

# **Basics I**

**COMP 388-002/488-002 Biometrics**

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Fall 2023



**LOYOLA**  
UNIVERSITY CHICAGO

# Today we will...

*Discuss*

What Biometrics is.

Reasons to use Biometrics.

Biometric traits.

How Biometric systems should look like.

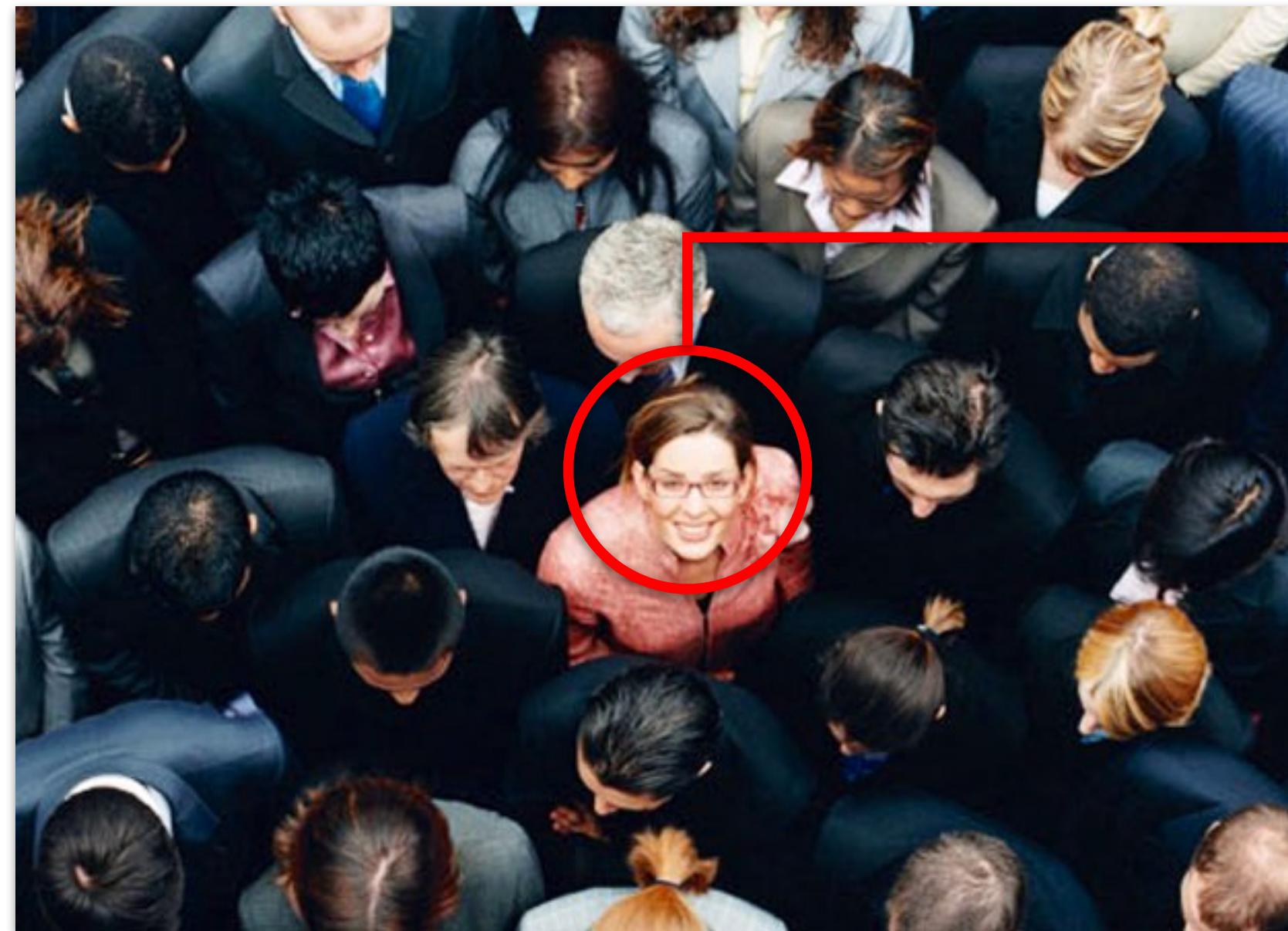
# Today's attendance

Please fill out the form

[bit.ly/3EgXf6S](https://bit.ly/3EgXf6S)



# What is Biometrics?



- 7 billion people
  - Who is this person? (*Identification*)
  - Is this person Jane Doe? (*Verification*)
- Biometrics aims at ***identifying*** or ***verifying*** the claimed or denied identity of an individual based on their *physical*, *chemical* or *behavioral* traits.

# What is Biometrics?



In this course, we aim at  
**computer-aided Biometrics**.

We'll focus on **software solutions**  
rather than hardware.

But we'll get to use some  
**devices**, I promise.

# What is Biometrics?

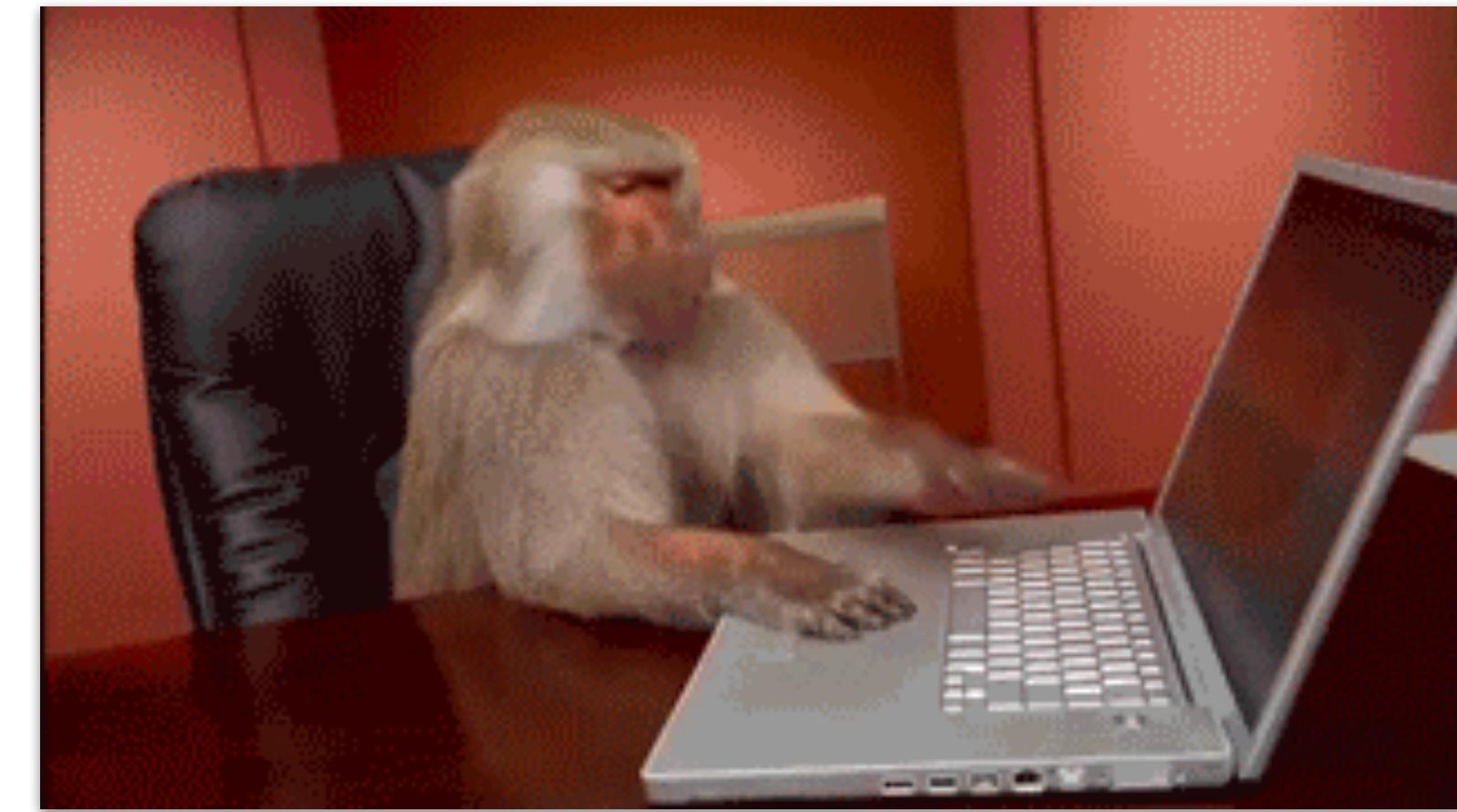
**Why computers?**



# What is Biometrics?

## Why computers?

- High throughput
- Repeatability
- Predictability
- Accountability

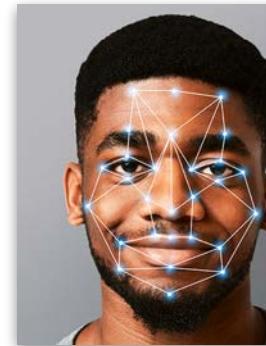


# What is Biometrics?

Identity verification through:



A unique trait  
of yours.



physical



chemical



behavioral



Not something  
you have.



Not something  
you know.



# Why use Biometrics?

## Consumers prefer biometric authentication to traditional passwords, Visa says

Jan 6, 2020 | [Chris Burt](#)

CATEGORIES

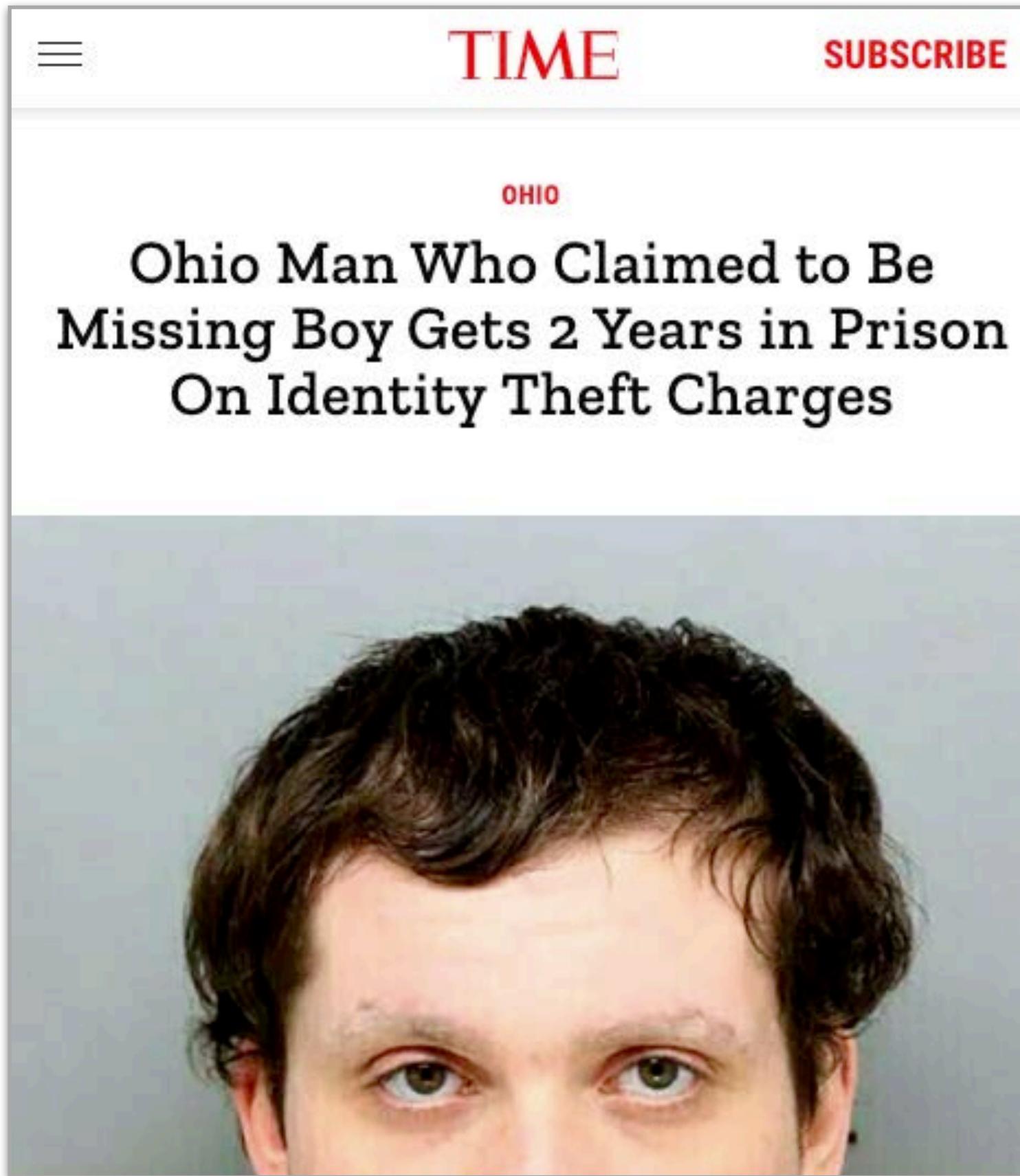
[Biometrics News](#) | [Financial Services](#)



Almost 70 percent of U.S. shoppers did not go through with an online purchase because they either forgot the password, couldn't log in or couldn't receive a one-time passcode, according to research conducted by [Visa](#), while another report from Verizon found that as many as 80 percent of data breaches are caused by compromised and weak passwords.

<https://www.biometricupdate.com/202001/consumers-prefer-biometric-authentication-to-traditional-passwords-visa-says>

# Why use Biometrics?



The screenshot shows a news article from TIME magazine. At the top, there are navigation links for a menu, the word "TIME" in red, and "SUBSCRIBE". Below this, the word "OHIO" is written in red. The main headline reads: "Ohio Man Who Claimed to Be Missing Boy Gets 2 Years in Prison On Identity Theft Charges". Below the headline is a black and white mugshot of a man with dark hair and green eyes. The background of the article area is light gray.

(CINCINNATI) — An Ohio man who claimed to be a child who disappeared at age 6 pleaded guilty Wednesday to aggravated identity theft and will serve two years in prison, minus time served.

Federal authorities said they were suspicious after he refused to be fingerprinted. DNA testing quickly revealed his true identity.

<https://time.com/5762223/brian-rini-missing-child-pleads-guilty/>

# Why use Biometrics?

**Biometrics is safer**  
But not absolutely safe!

The screenshot shows the BBC News website. The top navigation bar includes the BBC logo, a 'Sign in' button, and categories like News, Sport, Reel, Worklife, Travel, Future, and more. Below this is a large red 'NEWS' banner. The main menu below the banner includes Home, Video, World, US & Canada, UK, Business, Tech, Science, Stories, and Entertainment. Under the World section, links for Africa, Asia, Australia, Europe, Latin America (which is underlined), and Middle East are shown. The main article headline is 'Doctor 'used silicone fingers' to sign in for colleagues'. Below the headline is a timestamp '12 March 2013' and social sharing icons for Facebook, Messenger, Twitter, Email, and a green 'Share' button.

<https://www.bbc.com/news/world-latin-america-21756709>



A Brazilian doctor faces charges of fraud after being caught on camera using silicone fingers to sign in for work for absent colleagues, police say.



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# Why use Biometrics?

**Biometrics is safer**  
But not absolutely safe!

= WIRED

SUBSCRIBE



Experience that new-car feeling.

ANDY GREENBERG SECURITY 11.14.2017 07:00 AM

## Watch a 10-Year-Old's Face Unlock His Mom's iPhone X

Yes, twins can unlock each other's iPhones. But kids accessing their parents' devices raises different concerns.



<https://www.wired.com/story/10-year-old-face-id-unlocks-mothers-iphone-x/>

# Why use Biometrics?

**Biometrics is safer**  
But not absolutely safe!  
Even humans fail.

The New York Times

## ***Report Faults F.B.I.'s Fingerprint Scrutiny in Arrest of Lawyer***

By David Stout

Nov. 17, 2004

f    t    e-mail    share    bookmark

<https://www.nytimes.com/2004/11/17/politics/report-faults-fbis-fingerprint-scrutiny-in-arrest-of-lawyer.html>



latent  
fingerprint

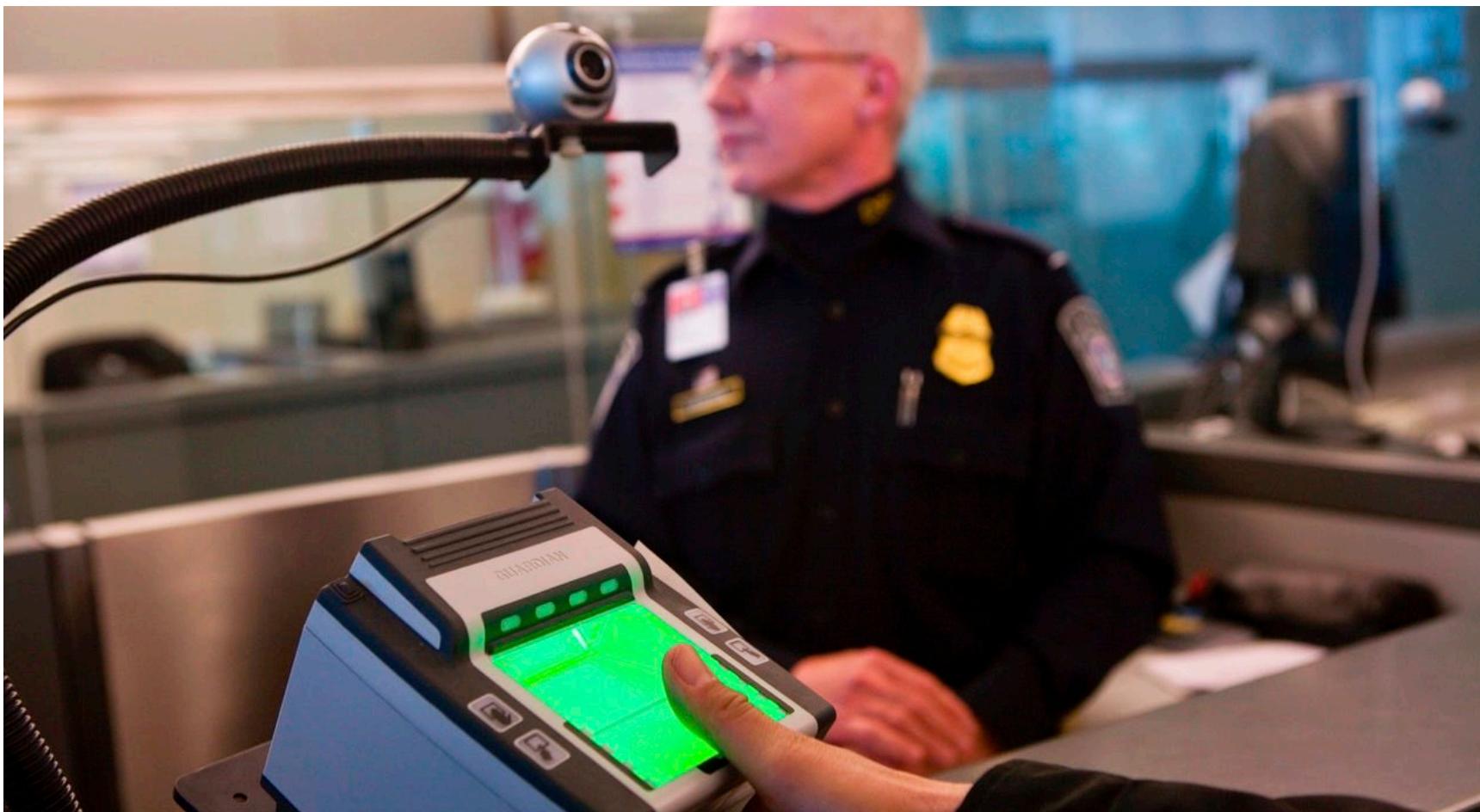


collected  
fingerprint

WASHINGTON, Nov. 16 - The Federal Bureau of Investigation wrongly implicated an Oregon lawyer in a deadly train bombing in Madrid because the F.B.I. culture discouraged fingerprint examiners from disagreeing with their superiors, a panel of forensic experts has concluded.

# Biometrics Use

**Biometrics is a reality**



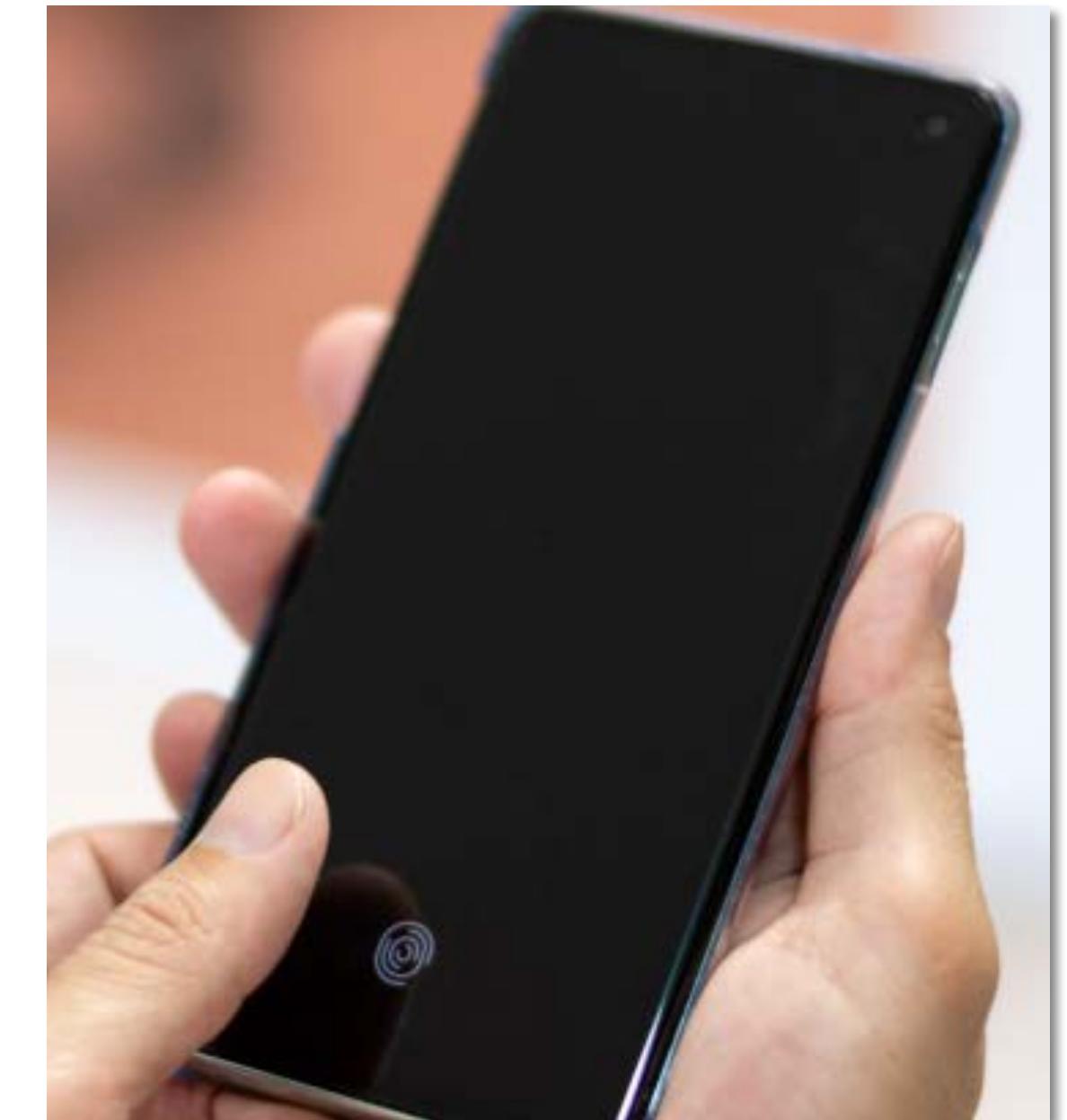
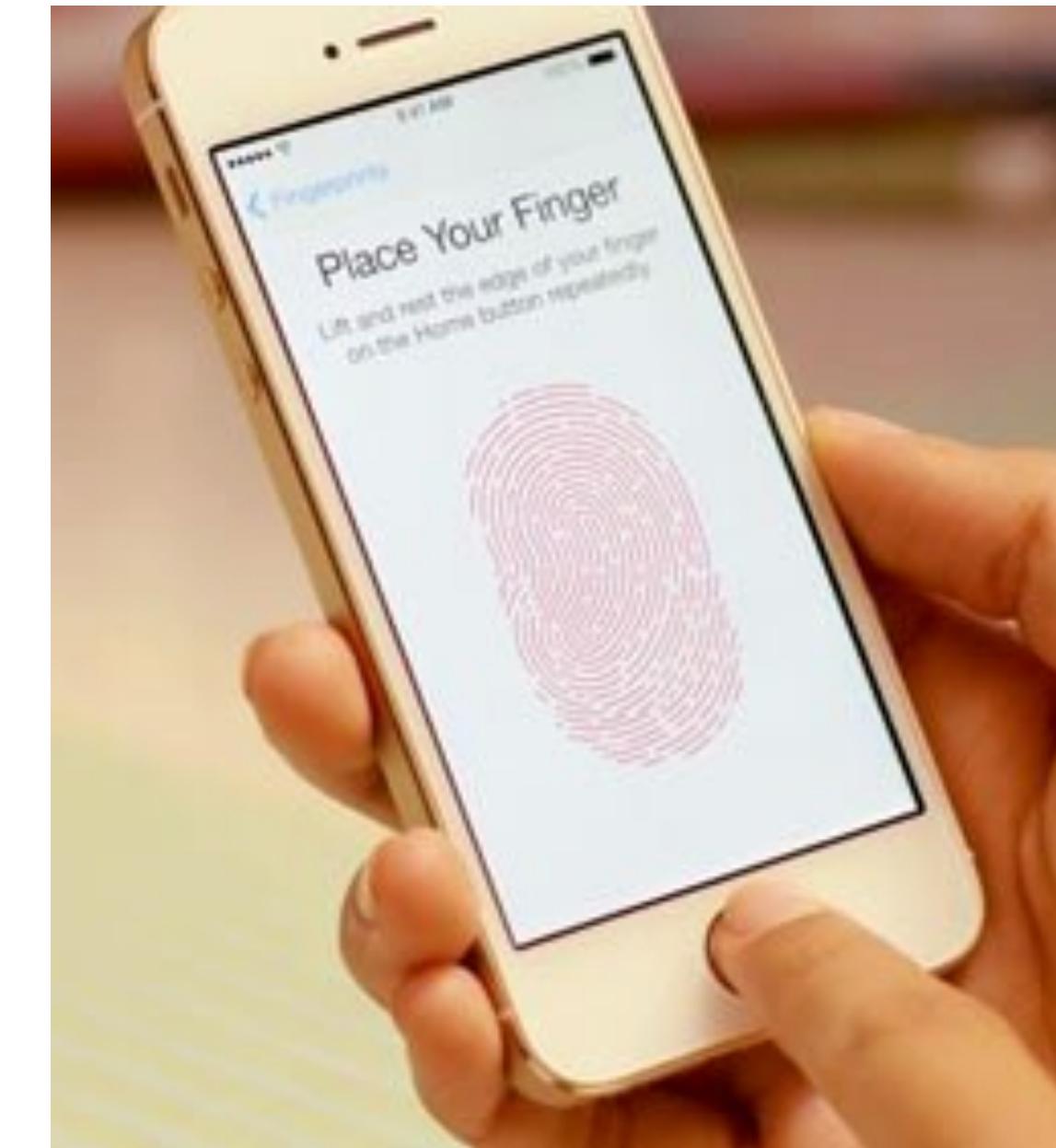
border patrol



entertainment

# Biometrics Use

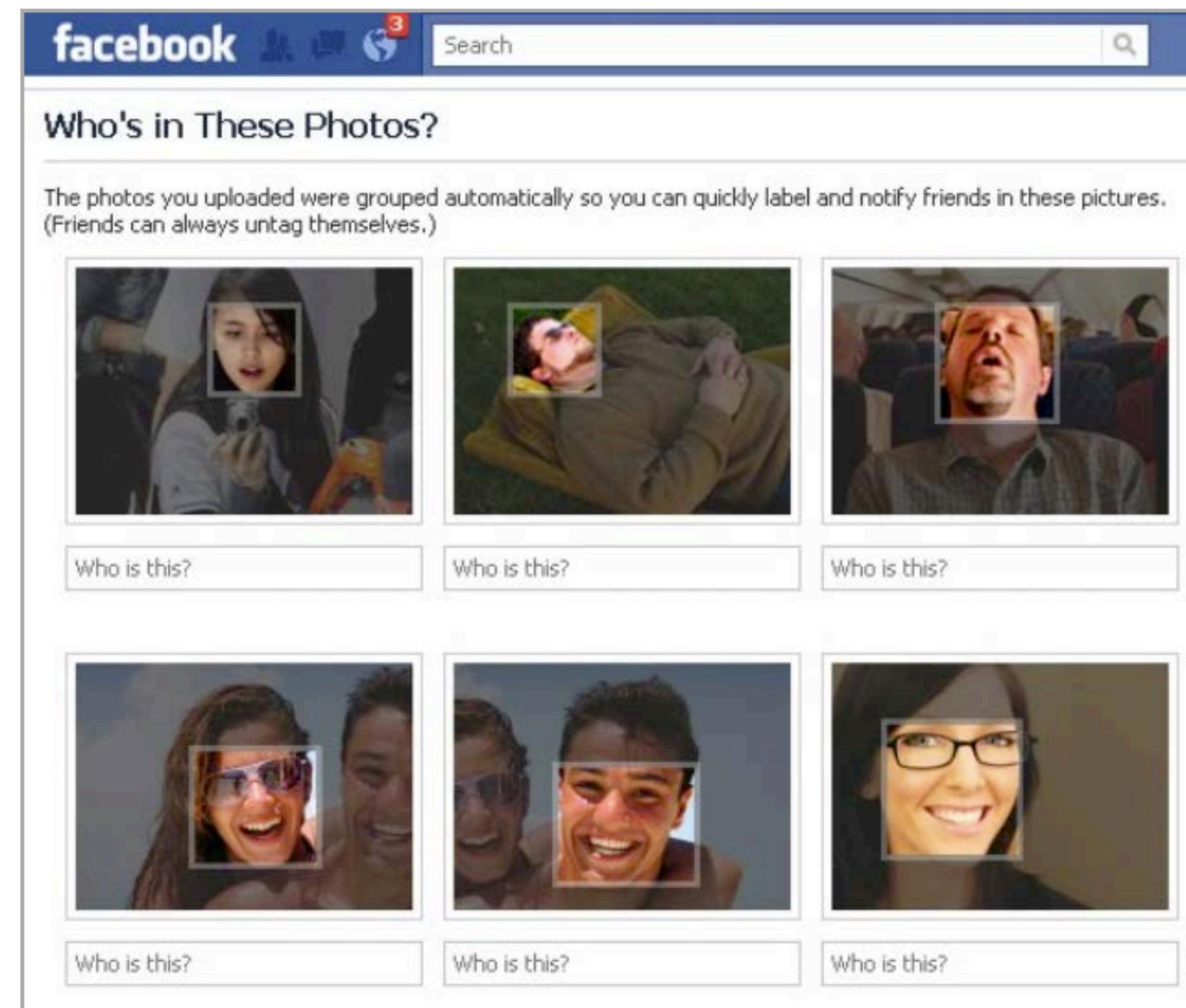
**Biometrics is a reality**



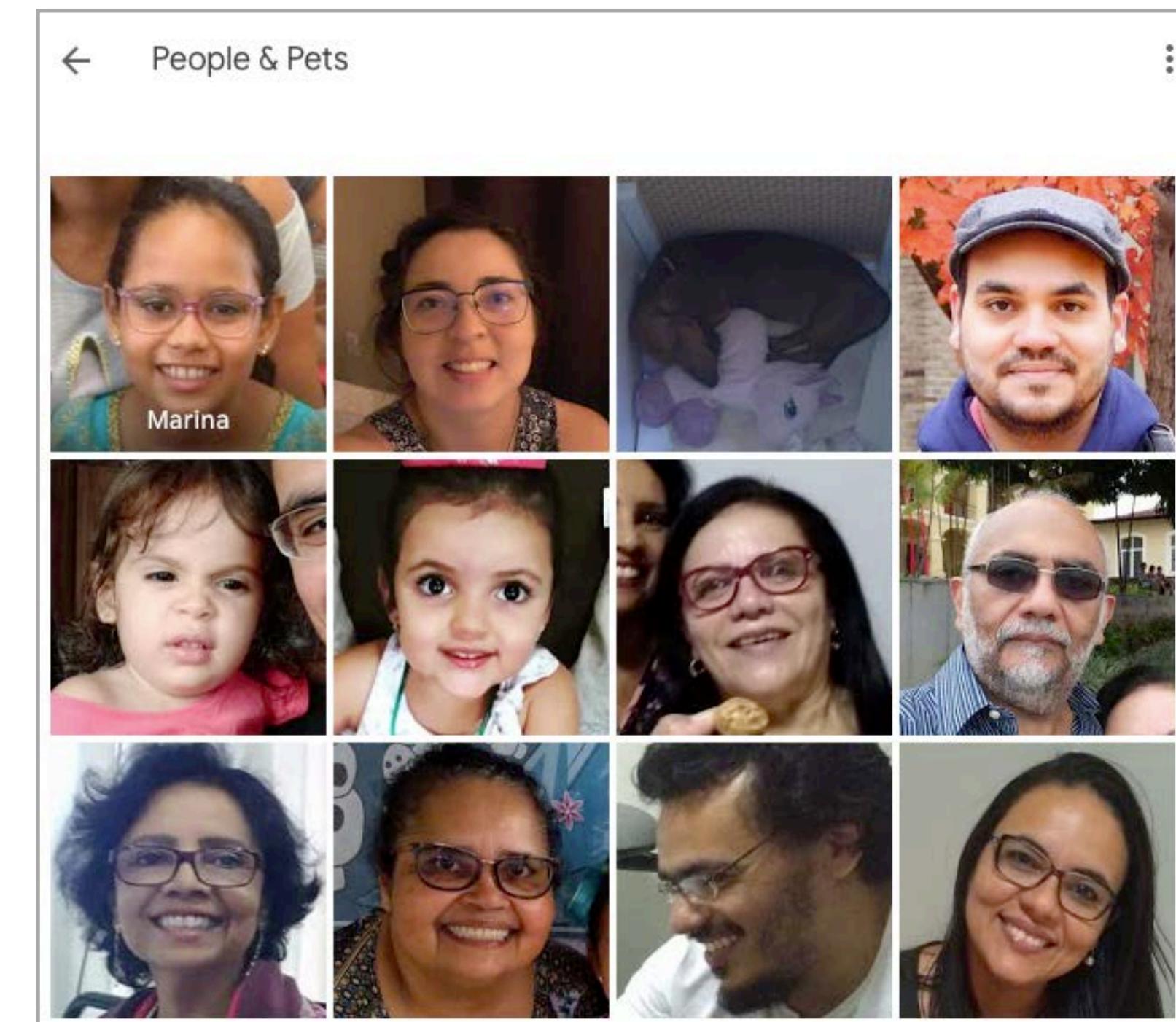
personal devices

# Biometrics Use

## Biometrics is a reality



Facebook



Google Photos

# Biometrics Use

**Biometrics is a reality**

**Indian AADHAAR program**

10-year initiative.

1.2 billion people enrolled  
(99% of adult population).

Iris scans, faces, and fingerprints.

Claimed to have saved the  
Indian government \$12.4 billion.



civil rights

# Biometrics Abuse

## Function Creep

Widening of the use of a technology beyond the purpose for which it was originally intended.



US typical example: SSN

The same may happen with Biometric systems.

# Biometrics Abuse

## Function Creep

In 2001, Colorado state was caught selling its DMV\* face and fingerprint databases to corporations.



\*Department of Motor Vehicles

Source: <https://i2i.org/wp-content/uploads/2011/02/IP-8-2001-1.pdf>

# Biometrics Abuse

## Segregating Profiling

**hindustantimes** Sign In Saturday, Jan 11, 2020 | New Delhi 16°C | e-paper

discover india cities opinion world cricket entertainment election trending videos tech ••• Q Search

Home / Bhopal / Linking benefits for AIDS patients to Aadhaar triggers privacy concerns

## Linking benefits for AIDS patients to Aadhaar triggers privacy concerns

Many patients are avoiding going to hospitals and ATR centres fearing mandatory submission of their Aadhaar number could lead to disclosure of their identity, inviting social stigma.

BHOPAL Updated: Apr 03, 2017 12:34 IST

<https://www.hindustantimes.com/bhopal/linking-benefits-for-aids-patients-to-aadhaar-triggers-privacy-concerns/story-iR6HB8RmqPDAwkwX2Oj5EJ.html>

# Biometrics Abuse

## Segregating Profiling

The New York Times

### ***China Uses DNA to Map Faces, With Help From the West***

Beijing's pursuit of control over a Muslim ethnic group pushes the rules of science and raises questions about consent.

By Sui-Lee Wee and Paul Mozur

Published Dec. 3, 2019 Updated Dec. 10, 2019

f t m r b 341

<https://www.nytimes.com/2019/12/03/business/china-dna-uighurs-xinjiang.html>

# Biometrics Abuse

## Data Leakage

[HOME](#) [NATION](#)

TRIBUNE INVESTIGATION — SECURITY BREACH

## Rs 500, 10 minutes, and you have access to billion Aadhaar details

JALANDHAR: It was only last November that the UIDAI asserted that &ldquo;Aadhaar data is fully safe and secure and there has been no data leak or breach at UIDAI.

Posted: Jan 04, 2018 02:07 AM (IST) Updated: 2 years ago

103612 0 0 0

<https://www.tribuneindia.com/news/archive/rs-500-10-minutes-and-you-have-access-to-billion-aadhaar-details-523361>

# Biometrics Abuse

## Compromised biometric data

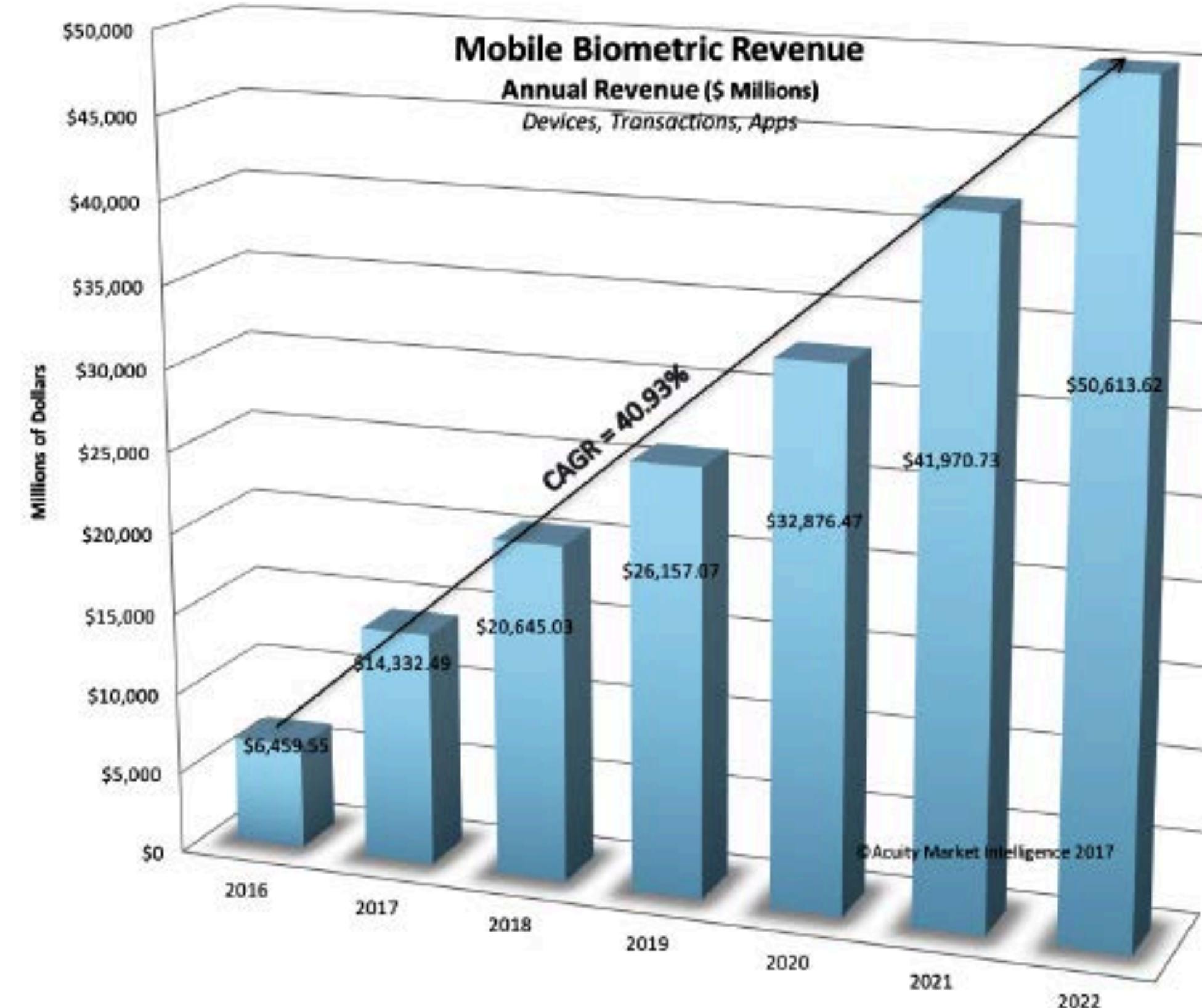
People cannot change their biometric data in response to a leak. Irreversible for whole lifetime.



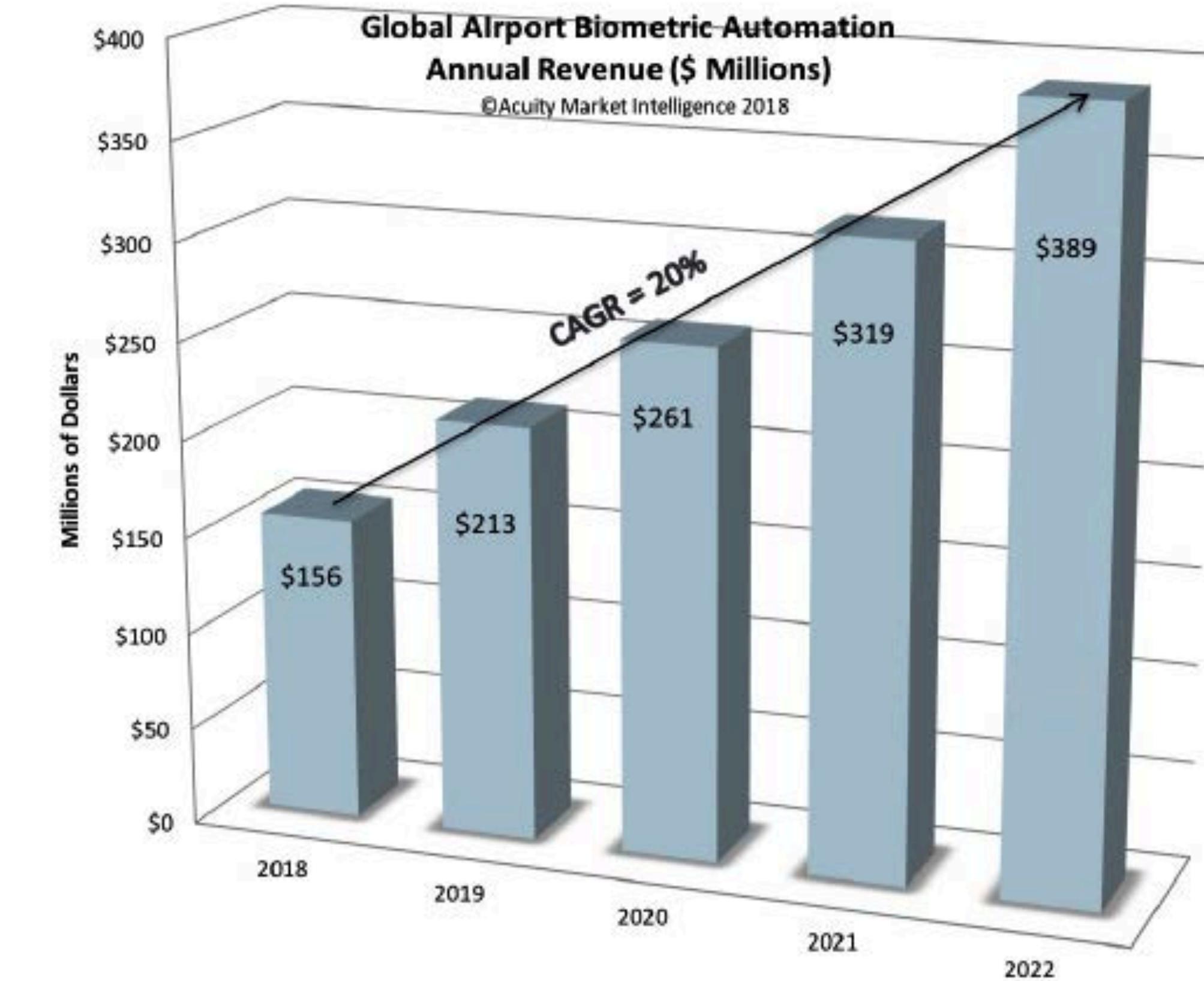
Please, don't.

# Biometrics Appeal

2017 Forecast



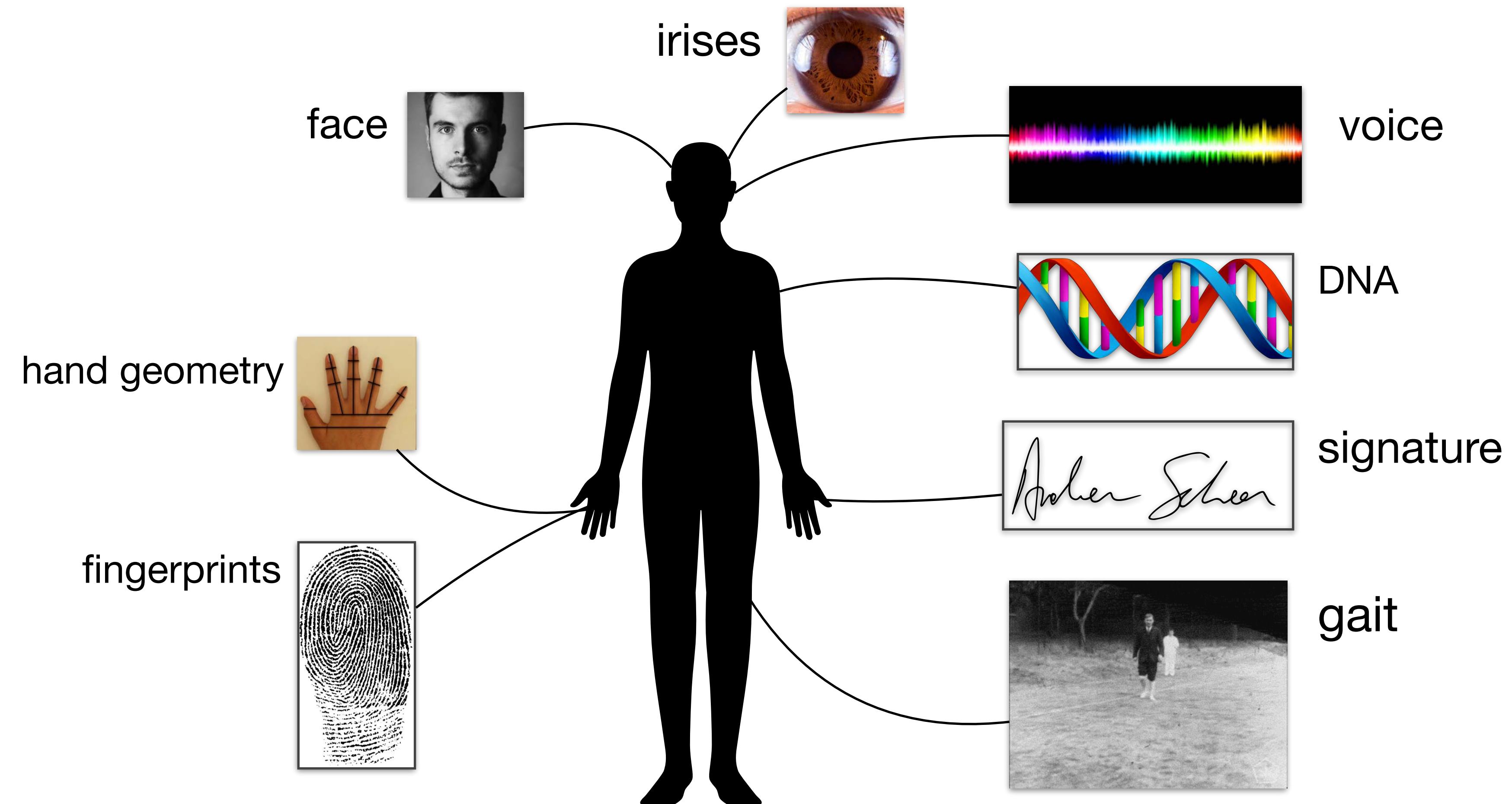
2019 Forecast



Source: Acuity Market Intelligence (<https://www.acuitymi.com/>)

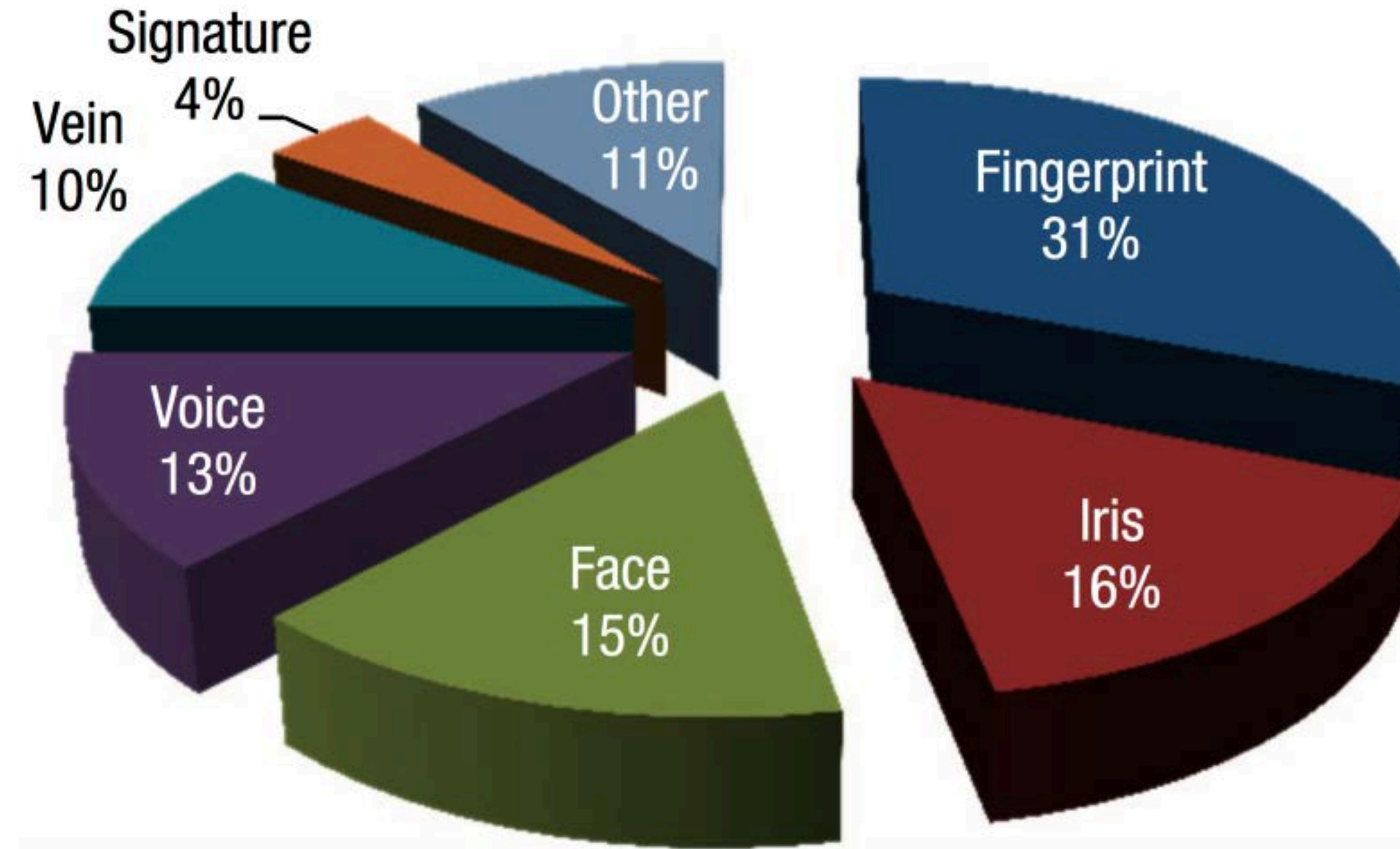
CAGR: Compound Annual Growth Rate

# Biometric Traits



# Biometric Traits

## Market



Source: Mani and Nadeski, *Processing solutions for biometric systems*, Texas Instruments, 2015

# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Universality (1/8)**



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Universality (1/8)**

Does everybody have the trait?



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Uniqueness (2/8)**



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Uniqueness (2/8)**

How likely two or more individuals will present the same trait?



# Biometric Traits

## What do we want to consider?

Some traits might be more suitable than others.

### Uniqueness (2/8)

How likely two or more individuals will present the same trait?

The New York Times

### *Who's the Daddy? Neither Twin Would Say. But They Both Will Pay.*

By Ernesto Londoño and Lis Moriconi

April 3, 2019



RIO DE JANEIRO — The judge was stumped.

He had ordered a pair of identical twins to take DNA tests in a paternity case in the central Brazilian state of Goiás. Both came back positive.

<https://www.nytimes.com/2019/04/03/world/americas/brazil-paternity-dna.html>

# Biometric Traits

**What do we want to consider?**  
Some traits might be more suitable than others.

**Uniqueness (2/8)**  
How likely two or more individuals will present the same trait?

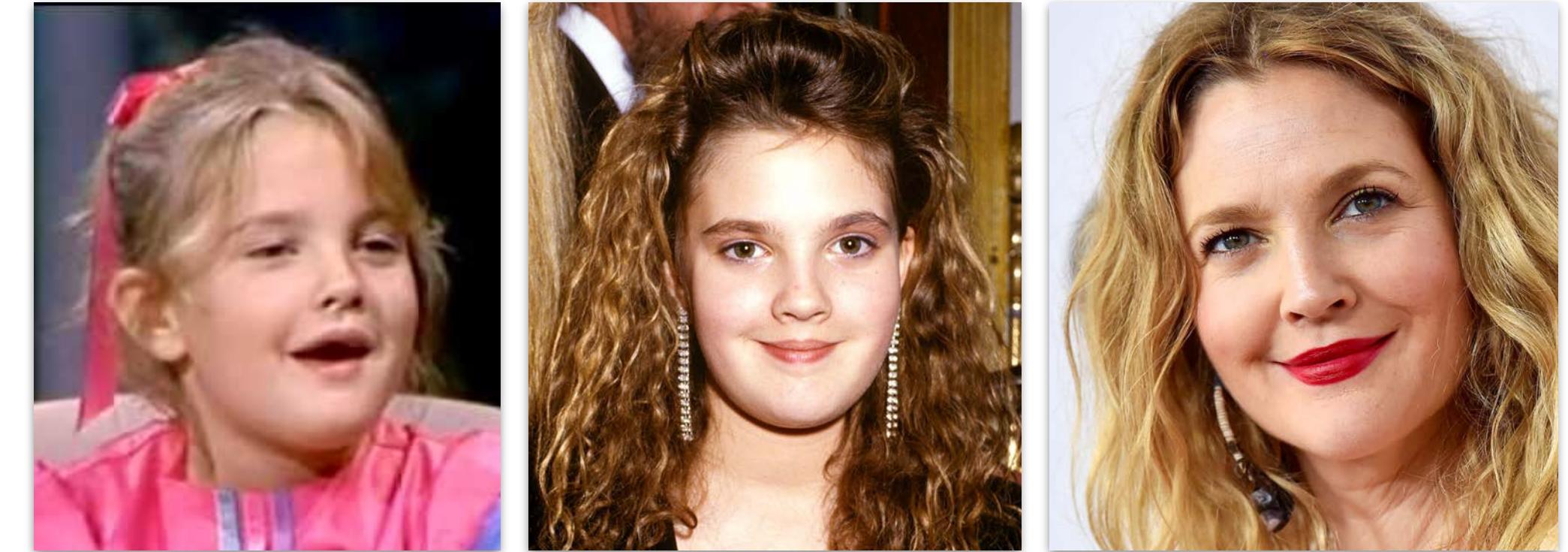
The image shows a screenshot of a BuzzFeed News article. The header features the BuzzFeed logo and navigation links for 'ABOUT US', 'GOT A TIP?', 'SUPPORT US', 'BUZZFEED.COM', and 'SECTIONS'. Below the header, there are several news headlines: 'Trending' (Taal Volcano Eruption, Cory Booker, Oscar Nominations, Royal Family), 'SCIENCE' (This Man Failed A Paternity Test Due To His Vanished Twin's DNA). The main headline is 'This Man Failed A Paternity Test Due To His Vanished Twin's DNA'. The article summary states: 'DNA researchers report a father failed a paternity test because the genes in his saliva differ from his sperm's. One in eight people might possess such "chimeric" genes caused by a twin lost in the womb.' The author is Dan Vergano, a BuzzFeed News Reporter, and the post was made on October 24, 2015, at 10:16 a.m. ET.

<https://www.buzzfeednews.com/article/danvergano/failed-paternity-test-vanished-twin>

# Biometric Traits

**What do we want to consider?**  
Some traits might be more suitable  
than others.

**Permanence (3/8)**



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Permanence (3/8)**

How does the trait change over time?

How can diseases affect the trait?



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Measurability (4/8)**



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Measurability (4/8)**

How easy is it to acquire and digitize the trait?



# Biometric Traits

**What do we want to consider?**  
Some traits might be more suitable than others.

## Acceptability (5/8)



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Acceptability (5/8)**

Will individuals collaborate during data collection?

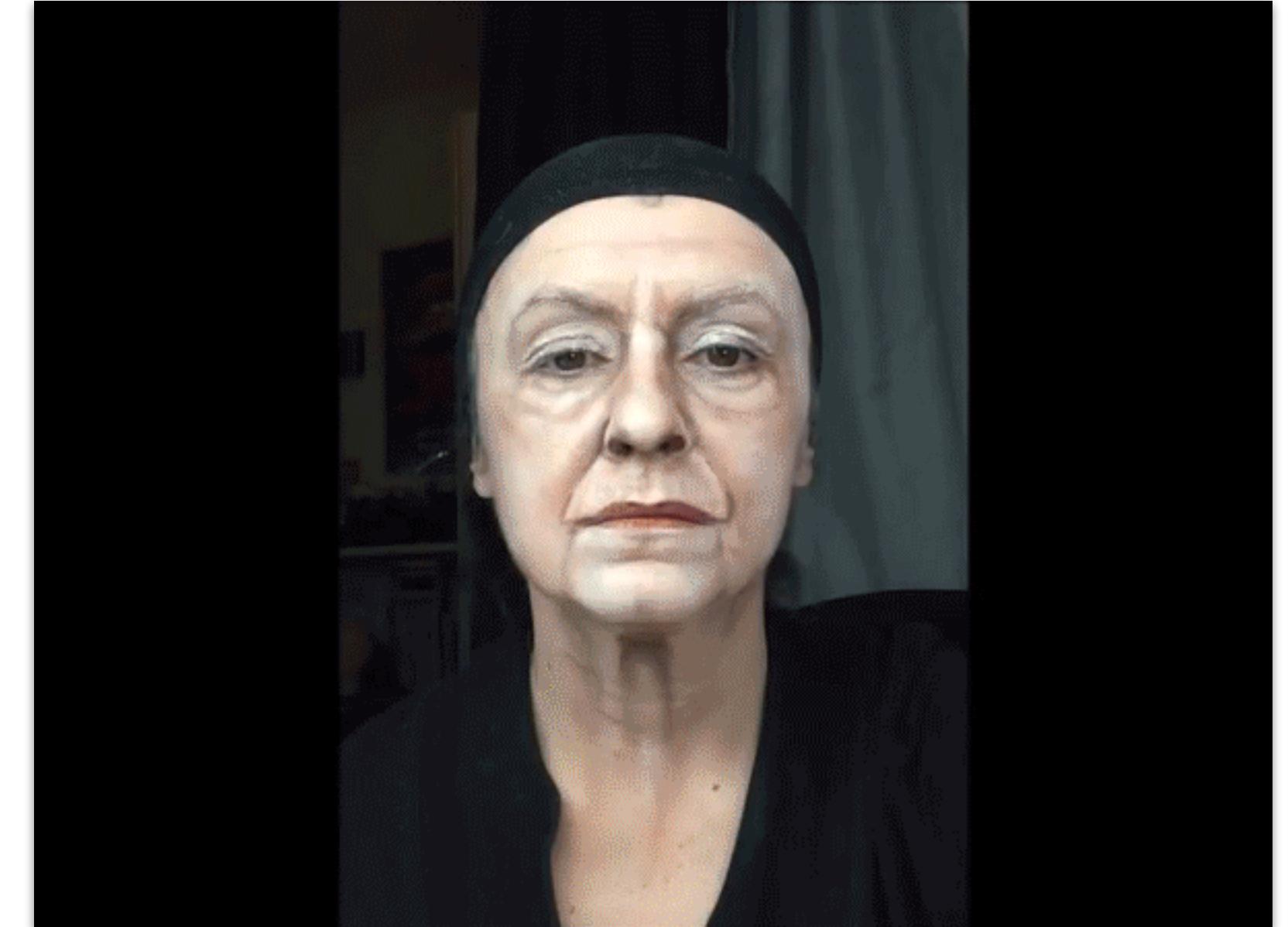


# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Circumvention (6/8)**



<https://www.youtube.com/watch?v=SIII8L43nng>

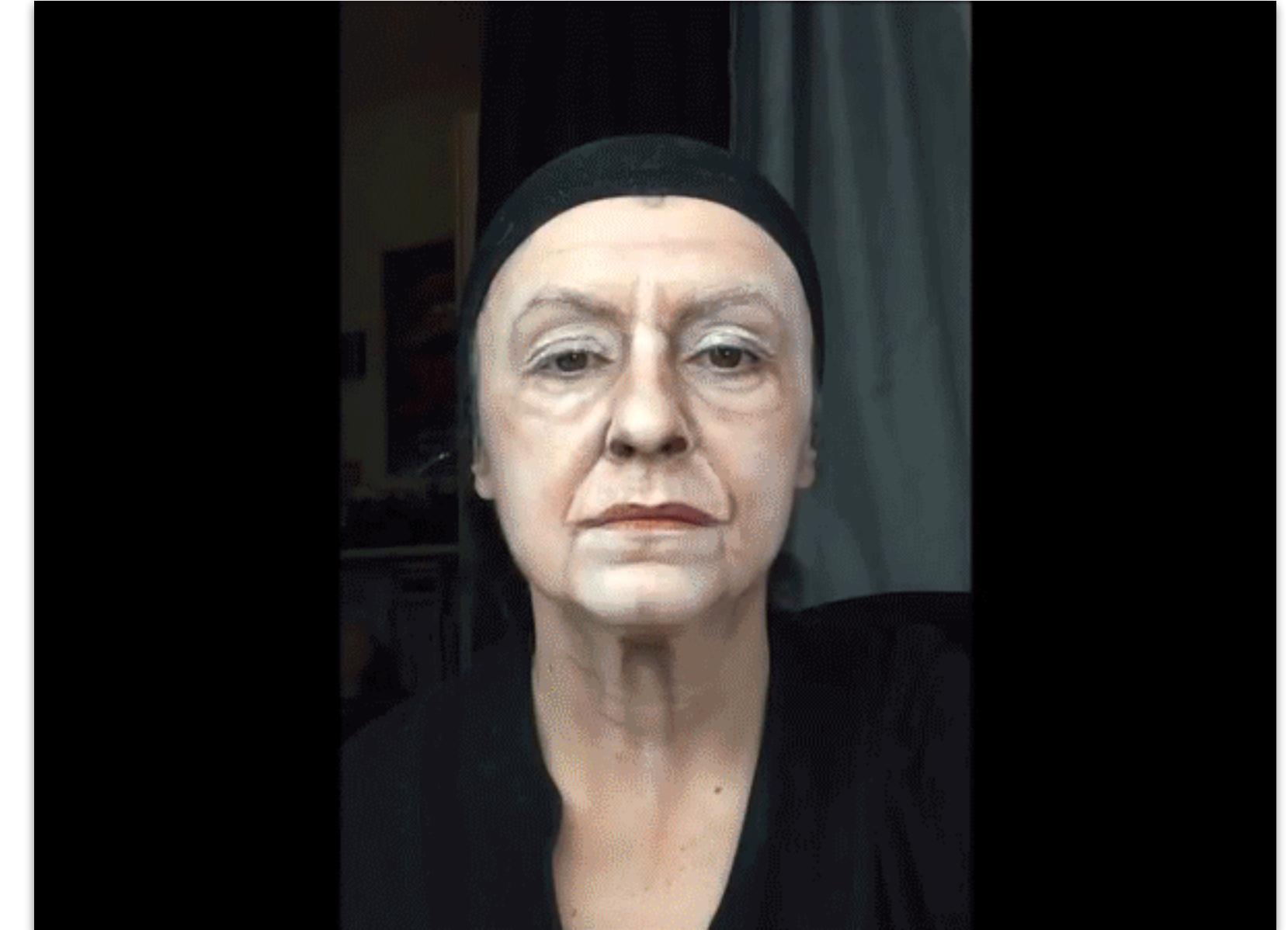
# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Circumvention (6/8)**

How easy can the trait be forged or imitated?



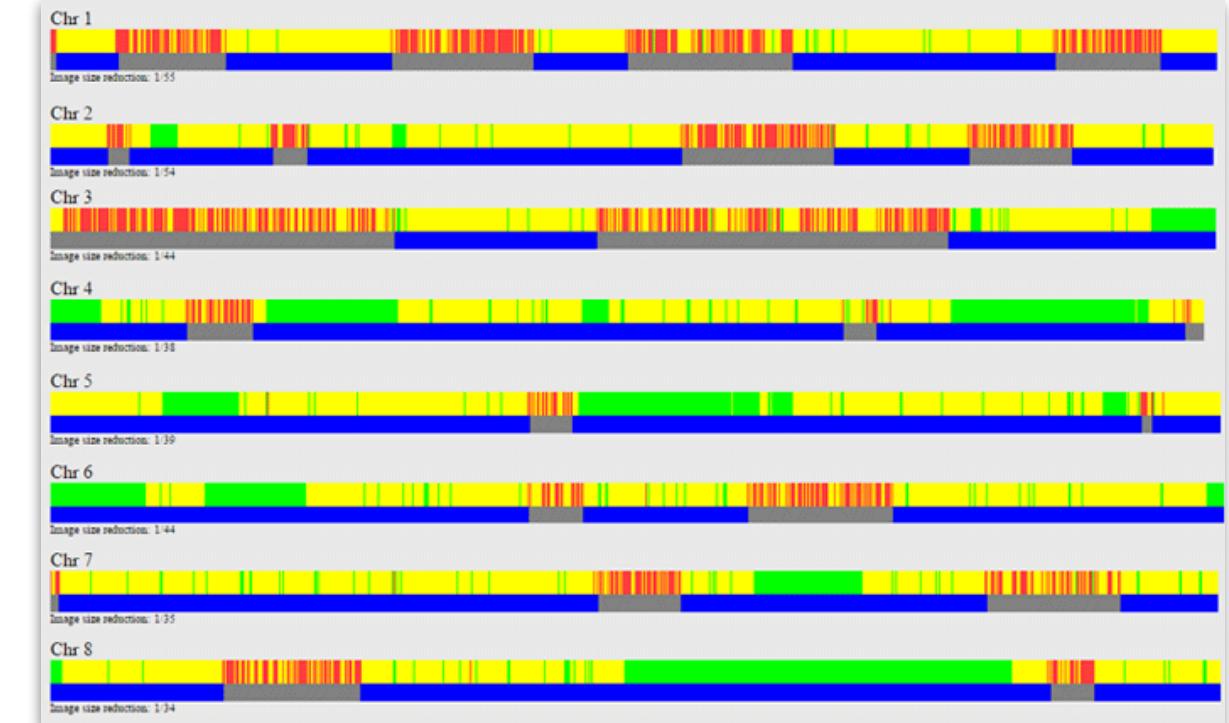
<https://www.youtube.com/watch?v=SIII8L43nng>

# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

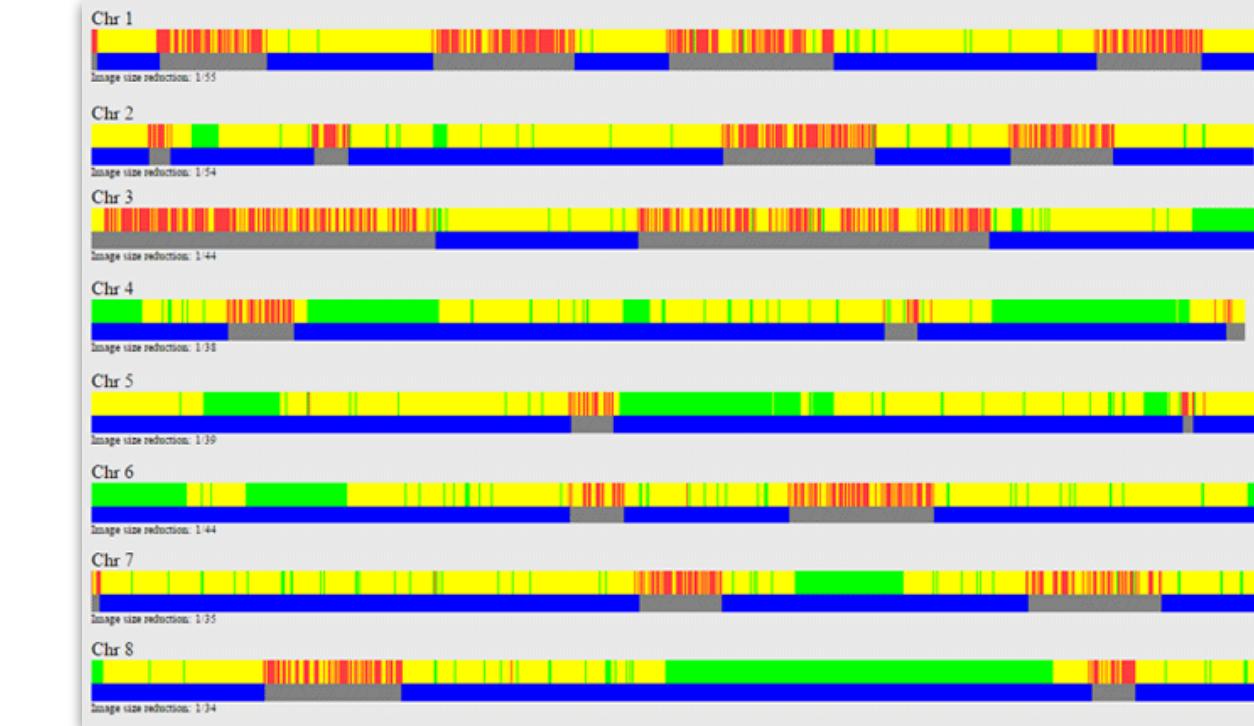
**Explainability (7/8)**



# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.



**Explainability (7/8)**

How easy is it for the everyman to understand the trait comparison?



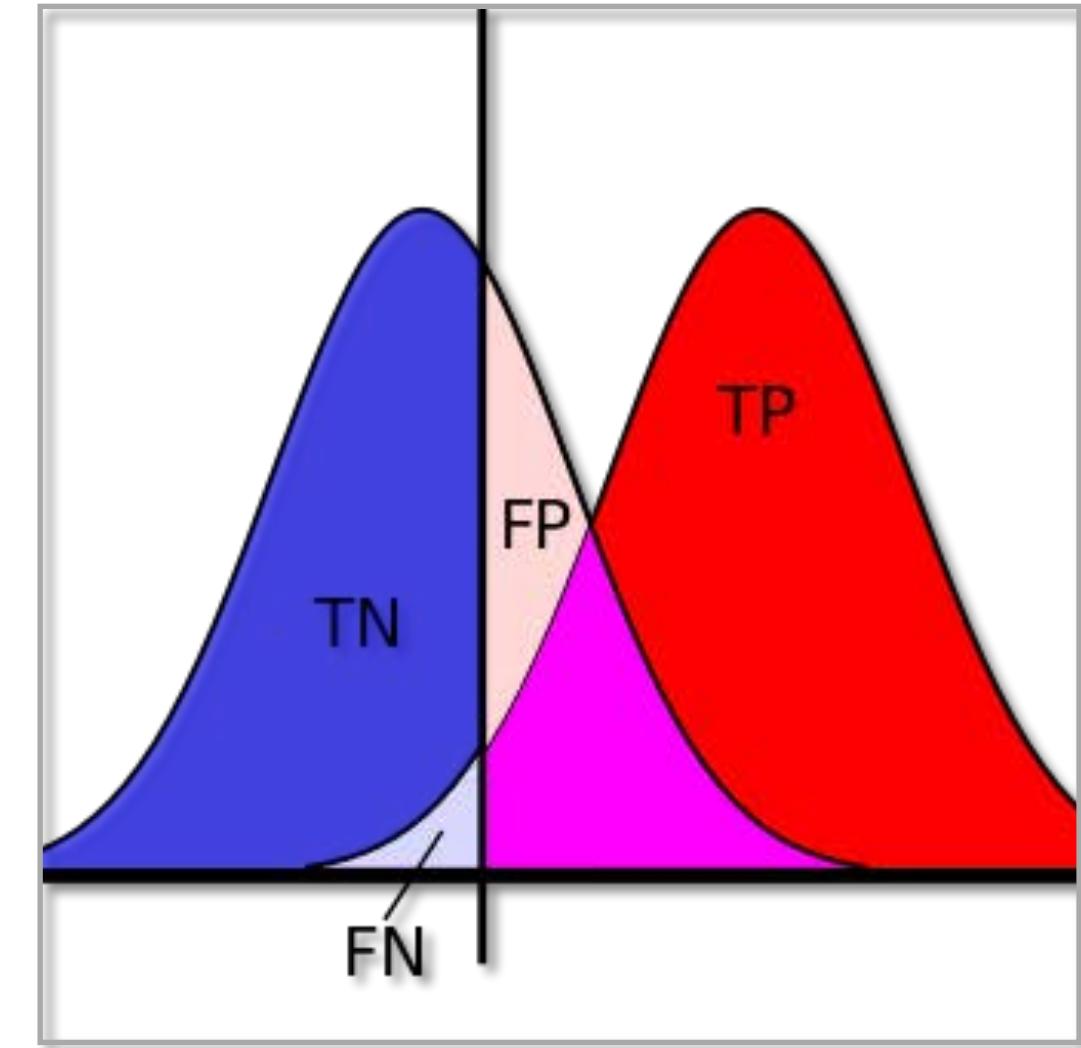
# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Performance (8/8)**

How good is the trait quantitatively according to objective **metrics**?  
(we'll see them soon)



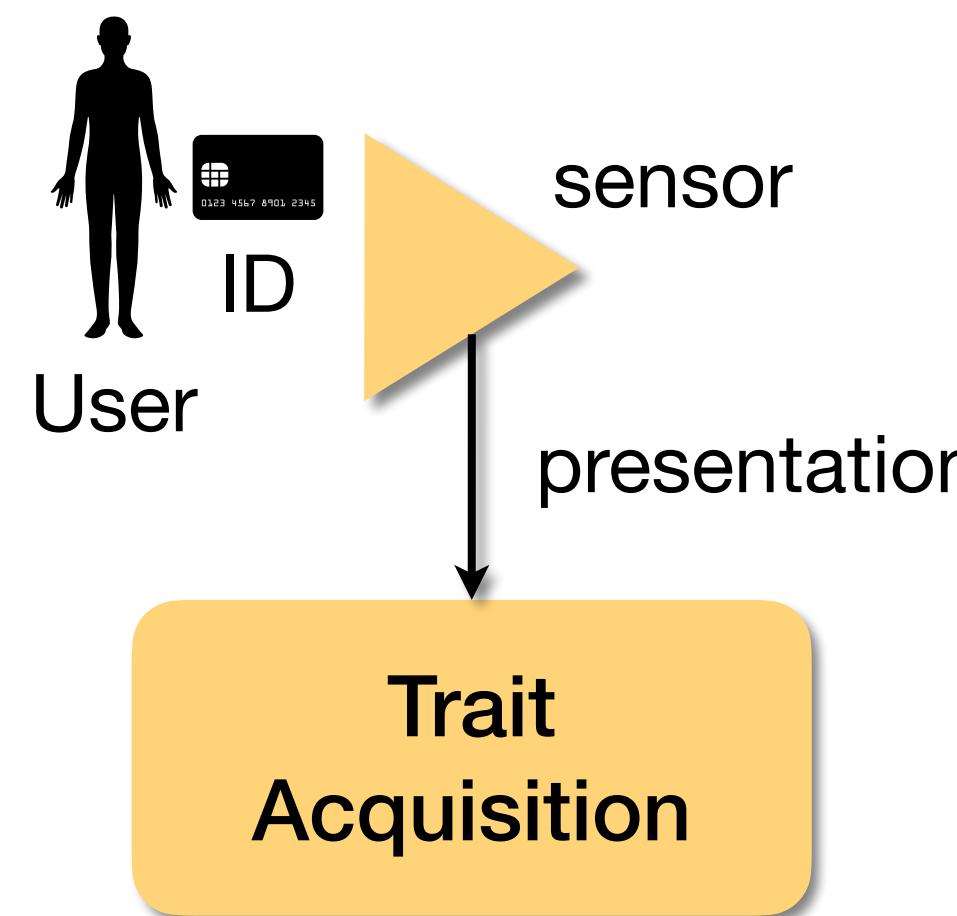
# Activity

Please go to **bit.ly/3Rj4xiz**  
and answer the questions.



# Biometric Systems

## Enrollment



## Trait Acquisition

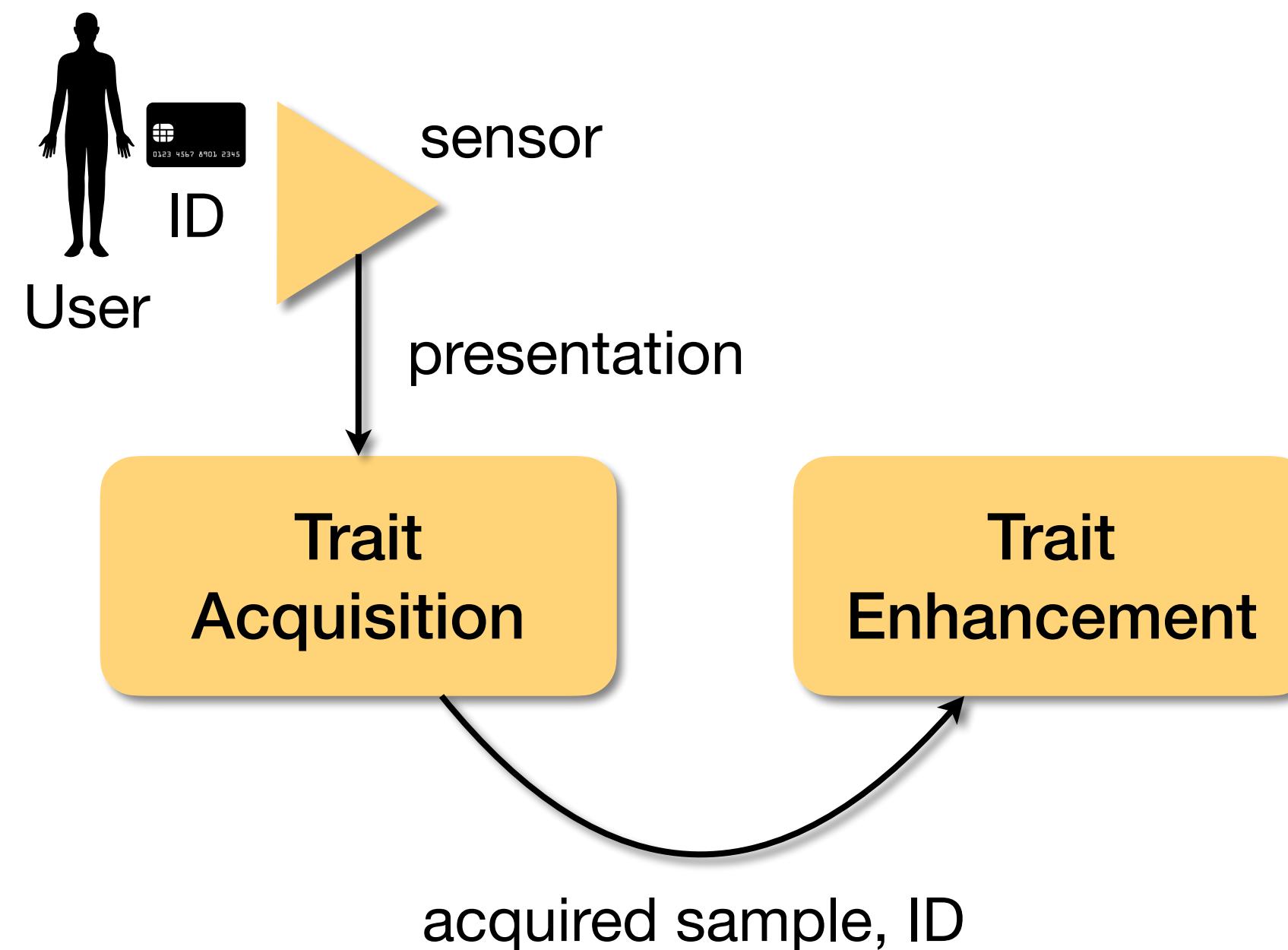
We'll have data-collection classes.  
We'll use real-world sensors.

## What to observe?

Sensors have different **quality**  
(in terms of precision, resolution,  
presence of noise, and usability)

# Biometric Systems

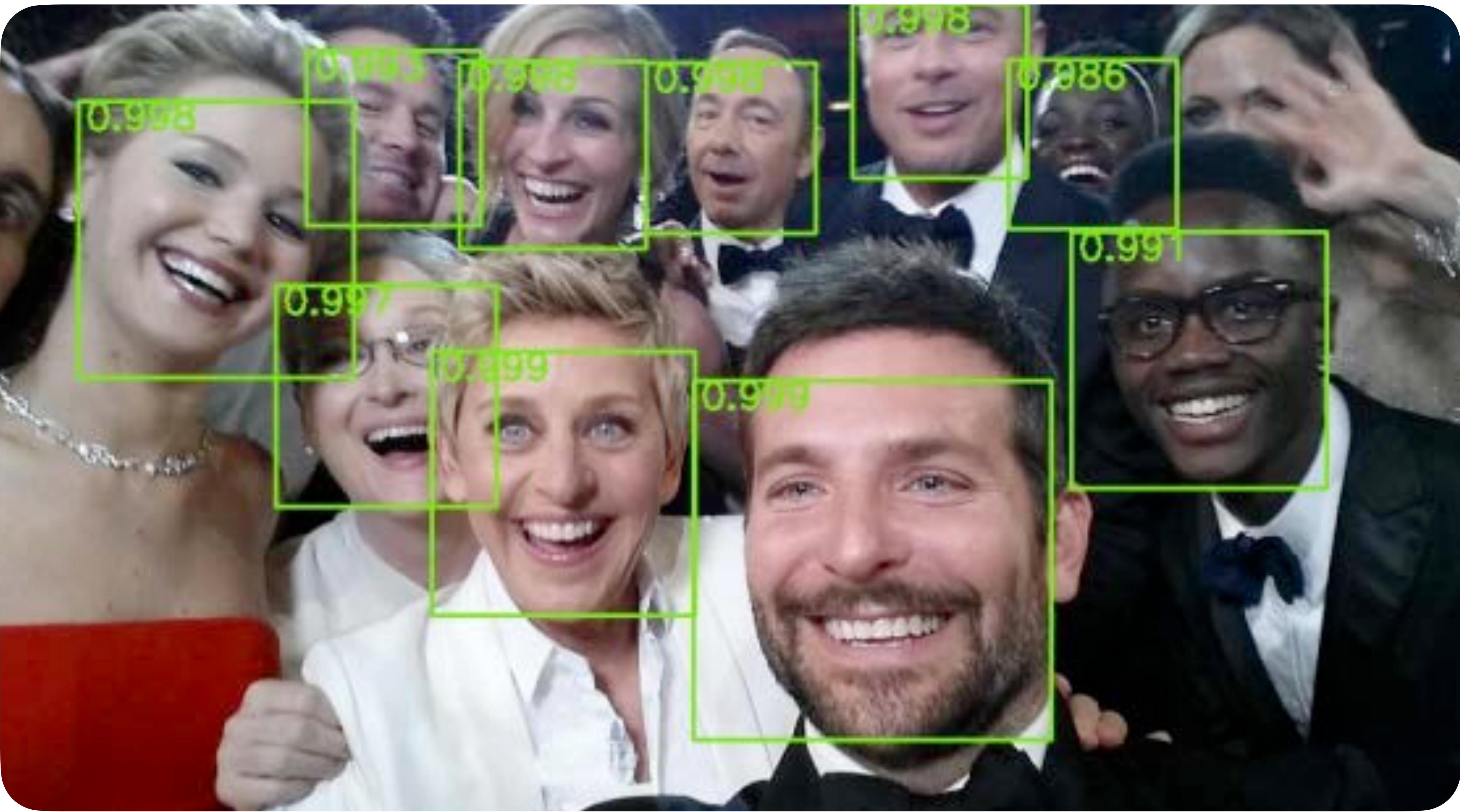
## Enrollment



## Trait Enhancement

Noise removal.

Operations to keep only **essential** information (consider universality, uniqueness, permanence, circumvention, accountability, and performance).



0.998

0.99

0.999

0.999

0.998

0.986

0.991

Load irises

Load examination

Save examination

Save report

Quit program

**Brightness**

-1.0      1.0  
0.0

**Contrast**

0.0      2.0  
1.0

**Sharpening**

0.0      10.0  
0.0

**Segment iris**

**Brightness**

-1.0      1.0  
0.0

**Contrast**

0.0      2.0  
1.0

**Sharpening**

0.0      10.0  
0.0

**Segment iris**

1.0      3.0  
1.0

1x

1.0      3.0  
1.0

**Human-Interpretable Features**

<input checked="" type="checkbox"/> TSHEPII	<input type="checkbox"/> Show Matched	<input type="checkbox"/> Show Unmatched	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td>-</td><td>0</td><td>+</td></tr> <tr><td>-</td><td>1</td><td>+</td></tr> </table>	-	0	+	-	1	+	out of 0	<input checked="" type="checkbox"/> MSER	<input type="checkbox"/> Show Matched	<input type="checkbox"/> Show Unmatched	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td>-</td><td>0</td><td>+</td></tr> <tr><td>-</td><td>1</td><td>+</td></tr> </table>	-	0	+	-	1	+	out of 0
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-	0	+																			
-	1	+																			

**Manual Annotation**

Annotate...  Matching Regions  Non-Matching Regions

Show Matching Regions  Show Non-Matching Regions

**Undo last removal**

**Non-Human-Interpretable Features**

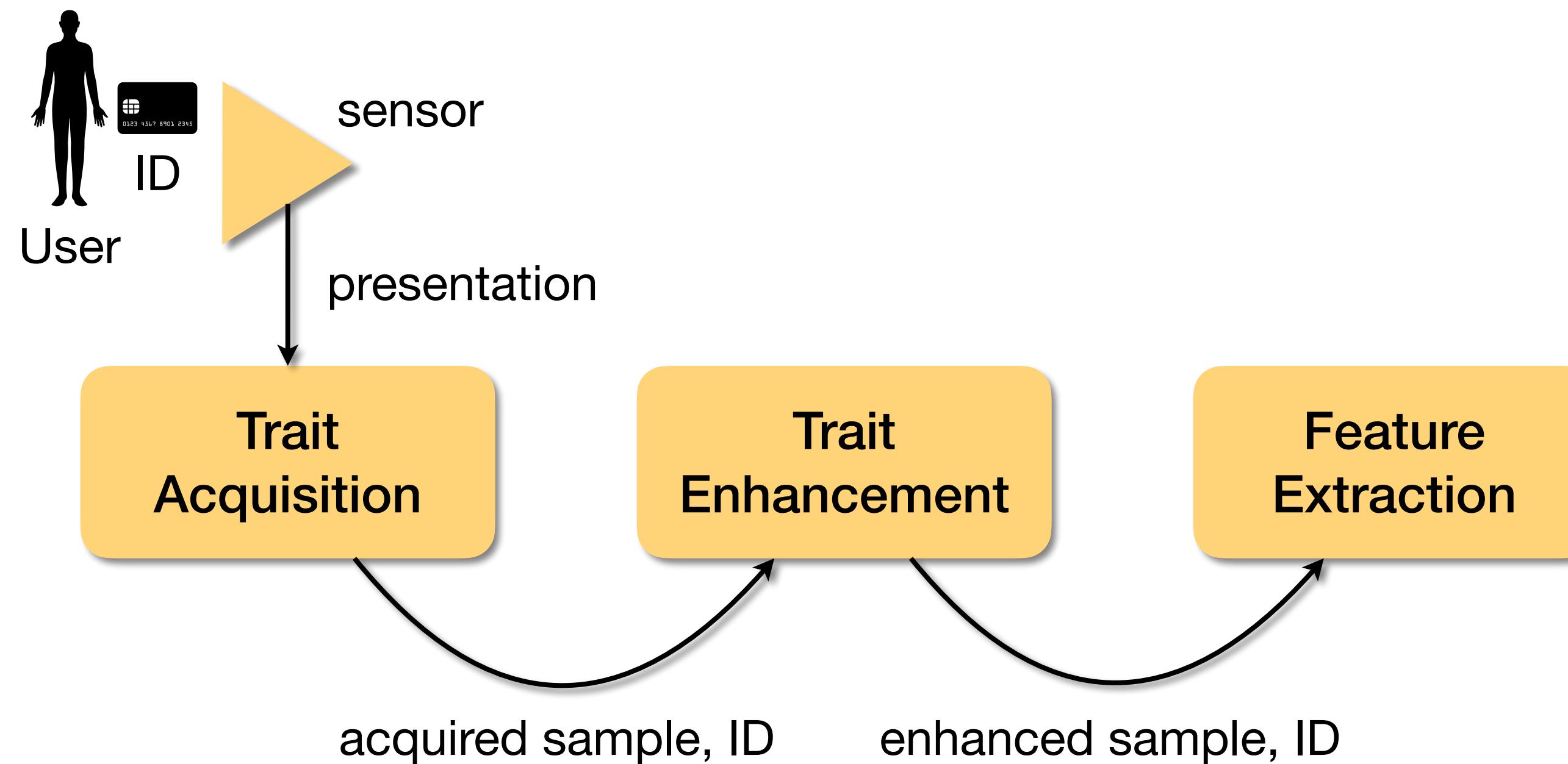
**Gabor Filters** thr: 0.4461

**BSIF Filters** thr: 0.4216

**Global match score**

# Biometric Systems

## Enrollment Modules



### Feature Extraction

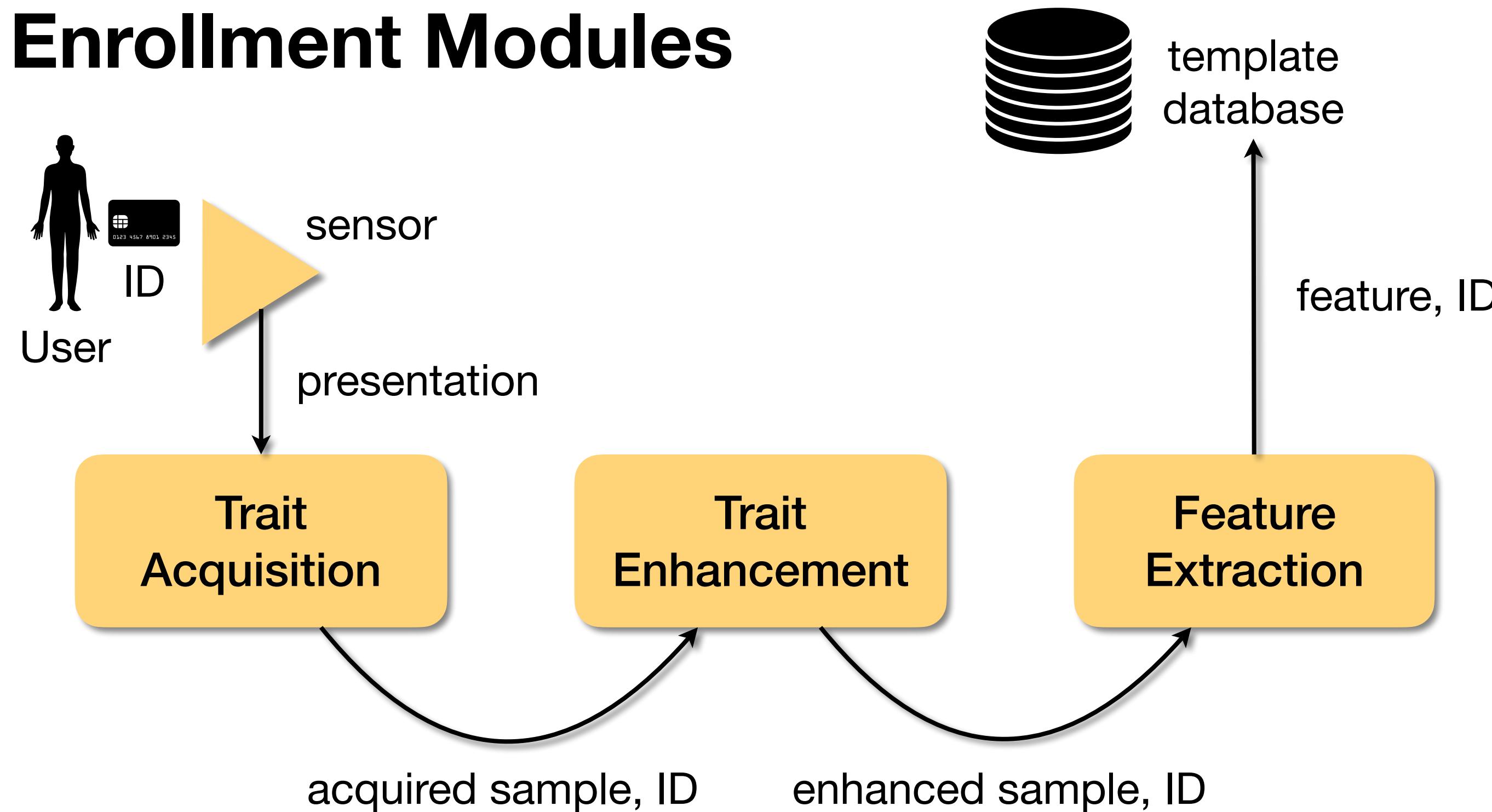
Compact but expressive digital representation of the trait.

### Types

**Handcrafted or learned** with machine learning.  
We'll see both cases.

# Biometric Systems

## Enrollment Modules

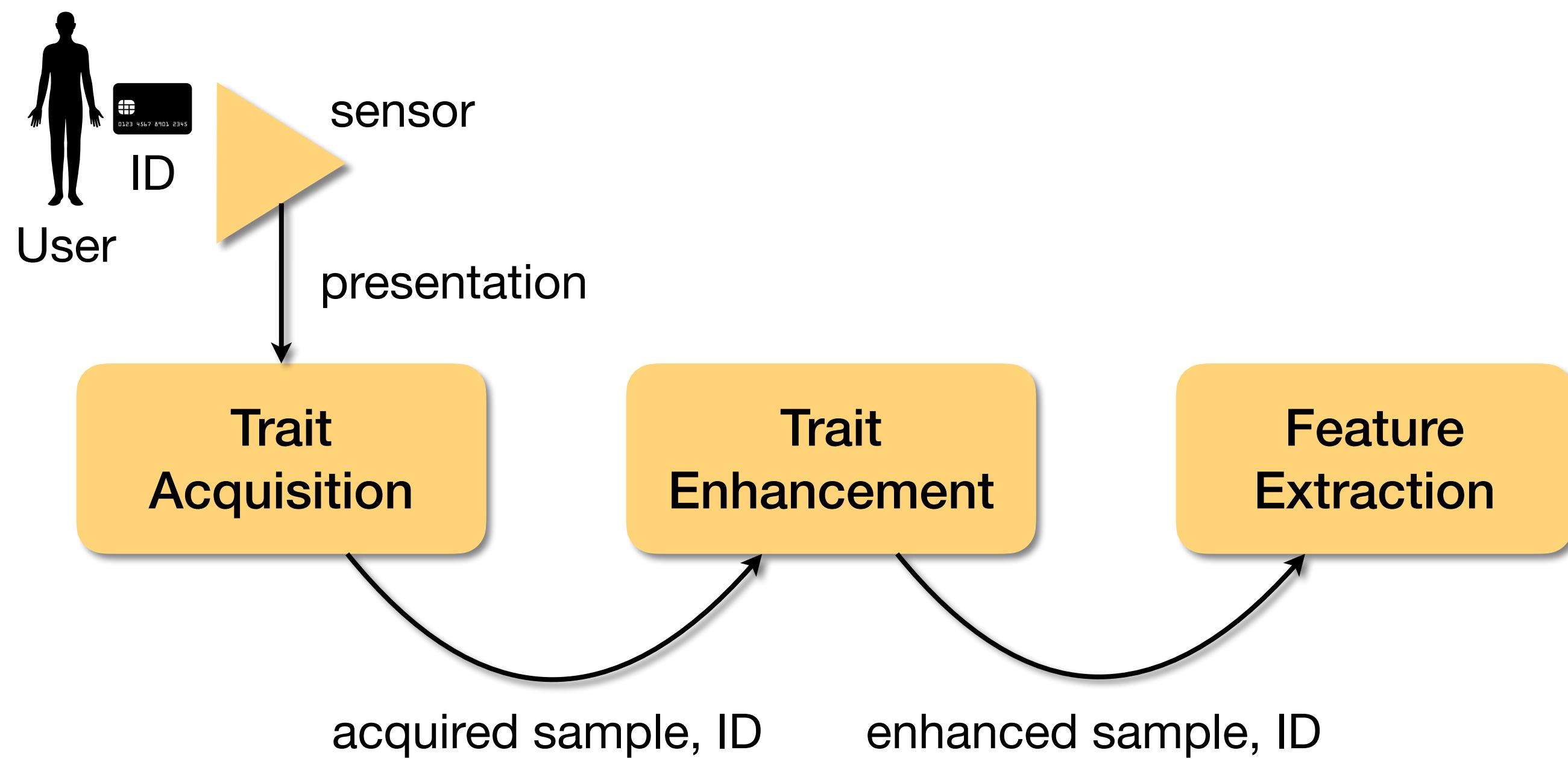


## Template Database

It inherits all the security and privacy issues from database systems. Be careful with invasions, leaks, etc.

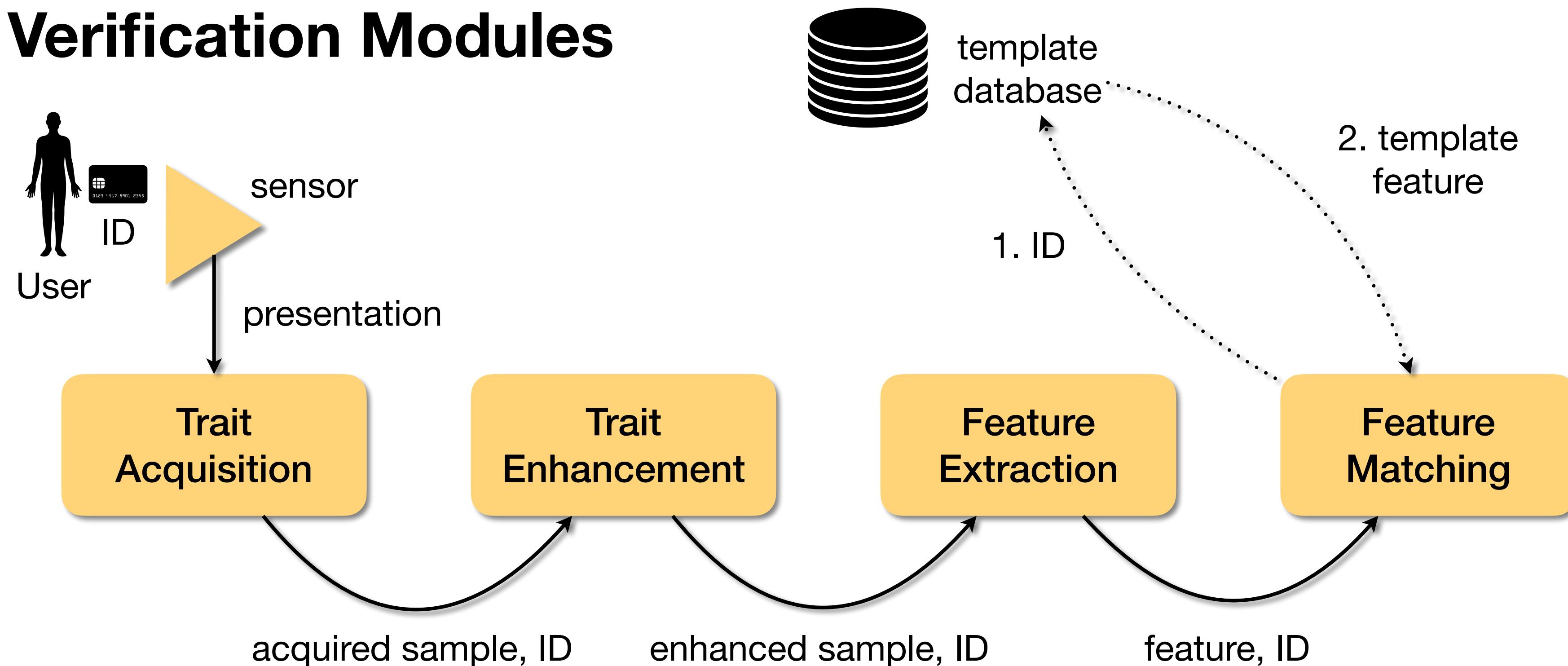
# Biometric Systems

## Verification Modules



# Biometric Systems

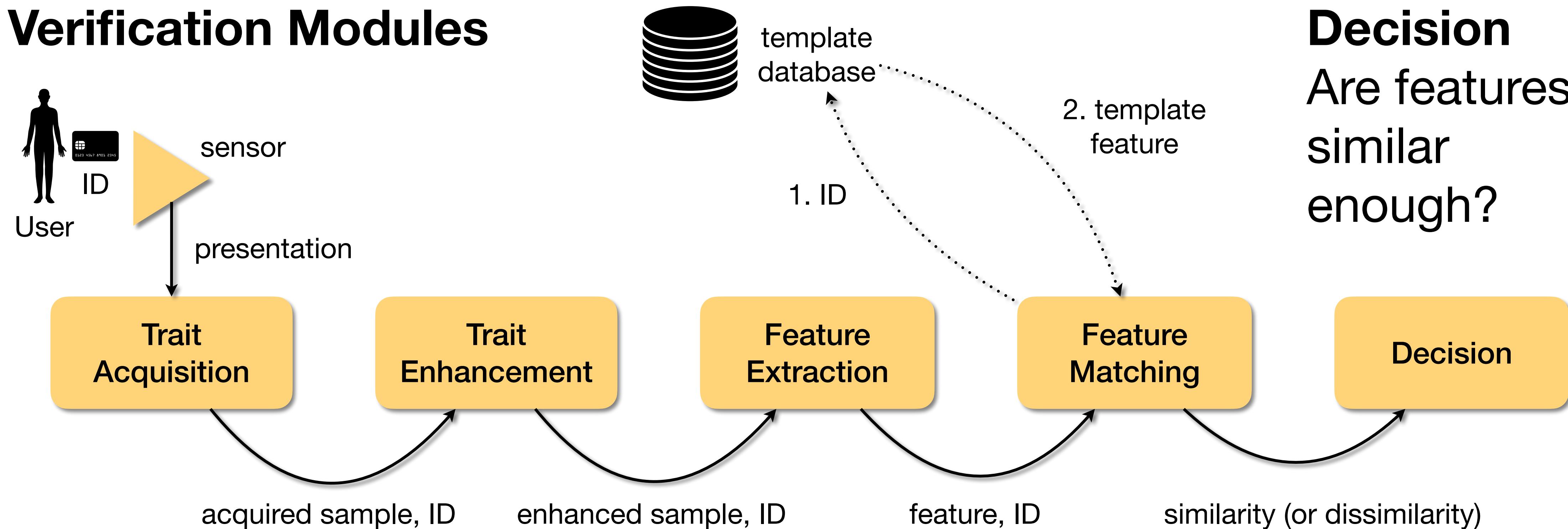
## Verification Modules



**Feature Matching**  
Comparison of **acquired** and **template** features.

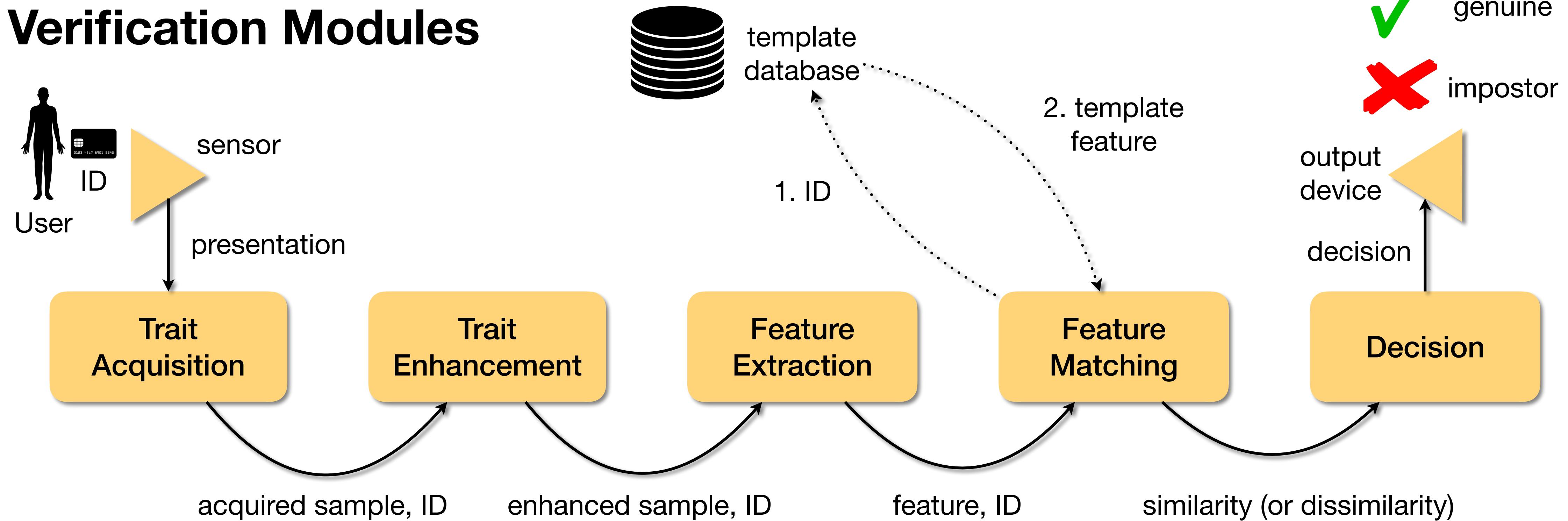
# Biometric Systems

## Verification Modules



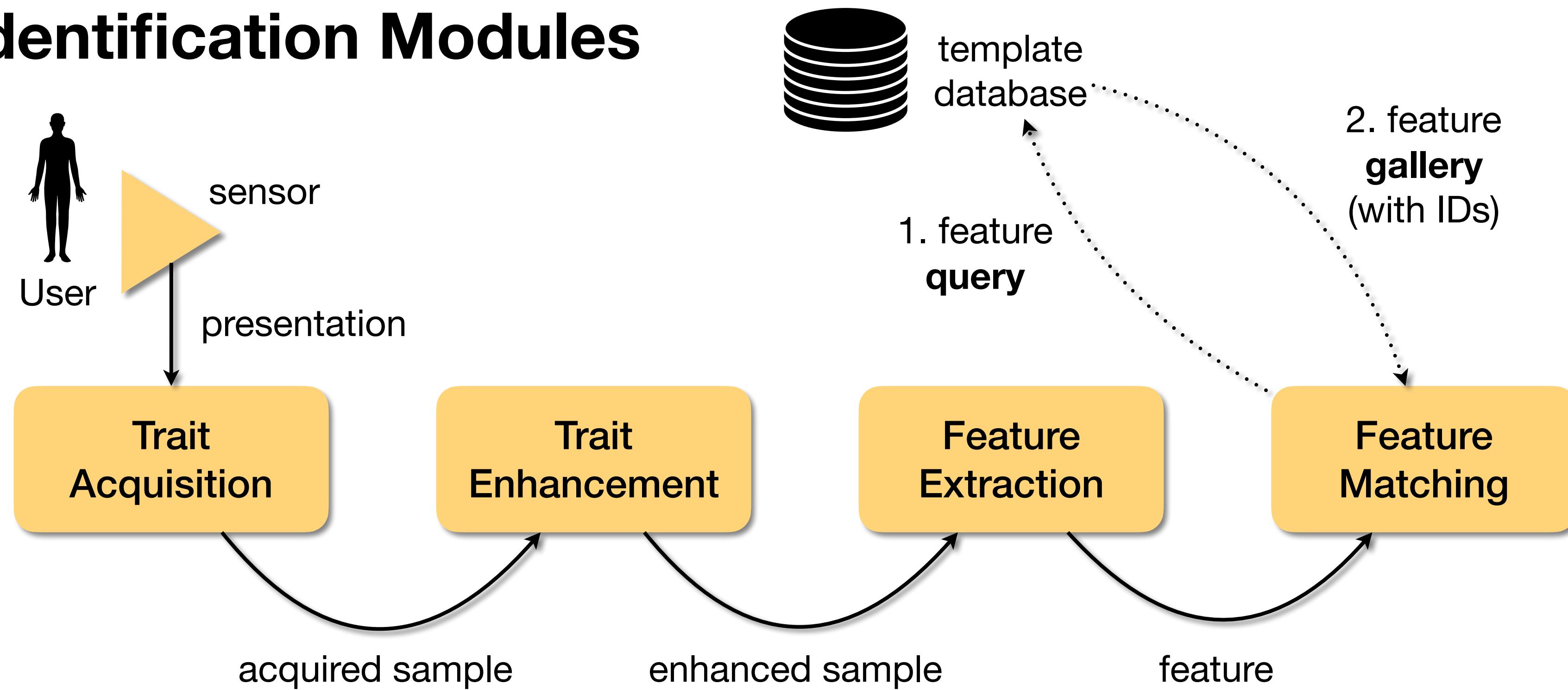
# Biometric Systems

## Verification Modules



# Biometric Systems

## Identification Modules



**Gallery**  
Closest template features to query.

# Biometric Systems

## Query and Gallery Example



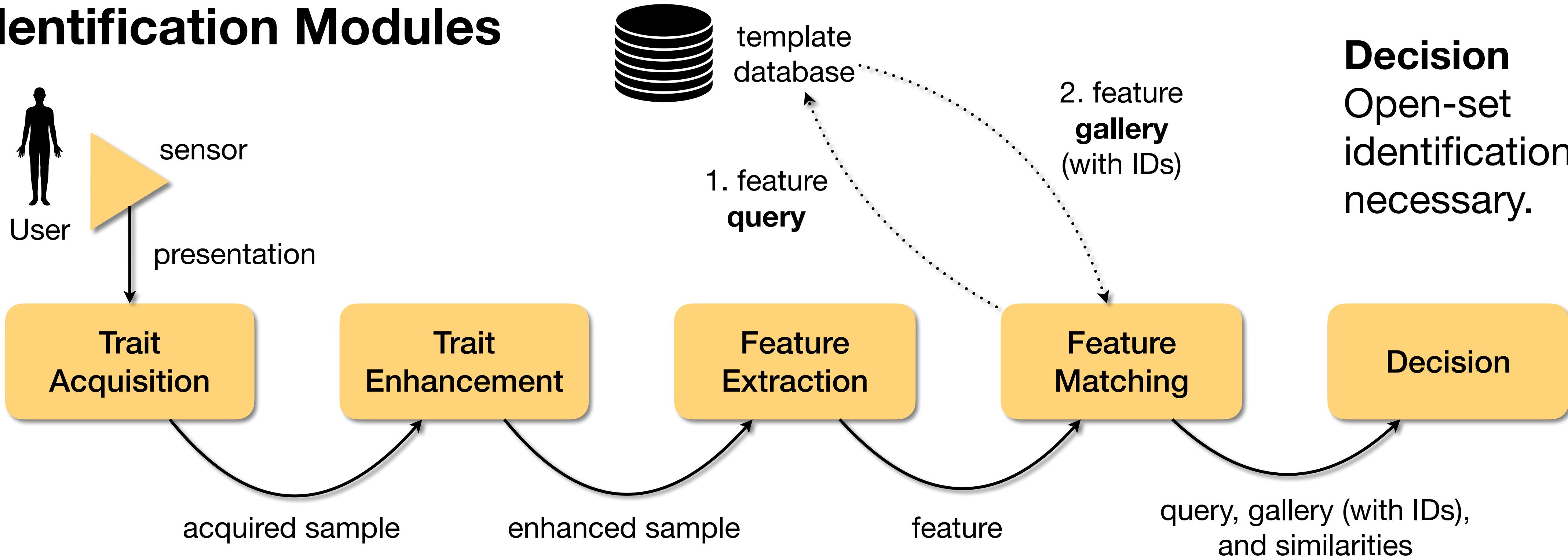
query



gallery

# Biometric Systems

## Identification Modules



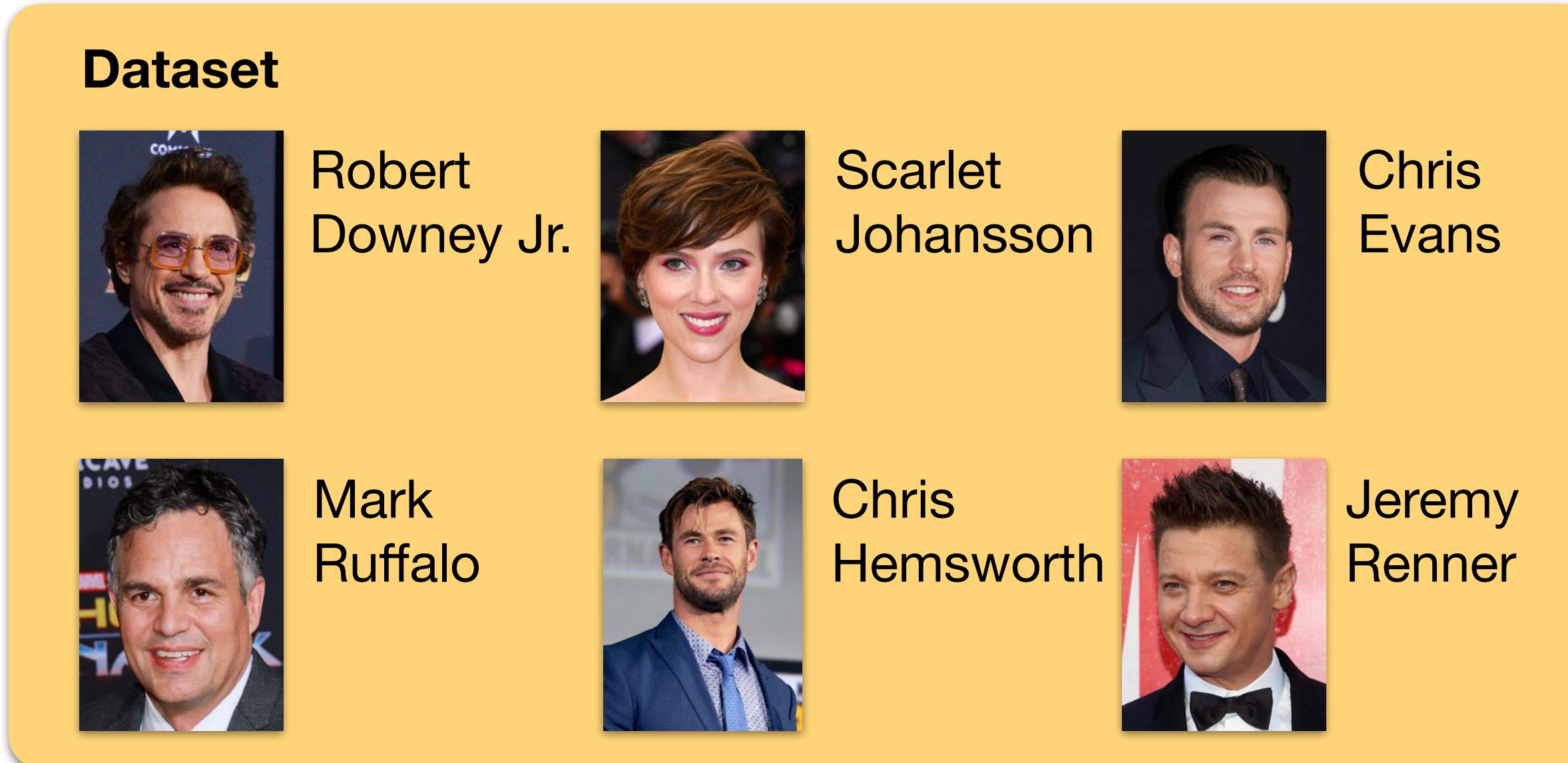
**Decision**  
Open-set  
identification is  
necessary.

# Biometric Systems

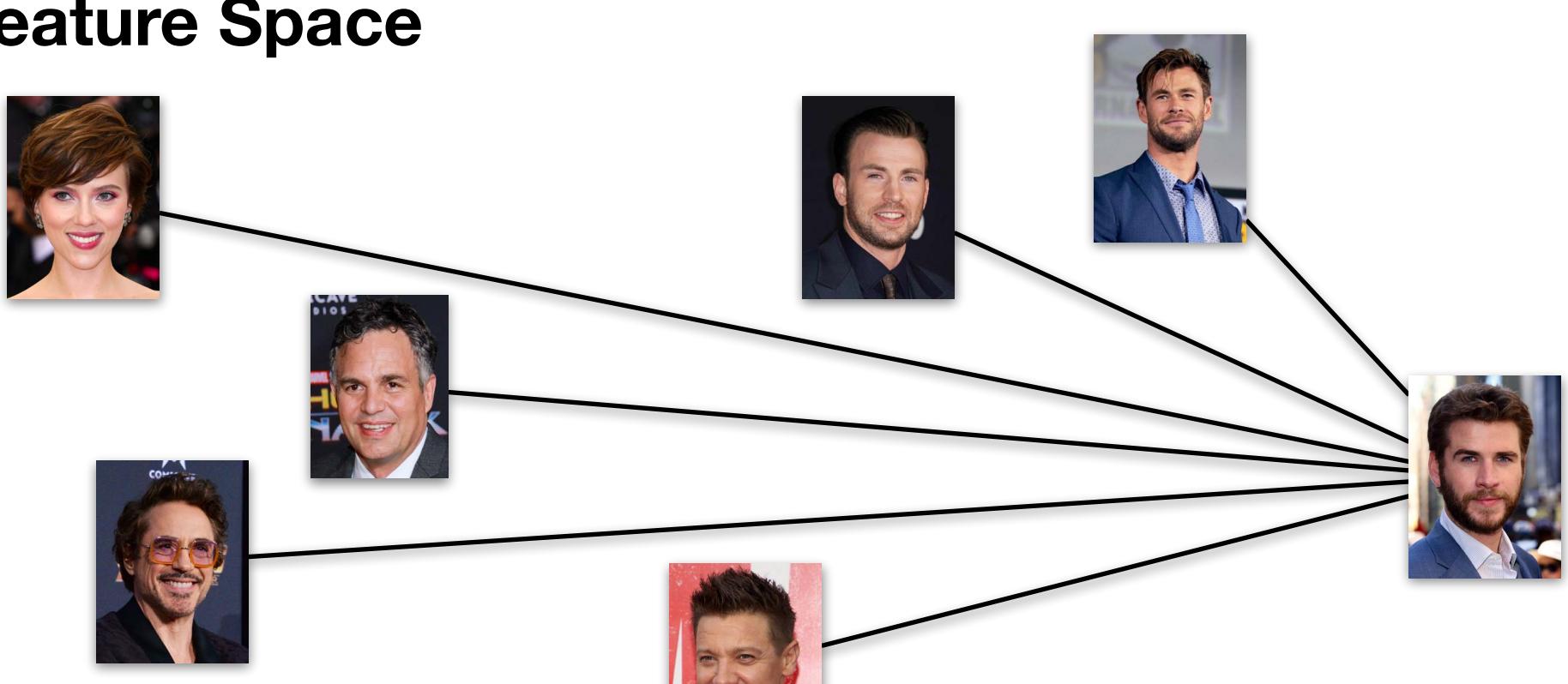
## Open-set vs. Closed-set Identification



**Query**  
(Liam Hemsworth)



### Feature Space



### Closed Set

**Output**  
This is  
Chris Hemsworth!



### Open Set

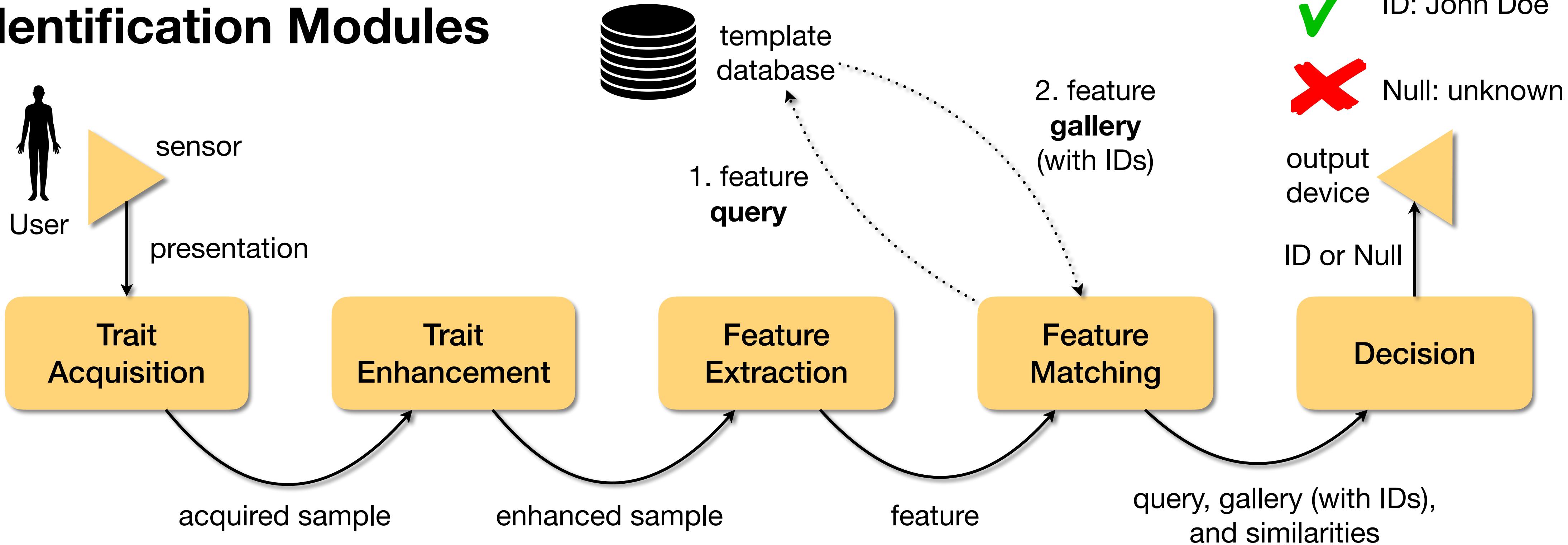
**Output**  
I don't know  
this person!



**LOYOLA**  
UNIVERSITY CHICAGO

# Biometric Systems

## Identification Modules



# What's Next?

**Keep relaxed**

Any issues? Please come and talk to me.

Enjoy Labor Day!

**More basics**

Biometric system errors,  
metrics, and attacks.

**Fill out your *Today-I-missed* Statement**

<https://sakai.luc.edu/x/PnQvIG>

