

# Basics I

COMP 388-002/488-002 Biometrics

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Fall 2024



**LOYOLA**  
UNIVERSITY CHICAGO

# Today we will...

*Discuss*

What Biometrics is

Reasons to use Biometrics

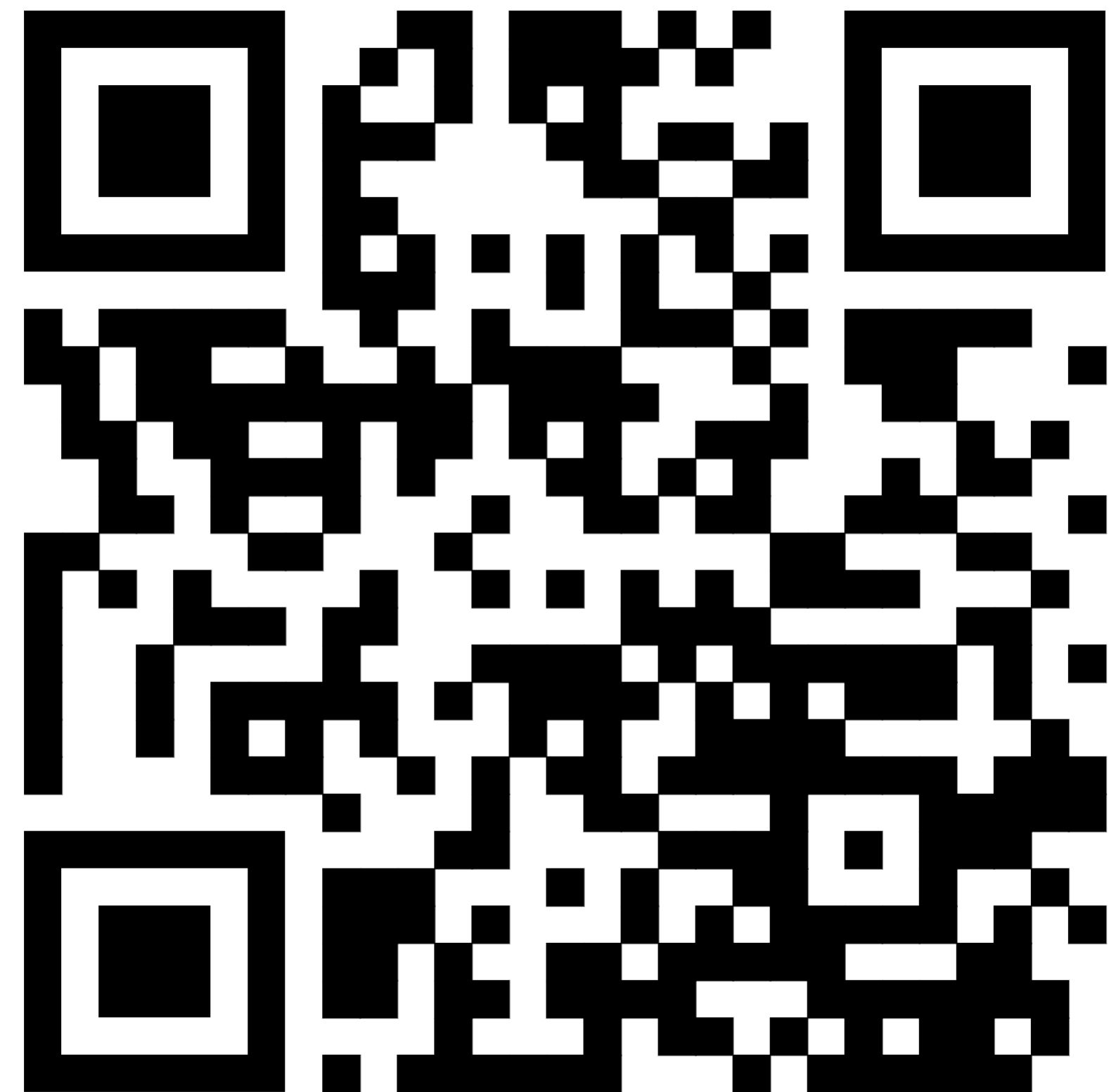
Biometric traits

Biometric system modules

# Today's Attendance

**Please fill out the form**

<https://tinyurl.com/2p934d83>



# What is Biometrics?



**7.9 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?



[tinyurl.com/  
4yu228t6](https://tinyurl.com/4yu228t6)



# What is Biometrics?

## Why computers?

High throughput

Repeatability

Predictability

Accountability

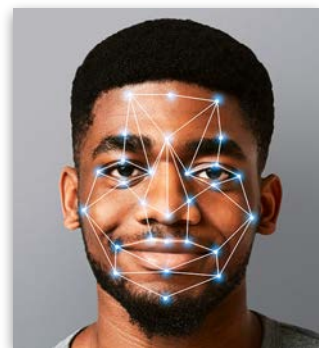


# What is Biometrics?

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](#)

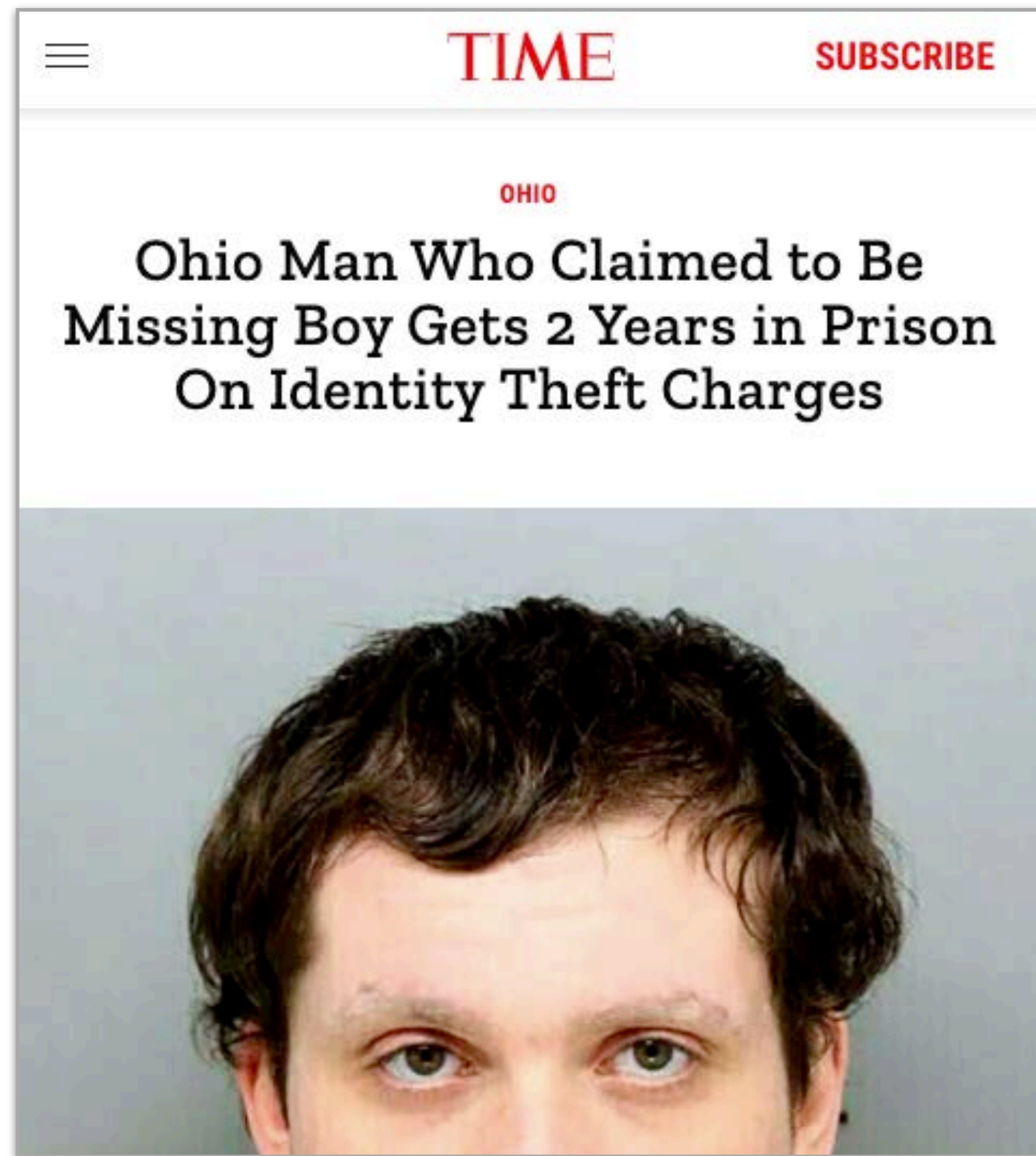


Almost 70 percent of U.S. shoppers did not go through with an online purchase because they either forgot the password, couldn't log in or couldn't receive a one-time passcode, according to research conducted by [Visa](#), while another report from Verizon found that as many as 80 percent of data breaches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

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



# Why use Biometrics?



(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!



<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.**



# Why use Biometrics?

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



The image shows a screenshot of a Wired article. At the top left is the Wired logo with a hamburger menu icon, and at the top right is a 'SUBSCRIBE' button. Below the logo is a Capital One advertisement with the text 'Experience that new-car feeling.' and an image of a woman. The article header includes the author 'ANDY GREENBERG', the category 'SECURITY', and the date '11.14.2017 07:00 AM'. The main headline reads 'Watch a 10-Year-Old's Face Unlock His Mom's iPhone X'. The sub-headline states: '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.



latent  
fingerprint



collected  
fingerprint

The New York Times

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

By David Stout

Nov. 17, 2004



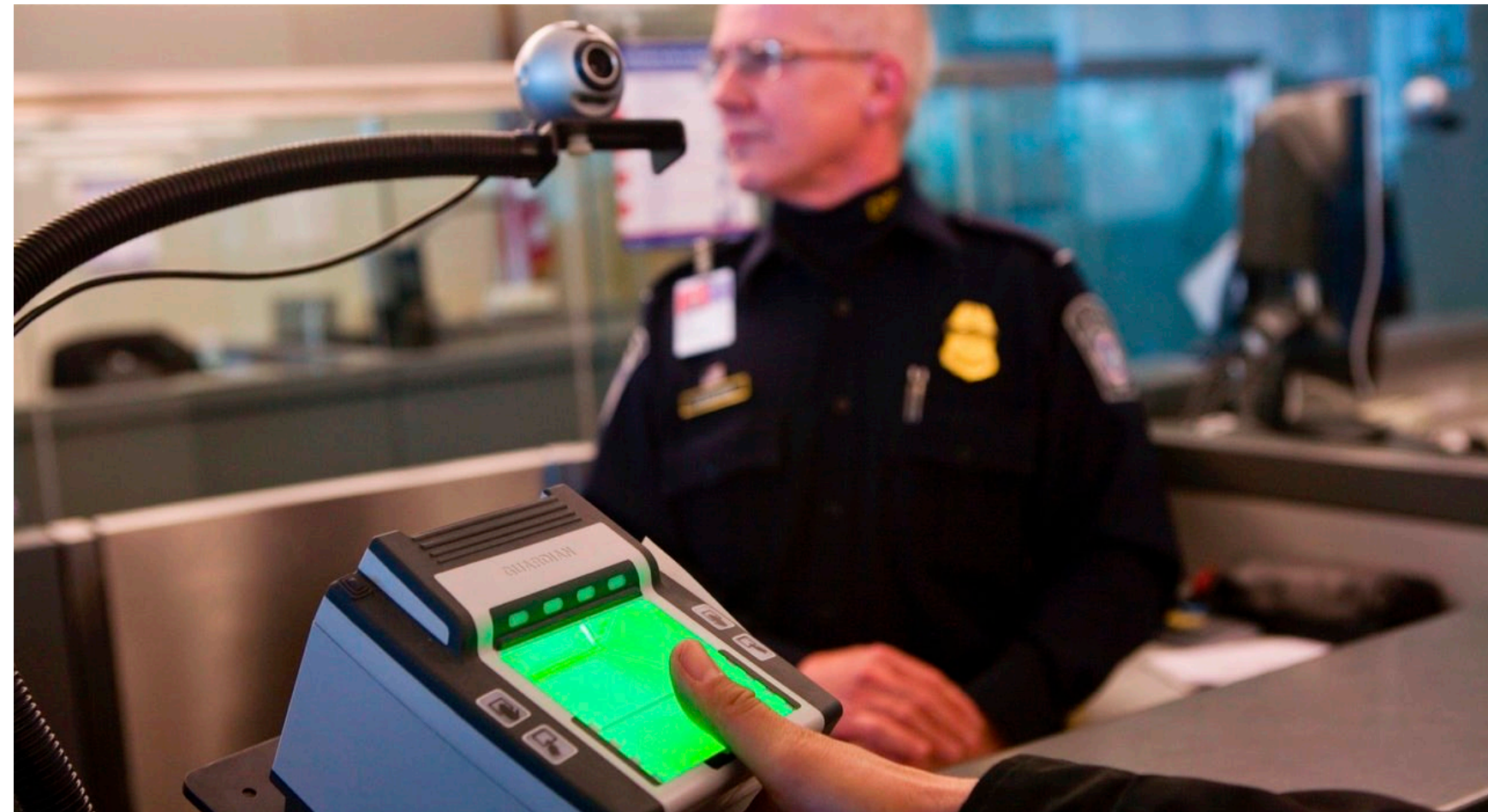
<https://www.nytimes.com/2004/11/17/politics/report-faults-fbis-fingerprint-scrutiny-in-arrest-of-lawyer.html>

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

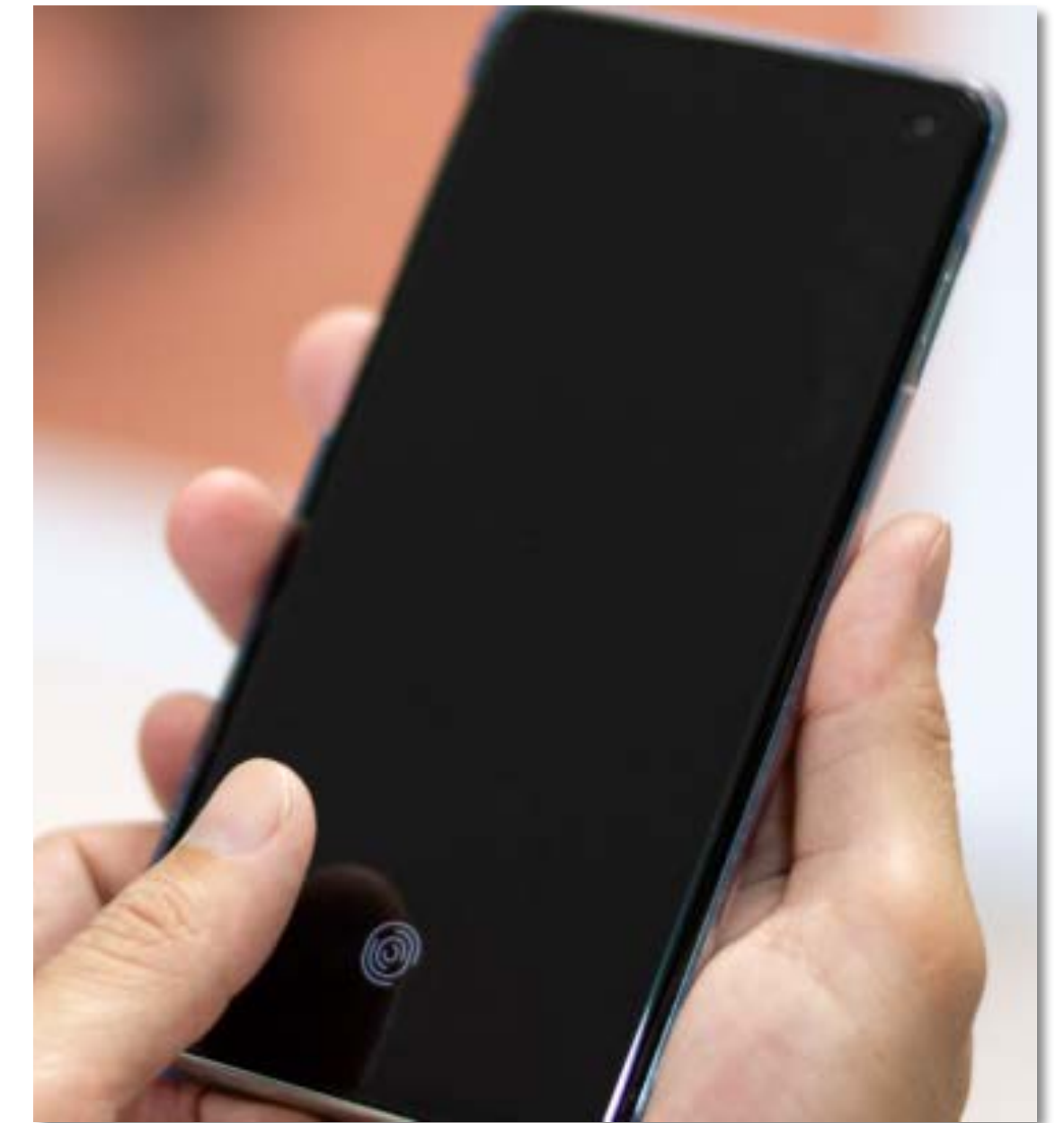


entertainment



# Biometrics Use

**Biometrics is a reality**

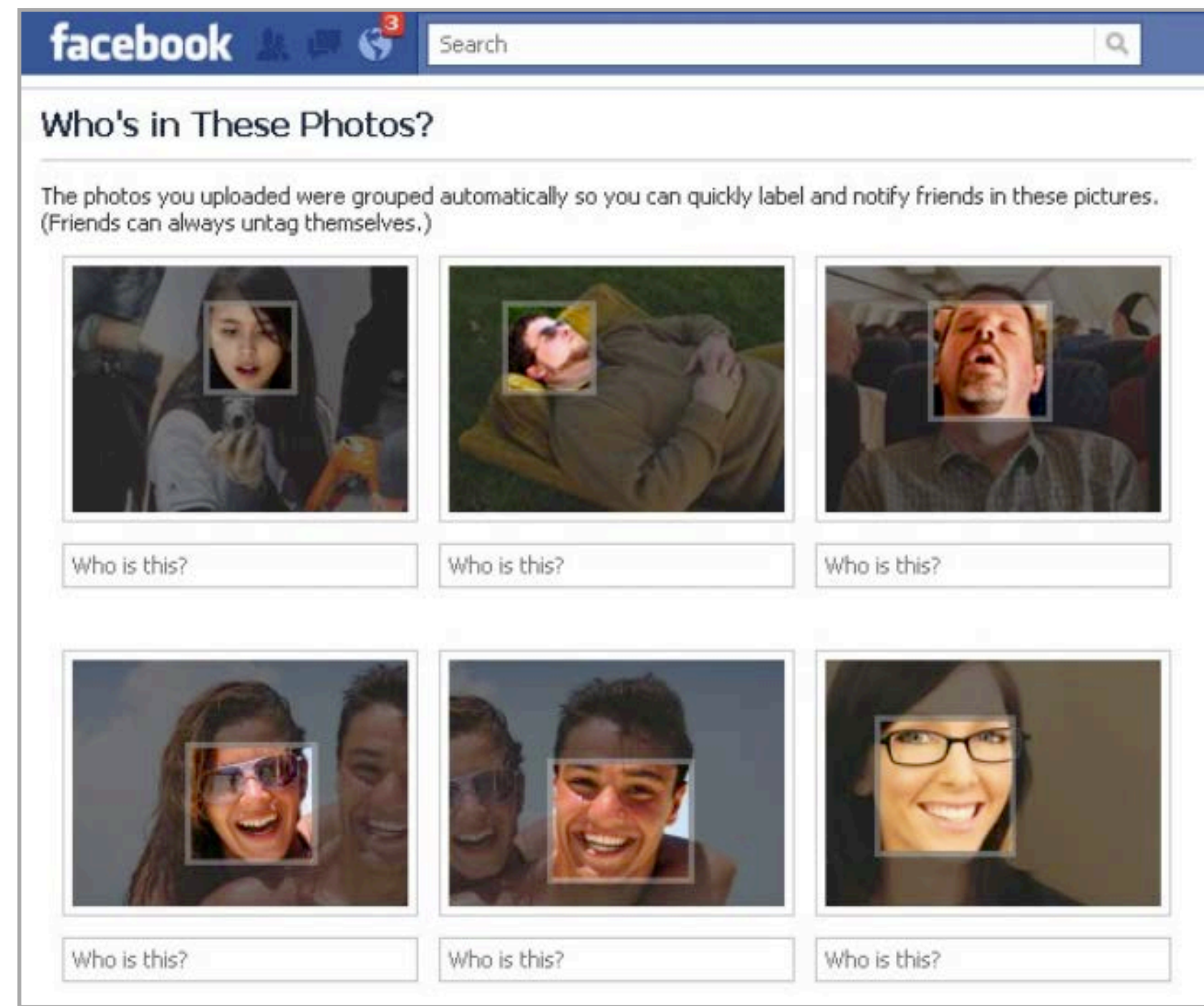


personal devices

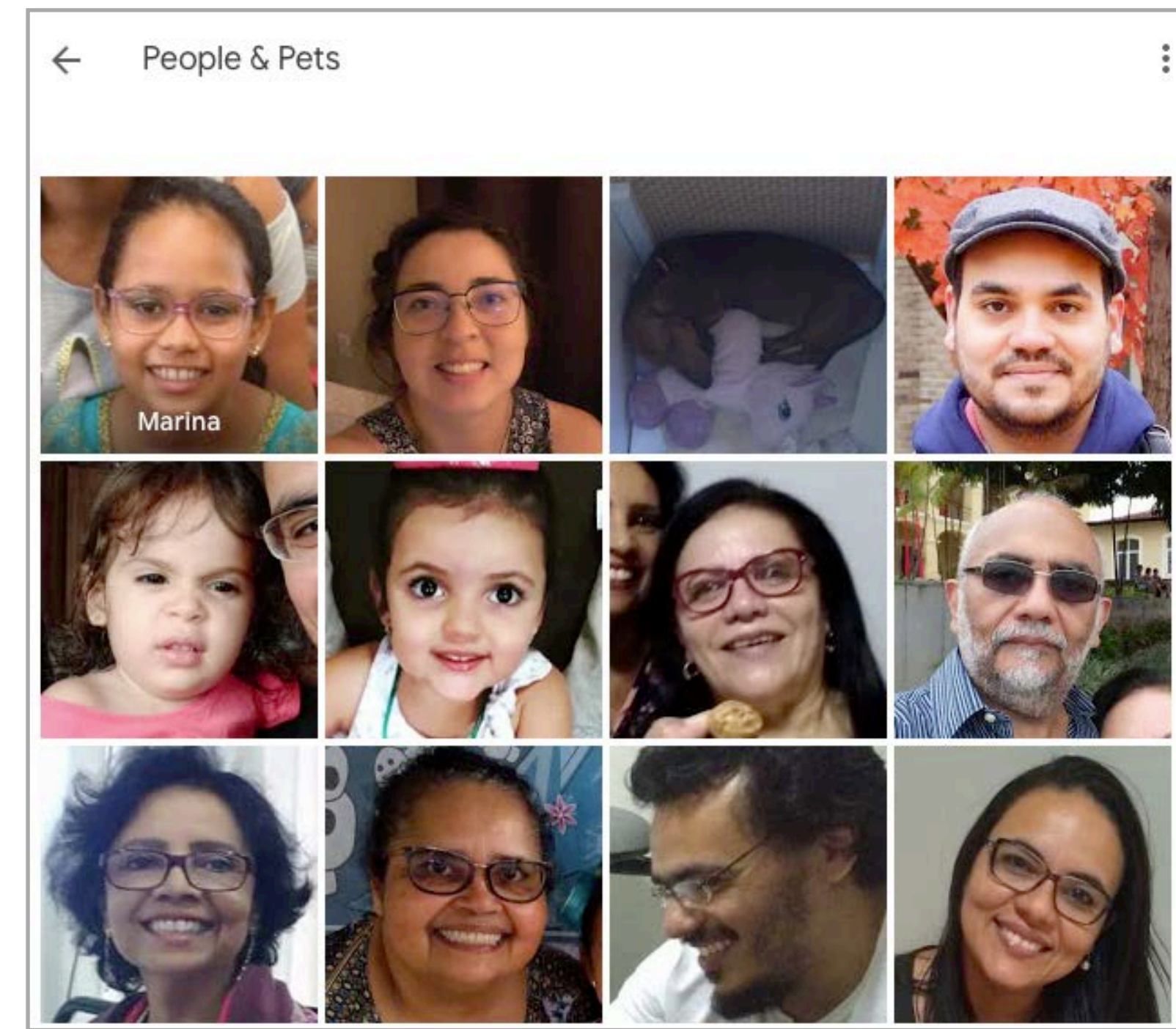


# Biometrics Use

## 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



The screenshot shows the top portion of a news article on the Hindustan Times website. The header includes the 'hindustantimes' logo, a 'Sign In' button, and the date 'Saturday, Jan 11, 2020' with a weather indicator for New Delhi (16°C) and an 'e-paper' link. Below the header is a navigation bar with categories like 'discover', 'india', 'cities', 'opinion', 'world', 'cricket', 'entertainment', 'election', 'trending', 'videos', and 'tech', along with a search icon and the word 'Search'. The main content area features a breadcrumb trail: 'Home / Bhopal / Linking benefits for AIDS patients to Aadhaar triggers privacy concerns'. The article title is 'Linking benefits for AIDS patients to Aadhaar triggers privacy concerns'. A sub-headline reads: '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.' At the bottom left of the article snippet, there is a location tag 'BHOPAL' and an update timestamp 'Updated: Apr 03, 2017 12:34 IST'.

<https://www.hindustantimes.com/bhopal/linking-benefits-for-aids-patients-to-aadhaar-triggers-privacy-concerns/story-iR6HB8RmqPDaNwkX2Oj5EJ.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

      341

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

# Biometrics Abuse

## Data Leakage

 **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 “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.

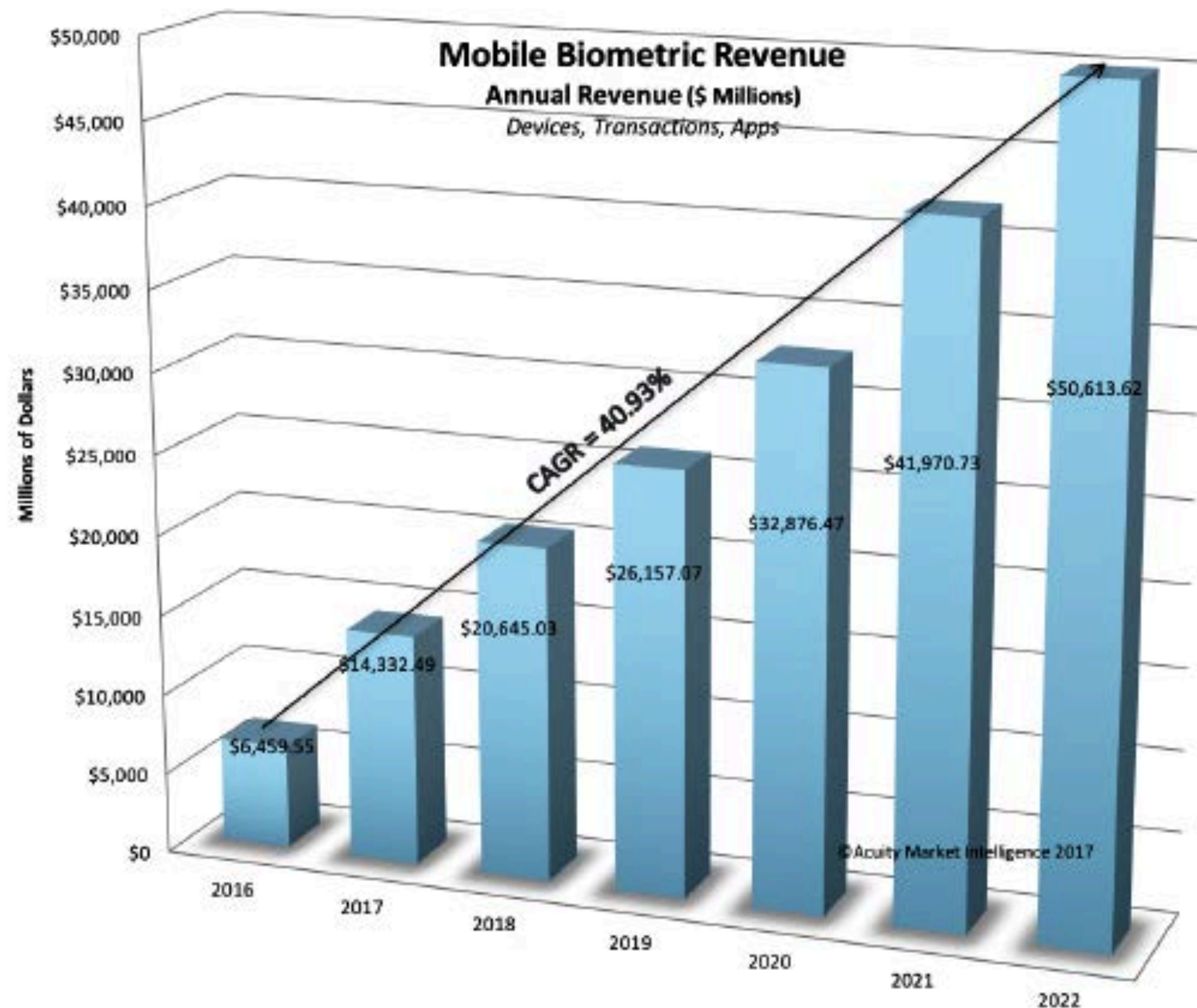


Please, don't.

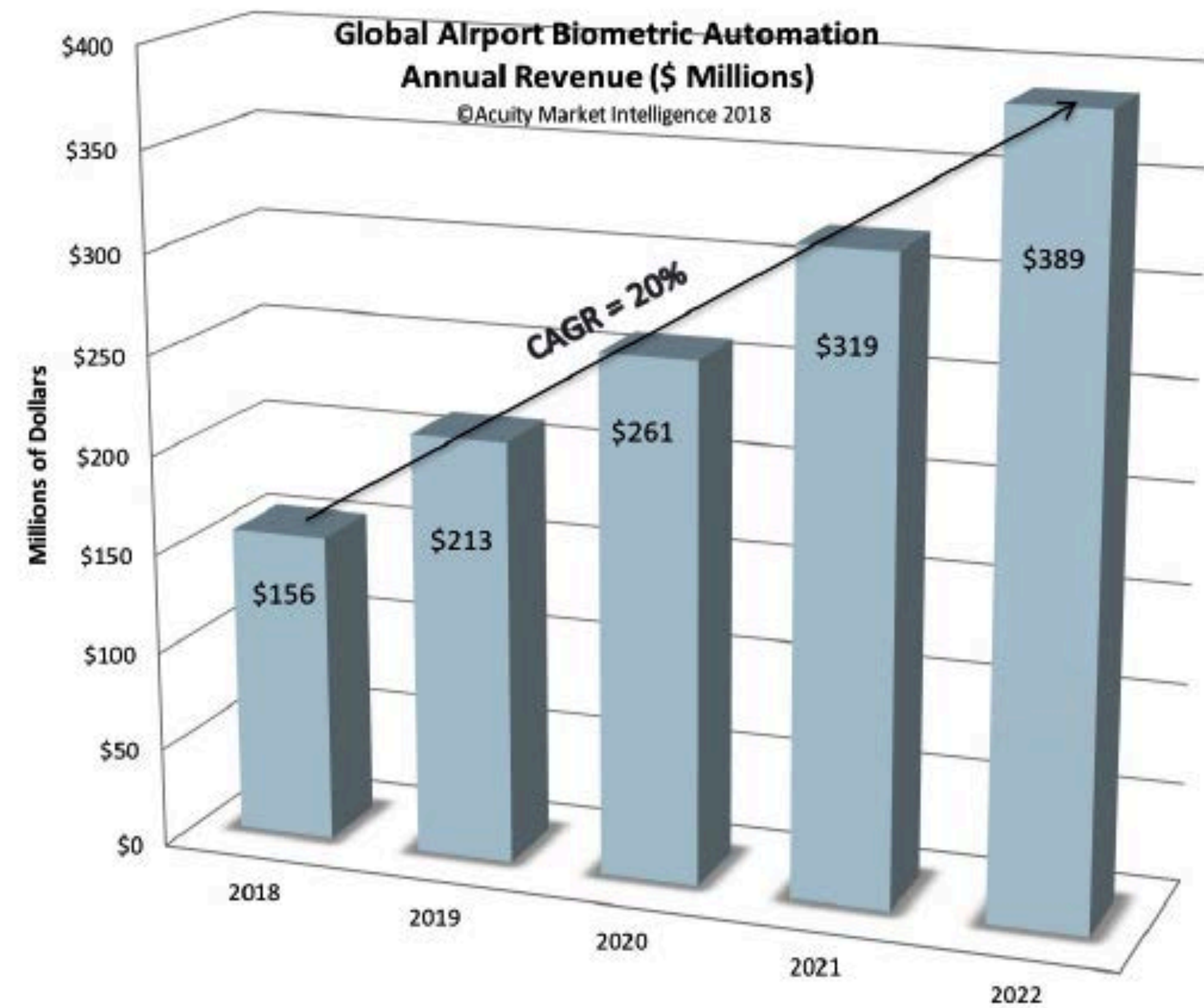


# Biometrics Appeal

2017 Forecast



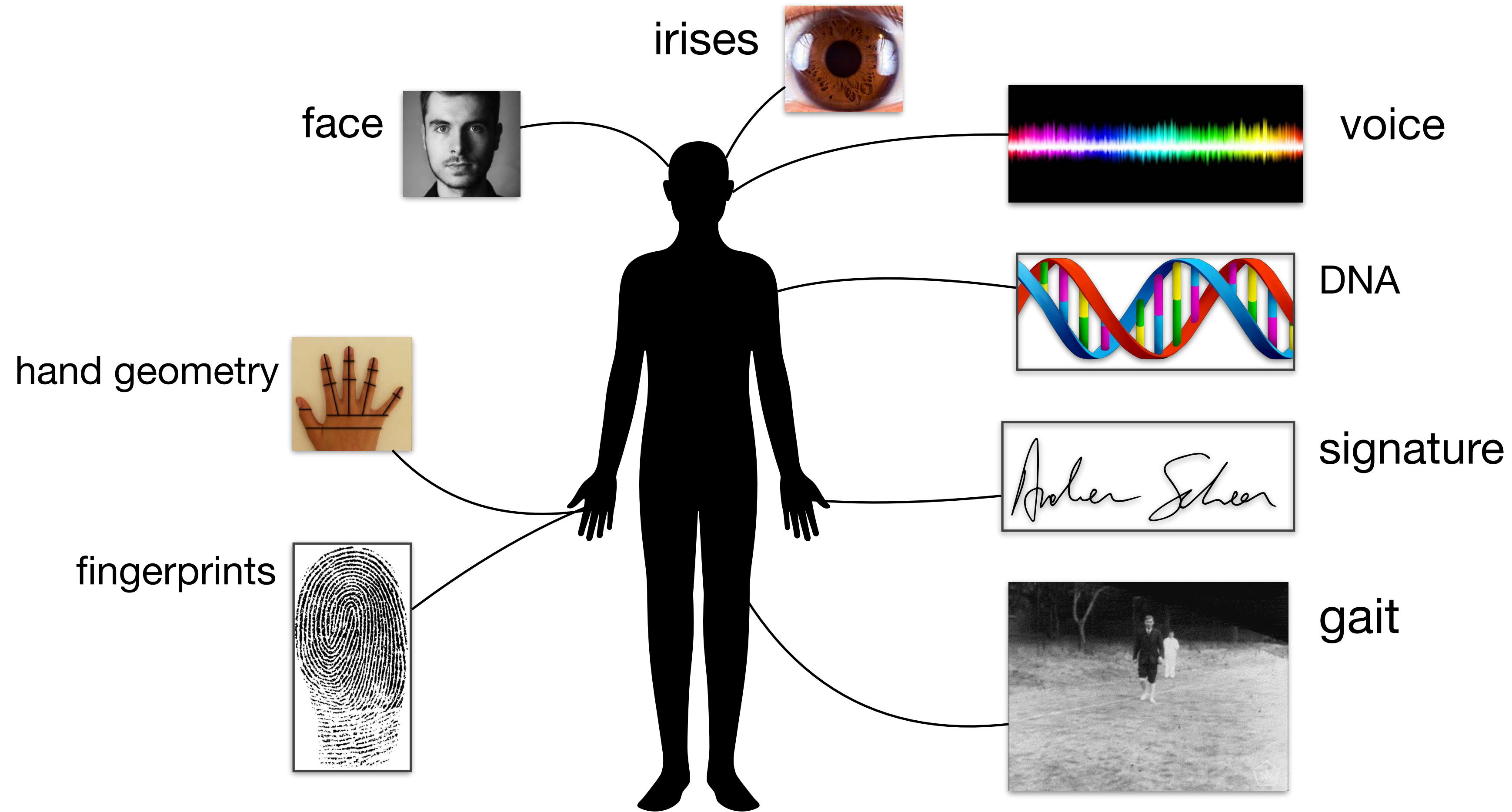
2019 Forecast



Source: Acuity Market Intelligence (<https://www.acuitymi.com/>)  
CAGR: Compound Annual Growth Rate

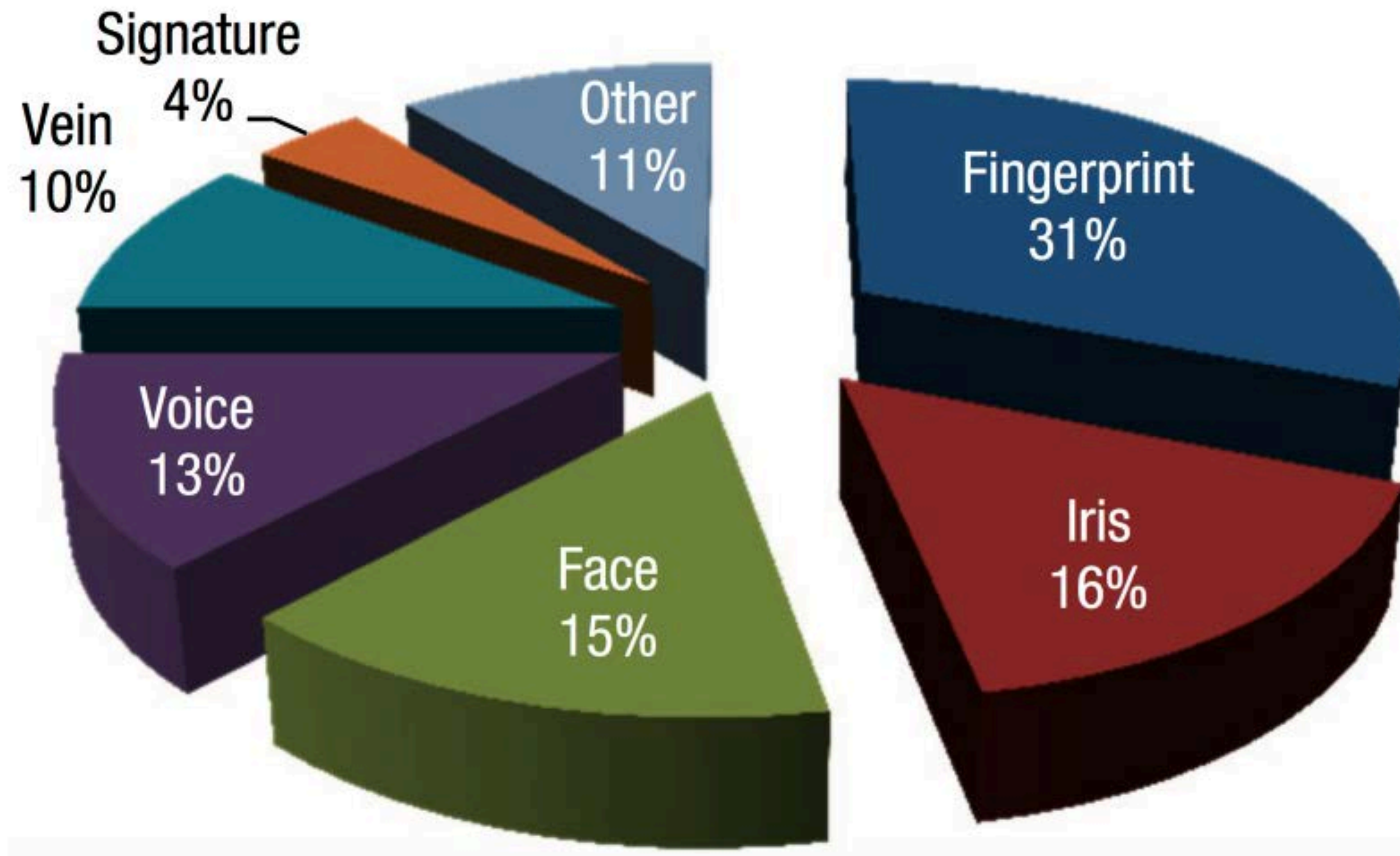


# Biometric Traits



# Biometric Traits

## Market



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



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# 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 screenshot shows the BuzzFeed News website interface. At the top, the logo "BuzzFeed News" is displayed with the tagline "REPORTING TO YOU" below it. A navigation bar includes links for "ABOUT US", "GOT A TIP?", "SUPPORT US", "BUZZFEED.COM", and "SECTIONS". Below this is a "TRENDING" section with a red circular icon, listing topics like "Taal Volcano Eruption", "Cory Booker", "Oscar Nominations", and "Royal Family". The main article is in the "SCIENCE" category. The headline reads "This Man Failed A Paternity Test Due To His Vanished Twin's DNA". The sub-headline 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 identified as "Dan Vergano, BuzzFeed News Reporter" with a small profile picture. The post date is "Posted 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

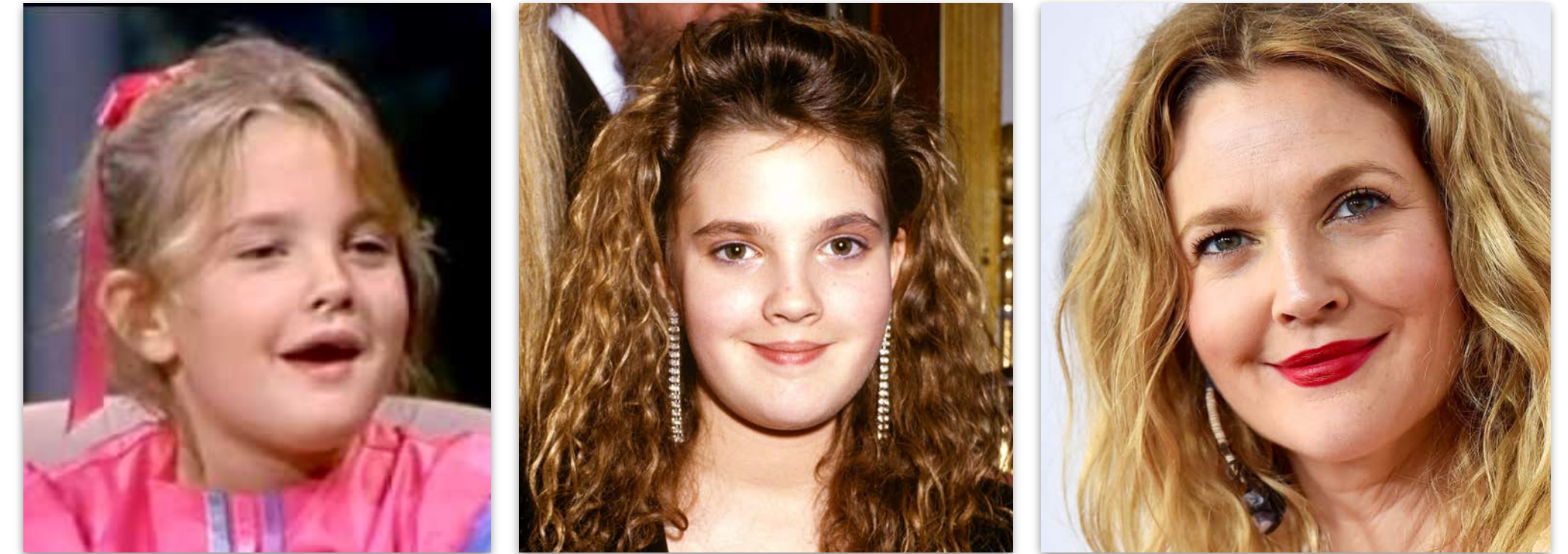
**What do we want to consider?**

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>

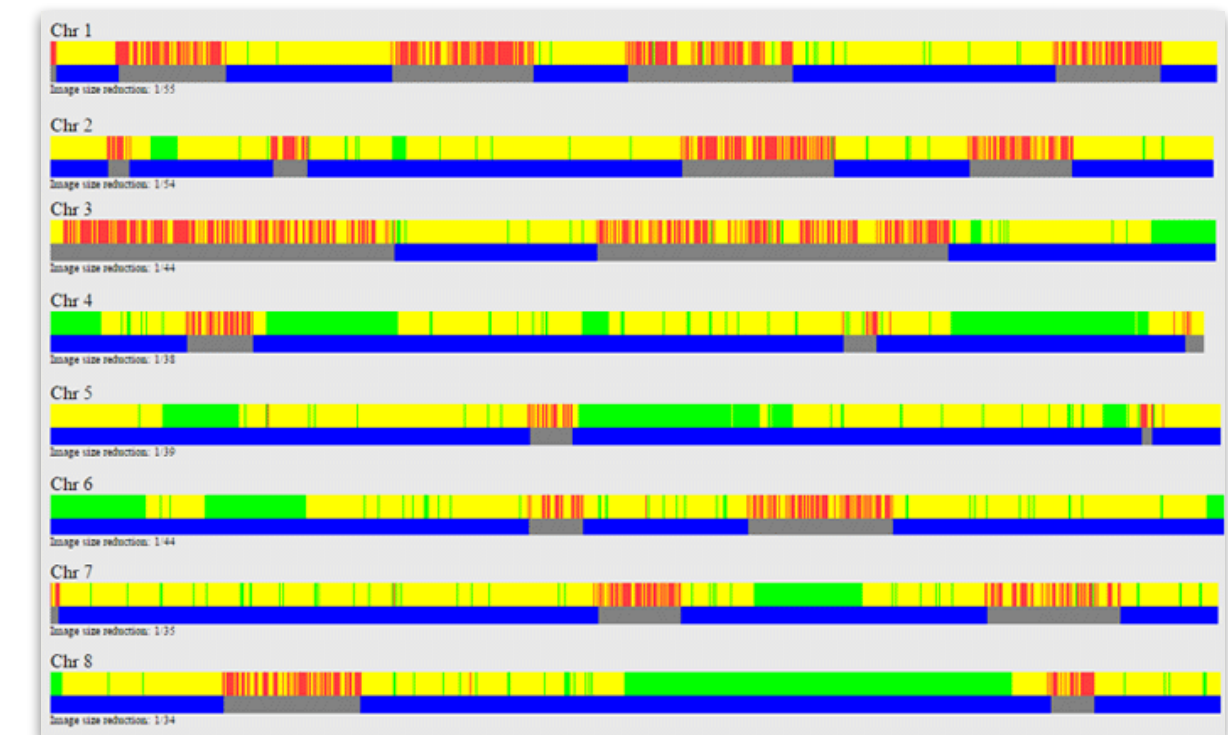


# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Explainability (7/8)**



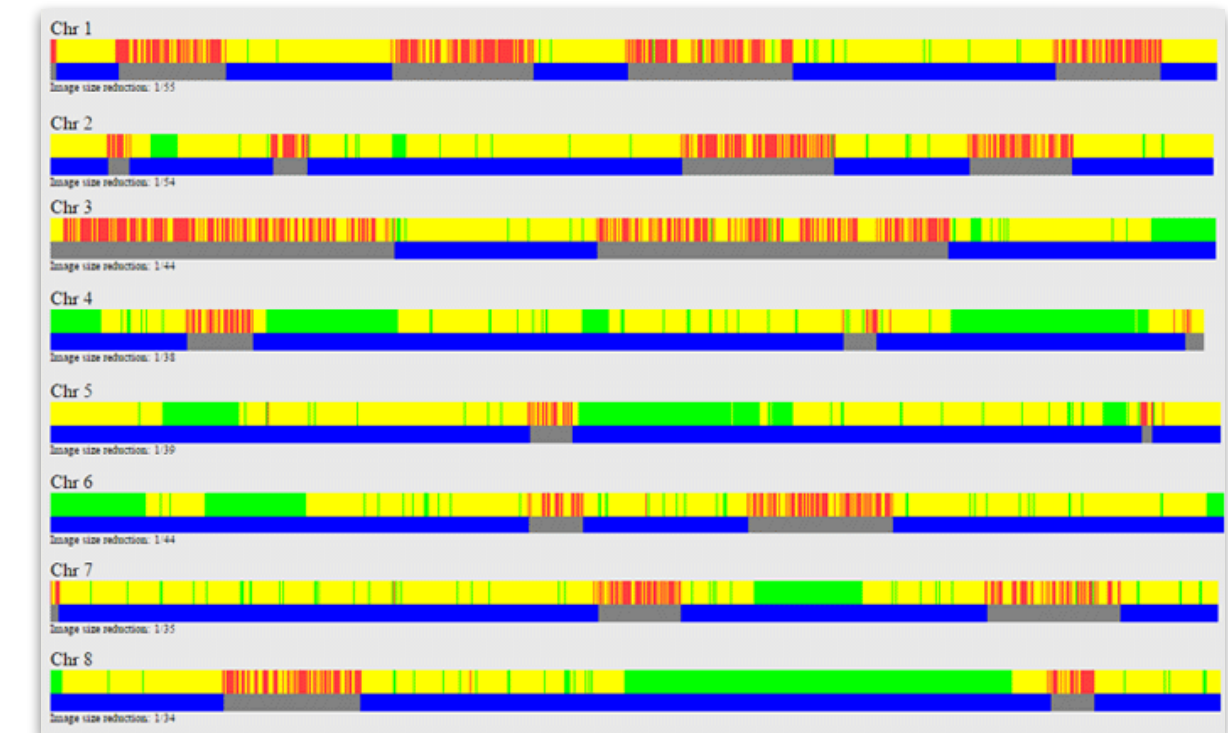
# Biometric Traits

**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?



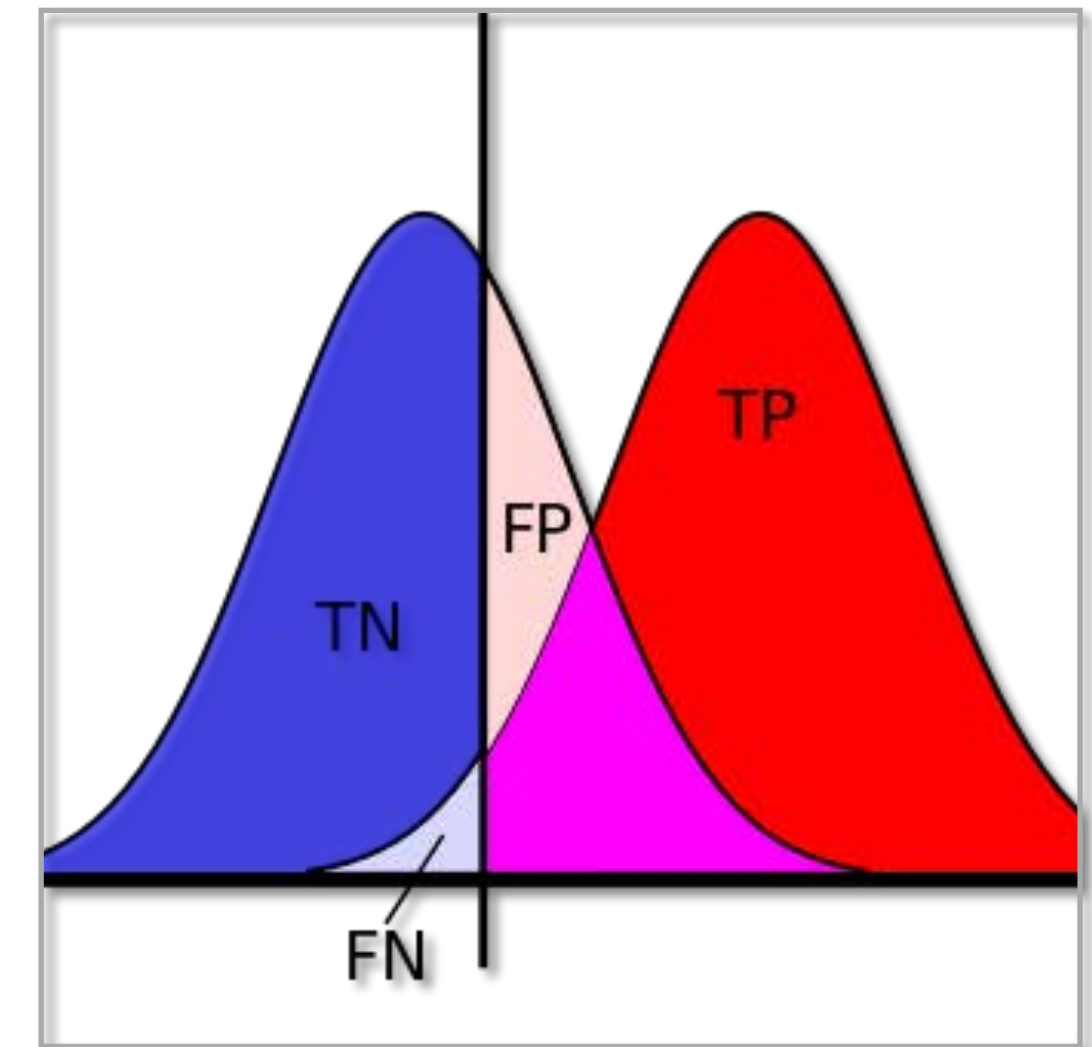


# Biometric Traits

**What do we want to consider?**

Some traits might be more suitable than others.

**Performance (8/8)**



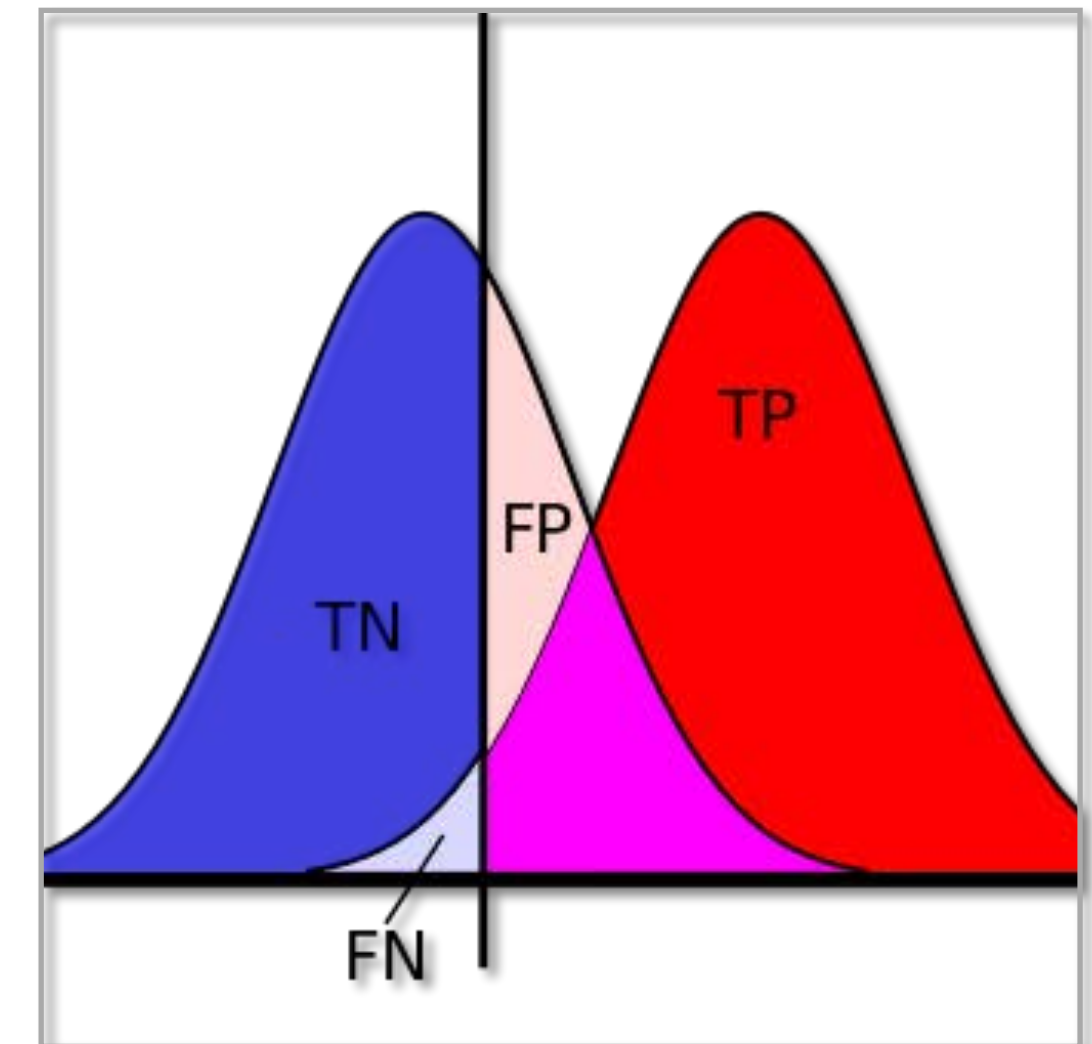
# Biometric Traits

**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)





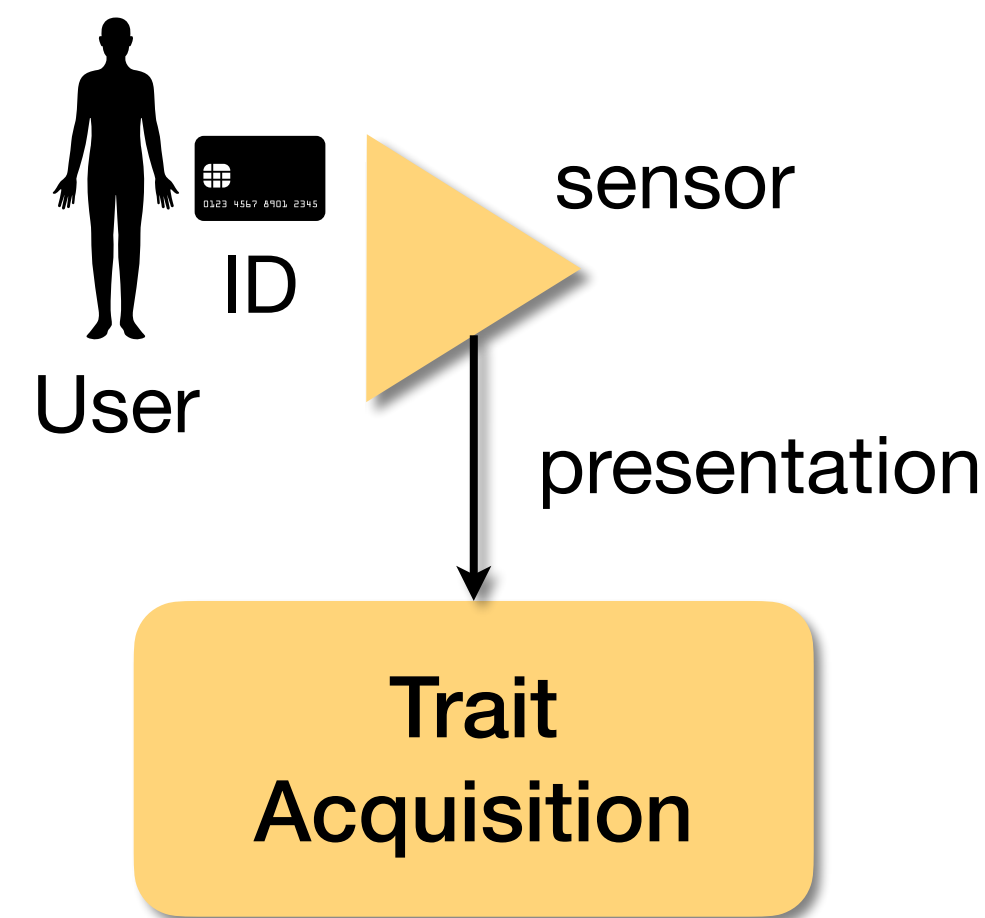
# Activity

Please go to [bit.ly/3Rj4xiz](https://bit.ly/3Rj4xiz)  
and answer the questions.



# Biometric Systems

## Enrollment



## Trait Acquisition

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

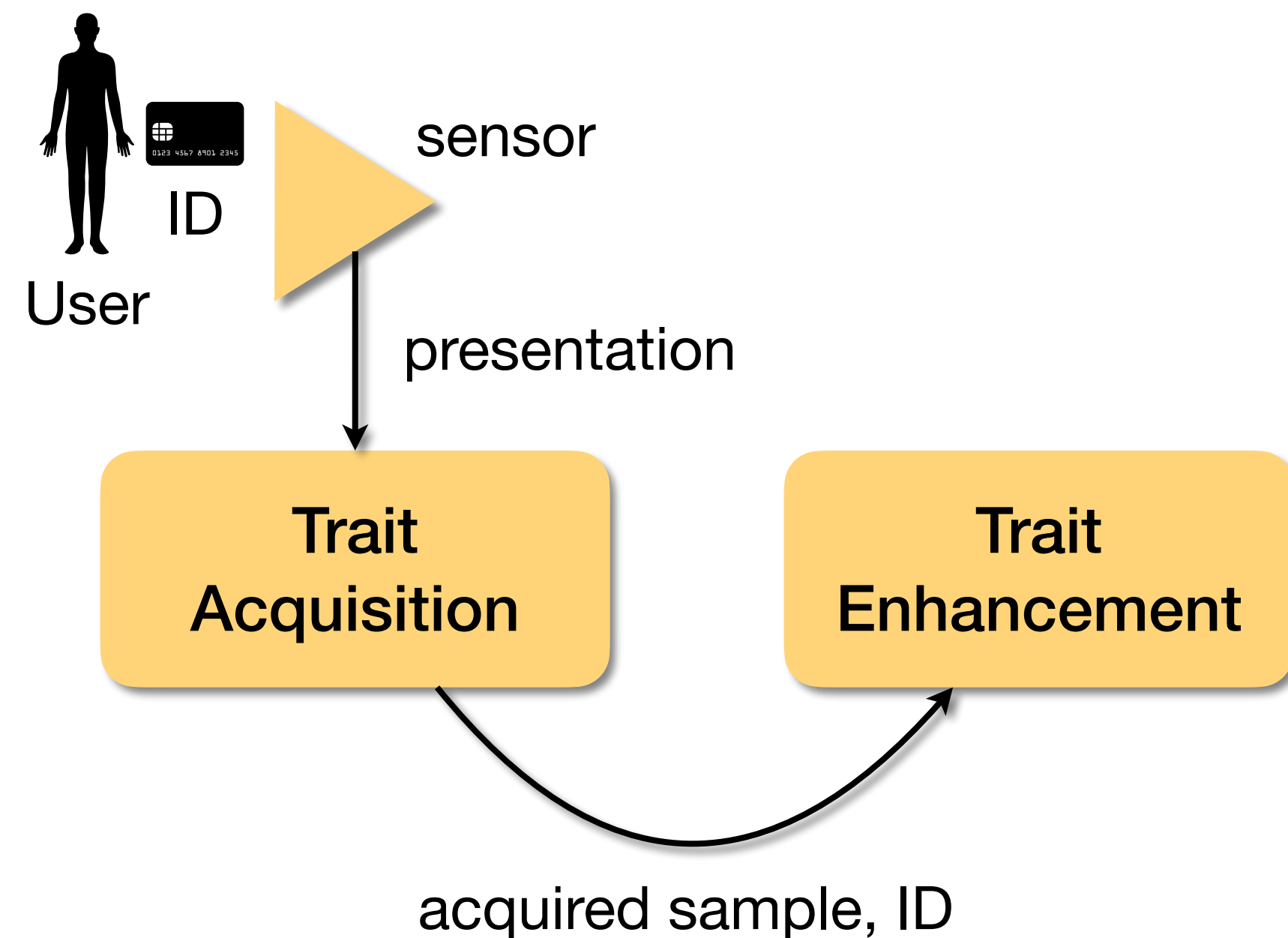
## What to observe?

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



# Biometric Systems

## Enrollment

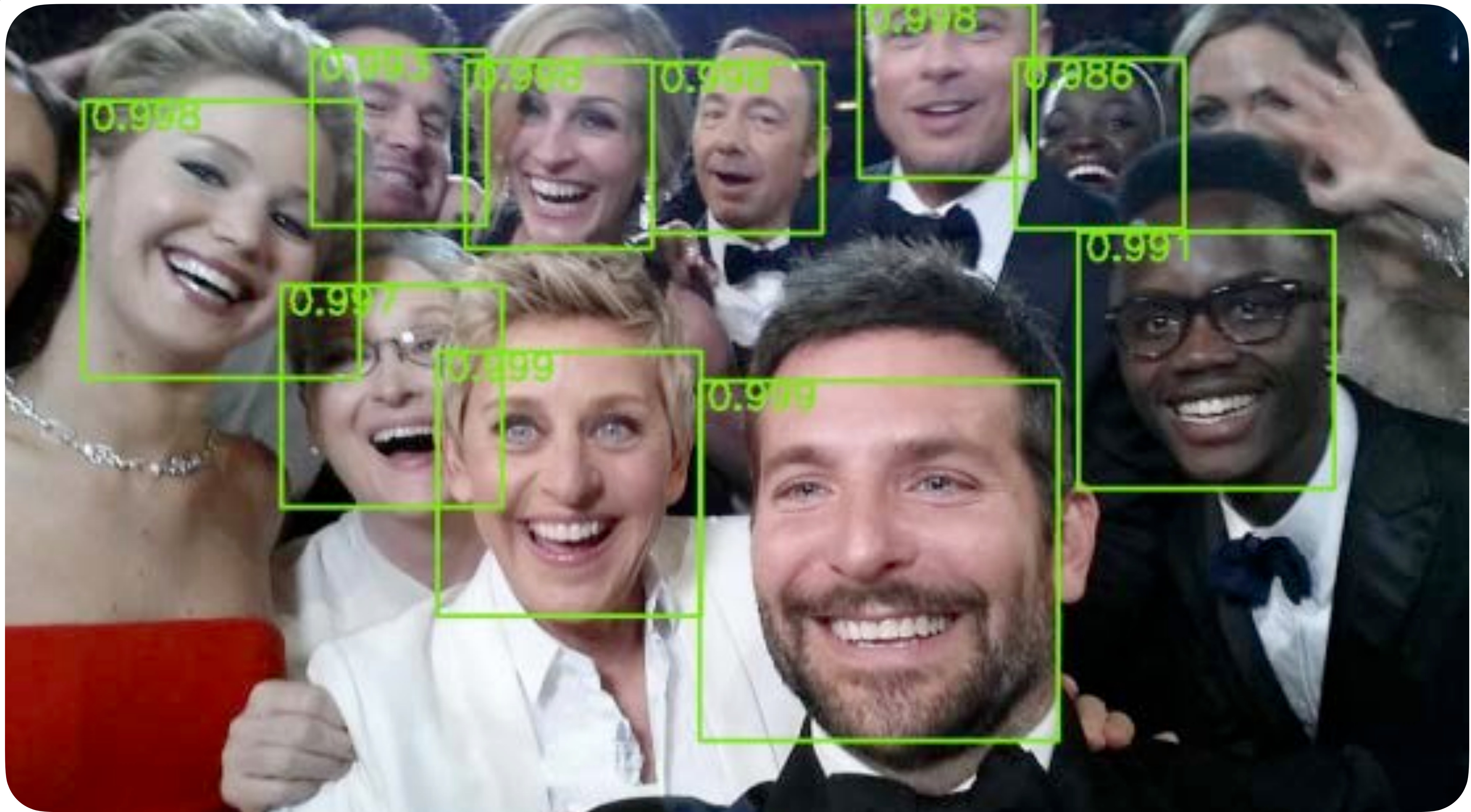


## Trait Enhancement

Noise removal.

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





0.998

0.995

0.998

0.998

0.998

0.986

0.997

0.999

0.999

0.991



Brightness  
-1.0 0.0 1.0

Contrast  
0.0 1.0 2.0

Sharpening  
0.0 10.0

Segment iris

Brightness  
-1.0 0.0 1.0

Contrast  
0.0 1.0 2.0

Sharpening  
0.0 10.0

Segment iris

1.0 3.0 1x 1.0 3.0

Human-Interpretable Features

<input checked="" type="checkbox"/> TSHEPII	<input type="checkbox"/> Show Matched	- 0 + out of 0	<input checked="" type="checkbox"/> MSER	<input type="checkbox"/> Show Matched	- 0 + out of 0
	<input type="checkbox"/> Show Unmatched	- 1 + out of 0		<input type="checkbox"/> Show Unmatched	- 1 + out of 0
<input checked="" type="checkbox"/> SURF	<input type="checkbox"/> Show Matched	- 0 + out of 0	<input checked="" type="checkbox"/> SIFT	<input type="checkbox"/> Show Matched	- 0 + out of 0
	<input type="checkbox"/> Show Unmatched	- 1 + out of 0		<input type="checkbox"/> Show Unmatched	- 1 + out of 0
<input checked="" type="checkbox"/> Crypts	<input type="checkbox"/> Show Matched	- 0 + out of 0			

Undo last removal

Manual Annotation

Annotate...

Matching Regions  Non-Matching Regions

Show Matching Regions  Show Non-Matching Regions

Non-Human-Interpretable Features

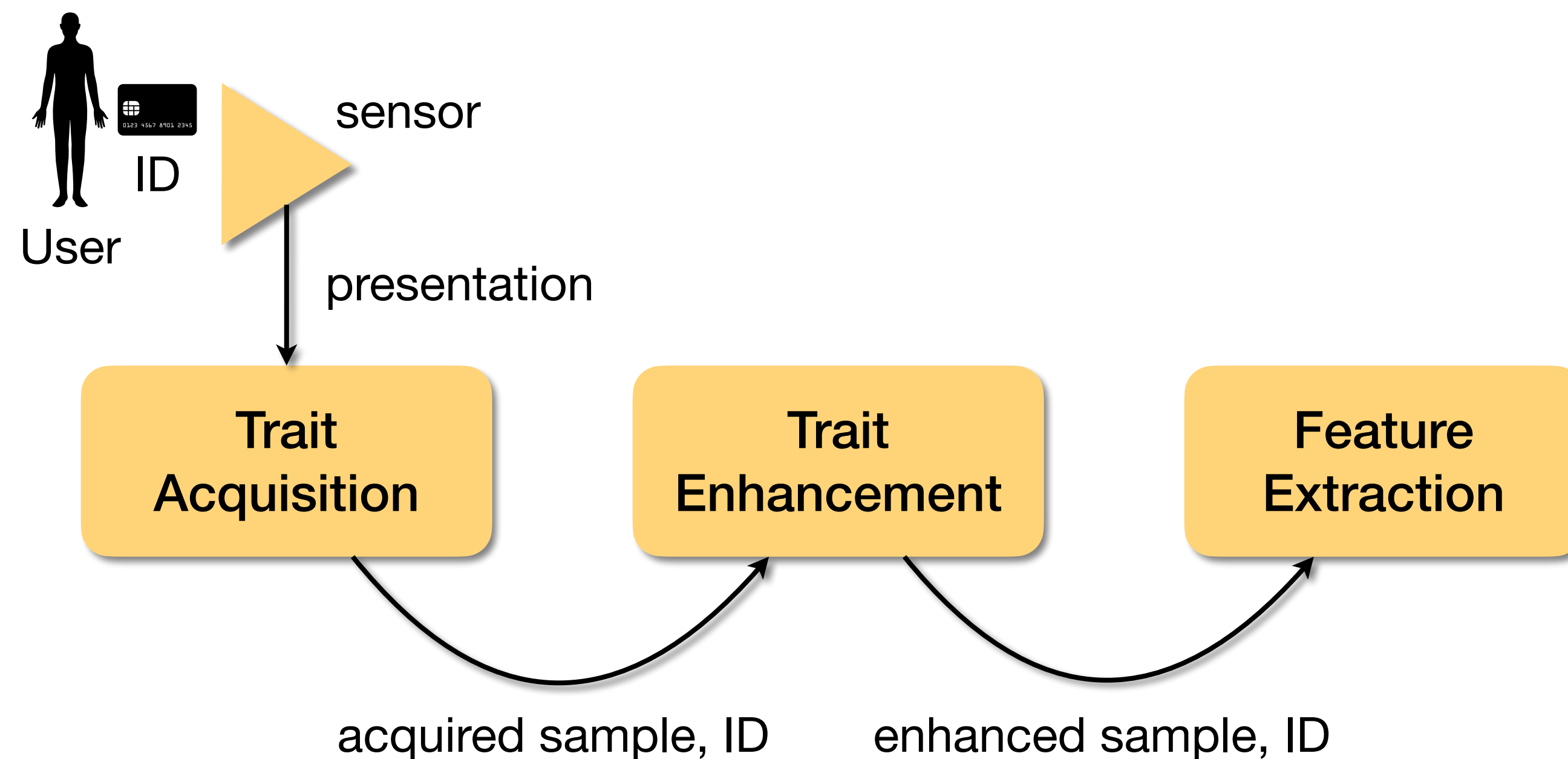
Gabor Filters thr: 0.4461

BSIF Filters thr: 0.4216

Global match score

# Biometric Systems

## Enrollment Modules



## Feature Extraction

Compact but expressive digital representation of the trait.

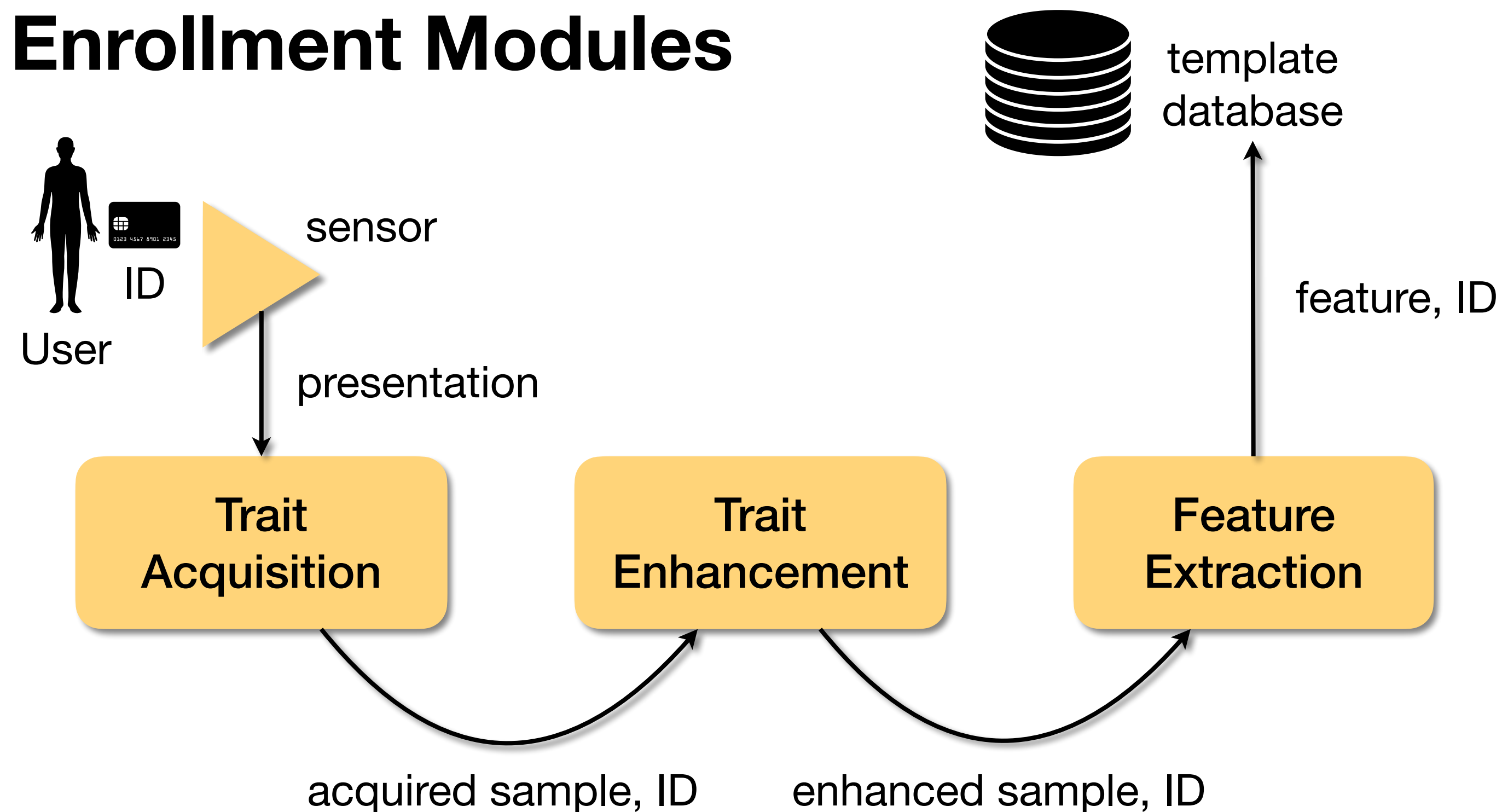
## Types

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



# Biometric Systems

## Enrollment Modules

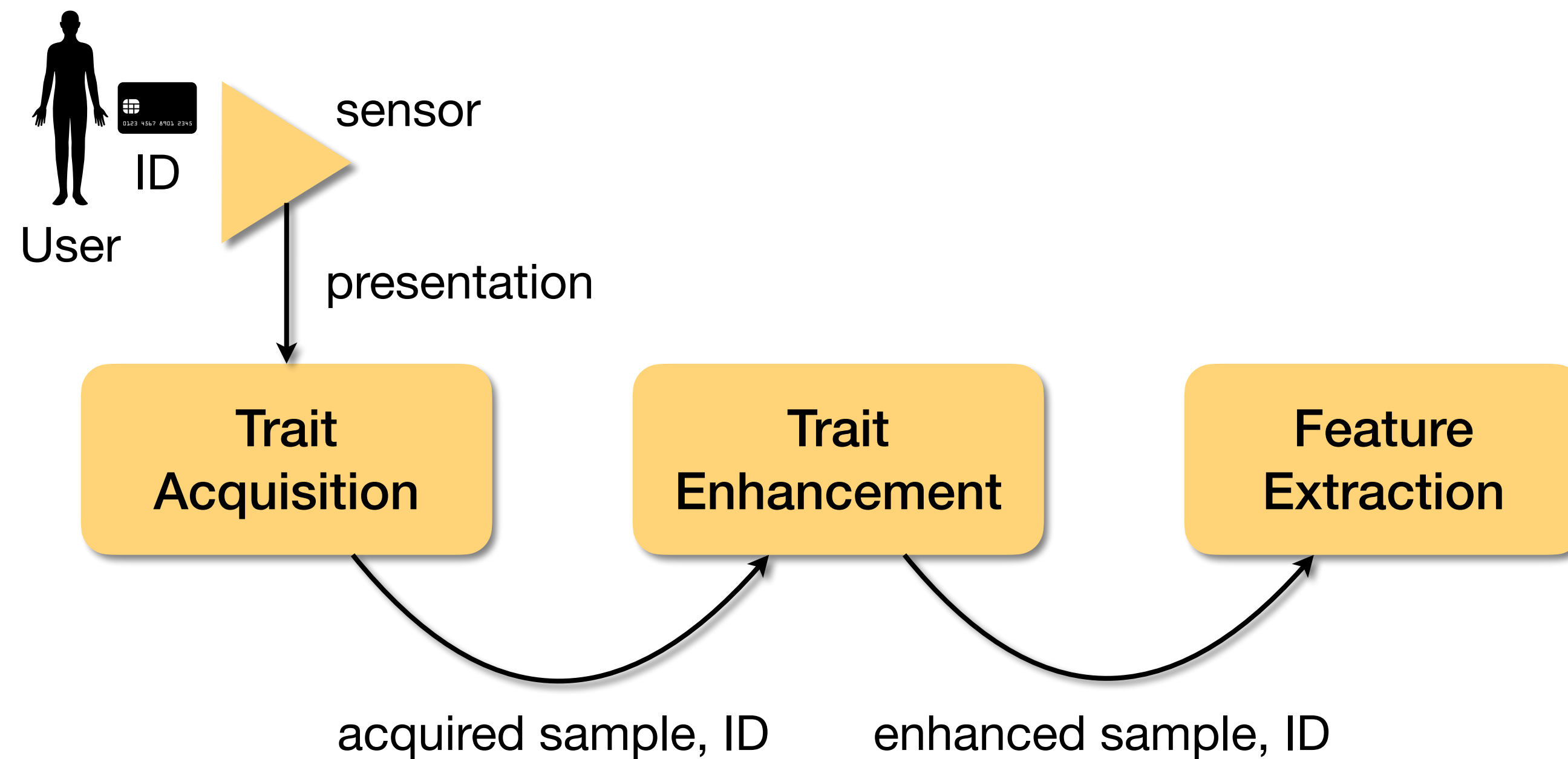


## Template Database

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

# Biometric Systems

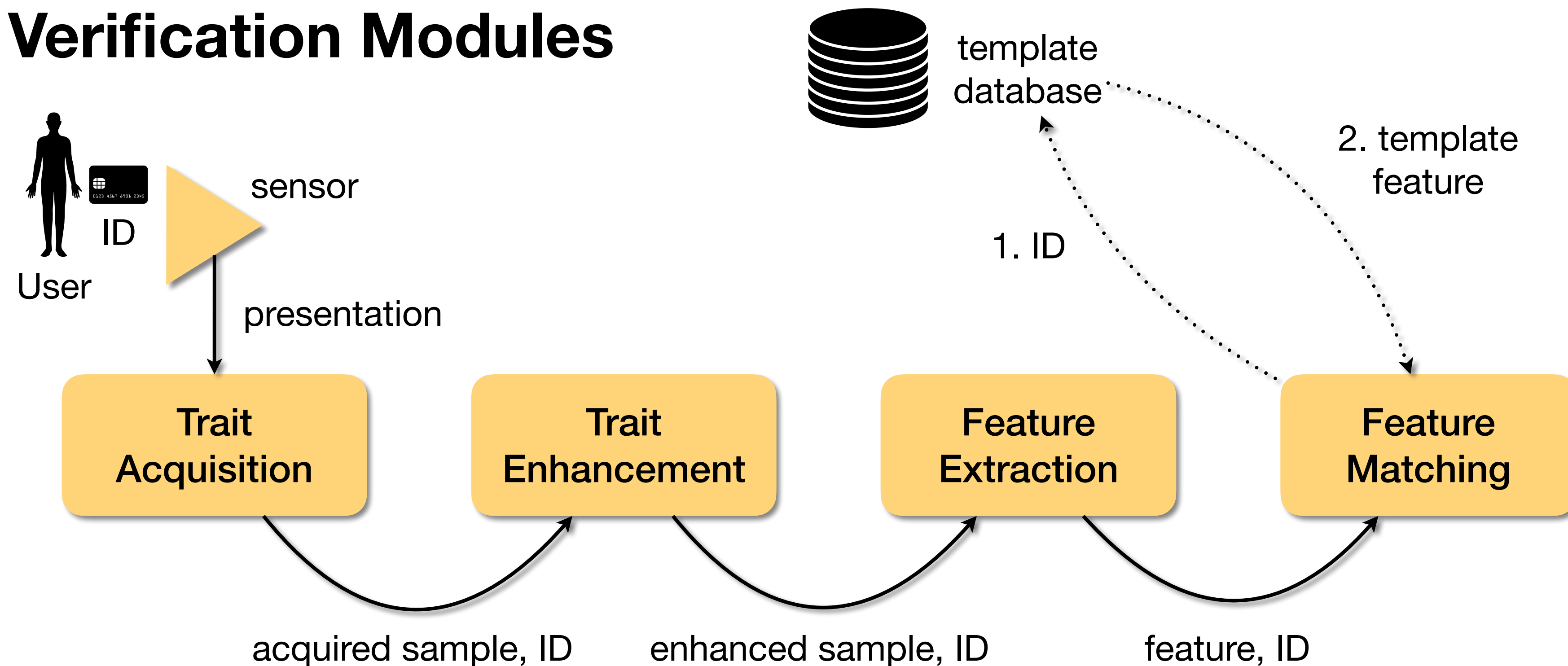
## Verification Modules





# Biometric Systems

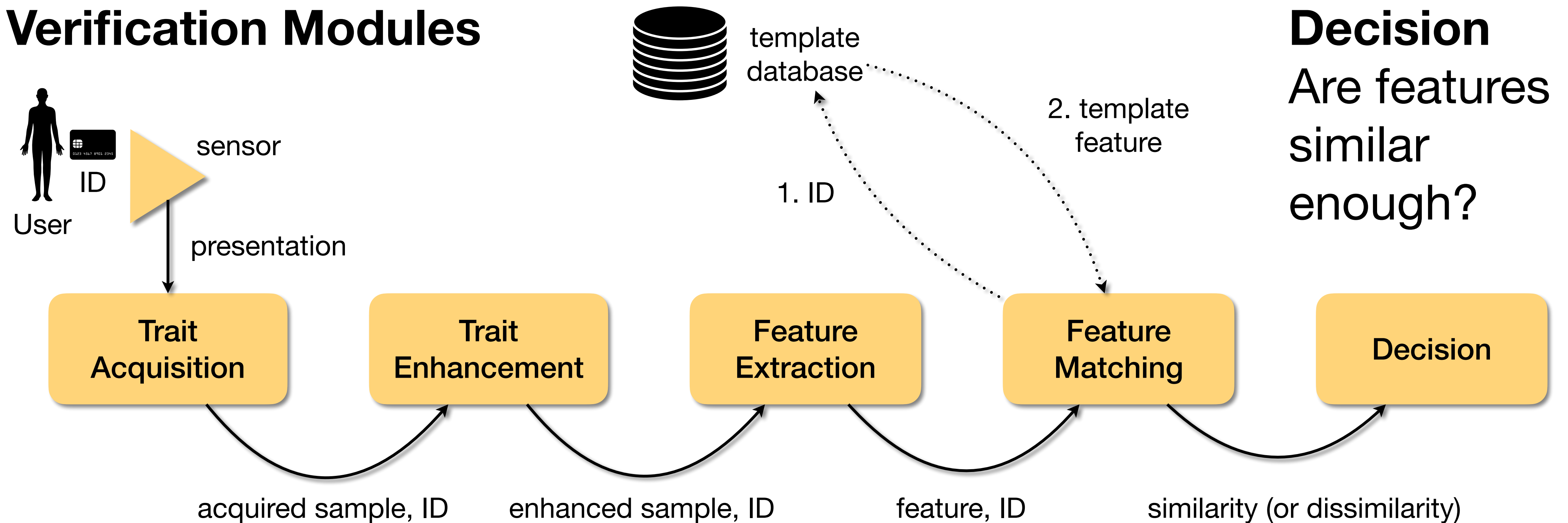
## Verification Modules



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

# Biometric Systems

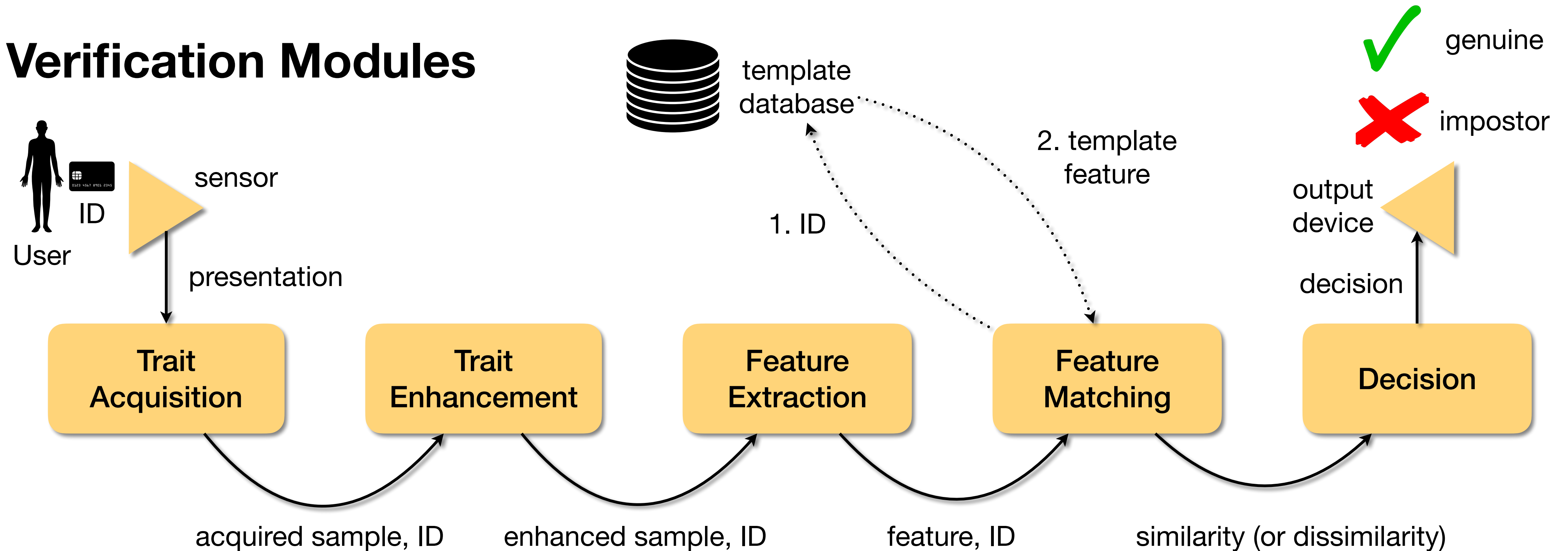
## Verification Modules





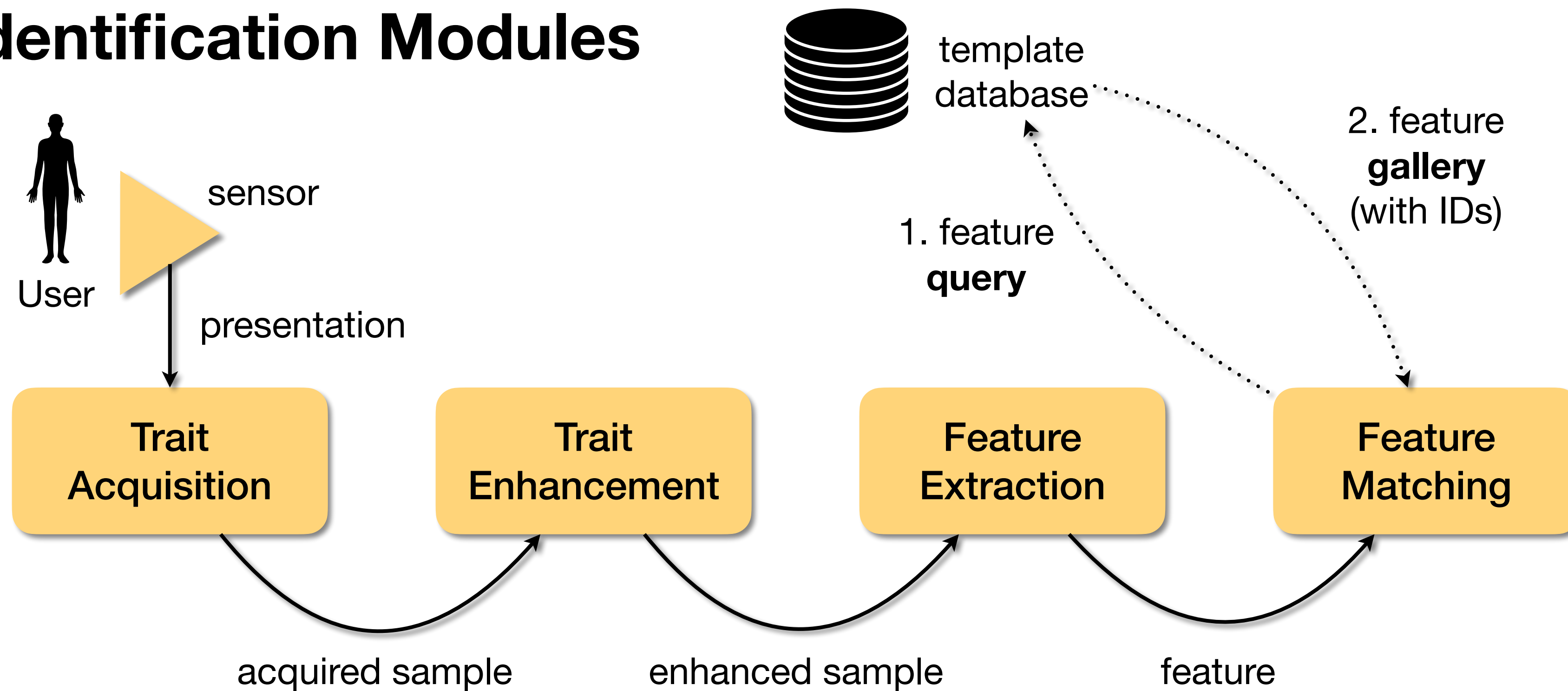
# Biometric Systems

## Verification Modules



# Biometric Systems

## Identification Modules



**Gallery**  
Closest  
template  
features to  
query.



# Biometric Systems

## Query and Gallery Example



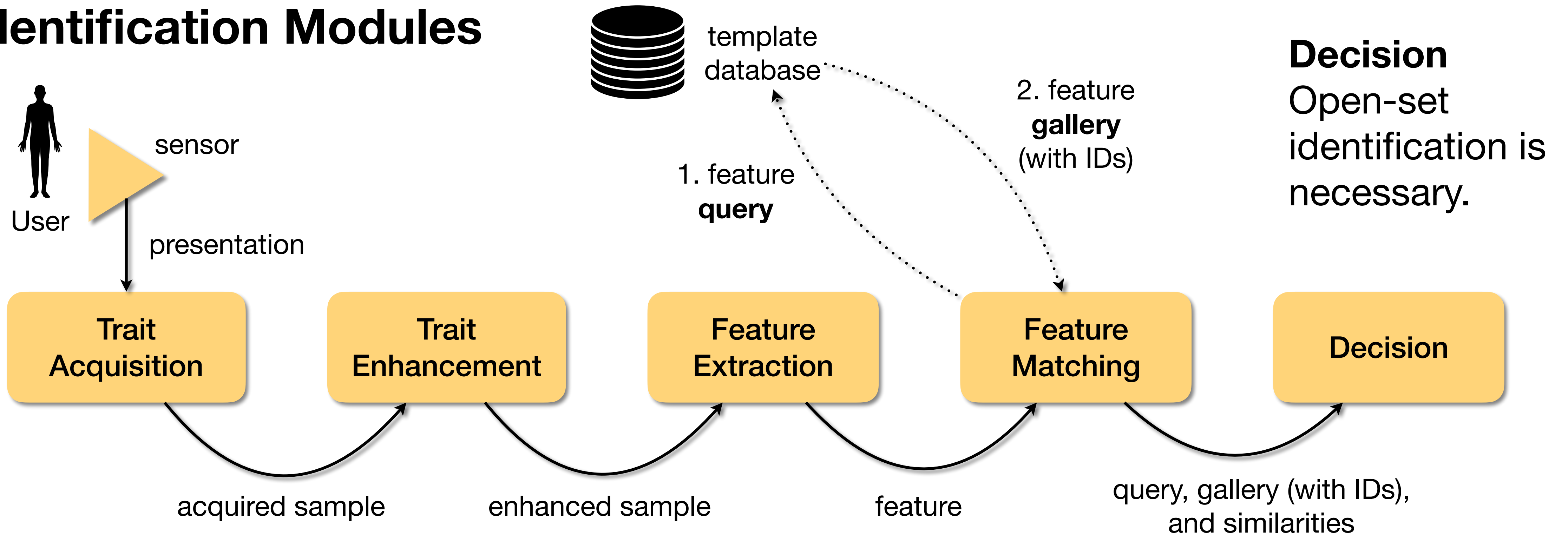
query

gallery



# Biometric Systems

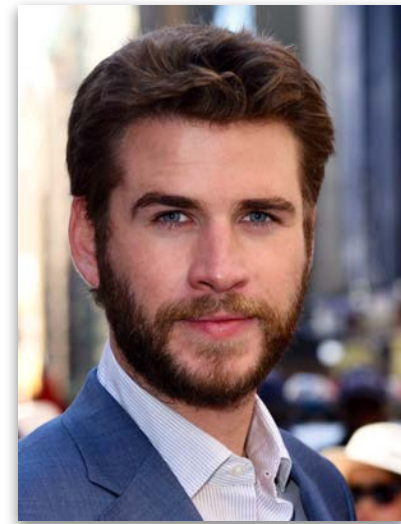
## Identification Modules





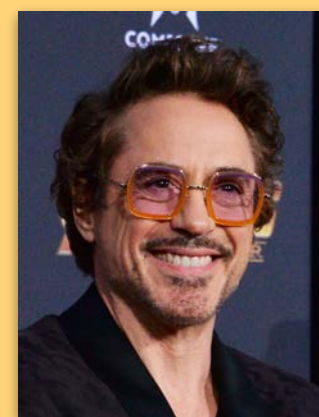
# Biometric Systems

## Open-set vs. Closed-set Identification



**Query**  
(Liam Hemsworth)

### Dataset



Robert Downey Jr.



Scarlet Johansson



Chris Evans



Mark Ruffalo

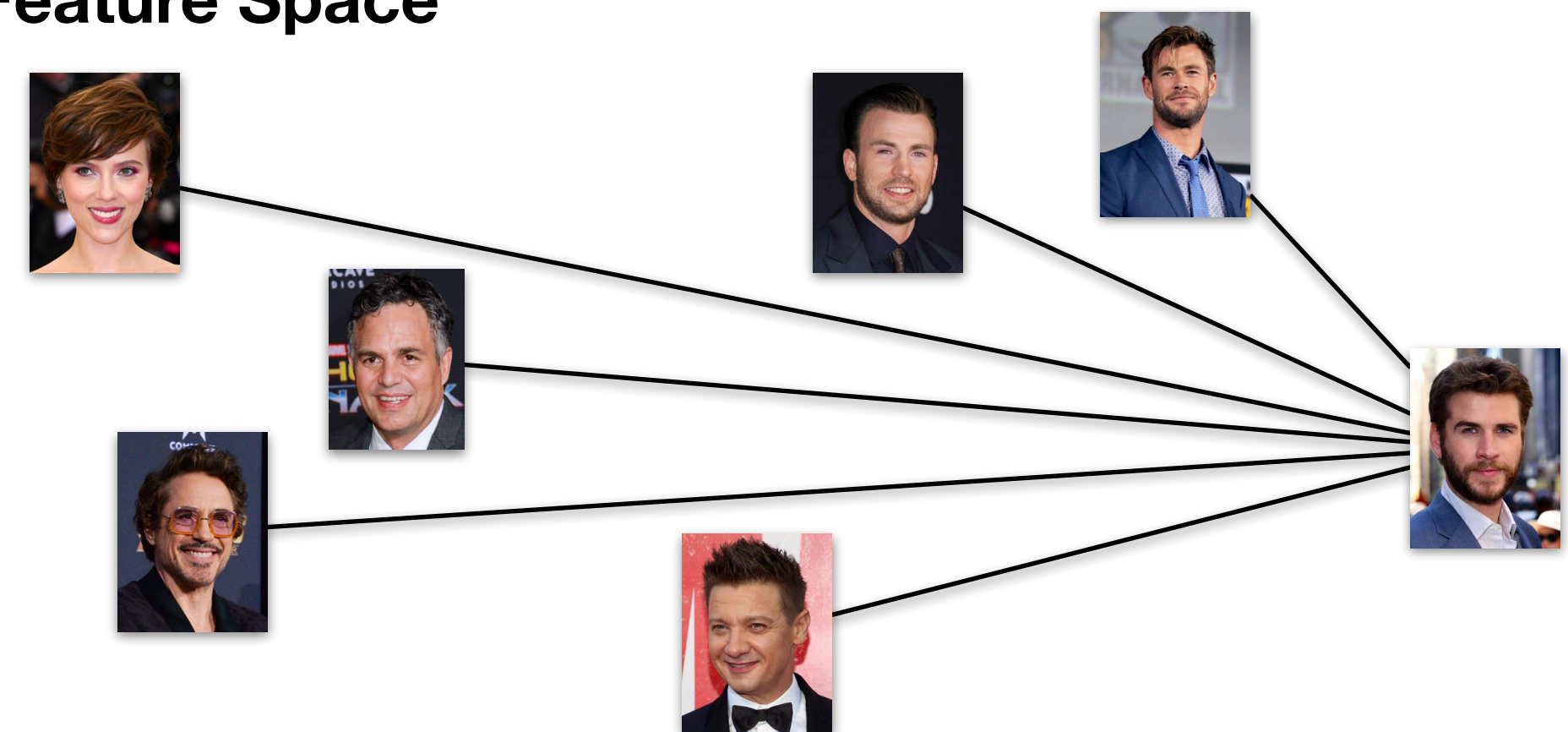


Chris Hemsworth



Jeremy Renner


### Feature Space



### Closed Set

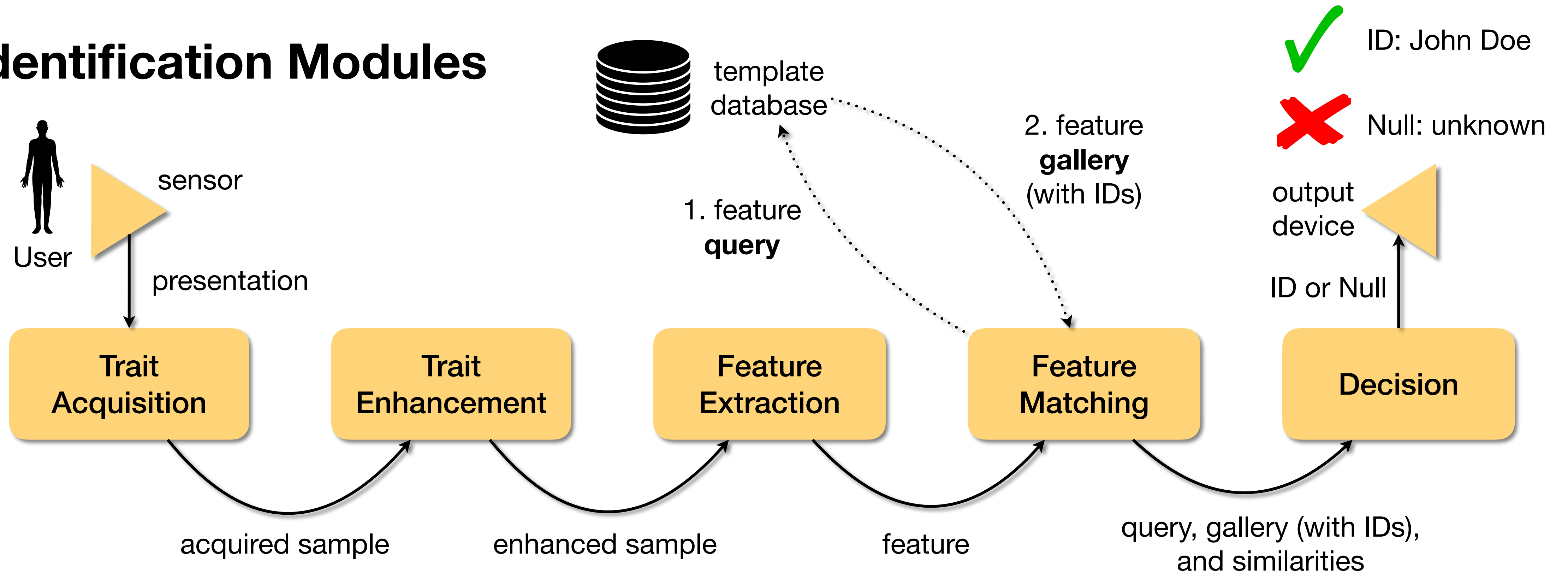
**Output**   
This is  
Chris Hemsworth!

### Open Set

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

# 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 and metrics.

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

<https://sakai.luc.edu/x/HAZC1P>

