History of Biometrics
Biometric Systems (DTU 02238)

Christoph Busch

Session 3

Biometrics - a new Technology?

“We have to counter new threats with innovative technologies - such as biometrics!”

- Is Biometrics an innovative technology?
- Which IT enterprise invented Biometrics?

Milestones ...

Hand-Geometry and fingerprint patterns were recorded by the Micmac tribe

- Prehistoric petroglyphs were discovered at lake Kejimkoojik - close to Halifax

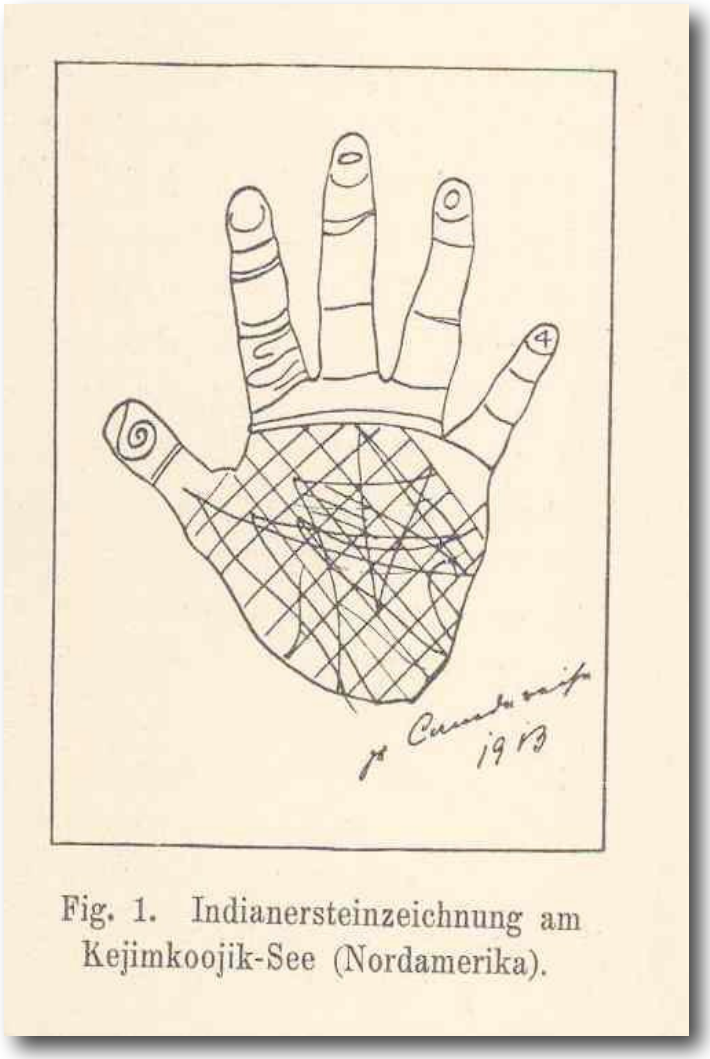


Fig. 1. Indianersteinzeichnung am Kejimkoojik-See (Nordamerika).

Source: Heindl

Milestones ...

China has a long tradition with fingerprints

- Prehistoric clay seal was found in province Honan from 6000 B.C.
- The Chinese author Kia Kung-Yen reports on identification systems based on fingerprints from 650 A.D.
- A loan contract from 782 A.D. with fingerprints is preserved
  - with 10 % interest

Fig. 3. Rückseite eines chinesischen Tonsiegels aus der Zeit vor Christi Geburt (auf der Rückseite mit Fingerabdruck versehen). Original im Field-Museum.

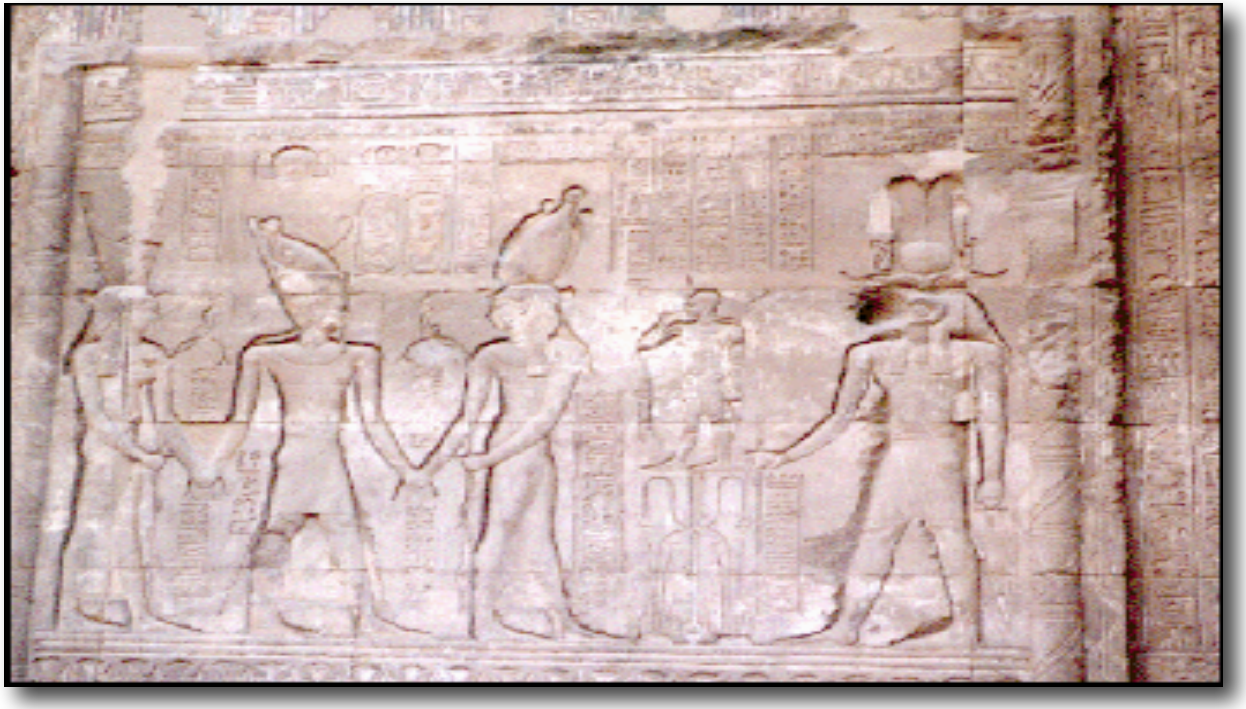
Source: Heindl

Milestones ...

Egypt had an old tradition

- Describing biometric characteristics

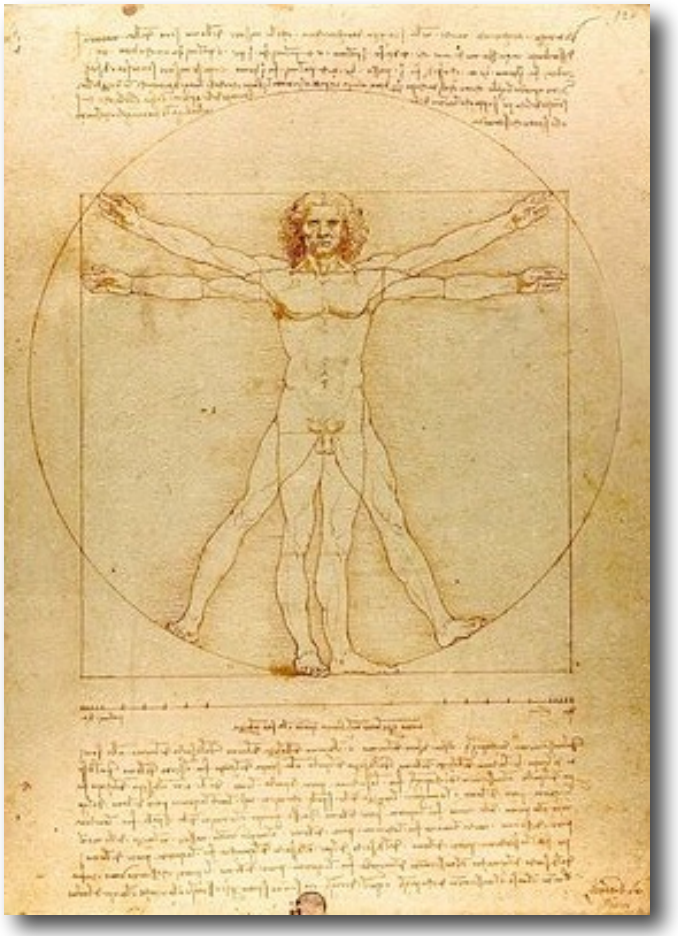
„Nechutes, son of Asos, aged forty of middle size, sallow complexion, cheerful countenance, long face with straight nose and a scar upon the middle of his forehead“



Human Proportions

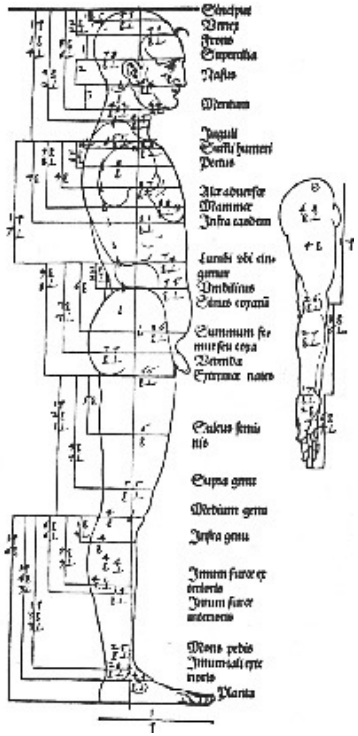
Leonardo da Vinci

- Vitruvian man
- Canon of proportions created in 1487
- Based on the correlations of ideal human proportions



Albrecht Dürer

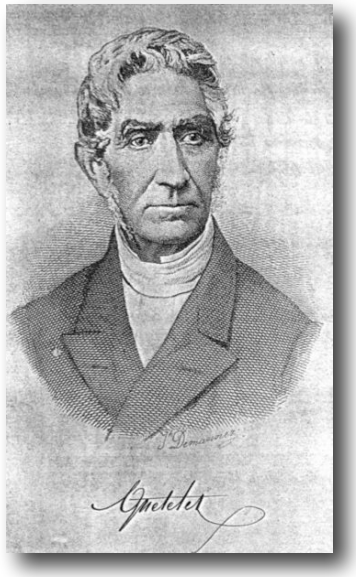
- Four books on human proportion - (vier Bücher von Menschlicher Proportion)
- Created in 1528



Anthropometry

Adolphe Quetelet - France 1871

- *„L'anthropometrie ou mesure des differentes facultes de l'homme"*
- Measurement of various characteristics of the human body such as weight, body height, perimeter of extremities etc. for the purpose of understanding the physical variation



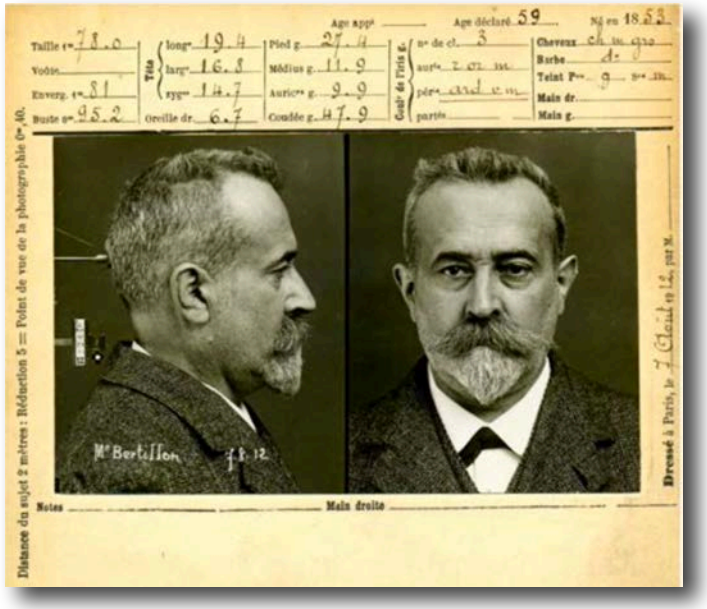
Nowadays Anthropometry:

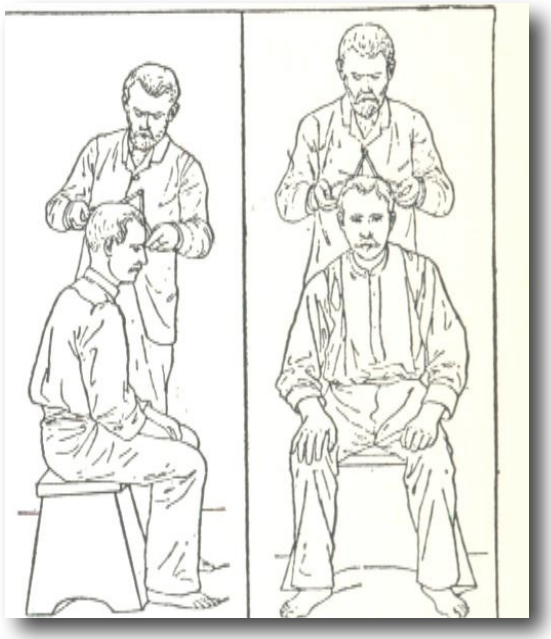
- Contributes to the ergonomics and industrial design of work places, tools and furniture.
- Contributes to safety at work, when security measures (e.g. size of protection covers) or minimum distance from critical processes are defined.
- International Standard: ISO 7250-1:2017 Basic human body measurements for technological design
  https://www.iso.org/obp/ui/#iso:std:iso:7250:-1:ed-2:v1:en

Forensic Anthropometry

Alphonse Bertillon - France 1883

- Forensic use of measurements
- Identification (of criminals) with anatomical measurements
  - Weight, size, length and width of the head
  - Categorization of Iris-Color and Iris-Patterns
- The principle was widespread in France for primary classification and noted elsewhere.





Bertillonage

Forensic Anthropometry

Bertillonage -
included eleven measurements:

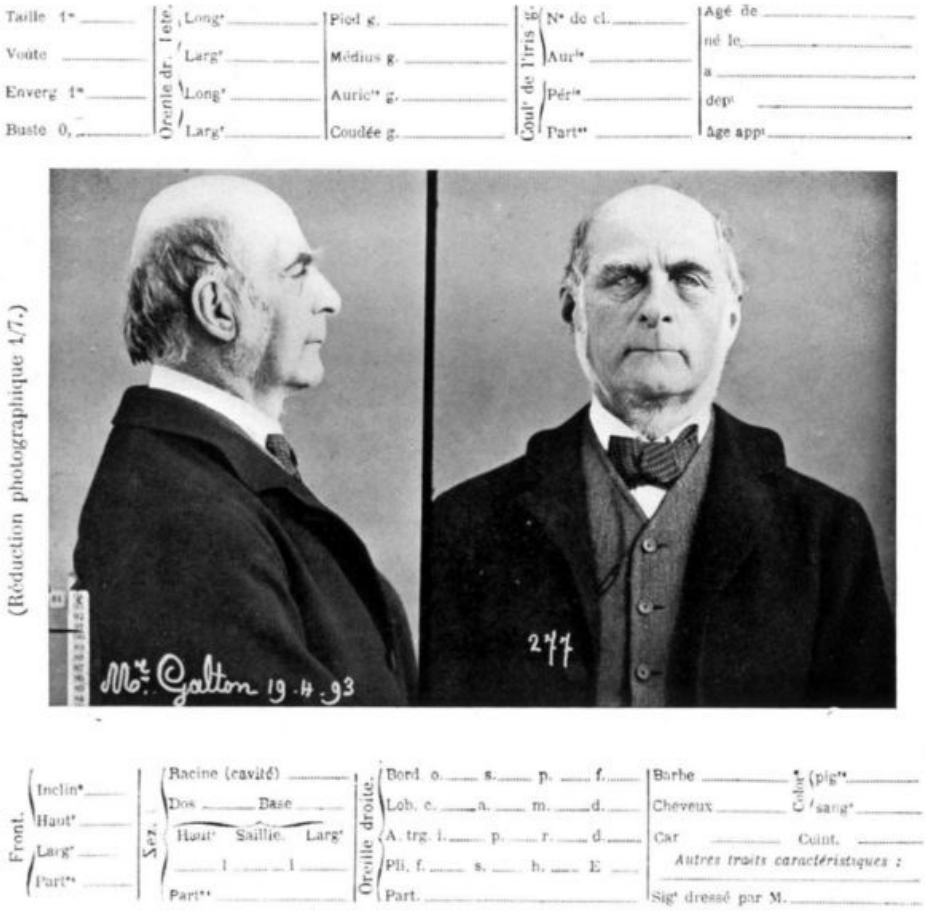
1. Height
2. Stretch: Length of body from left shoulder to right middle finger when arms raised
3. Brust: length of torso from head to seat, taken when seated
4. Length of head: Crown to forehead
5. Width of head: Temple to temple
6. Length of right ear
7. Length of left foot
8. Length of left middle finger
9. Length of left cubit: Elbow to tip of middle finger
10. Width of cheeks
11. Length of left little finger

1. Taille. — 2. Envergure. — 3. Buste. —
4. Longueur de la tête. — 5. Largeur de la tête. — 6. Oreille droite. —
7. Pied gauche. — 8. Médius gauche. — 9. Coudée gauche.

Forensic Anthropometry

Bertillonage

- Still in use today - but in a different context!



A Bertillon record for Francis Galton

A head measurer tool in the early 1910s

Fingerprints and Dactyloscopy

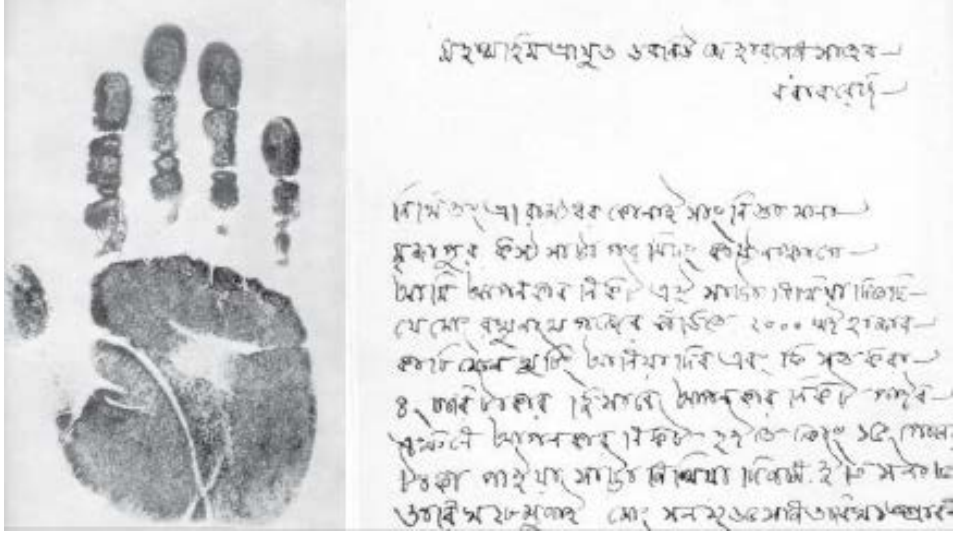
Marcello Malpighi - Italy 1686

- Investigates ridges with a microscope
- Reports various patterns and formations
  - Commented upon "diverse figures on palmar surfaces, and loops and spirals”
- Failed to make the link between fingerprints and their use as means of identification

Fingerprints and Dactyloscopy

William J. Herschel - India 1888

- English officer
  - responsible for the payment of allowances to pensioned soldiers
  - difficulty preventing impersonation
  - signature on pension contracts with palm-prints and finger-prints
- Collection of thousands of fingerprints - since 1858
  - 28 years long observation of his personal palm- and finger-prints
- Proof of the principle of persistency of epidermal ridges



Contract between Herschel and Rajyadhar Konai - Konai‘s palm-print is in the backside of the contract. Bengal, India, July 28, 1858

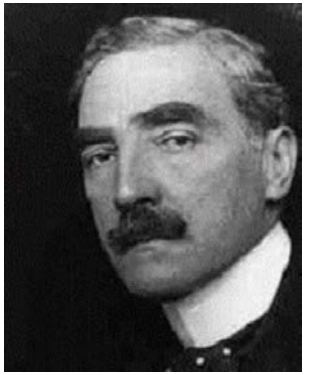
Fingerprints and Dactyloscopy

Francis Galton - England 1892

Galton

- Known as statistician, sociologist, antrhopologist, tropical explorer, geographer, inventor, ..
- Classification of fingerprint patterns
- Proposal of a classification scheme for dactyloscopy at crime scenes
- Honored by naming of the ridge lines: “Galton-Ridges“

Edward Henry - England 1905



Henry

- Refinement of the classification scheme
  - Each fingerprint pattern is assigned to a distinct pattern class according to the ridge flow
- Classification scheme has been adapted by the Federal Bureau of Investigation (FBI) and is still in use in most of nowadays Automated Fingerprint Identification Systems (AFIS)

Basic Dactyloscopic Patterns

Right Loop („R“)

- The loop pattern contains a characteristic delta structure
- Ridges tend to be outward bounded from the core to the right side
- The characteristic delta is located on the opposite side

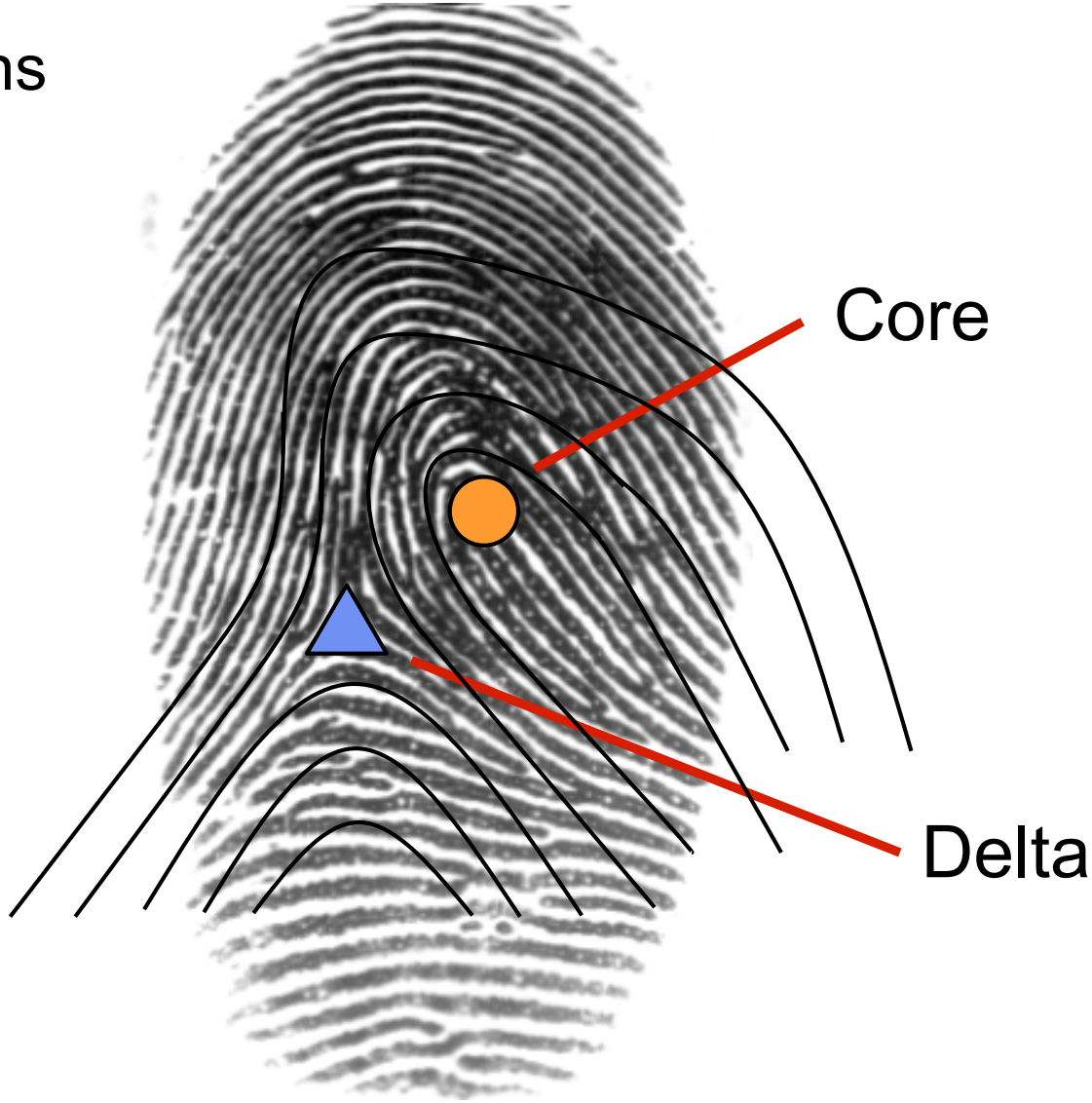


Image Source: FVC2004 database

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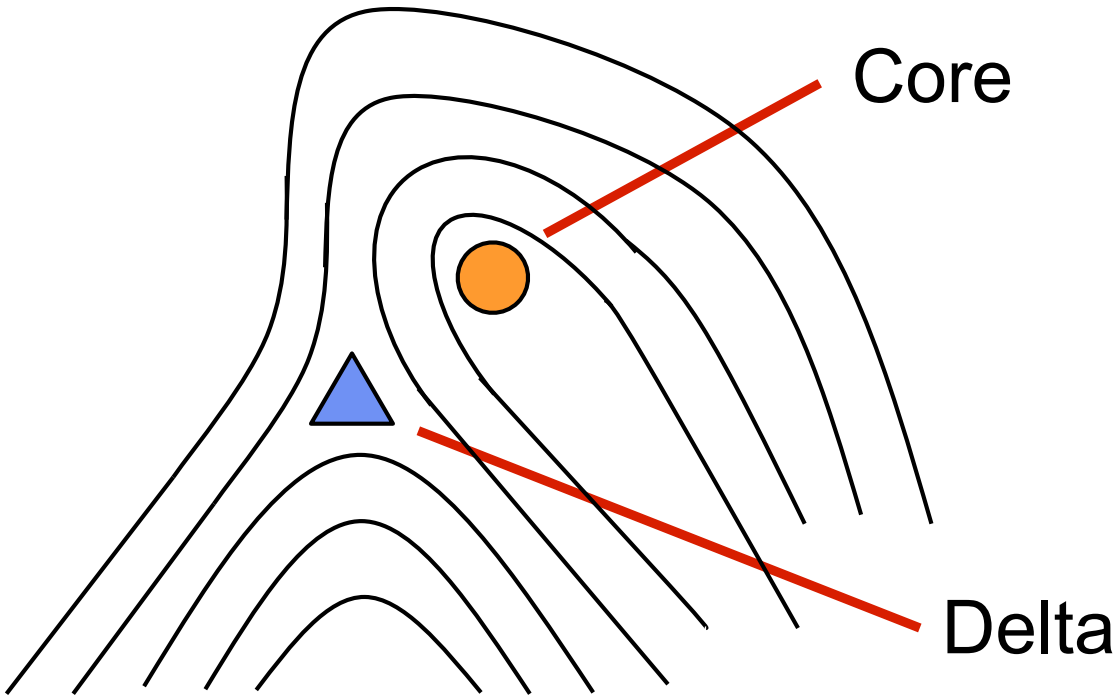

Basic Dactyloscopic Patterns

Left Loop („L“)

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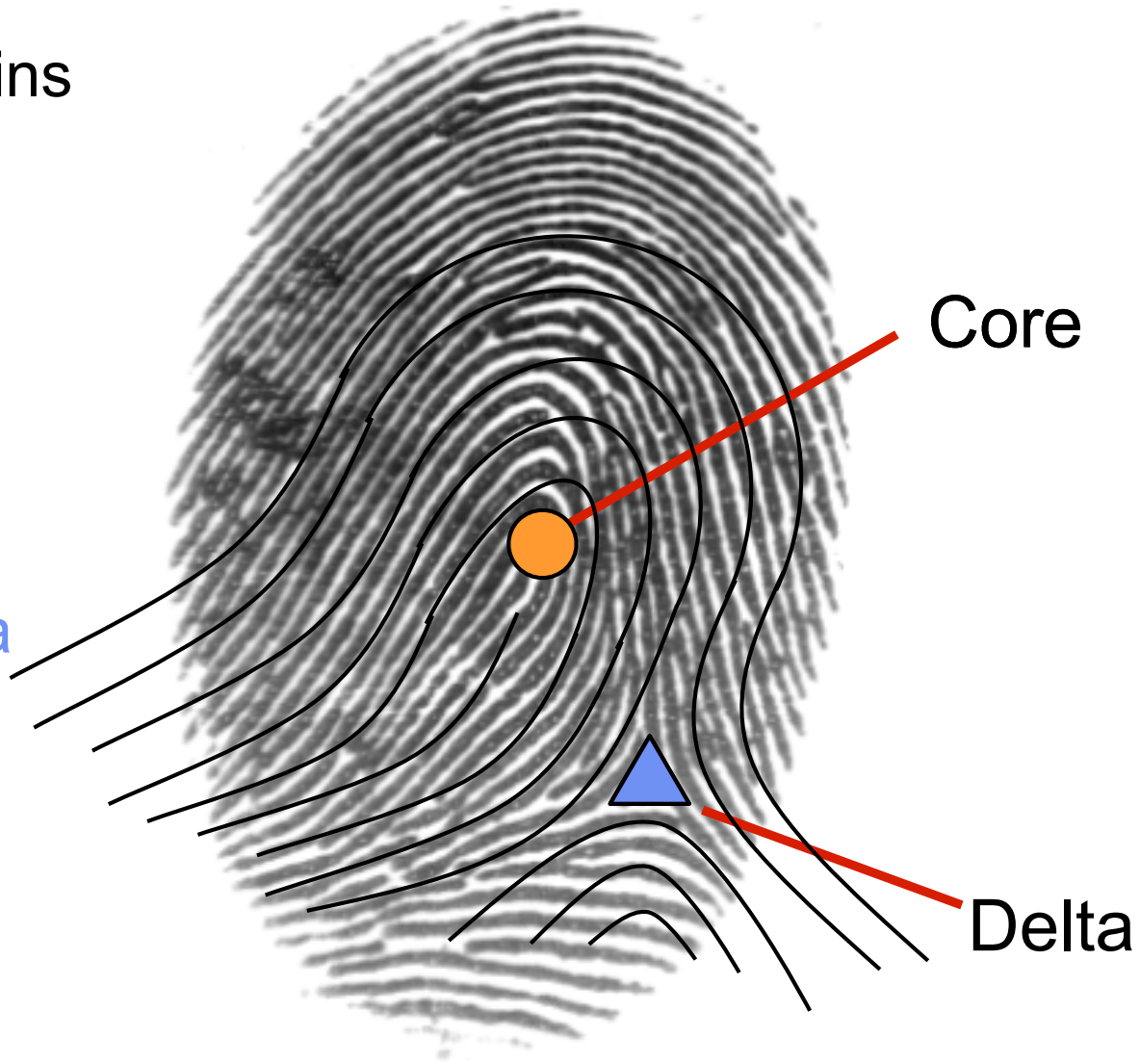

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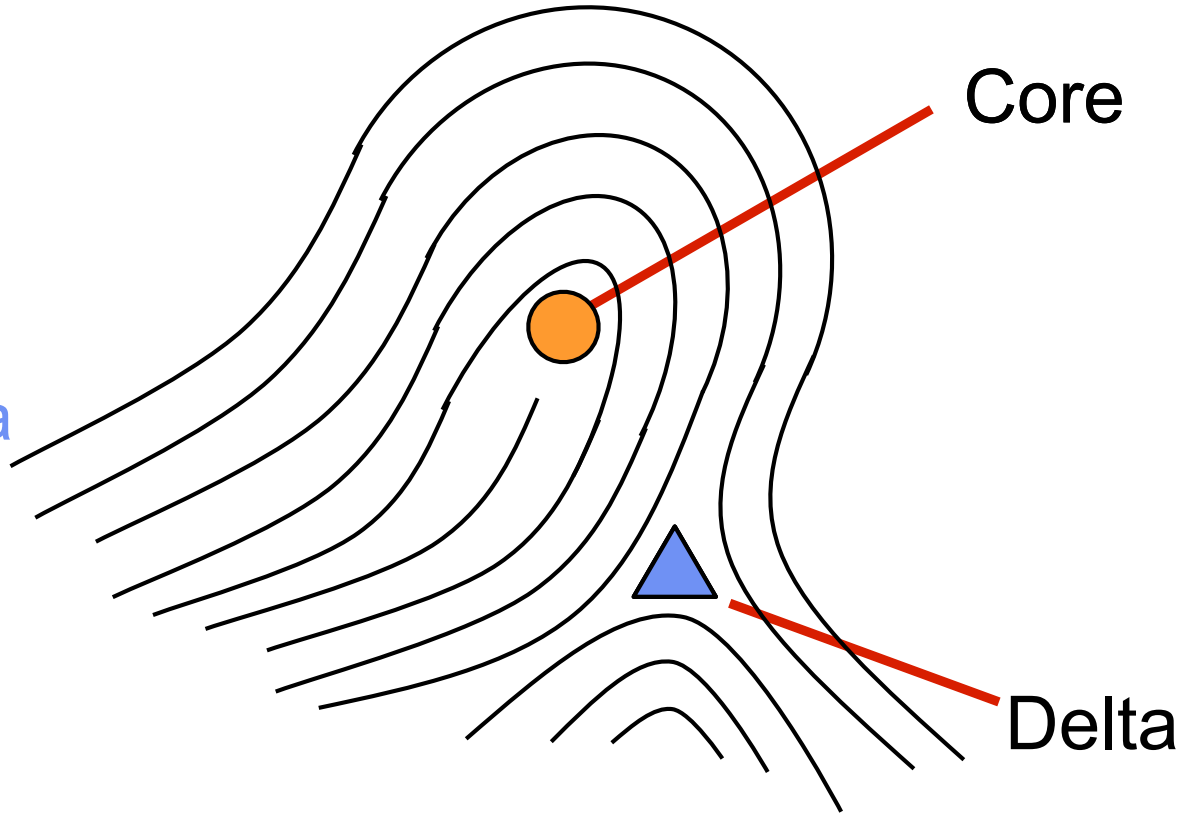

Basic Dactyloscopic Patterns

Whorl („W“)

- The basic pattern contains two characteristic delta structures
- The ridges in the core of the pattern are curled

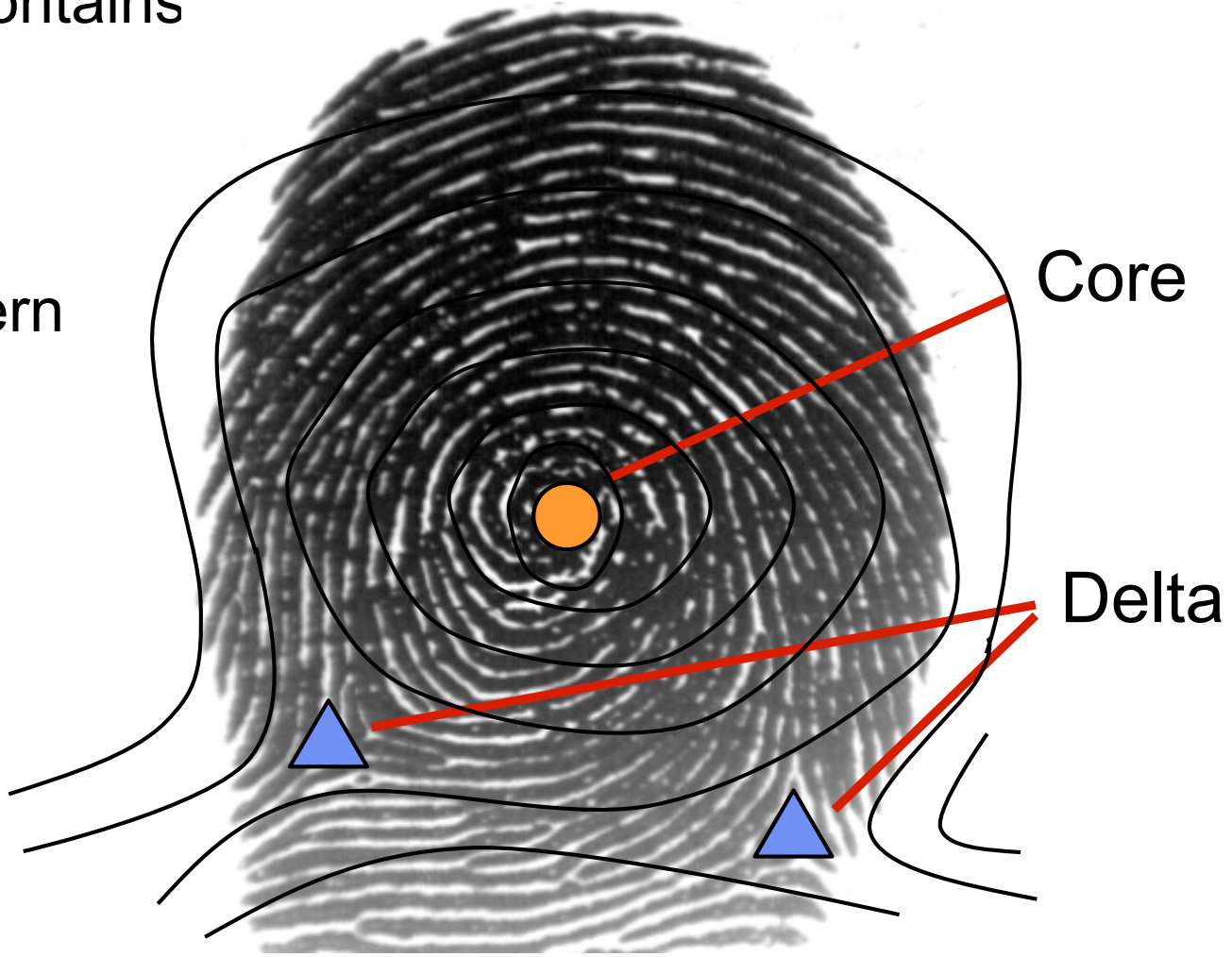

Image Source: FVC2004 database

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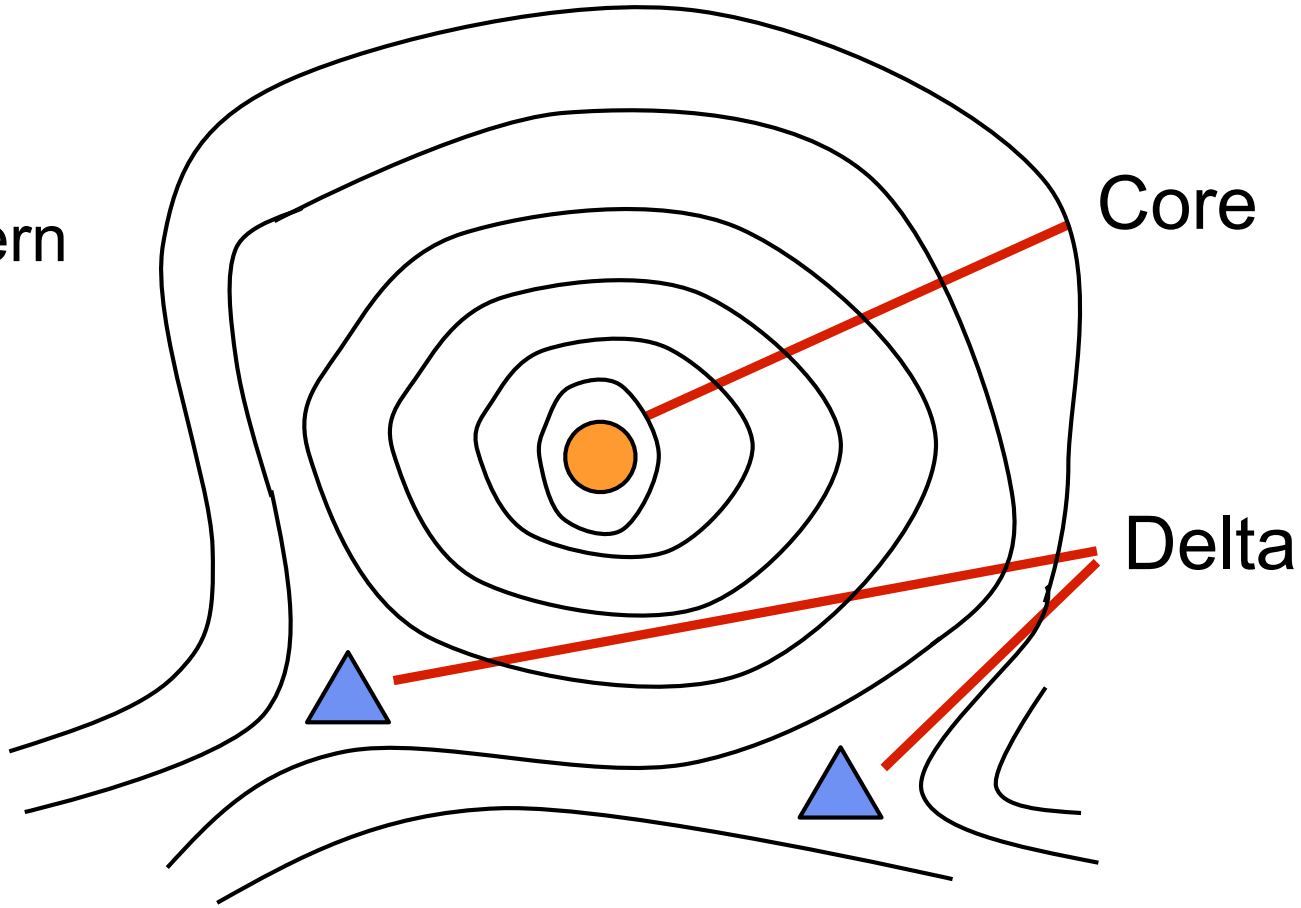

Basic Dactyloscopic Patterns

Arch („A“)

- The basic pattern does not contain a characteristic delta structure
- The ridges in the centre of the pattern run - curved upwards - from one side to the other side

Image Source: FVC2004 database

Basic Dactyloscopic Patterns

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- The basic pattern does not contain a characteristic delta structure
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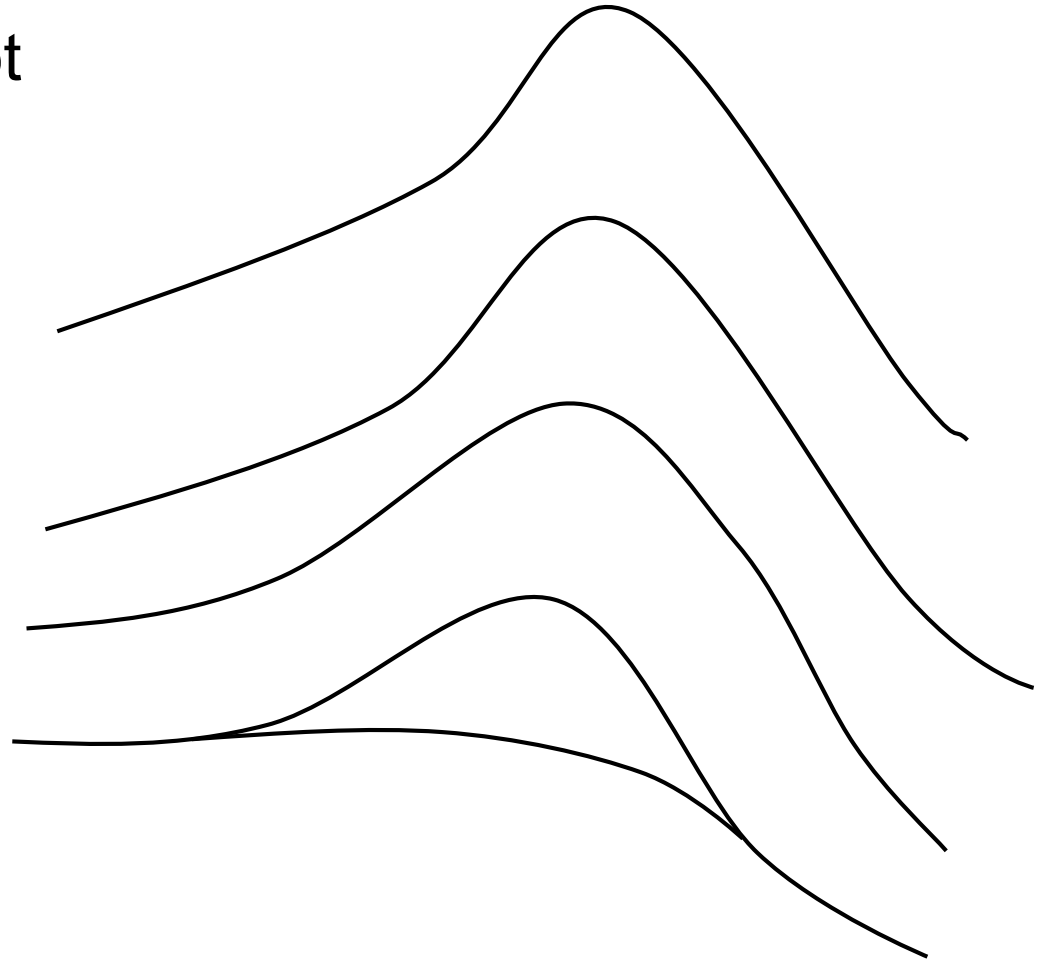


Image Source: FVC2004 database

AFIS

Automated Fingerprint Identification Systems (AFIS)

- Exploiting the capabilities of computers and databases to look up millions of records for potential candidates
- Analysis and interpretation of candidates by manual inspection through dactyloscopic experts
- Binning according to fingerprint patterns

AFIS @ FBI in USA

FBI:

- 111 million Tenprint card (in 2016)
  - 71m criminal
  - 40m civil

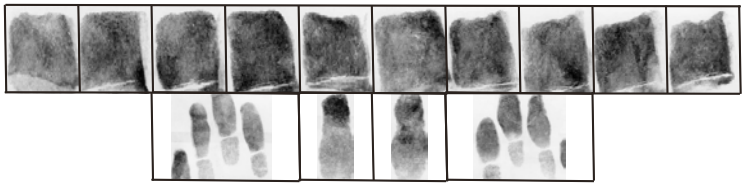
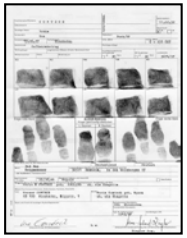
Rolled fingerprints ("nail-to-nail")

Slap fingerprints

AFIS - Forensic Data Interchange

Fingerprint-Record

- Standard Data Format ANSI/NIST-ITL-2015

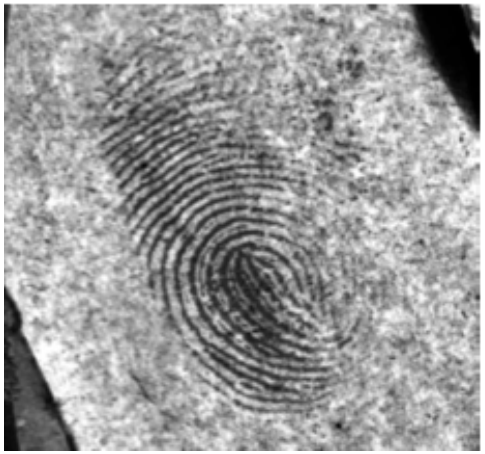
Type-1 Record	Type-2 Record	Type-3 to 6 Record	Type-7 Record	Type-10 Record
Trans-action Record File Header	User Defined Text Record	High Resolution Gray Scale Record 	User defined Image Record 	Facial Image Record 

Source: BKA

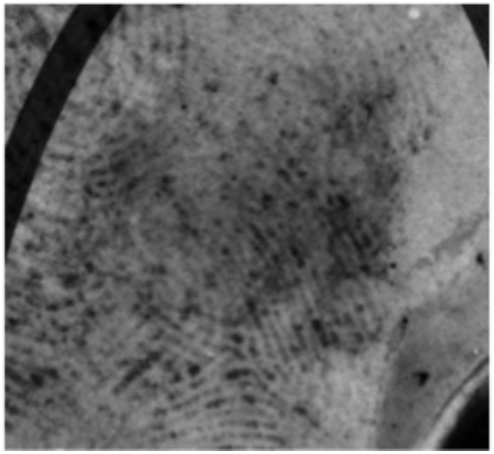
Forensic Challenges

Latent fingerprint quality

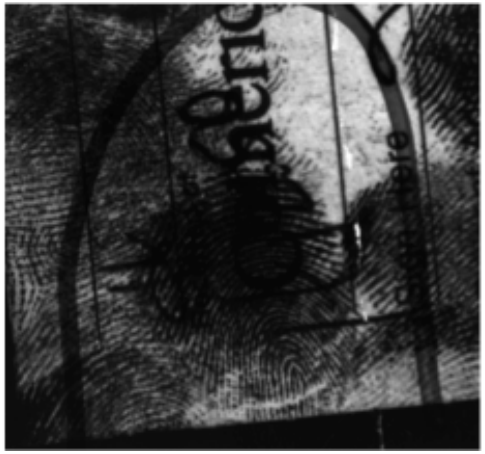
- Poor quality of the latent print
- Partial prints
- Complex background



Partial prints



Unclear ridges



Overlap with other prints

Complex background

Image Source: A. K. Jain 2013

AFIS in Europe

EURODAC

- Distinct categories of illegal immigrants
- Database
  - no name, no facial image
  - only Tenprint cards of asylum applicants (14 years and older)

Visa Information System

- 10 fingerprints of visa applicants

Entry Exit System

- 4 fingerprints of third country travelers

Milestones ...

Vein pattern recognition - 1927

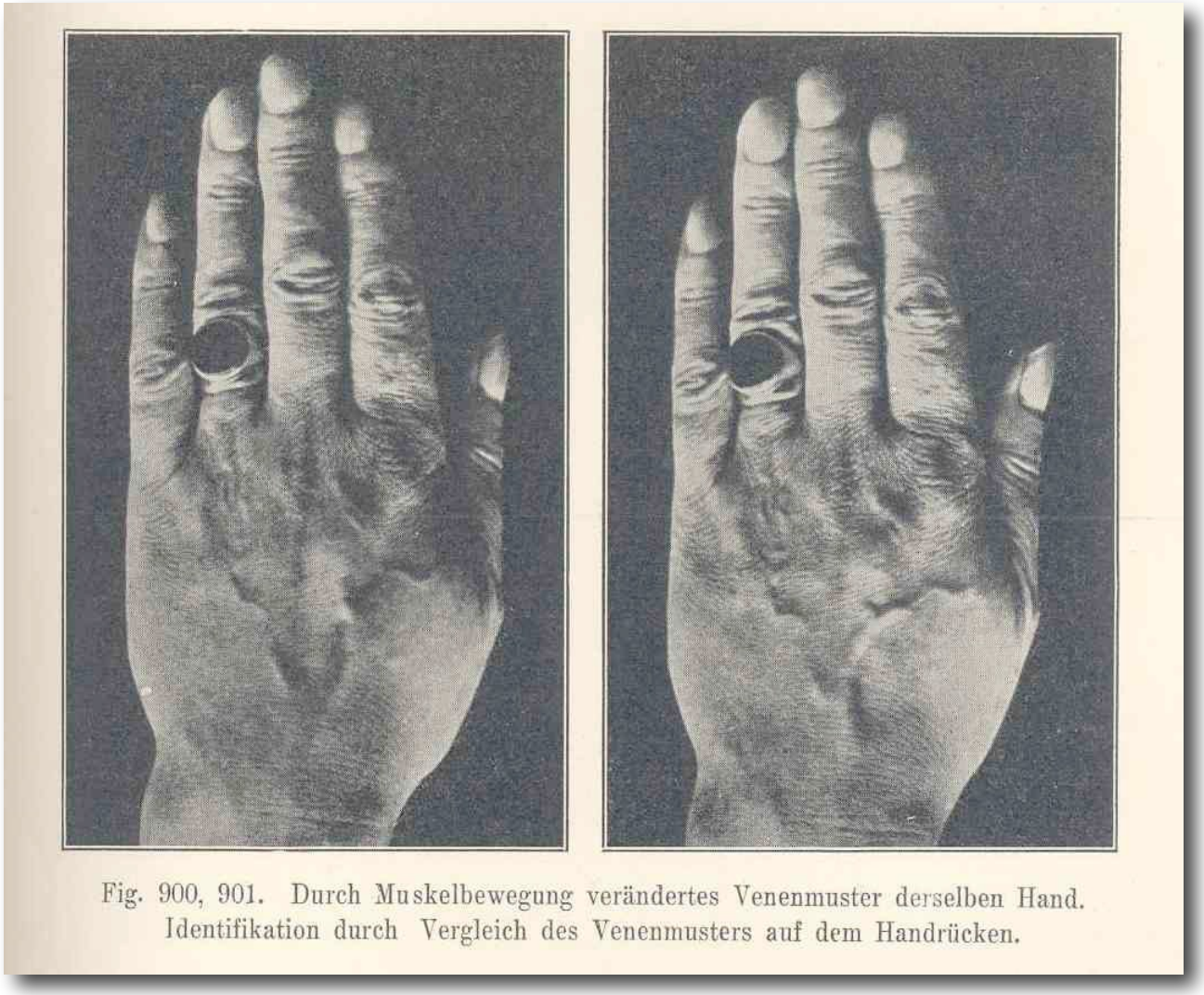


Fig. 900, 901. Durch Muskelbewegung verändertes Venenmuster derselben Hand. Identifikation durch Vergleich des Venenmusters auf dem Handrücken.

Source: Heindl

Milestones ...

.. and even
multi-modal biometrics

Fig. 877. Handelt es sich um zwei Bilder derselben Person oder um solche zweier verschiedener Individuen?

Zwei verschiedene Individuen (Zwillinge). (Polizeidirektion Wien.)

Source: Heindl

Overview

Milestones:

- 700 China: Fingerprints used to confirm contracts
- 1835 The first photo cameras (sensors)
- 1903 Introduction of Dactyloscopy in U.K., Germany, etc.
- 1910 Facial image included in personal documents
- 1947 Speaker recognition
- 1970 Computer supported recognition
- 1990 Artificial neural networks
- 1995 Civil applications of biometric systems
- 1998 AFIS introduction (Germany)
- 2003 EURODAC
- 2005 Biometric ePassport
- 2011 SIS-II/VIS/BMS
- 2013 Smartphones with embedded fingerprint sensors
- 2023 Entry Exit System

Biometrics Today

Significant progress in:

- Computing power and Deep Learning
- Sensor technology in every Smartphone
- Storage media Smartcards (e.g. MasterCard and Visa)
- Biometric recognition in Social Networks

References

Complementary reading

- R. Heindl: „System und Praxis der Daktyloskopie“, Walter de Gruyter & Co, 1927
- Clause 2.2 of ISO/IEC TR 24741 Biometrics Tutorial, 2007
- Section 5.1 of R. Müller: „Fingerprint Verification with Microprocessor Security Tokens“, Dissertation, 2001