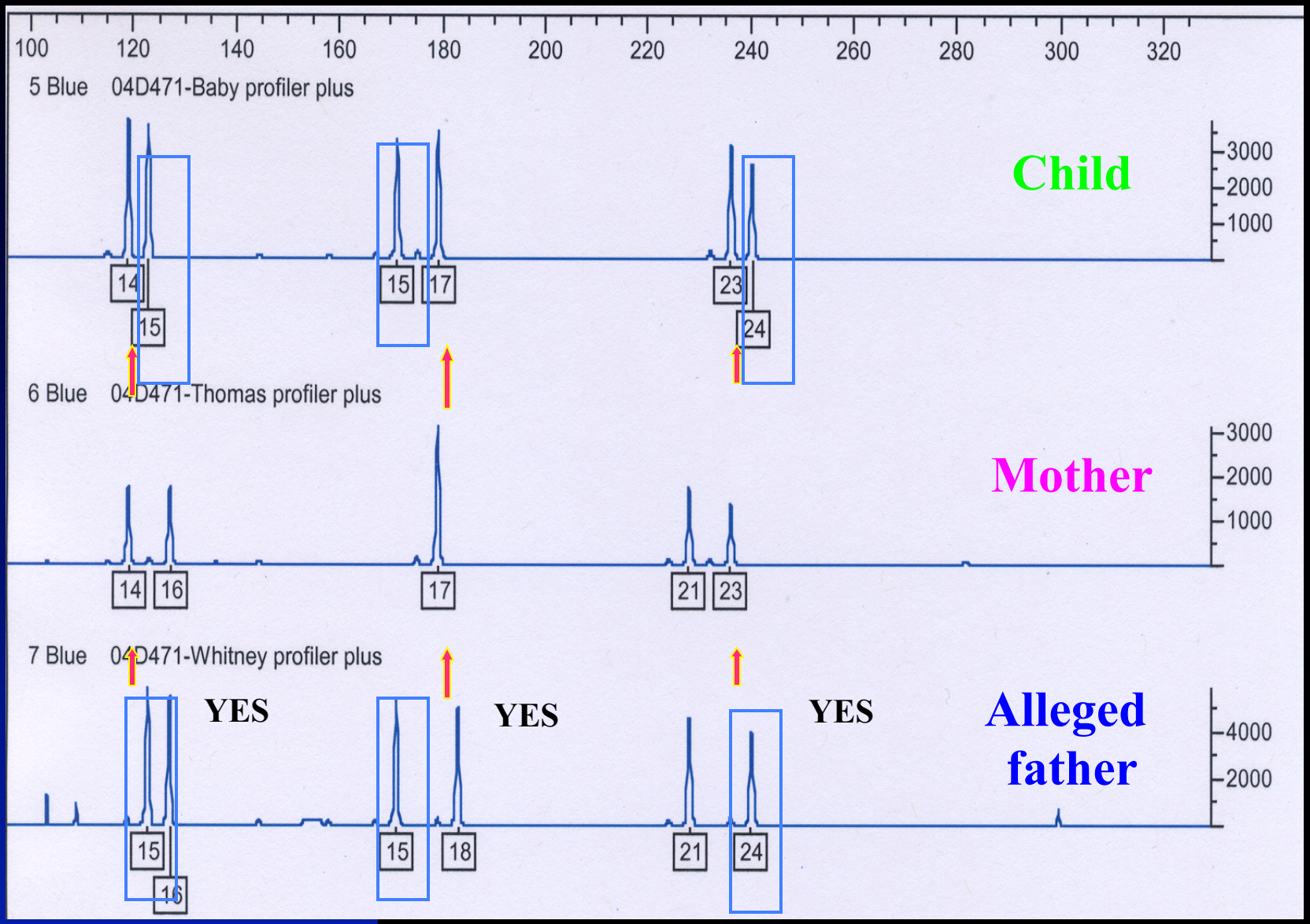
Degraded/Trace DNA Samples



Larger alleles "drop-out" when template DNA is low in quantity or quality, reducing certainty of genotypes.


100 120 140 160 180 200 220 240 260 280 300 320 340
D8S1179
D21S11
D18S51
2 Green P 98D109-01B/M Profiler Plus
Fingernail scrapings
6000
4000
2000
X
Y
13
14
29
30
34
32.2
13
16
14
15
6 Green P 98D109-02B Profiler Plus
Victim
6000
4000
2000
X
13
14
29
32.2
13
14
3 Green 98D109-200 PROFILER PLUS
Glove interior
400
300
200
100
X
Y
13
14
30
34
15
16

Paternity Testing

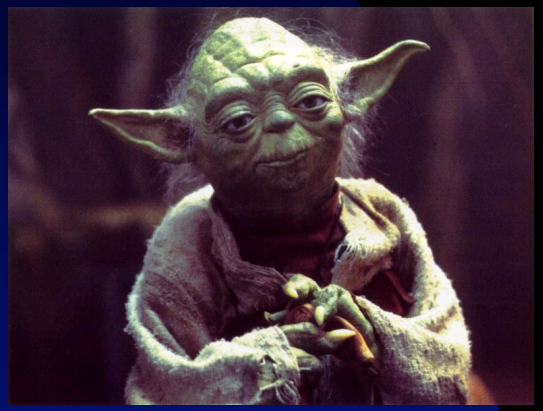


The Combined DNA Index System (CoDIS)

- A database of DNA profiles from violent felons and crime scene samples
- Laws concerning who is eligible for the database vary from state to state
- Database currently contains 2,826,505 COs, 126,315 forensic profiles, >28,300 hits (12/05)

>30,200 investigations aided

The Mystical Power of CoDIS



Master Yoda

- Extremely powerful investigative tool, linking crimes, and pulling suspects out of thin air!
- *Prevent, as well as solve crimes, it can!*

The Dark Side of The CoDIS

The Emperor
Savvy Politico
Surfer

- DNA mixtures and degraded DNA profiles have lead to spurious "matches"
- Stringent laws explicitly permit databasing innocent people
- Adding arrestees to database violates presumption of innocence
- However, the prosecution rate on case to offender matches is shockingly low! (~10%)

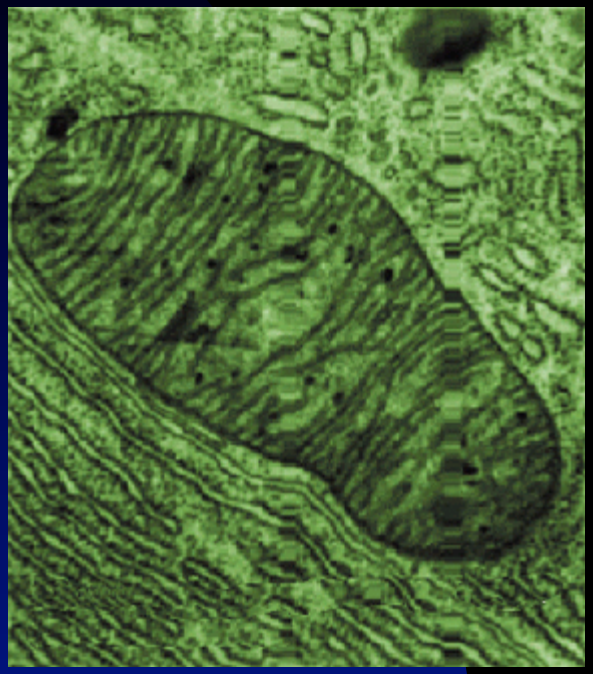
LAPD CoDIS Stats (9/05)

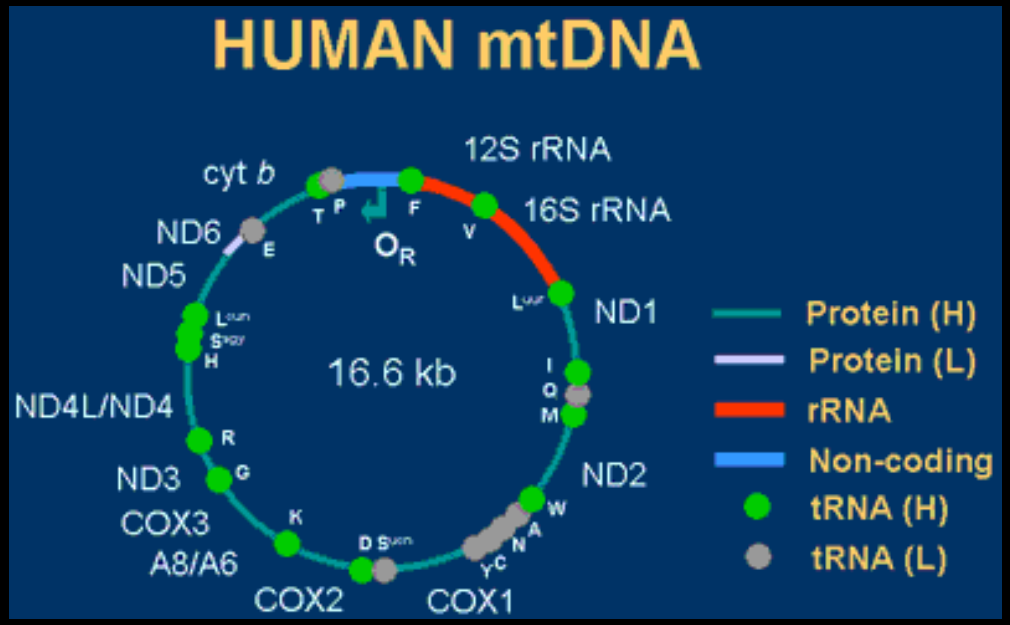
- 236/209 Case-to-Offender matches
- 113 Case-to-Case hits with 61 as yet unidentified suspects
- 9 official DA “rejects” plus 22 with “victim issues”
- 9 Convictions; charges filed in 45 more; 6 defendants plead guilty
- 197 investigations aided…

“Specialized” PCR-based systems

- Mitochondrial DNA
- Y-STRs
- SNPs

Mitochondrial DNA (mtDNA)

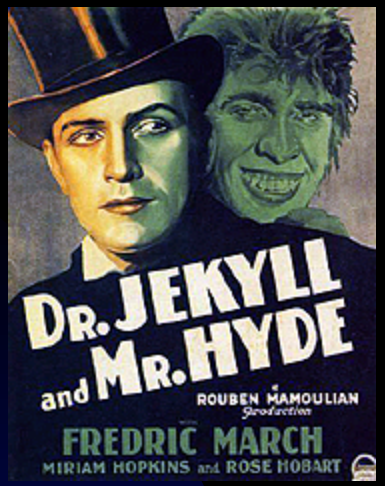




Mitochondrial DNA (mtDNA)

Pros:

- Single-cell sensitivity because each cell contains ~1000 mitochondria
- Especially useful for shed hairs, burnt remains
- Can be used to establish kinship directly because entire complement of mtDNA is maternally inherited



Y-STRs

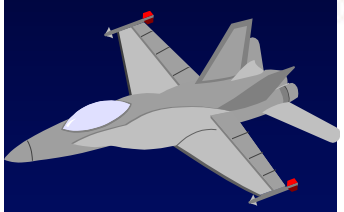
Problem:

- ~99% of violent crimes are committed by men
- DNA mixtures of male suspect and female victim can pose an analytical challenge, especially when the female contribution is much greater than the male = preferential amplification

Y-STRs

Solution:

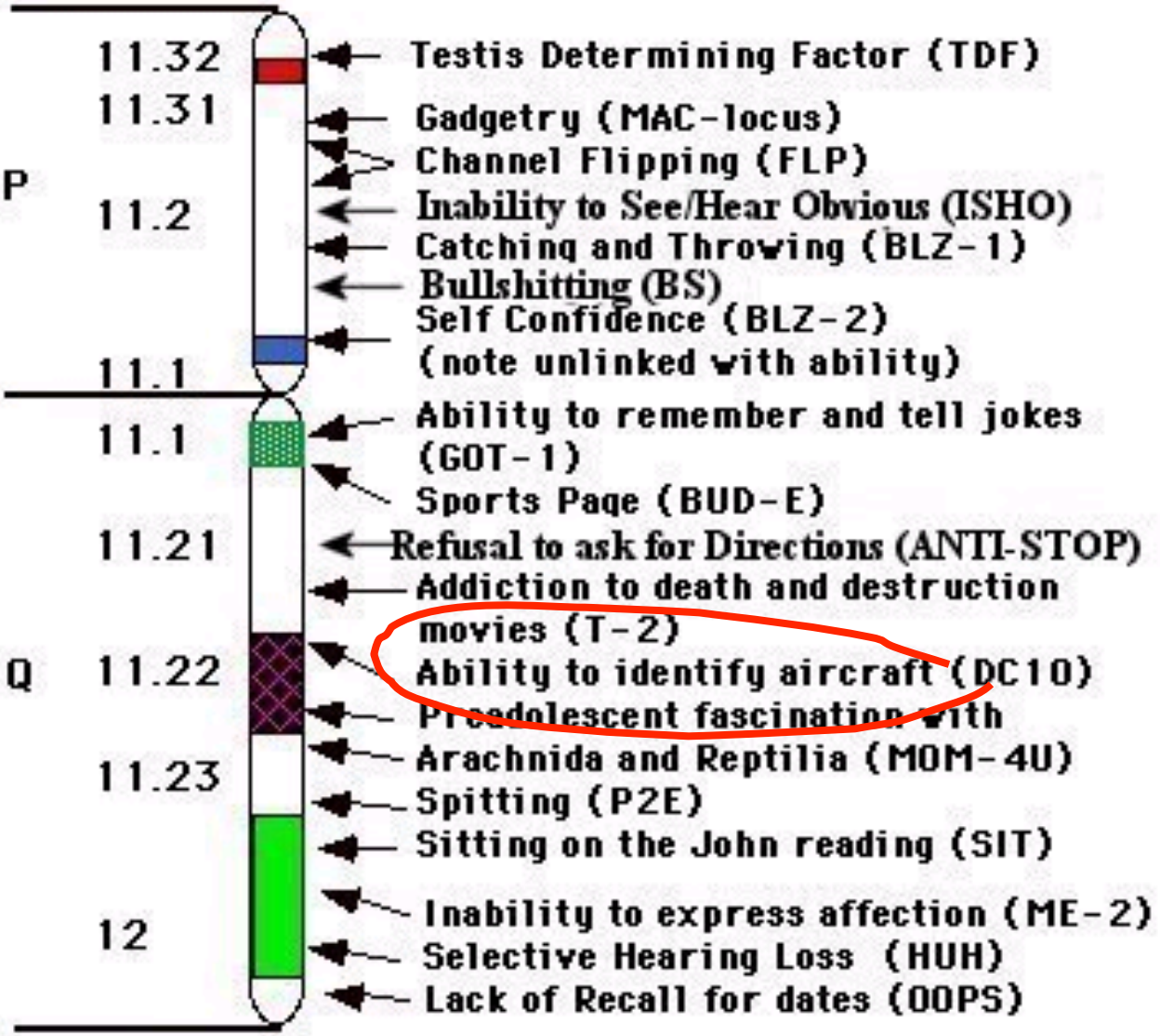
- Test for markers found only on the Y-chromosome. Only male DNA is amplified!



F/A-18

"Hornet"

Y Chromosome map

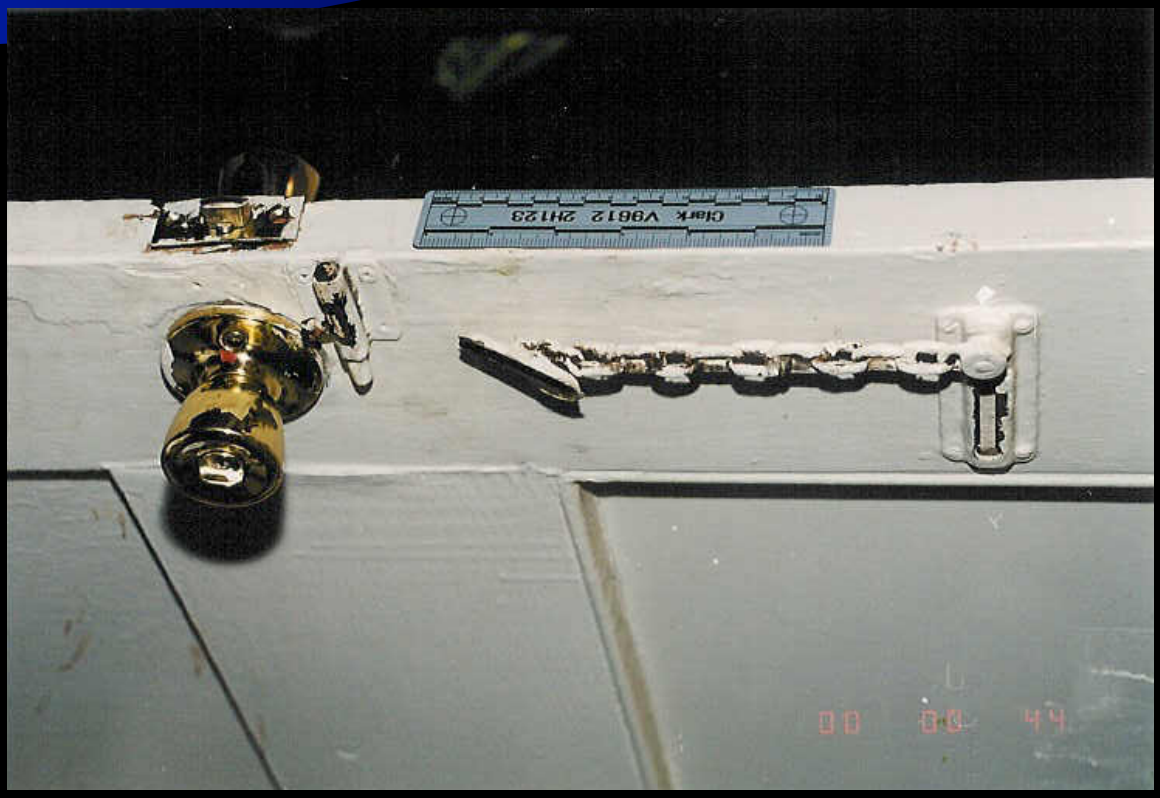


- Jane Gitschier, UCSF Science, 261, 679 (Aug. 93)

Single Nucleotide Polymorphisms SNPs (cont´d)

- ~50 SNPs provides same power of discrimination as 13 STR loci
- Certain SNPs used as predictors of ancestry/ethnicity by a private sector lab (DNA Witness)

A Hollywood Homicide

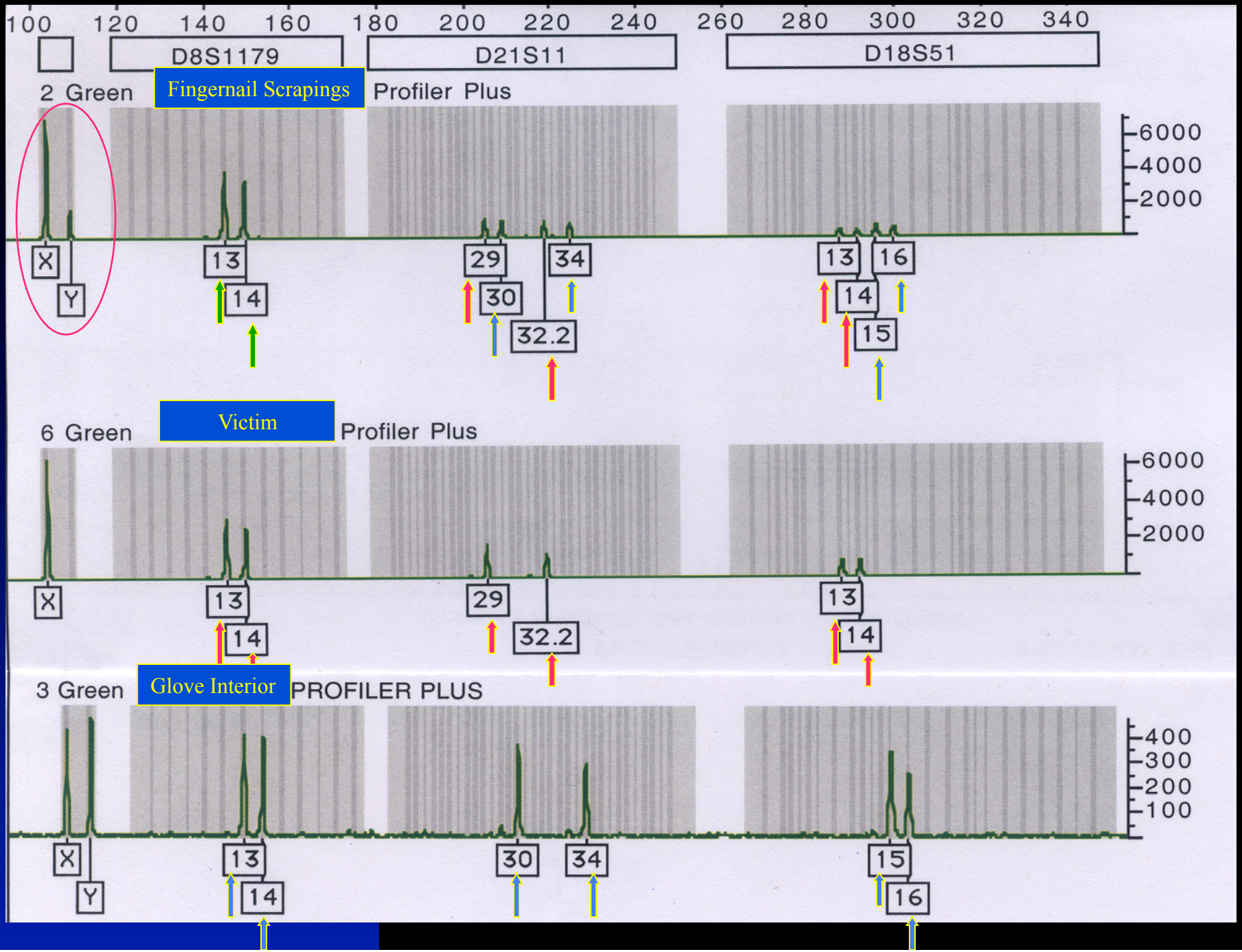

Clark V9612 2H123

Clark V9612 2H123
2
2
2

8
Clark V9612 2H123

12
12

12
12
Clark V9612 2H123


100 120 140 160 180 200 220 240 260 280 300 320 340
D8S1179
D21S11
D18S51
2 Green
Fingernail Scrapings
Profiler Plus
6000
4000
2000
X
Y
13
14
29
30
34
32.2
13
16
14
15
6 Green
Victim
Profiler Plus
6000
4000
2000
X
13
14
29
32.2
13
14
3 Green
Glove Interior
PROFILER PLUS
400
300
200
100
X
Y
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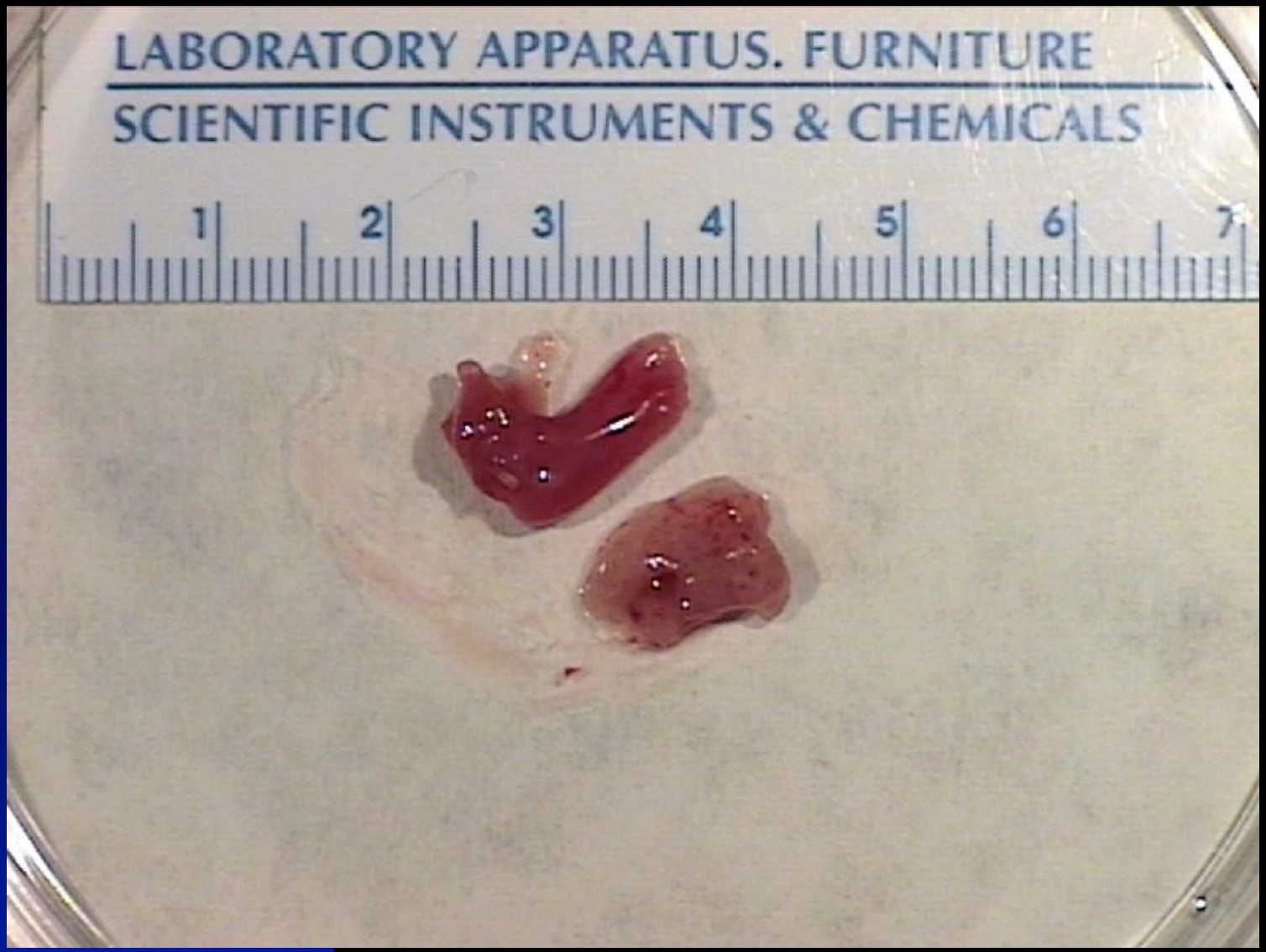
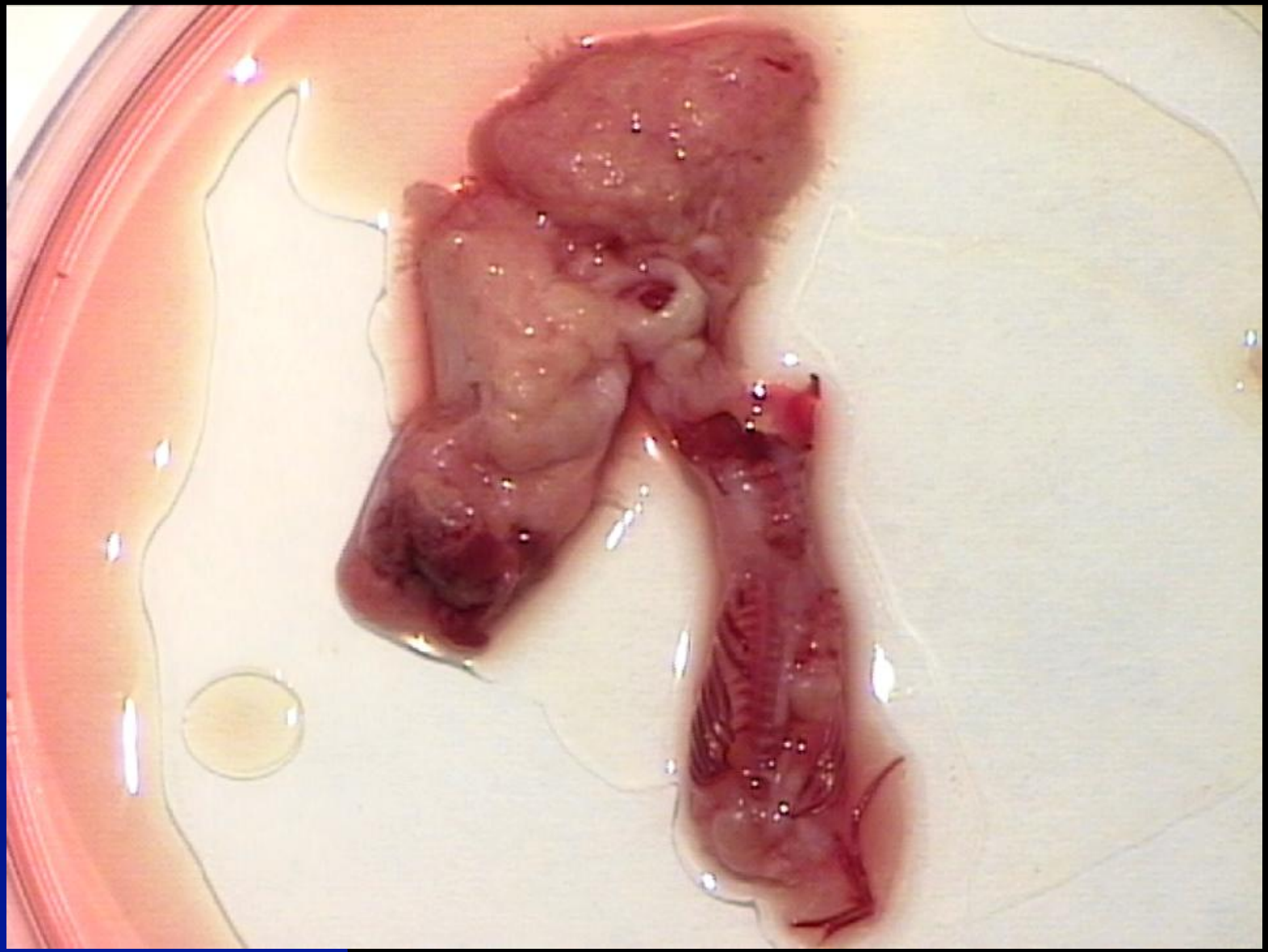
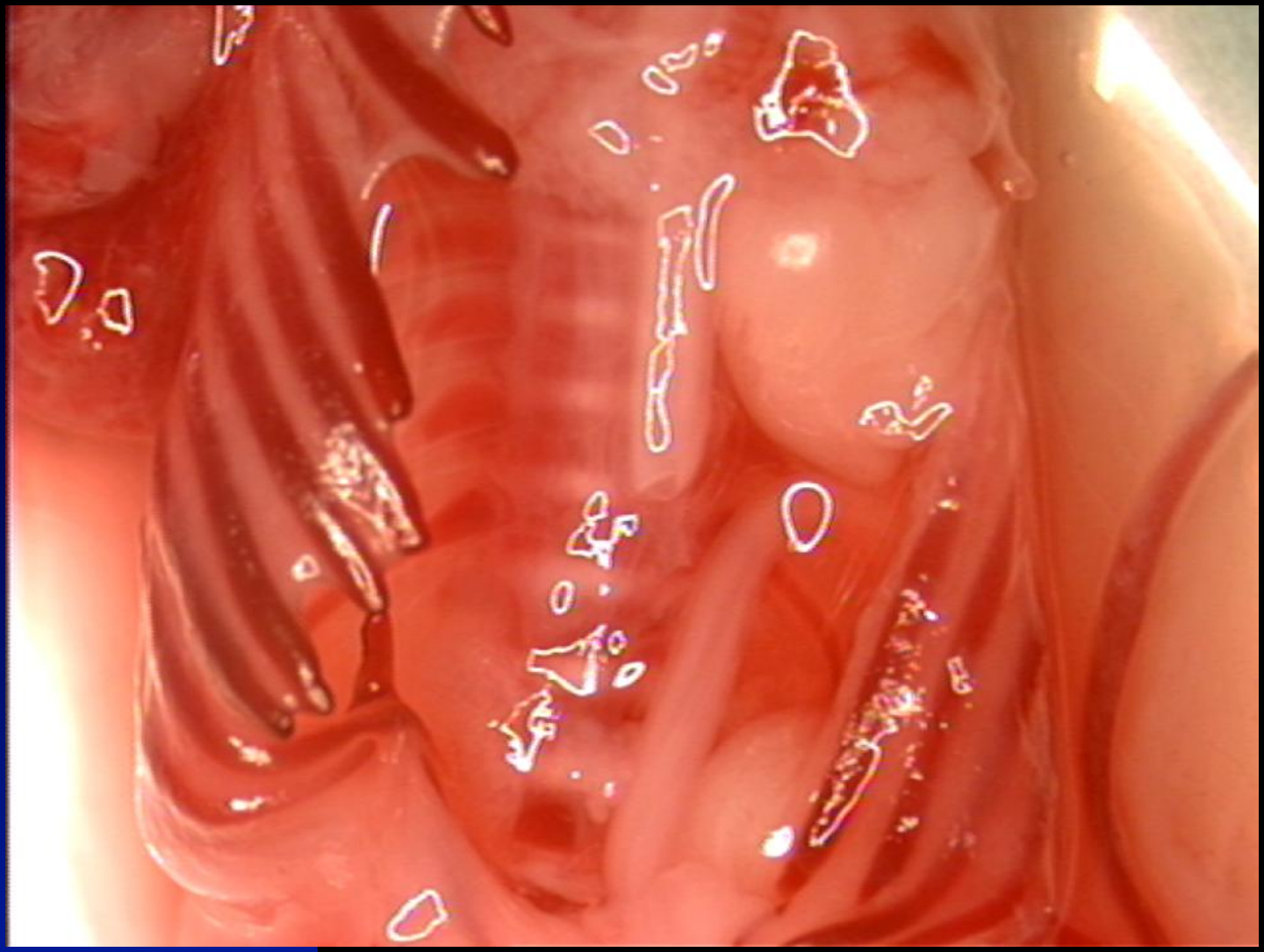
14
30
34
15
16

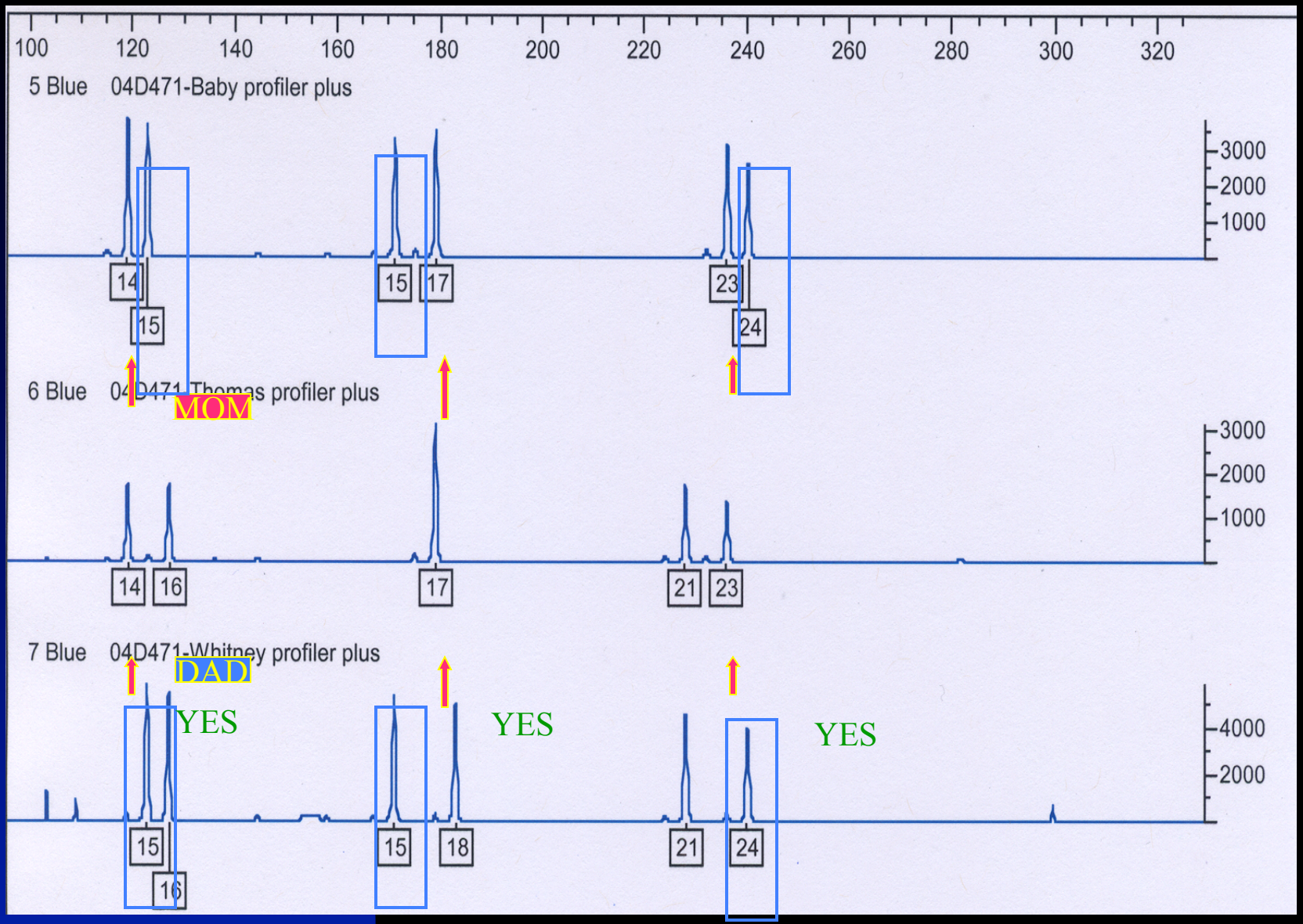
Paternity testing on abortus in sexual assault cases



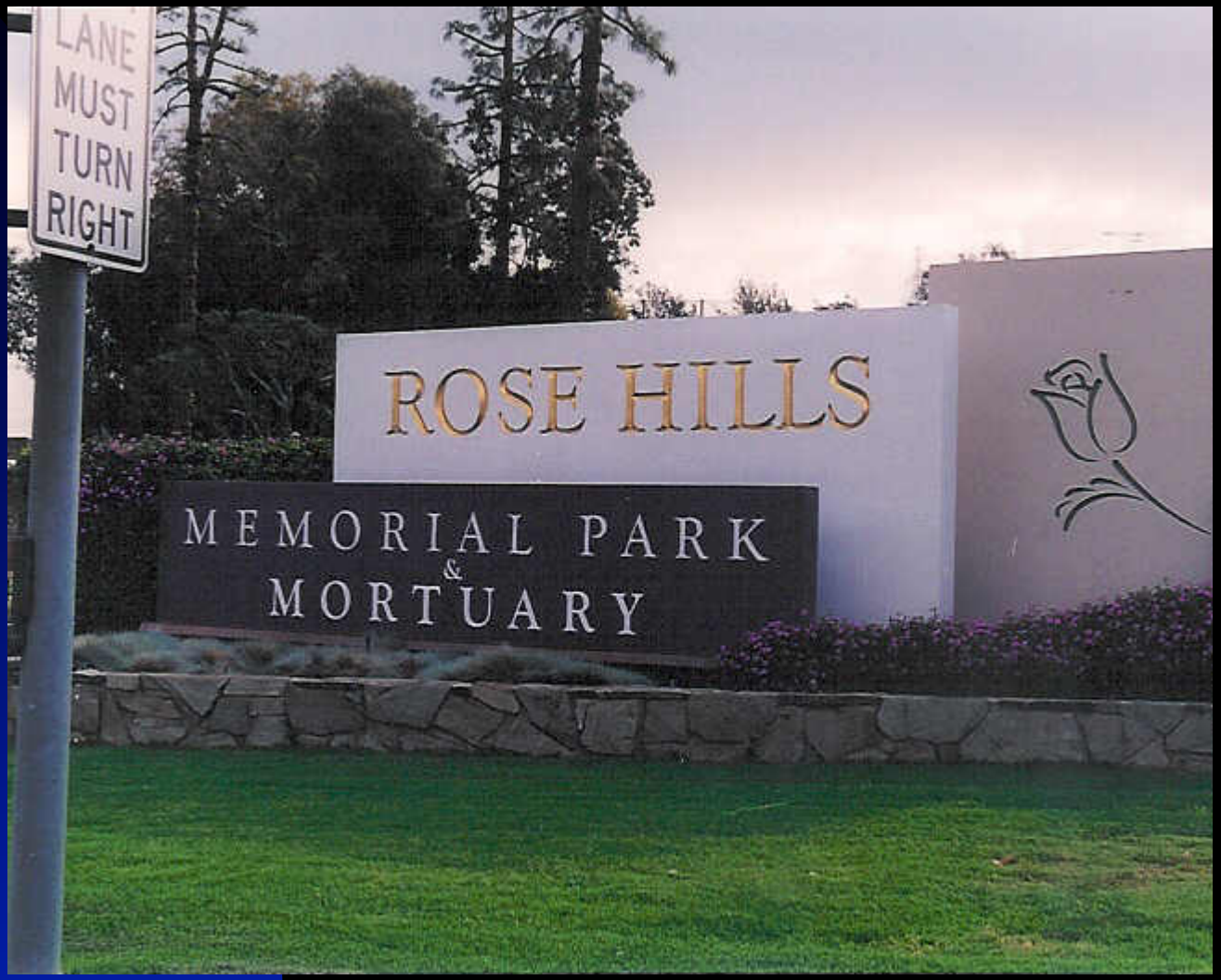




PATERNITY TESTING



Exhumation of a suspect in an unsolved homicide

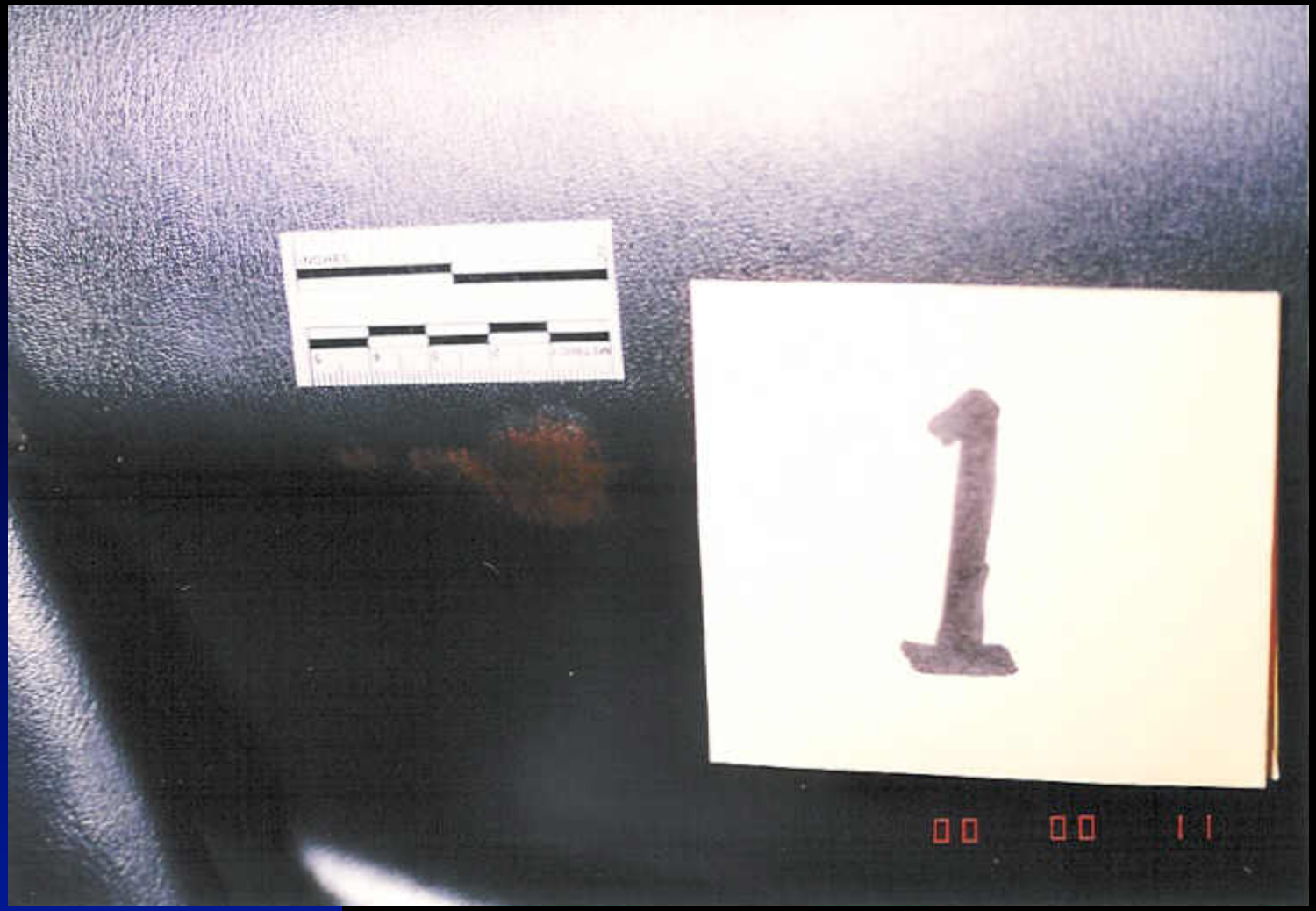


METRIC 1

INCHES

Vehicle Search: alleged get-away-car in a homicide

INTERIOR
RENEW
CLEANER
FOR
LEATHER, VINYL
RUBBER AND FABRIC


1
00 00 11

WWGD: What Would Grissom Do?

00 00 82

TIGER
00 01 15
BERLAND

00 01 36

QUESTIONS?