# BLOOD PRESSURE MONITORING

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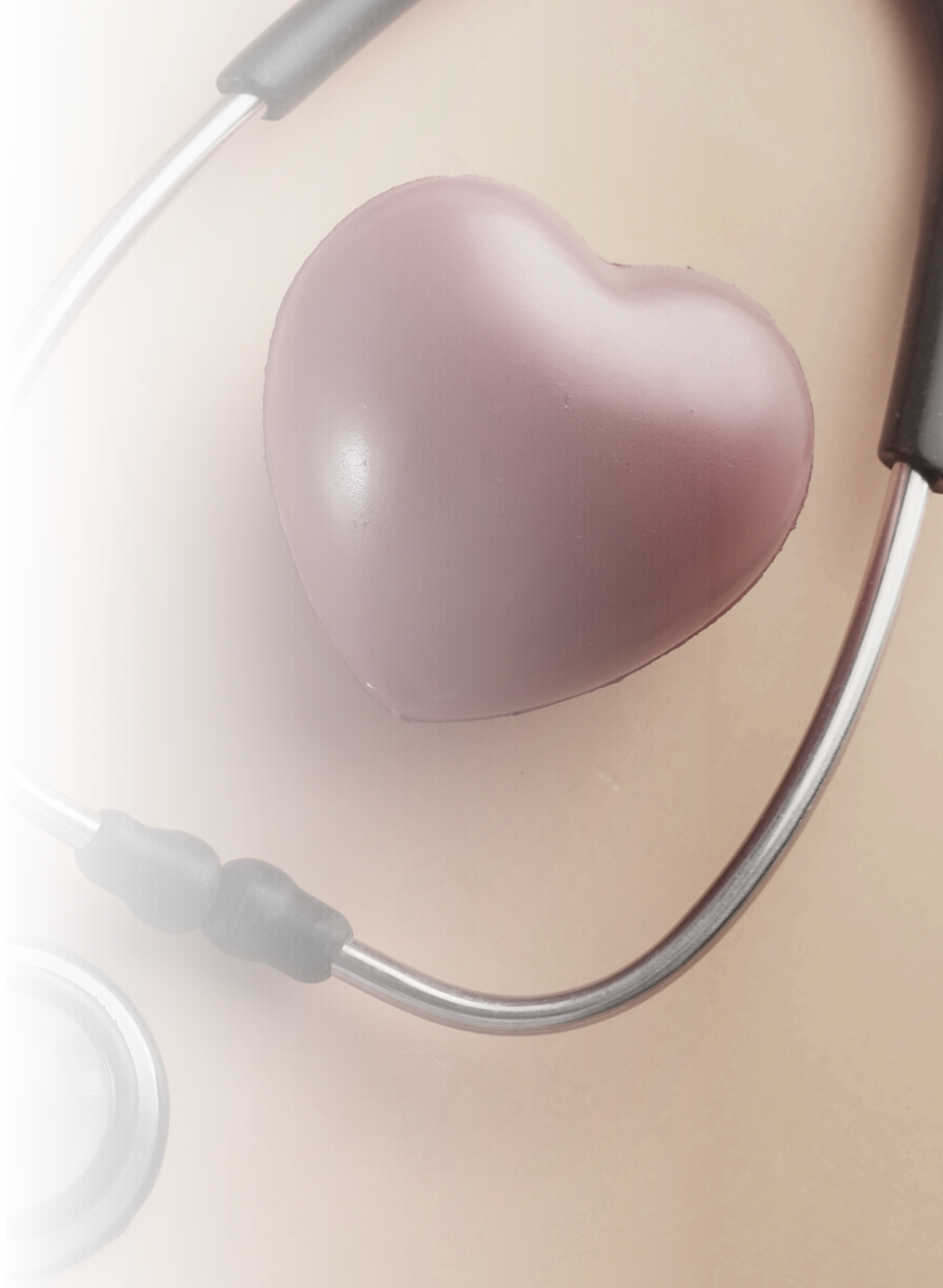

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# Introduction

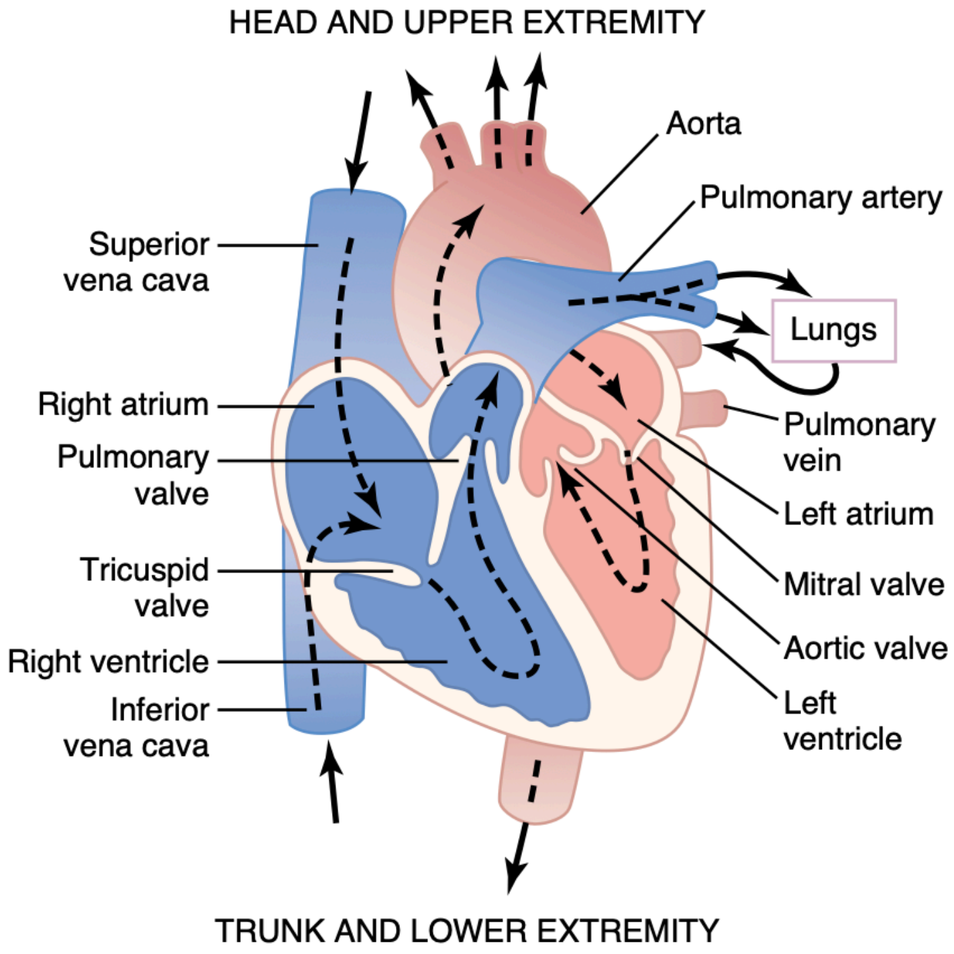
- Blood Pressure is one of the 4 **main vital signs**
- Used daily in:
  - Emergency medicine
  - Primary care
  - Home monitoring
- Essential for early detection of **cardiovascular risk**
  - *silent killer*
- First aider at EPFL

# Why does Blood Pressure matters ?

- Blood pressure determines **organ perfusion**
- Essential for adequate delivery of:
  - Oxygen
  - Nutrients
- Two types of Abnormal blood pressure:
  - **HYPERTENSION** *(too high) - ⅓ of adults between 30 & 79*
    - Cardiovascular events (Strokes, Heart attacks…)
    - Internal bleeding
    - Organ dammage
  - **hypotension** *(too low)*
    - Organ dammage
    - Faintness → falls

# The Heart as a Pump

## Physiologic aspects



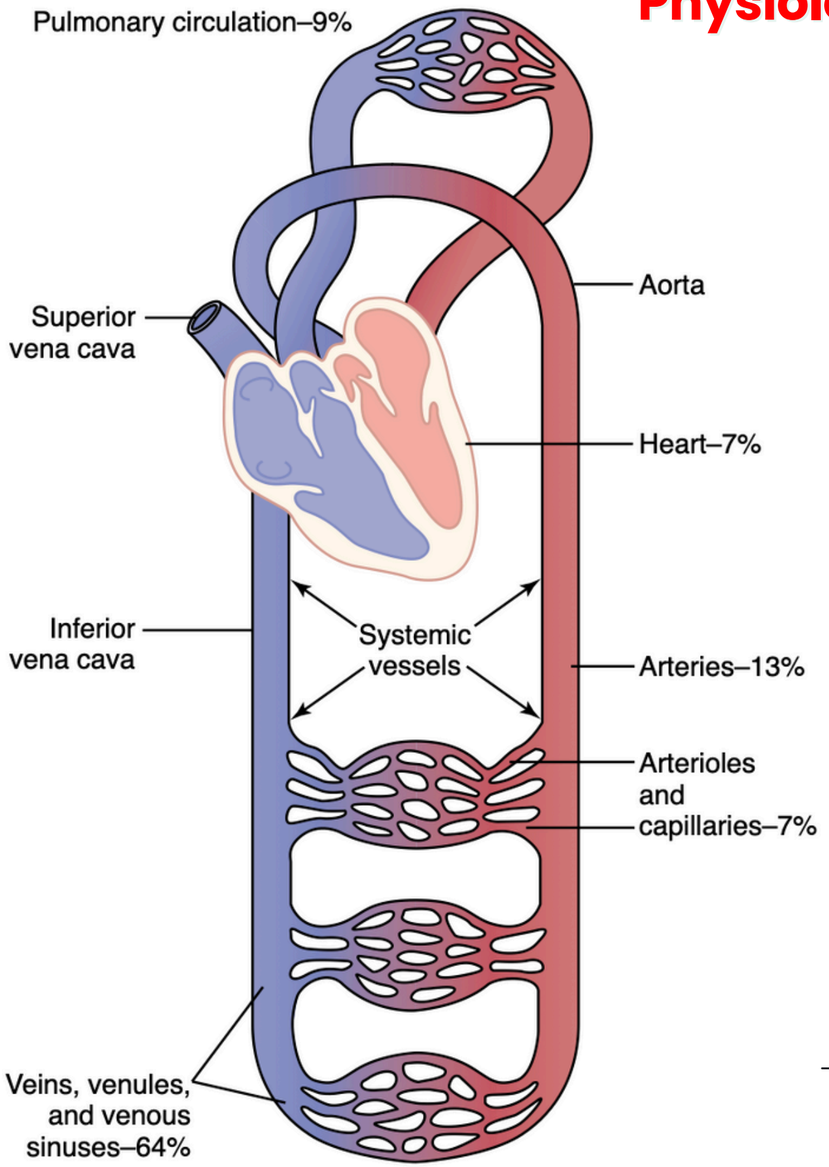

- Two separated pumps :
  - **Right heart** =
    - Receives deoxygenated blood
    - pumps blood through the lungs (low P)
  - **Left heart** =
    - Receives oxygenated blood
    - pumps blood through the peripheral organs (high P)
- Each heart are composed of an ***atrium*** and a ***ventricule***
- **Cardiac cycle:**
  - **systole** : ventricular *contraction*
  - **diastole** : ventricular *relaxation*



P=Pressure

# Blood Circulation

## Physiologic aspects




- Blood circulates through a **closed vascular system**
- **Primary Roles of the circulation:**
  - Transport oxygen and nutrients to muscles & tissues
  - Remove waste products
  - Conduct hormones
  - Support the immune system
  - Regulate the body temperature

- **<u>Vessel types:</u>**
  - *Arteries* – high pressure, elastic
  - *Arterioles* – resistance vessels
  - *Capillaries* – exchange of gases and nutrients →
  - *Venules & veins* – low pressure, blood reservoir

→ Blood pressure **decreases** progressively along the circulation

# How to calculate Blood Pressure ?

**Definition:** BP is the **force** that our blood places on our vessels

Blood Pressure = Cardiac Output x Systemic Vascular Resistance

**BP = CO x SVR**

**HR x SV**

Heat Rate x Stroke Volume
(beats / min) x (Volume ejected / beat)

Vasodilatation | Normal artery | Vasoconstriction

*(measured in mmHg)*

# Normal BP values

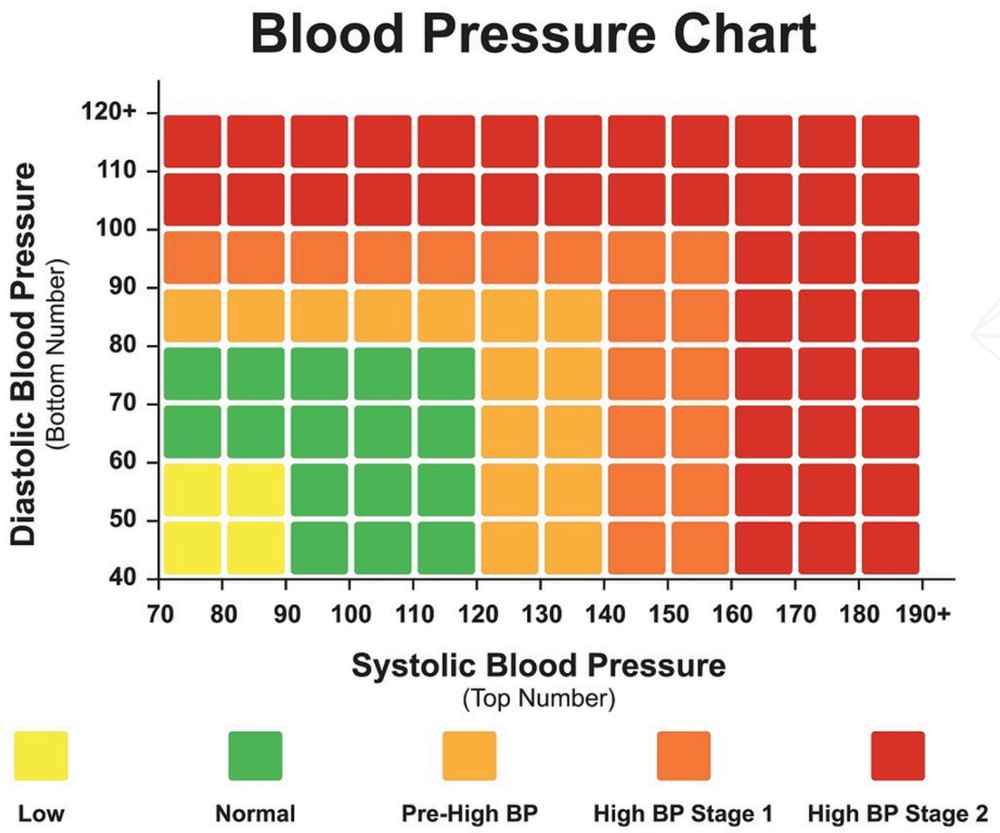
**Low BP:**
→ Alarming only if ***symptomatic***

**Pre-High BP:**
→ *Lifestyle modification* **recommended**:
- Reduce salt intake, increase physical activity, weight management, stress reduction

**High BP Stage 1:**
→ *Lifestyle modification* **mandatory**:
- Medical follow-up ***advised***, pharmacological treatment may be considered

**High BP Stage 2:**
→ Medical evaluation **required**:
- Antihypertensive medication usually initiated
- Regular and strict BP monitoring
- Risk of long-term organ damage

**>180 /(or) >120:**
→ **Medical emergency ==> Hospital**



# Different types of Monitoring

Blood Pressure can be measured using *two main approach*:

- **Non-invasive technique:**
  - Pressure-based
  - Optical-based
- **Invasive technique:**
  - Invasive Blood Pressure Sensor
- **5 distinct techniques**, each with different principles, accuracy, and clinical applications

# Non-invasive Pressure-based :

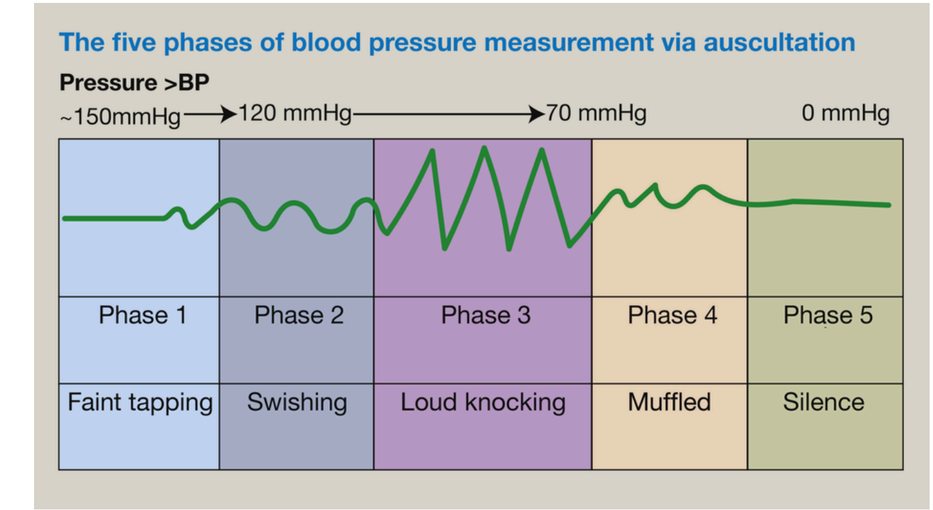
## **Auscultatory** BP monitoring

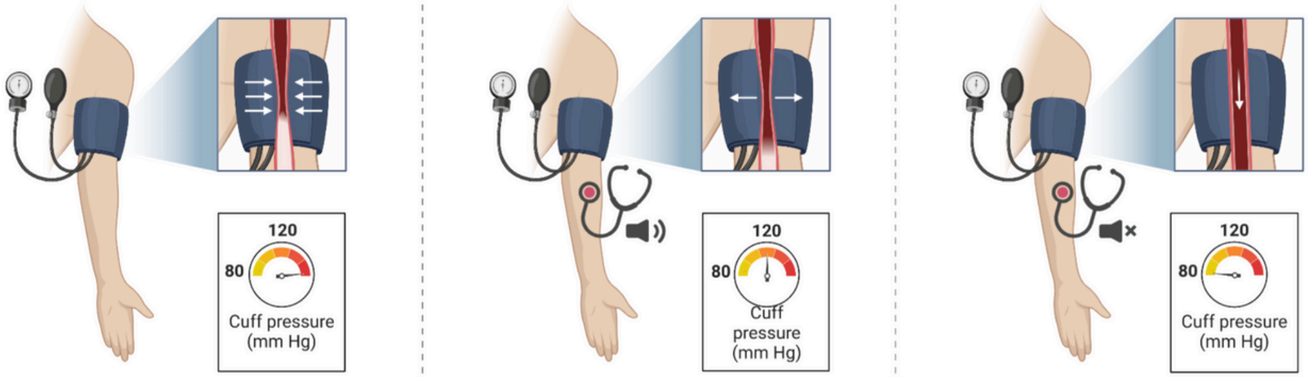
Working principal :

- **Sphygmomanometer** (*inflatable cuff* and *manometer*)
- **Stethoscope** on brachial artery

Based on **Korotkoff** sound.

Considered the **clinical reference method**




**Pros :**

- High accuracy
- Direct identification of S. and D. BP
- Low cost & no battery needed

**Cons:**

- Operator dependant (skills)
- Non-continuous

# Non-invasive Pressure-based :

## **Oscillometric** BP monitoring

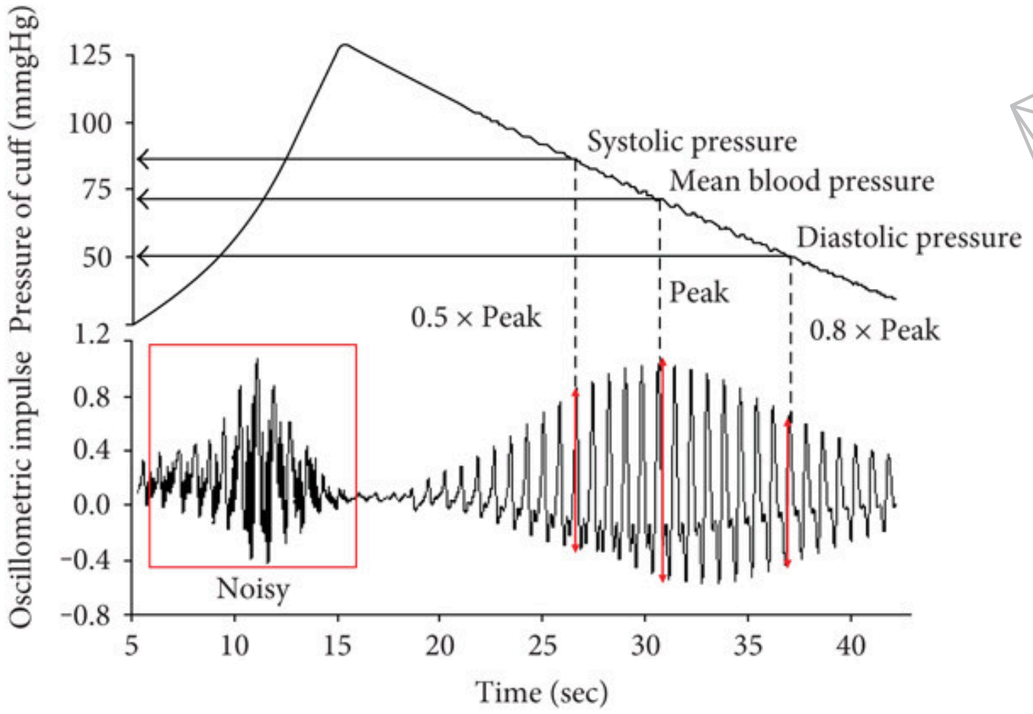
Working principal :

- **Sphygmomanometer** with electronic pump
- **Pressure sensors** inside the cuff
- **Displayer**

Measures Pressure changes of the artery (oscillations).

→ Detecting the peak oscillation to find **Mean Arterial Pressure**

- *Secret algorithm* to <u>calculate</u> SBP and DBP



# Non-invasive Pressure-based :

## **Oscillometric** BP monitoring


**80CHF**

**Electronic BP Monitor**

→ one of the most used in the world

Used in different context :

- Hospital, Doctors
- Home
- Emergency, First responder

**Pros:**

- Clinicaly validated
- Affordable/Accessible

**Cons:**

- Intermittent measurements only

OMRON Healthcare


**560CHF**

**Cuff-based Smartwatch BP Monitor**

→ new technology

Used in for ambulatory monitoring, for people with hypertension

**Pros:**

- Comfortable
- Continuous monitoring

**Cons:**

- Less accurate than upper-arm cuff monitors
- Intrusive measurement
- Expensive

# Non-invasive Optic-based :

Uses **photoplethysmography** (PPG)

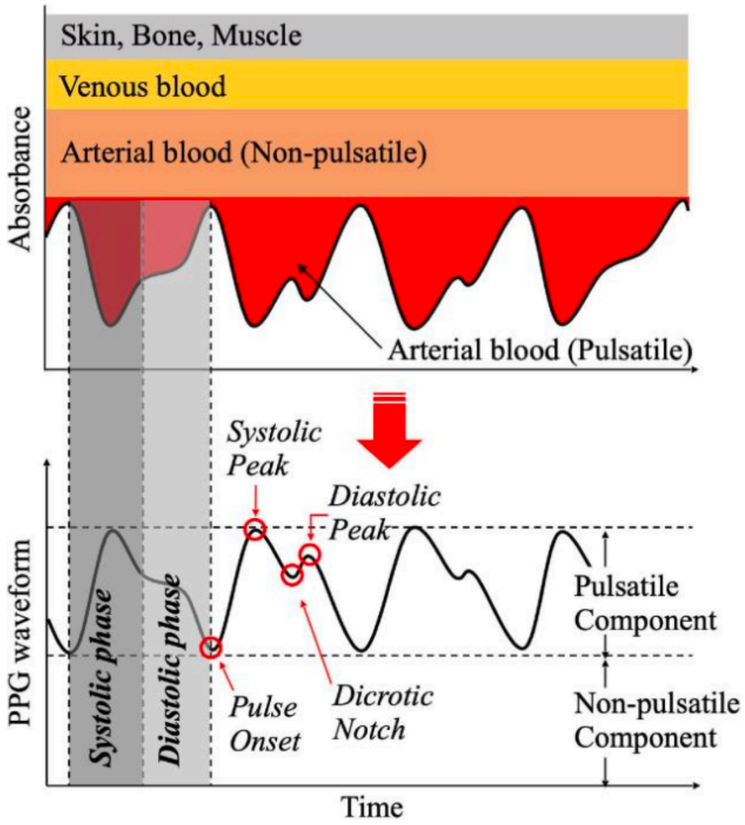
→ Measures blood volume changes in the skin

Blood pressure is estimated, not directly measured → not diagnostic tool

Requires calibration with a cuff

<u>Working principles:</u>

- **Light emission** (by the device)
- Interaction with Arterial blood
- **Photodetection** of the reflected light
- Signal Analysis
- **Displayer**





**240CHF**

**Pros:**

- Comfortable
- Continuous monitoring
- No inflation

**Cons:**

- Indirect measurement
- Sensitive to motion and skin properties
- Lower clinical accuracy

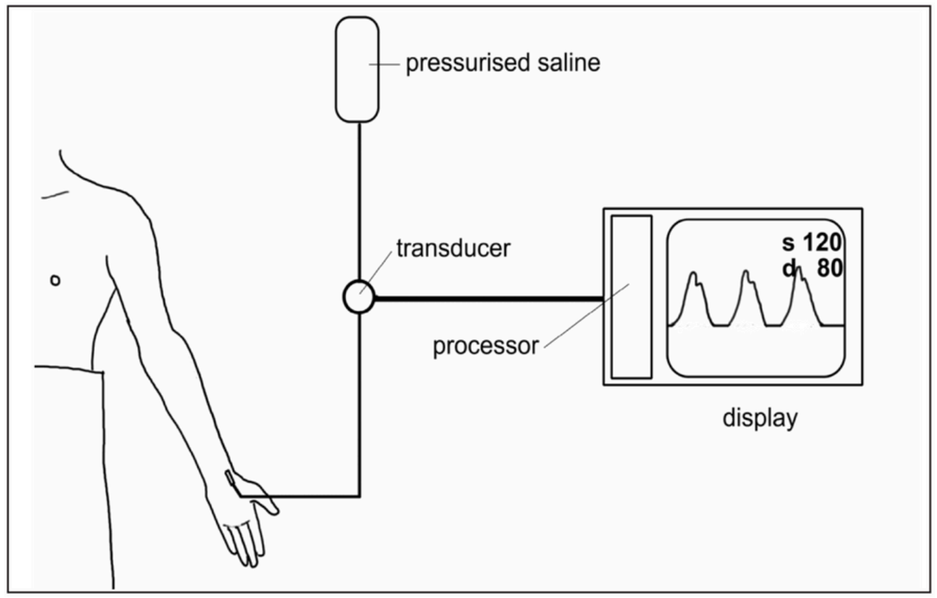
# Invasive Blood pressure monitor:

Continuous real-time blood pressure waveform

**Working principle:**

- Arterial cannula
- Fluid filled pressure system
- **Pressure transducer** → convert pressure into elec. signal
  - should be zeroed at atm P. and placed at heart level
- Displayer

Used in ICU, Surgery, High-risk patients




**Pros:**

- Very high accuracy
- Continuous monitoring

**Cons:**

- Invasive procedure
- Risk of infection and thrombosis
- Not suitable for routine use
  -

# Product comparison :

## Different product, different use

| Technique | Invasiveness | Accuracy | Continuous Monitoring | Ease of Use | Clinical Use | Cost |
|---|---|---|---|---|---|---|
| Auscultatory | Non-invasive | High (reference) | No | Medium | Clinical, emergency | $ |
| Oscillometric BP monitor | Non-invasive | Good | No | High | Clinical, home, ambulance | $$ |
| Oscillometric Smartwatch | Non-invasive | Good | Limited | High | Ambulatory monitoring | $$$$ |
| Optical Wristband | Non-invasive | Moderate | Yes | Very high | Wellness, trends | $$$ |
| Invasive Pressure Sensor | Invasive | Very high | Yes | Low | ICU, surgery | $$ |

# Future perspective...

## Current Limitations

- Non-invasive continuous methods **lacks clinical-grade accuracy**
- Optical-based methods require frequent calibration
- High inter-individual variability (skin tone, vessel stiffness, motion artifacts)
- Invasive monitoring remains limited to critical care

## Technology trends

- **Wearable continuous monitoring**
- Smaller, lower-power sensors integrated into:
  - Smartwatches, Wristbands, Smart textiles
- Advanced signal processing & AI personalize BP estimation

## Implantable & Semi-invasive Sensors (Research Stage)

- Implantable pressure sensors for long-term cardiovascular monitoring
- Potential benefits:
  - Continuous, high-accuracy measurements, reduced user dependency
- Challenges:
  - Biocompatibility, long-term stability, infection and ethical considerations

# Conclusion

Blood pressure is a **key vital sign**

**Hypertension** remains a major public health issue due to its silent progression

Blood pressure results from the interaction between:

- Cardiac output
- Systemic vascular resistance

Several monitoring techniques are available:

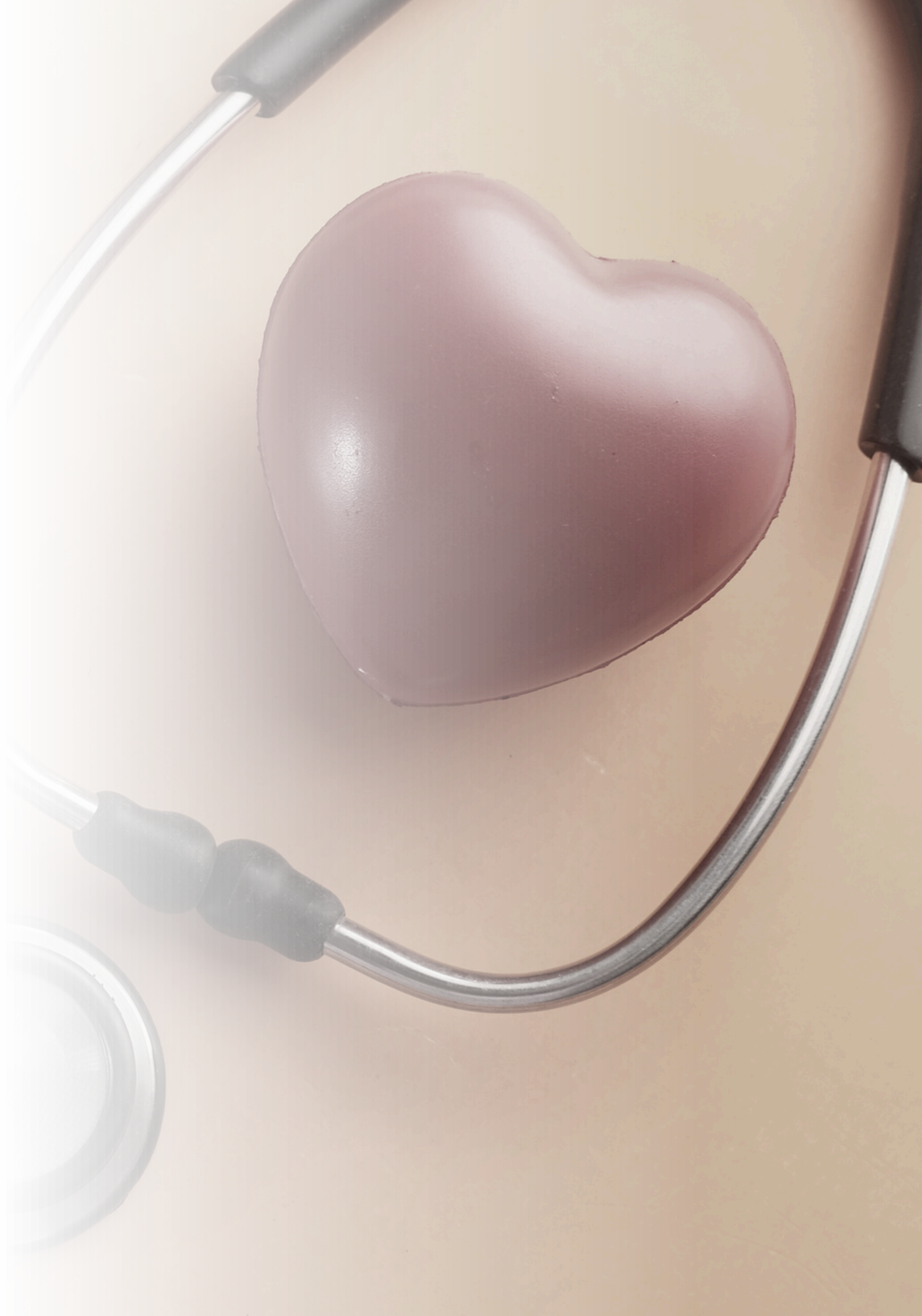
- *Auscultatory* methods as the clinical reference
- *Oscillometric* devices for routine and home monitoring
- *Photoplethysmography-based* wearables for continuous trend analysis
- *Invasive* method for critical care

→ No single technique combines accuracy, continuity, and comfort

**Why not Implantable BP sensors?**

# THANK YOU

**Any Question?**



# Appendix : EPFL implatable BP sensor



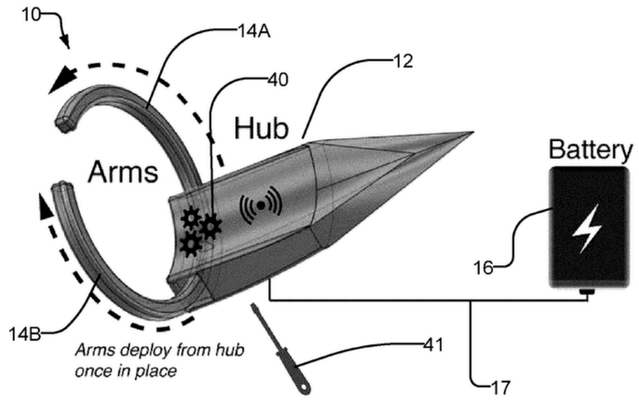



FIG. 1

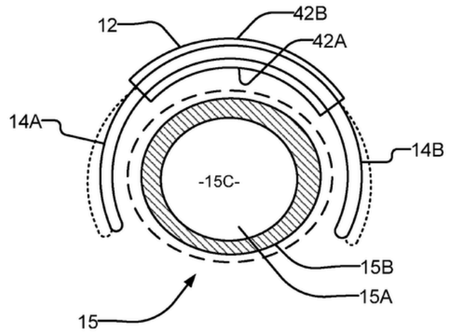



FIG. 2

issued the 25.11.2021 → Worlwide