

Introduction to sensing technologies of home vital sign measurement devices

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Personal home VSP monitors

✓ Design Considerations

- Affordable
- Easy-to-use
- Non-invasive, non- or less intrusive measurement
- Adequate accuracy

✓ What VSPs can be measured at home?

- Temperature
- Weight, body fat
- Blood pressure
- Blood glucose
- Blood oxygenation
- Electrocardiogram (ECG/EKG)

Thermometer

✓ Higher accuracy, usually 0.1K or even 0.05K in a narrow range, is required

✓ Type:

- **Mercury-in-glass**

- Uniform thermo-expansion in volume → accurate
- Larger specific heat capacity → slow response
- Glass tube might break → mercury contamination
- Limited use, import and sale since Sep. 2008 in Taiwan

- **Thermistor**

- Metal probe connected with temperature-variable thermistor. Temperature results in a voltage difference
- Digital reading display, fast, accurate and low cost.



www.niea.gov.tw



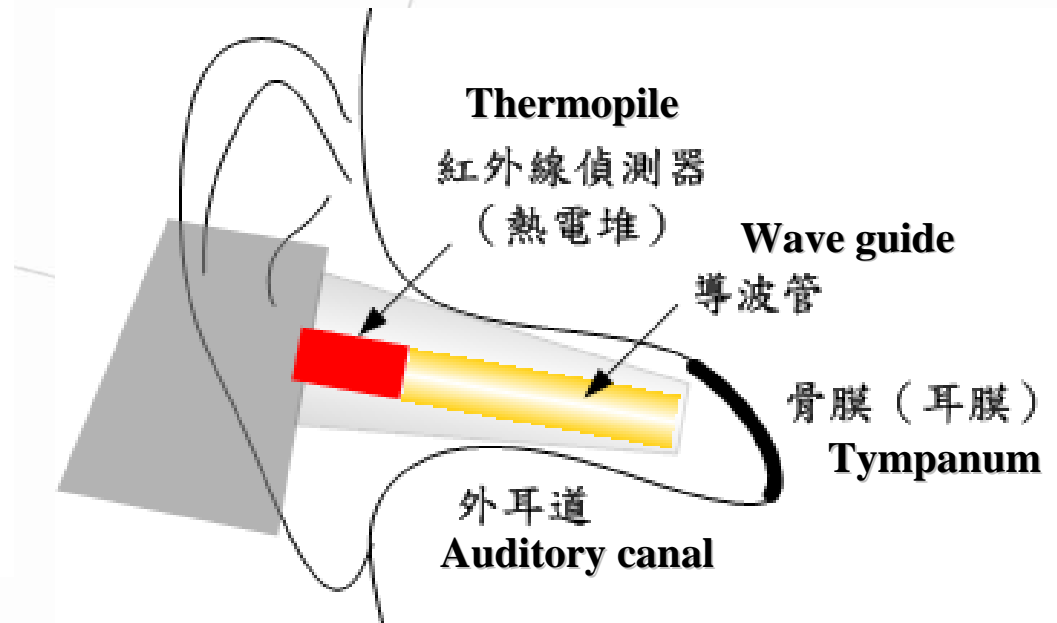
Omron Healthcare, Inc

Infrared thermometer

- ✓ **Ear or forehead** thermometer
- ✓ Safe, fast response, accurate, hygiene concerns minimized
- ✓ Infrared techniques use **thermopile** to measure the intensity of infrared radiation around **tympanum**, being close to **hypothalamus** that reflects body temperature quickly.

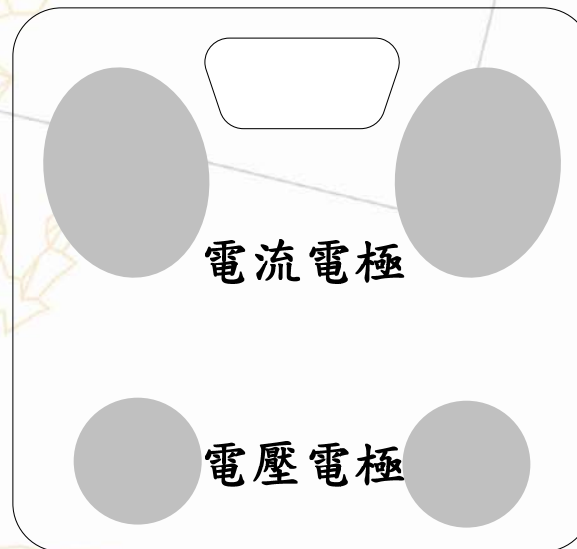
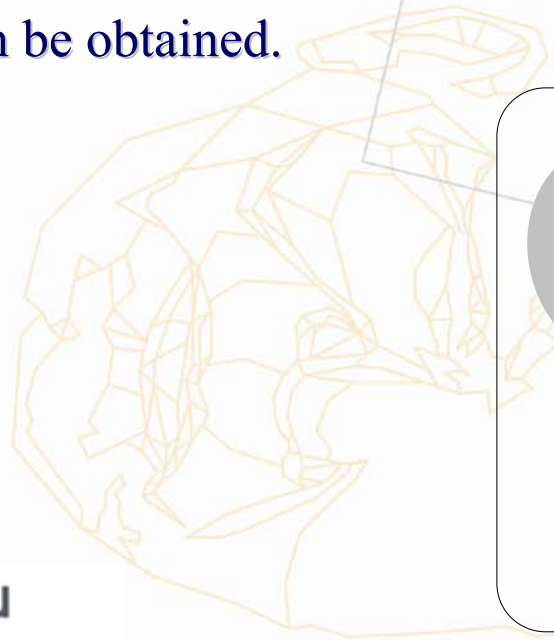


Braun GmbH



Weight and body fat meter

- ✓ A common function accompanying with electrical weight scales
- ✓ Bio-electric Impedance Analysis (BIA) → impedance difference in body composition: e.g., high impedance in fat, and low in muscle.
- ✓ AC signals (50kHz-100kHz) are applied between heel and toe to measure the generated electrical current.
- ✓ With the parameters as body weight, height, gender inputted, body fat index can be obtained.



Current pad

Voltage pad

Blood pressure

- ✓ Blood pressure refers to the force exerted by circulating blood on the walls of blood vessels.
- ✓ English physiologist, chemist and inventor **Stephen Hales** first conducted experiments on the "force of the blood" in various animals in 1773.
- ✓ Blood pressure is highest when the heart beats to push blood out into the arteries; when the heart relaxes to fill with blood again, the pressure is at its lowest point.
- ✓ Blood pressure when the heart beats is called **systolic pressure**. Blood pressure when the heart is at rest is called **diastolic pressure**.

Hypertension

- ✓ Blood pressure is measured in millimeters of **mercury (mm Hg)**.
- ✓ **Hypertension**, high blood pressure, is defined as a repeatedly elevated blood pressure exceeding 140 over 90 mmHg -- a systolic pressure above 140 with a diastolic pressure above 90.

Classification of hypertension [WHO]

BP classification	SBP (mmHg)		DBP (mmHg)
Normal	<120	and	<80
Pre-hypertension	120–139	or	80–89
Stage 1 hypertension	140–159	or	90–99
Stage 2 hypertension	≥160	or	≥100

Blood pressure measurement

- ✓ The **mean arterial pressure (MAP)** is the average over a cardiac cycle, and can be approximately determined:

$$\text{MAP} = \frac{2}{3} \times P_{\text{diastolic}} + \frac{1}{3} \times P_{\text{systolic}}$$

- ✓ BP Measurement :

- Direct (invasive): Arterial intubation 動脈插管
- Indirect (non-invasive): Pulse detection approach

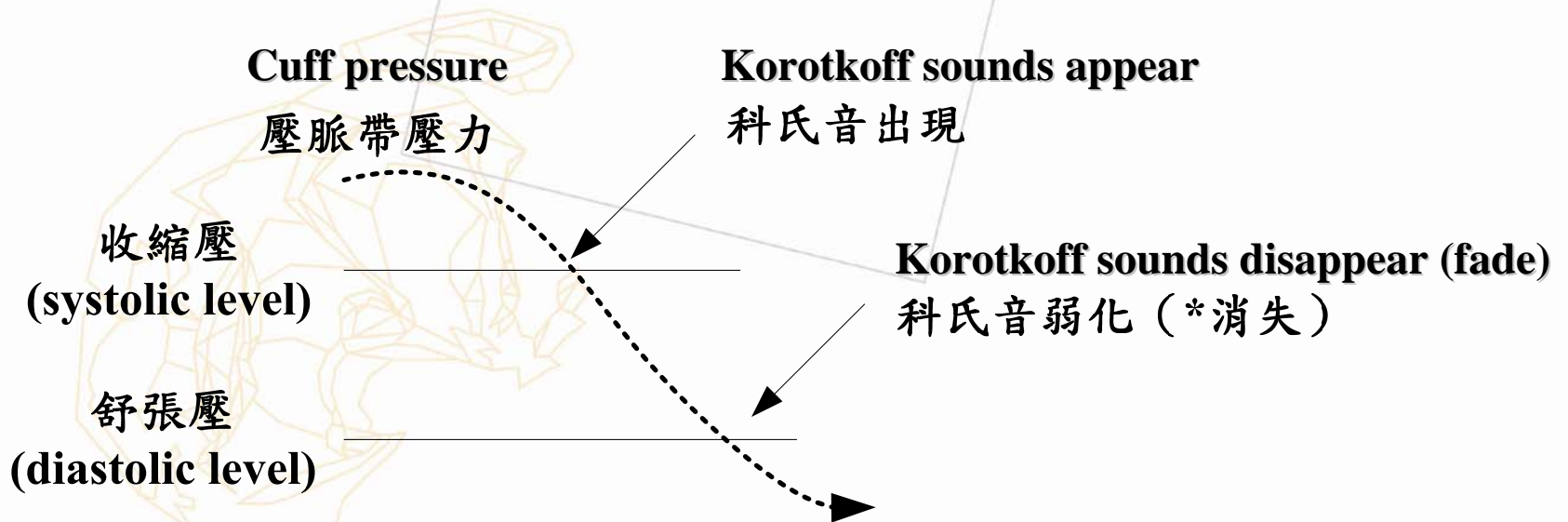
Auscultatory method 聽診法

Palpation method 觸診法

Oscillation method 共振法

BP Measurement - Auscultatory method

- ✓ Sphygmomanometer: pressure cuff, barometer, stethoscope.
- ✓ Korotkoff sounds (科氏音) to determine systolic/diastolic pressure



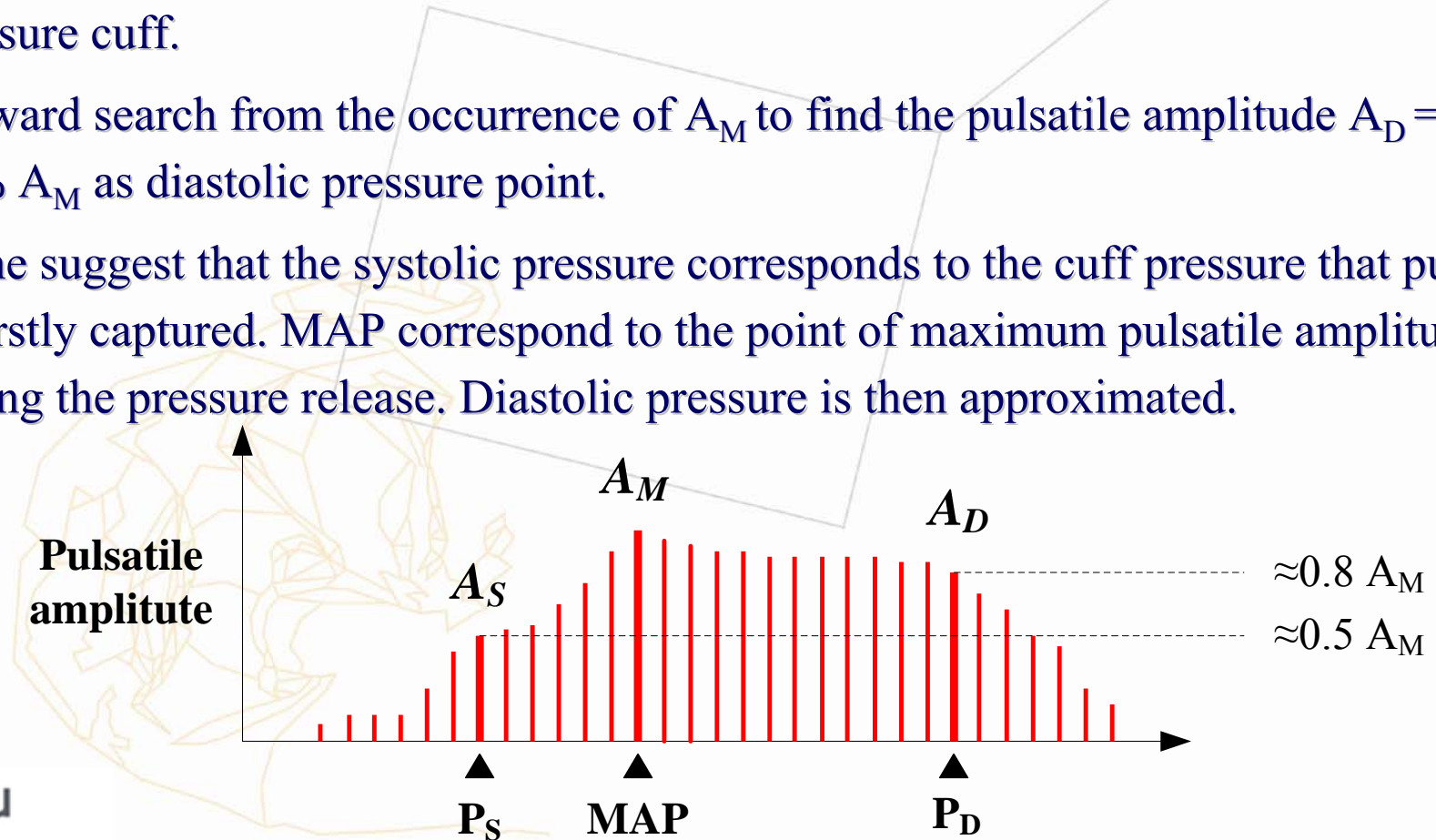
Home Automatic BP Meter

- ✓ Home automatic BP meters utilize **auscultatory method** and **oscillometric method** to determine BP.
 - **Auscultatory**: similar to a sphygmomanometer, korotkoff sounds are detected by a microphone.
 - **Oscillometric**: Pulse detected by a pulsatile sensor
- ✓ Noise interference or bodily movement will easily reduce the accuracy of auscultatory-based measurement
- ✓ Most products now are oscillometric-based



Oscillometric Method

- ✓ The peak pulsatile amplitude A_M in the pressure cuff corresponds to the MAP.
- ✓ From the occurrence of A_M , backward search chronologically to find its systolic pressure, whose pulsatile amplitude is approximately $A_S = 50\% A_M$ in the pressure cuff.
- ✓ Forward search from the occurrence of A_M to find the pulsatile amplitude $A_D = 80\% A_M$ as diastolic pressure point.
- ✓ Some suggest that the systolic pressure corresponds to the cuff pressure that pulse is firstly captured. MAP correspond to the point of maximum pulsatile amplitude during the pressure release. Diastolic pressure is then approximated.



Diabetes

- ✓ Diabetes is a chronic disease that occurs either when the pancreas does not produce enough **insulin** 胰導素 or when the body cannot effectively use the insulin it produces. Insulin is a hormone that regulates blood sugar.
- ✓ Hyperglycaemia, or raised blood sugar, is a common effect of uncontrolled diabetes and over time leads to serious damage to many of the body's systems, especially the nerves and blood vessels. [WHO]
- ✓ Blood glucose is the concentration of glucose (mg/dl, mmol/L) in the whole blood in vein.
- ✓ The current WHO diagnostic criteria for diabetes: fasting plasma glucose $\geq 7.0\text{mmol/l}$ (126mg/dl); 2-h plasma glucose $\geq 11.1\text{mmol/l}$ (200mg/dl).

Blood glucose measurement (1/2)

- ✓ Home BG monitor package: Meter, lancet, and test strip
- ✓ A small needle ($f = 0.3\text{mm} \sim 0.8\text{mm}$) is pushed into the skin $1.8\text{mm} \sim 3.0\text{mm}$ in depth to extract a small amount of blood sample (around 0.5mL).
- ✓ BG in capillary is similar to that in vein. BG change in capillary can be observed sooner than that from other sites.



Lancet
採血針



試片
Test strip



Meter
血糖機

Blood glucose measurement (2/2)

- ✓ Since glucose can not be directly measured, a **biosensor** determine glucose concentration by measuring its product after chemical reaction.
- ✓ **Enzymatic method 酵素法**: glucose oxidase (GOx or GOD, 葡萄糖氧化酶) or glucose dehydrogenases (GDH, 葡萄糖去氫酶) are the catalytic for the oxidation process.
- ✓ Enzyme is immobilized in the electrodes with amyllum gel 澱粉凝膠 or polyacrylamide 聚丙烯醯胺 to maintain its catalytic properties.
- ✓ Reaction with catalytic



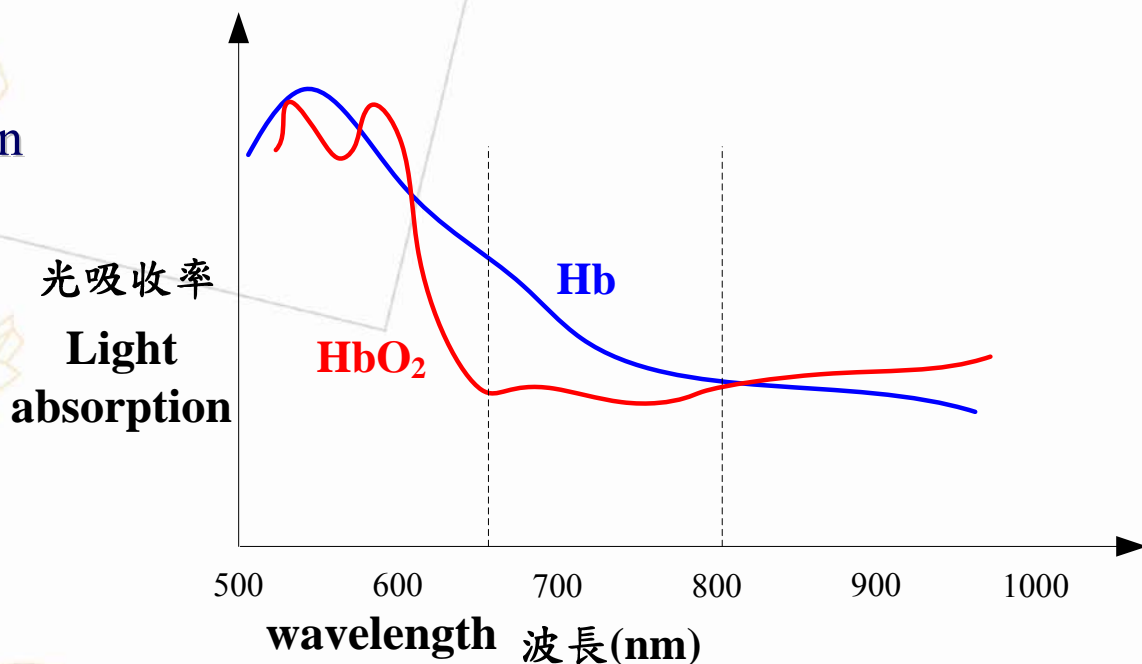
葡萄糖 + 氧 → 葡萄糖酸 + 過氧化氫

- ✓ The reaction generates electron transfer. By applying a voltage to drive the electron, its current is measured to determine the blood glucose



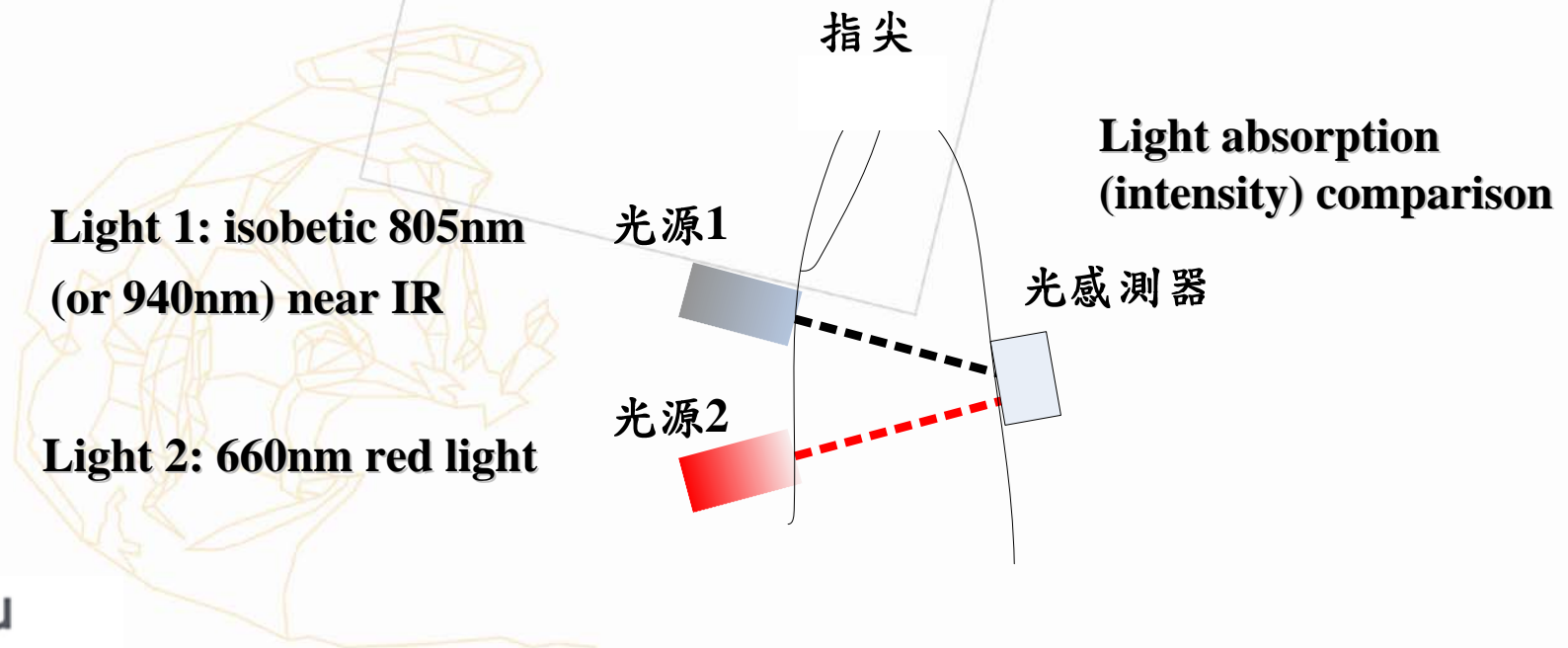
Blood oxygenation measurement (1/2)

- ✓ The optical absorption through Hemoglobin, Hb 血紅素 changes with its oxygenation level.
- ✓ High concentration of HbO₂ (oxygenated hemoglobin, 氧合血紅素) in the artery results in high optical absorption in 500-600nm (blue) and relatively low beyond 660nm.
- ✓ HbO₂ and Hb have maximum absorption difference around 660nm (red), while identical in isobetic point of 805nm (near infrared).



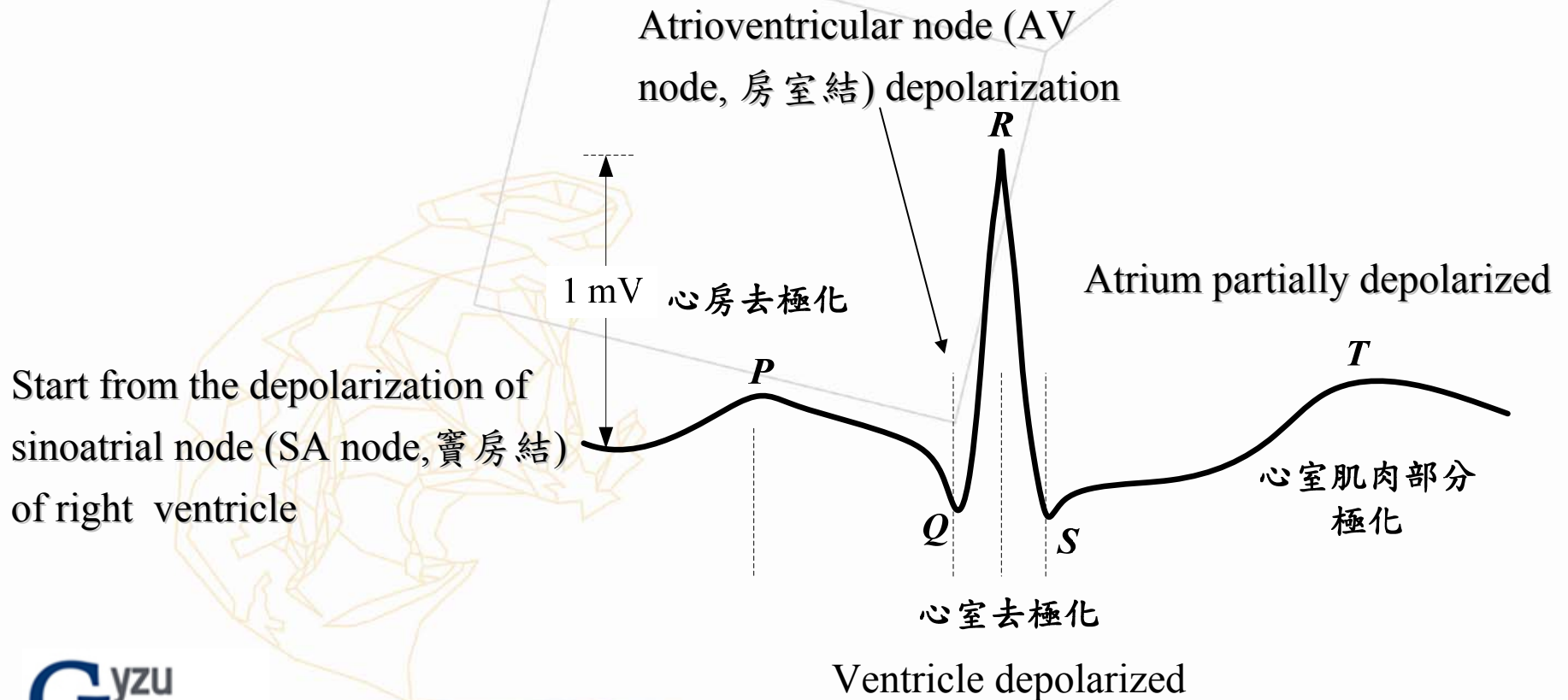
Blood Oxygenation Measurement (2/2)

- ✓ Optical Pulse Oximeter (SPO₂).
- ✓ Fingertip- or earlobe- attached: Capillary distribution in the thin tissue
- ✓ Light absorption comparison by two alternating light beams of different wavelength → Oxygenation
- ✓ Near IR plethysmography senses the blood flow to determine pulse (heart rate)



Electrocardiogram, ECG, EKG

- ✓ Ion imbalance → polarization and depolarization → produce muscle contraction and relaxation
- ✓ electron transfer → generate 生物電位 bio-potential



ECG Lead Map

- ✓ Two electrodes that produce relative electrical potential form a “lead”
- ✓ Clinical 12-lead ECG: 6 precordial (chest) leads 胸導程 and 6 limb leads 肢導程
 - 3 bipolar leads : Lead I, II, and III, also called “Einthoven Triangle” (Fig.1)
 - 9 unipolar leads:
 - 3 augmented limb leads 增大肢導程: aVR (vector right), aVL (vector left) and aVF (vector foot) (Fig.2);
 - 6 chest leads (Fig.3)

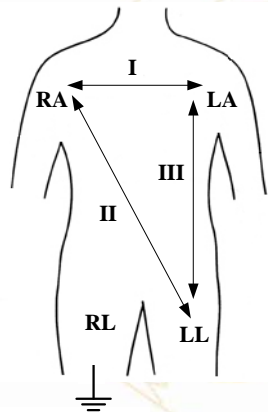


Fig.1

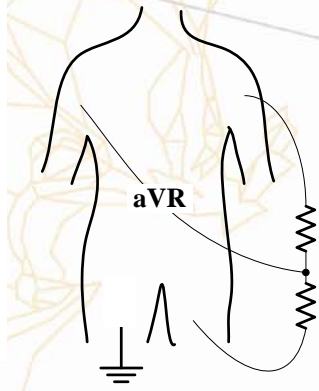


Fig.2

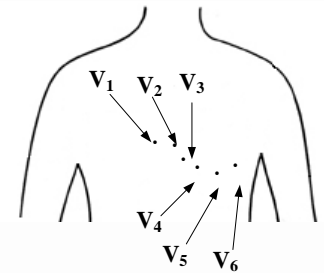
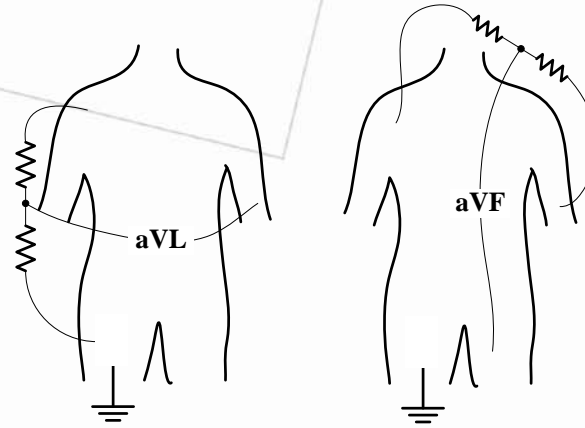
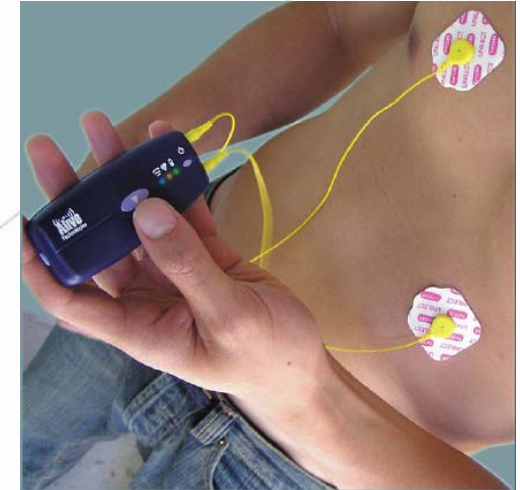


Fig.3

Home ECG Monitors (3/3)

- ✓ Most handheld and portable ECG monitor (holter) measure ECG signals with single lead, usually the lead I.
- ✓ Use skin-adhesive disposable Ag-AgCl electrodes, or the “wireless” thumb pad



Alive Technologies



DailyCare Biomedical Inc.



HealthFrontier



MSI



元智大學
Yuan Ze University



Thank You

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