生体情報工学 2025

Biological Information Engineering 2025

生産システム分野　生体医工学
Production Systems, Biomedical Engineering

高橋　淳子
Junko Takahashi

第1回	はじめに / Introduction	生体とは、生体の情報とは / What is a living body information?	4月16日	
第2回	生体情報の基礎(I) / Biological information Primer (I)	生体情報の種類と検出について / Types of biological information and detection	4月23日	
第3回	生体情報の基礎(II) / Biological information Primer (II)	センサ、トランスデューサーの原理と構造 / Sensors and transducers	4月30日	
第4回	生体情報計測(I) / Biological information measurement (I)	脳･神経･シナプス / Brain / nerve / synapse	5月7日	On Demand
第5回	生体情報計測(II) / Biological information measurement (II)	運動制御 / Motion control	5月14日	
第6回	生体情報計測(III) / Biological information measurement (III)	視覚情報処理 / Visual information processing	5月21日	
第7回	生体情報計測(IV) / Biological information measurement (IV)	聴覚の生理学,心理音響 / Auditory physiology, psychoacoustics	5月28日	
第8回	生体情報計測(V) / Biological information measurement (V)	体性感覚の情報処理 / Information processing of somatosensory	6月4日	
第9回	生体情報の網羅的解析-概要 / Cyclopedic studies in biological information – overview	生体情報の網羅的解析-概要 / Cyclopedic studies in biological information	6月11日	
第10回	生体情報の網羅的解析 - トランスクリプトミクス / Cyclopedic studies in biological information – transcriptomics	トランスクリプトミクス / Transcriptomics	6月18日	
第11回	生体情報の網羅的解析 - プロテオミクス,メタボロミクス / Cyclopedic studies in biological information - proteomics, metabolomics	プロテオミクス,メタボロミクス / Proteomics, metabolomics	6月25日	
第12回	生体情報の網羅的解析 - 次世代シーケンス / Cyclopedic studies in biological information - next-generation sequencing	次世代シーケンス / Next-generation sequencing	7月2日	
第13回	生体情報の網羅的解析 - データ解析 / Cyclopedic studies in biological information - data analysis	データ解析 / Data analysis	7月9日	
第14回	まとめ / Summary		7月16日	

Part 1. What is biological information engineering?

Part2. Classification of methods for collecting biological information

Part3. Examples of biological information collection

- Electroencephalogram, EEG
- Electrocardiogram, ECG

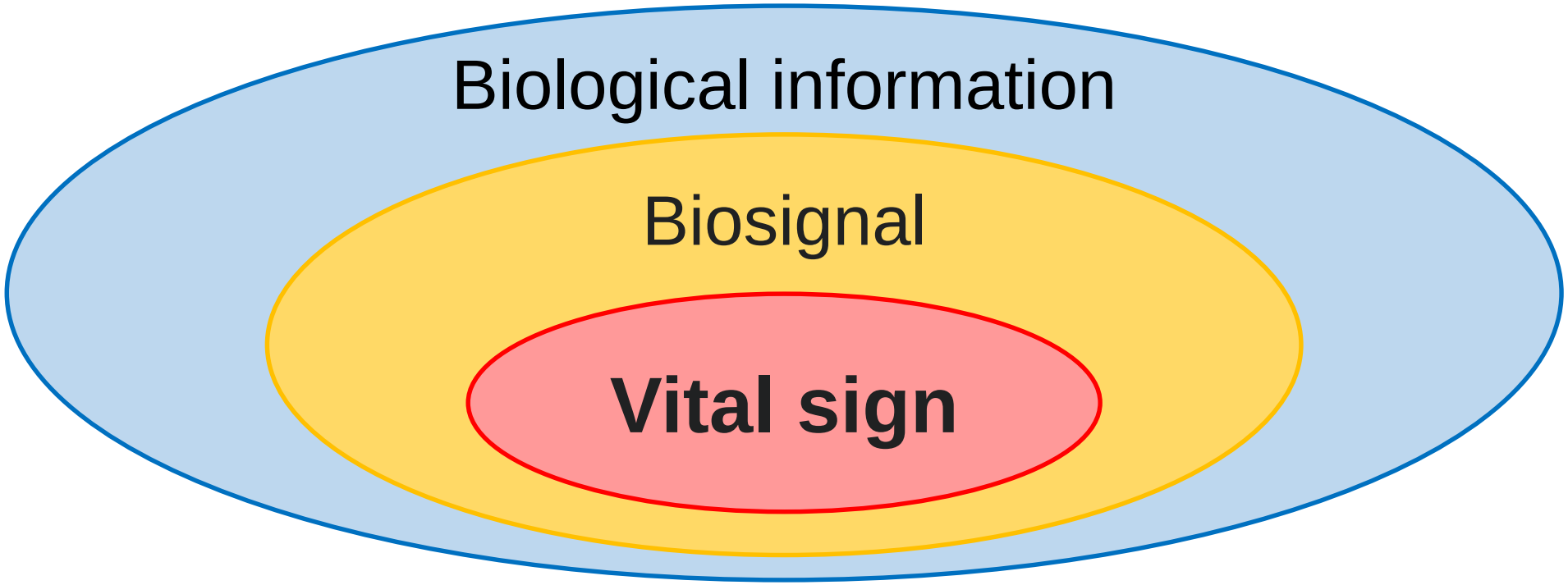
Part 1.
What is biological information engineering?

生体情報工学とは？

What is biological information engineering?

Information of living body

- Biological information　生体情報
- Biosignal　生体信号
- Vital sign　生命兆候



Vital signs

https://www.mindrayuk.com/mindray-launches-new-vital-signs-workstation/

Vital signs

Table 1. **Vital signs: normal values in adults**	
Temperature	37°C
Heart rate	60-99 beats per minute
Pulse	60-99 beats per minute
Blood pressure	120/80mmHg
Respiratory rate	12-16 breaths per minute
Oxygen saturation	95-100%

(Logical Observation Identifier Names and Codes)

https://www.grepmed.com/images/3754/adult-normal-diagnosis-vitals-signs
https://www.wish.com/product/5f61cf2da2641200558c080d?hide_login_modal=true&from_ad=goog_shopping&_display_country_code=JP&_force_currency_code=JPY&pid=googleadwords_int&c=%7BcampaignId%7D&ad_cid=5f61cf2da2641200558c080d&ad_cc=JP&ad_lang=JA&ad_curr=JPY&ad_price=46889.00&campaign_id=8688957323&exclude_install=true&gclid=CjwKCAjw9r-DBhBxEiwA9qYUpTA1djwGbS0N_42iYOVtV7TfTaau5YzTt5a40mSOhF1L2uVD6iDQJBoC8PgQAvD_BwE&share=web

Vital signs – pulse oximeter
パルスオキシメーター

Pulse oximeter

measures arterial blood oxygen saturation (SpO2) and pulse rate by shining light on the fingertip, without taking blood samples.

動脈血酸素飽和度と脈拍数を採血することなく、指先に光をあてることにより測定

96% - 99%	normal
93% - 96%	Moderate I :no respiratory failure 中等症I 呼吸不全無
93% <	Moderate II respiratory failure 中等症II 呼吸不全有

https://www.gakubun.net/pc/00000005/e/2202751/?track_cd=034698&gclid=Cj0KCQjw38-DBhDpARIsADJ3kjml3N6ALf5zbd1JHF70CJbeZYYxiM_Vz12Hffpk2zaJT9lf_wTgcAEaAlU_EALw_wcB

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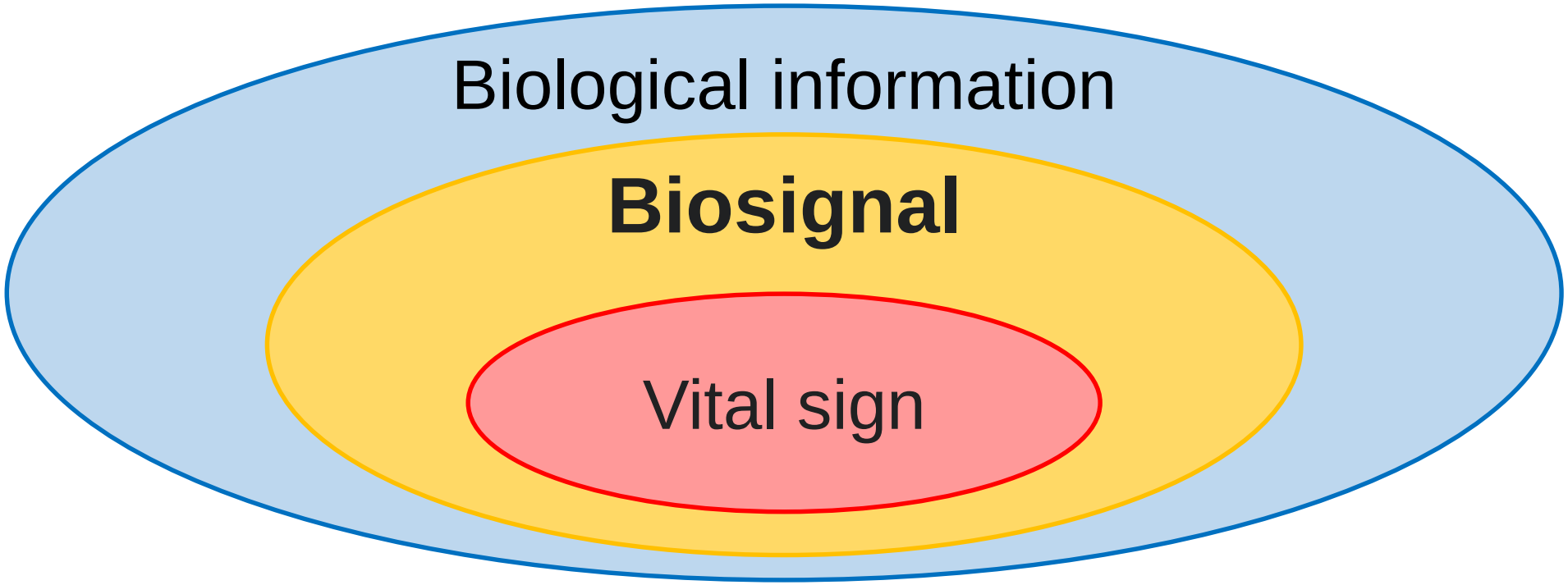


Biosignal

- Time-varying signals -

電気信号
Electronic signals

機械的信号
Mechanical signals

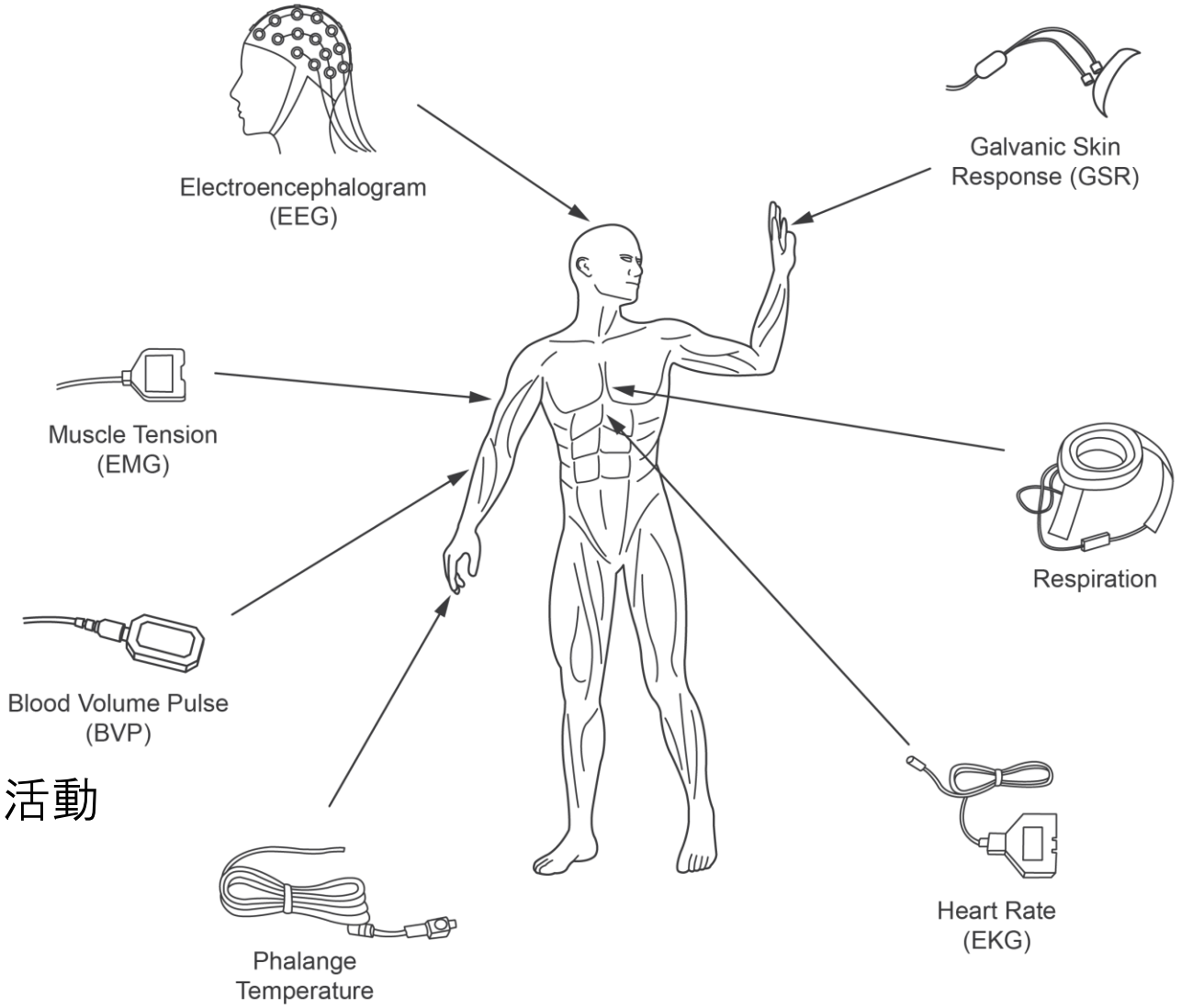
化学的信号
Chemical signal

電磁波･磁気･その他
Electromagnetic waves, magnetism, etc

https://en.wikipedia.org/wiki/Biosignal

Biosignal – electrical signals 電気信号

- ✓ Electroencephalogram (EEG) 脳波
- ✓ Electrocardiogram (ECG) 心電図
- ✓ Electromyogram (EMG) 筋電図
- ✓ Electrooculogram (EOG) 眼電図
- ✓ Electroretinogram (ERG) 網膜電図
- ✓ Electrogastrogram (EGG) 胃電図
- ✓ Galvanic skin response (GSR)
  or electrodermal activity (EDA)
  ガルバニック皮膚反応 or 皮膚電気活動



https://medium.com/@mindpass2050/biosignals-as-dynamic-biometrics-d93c3455e895

Uncovering the Secrets of Bioelectric Signals Exploring the Origins of Life

生体電気信号の秘密を解き明かす 生命の起源を探る

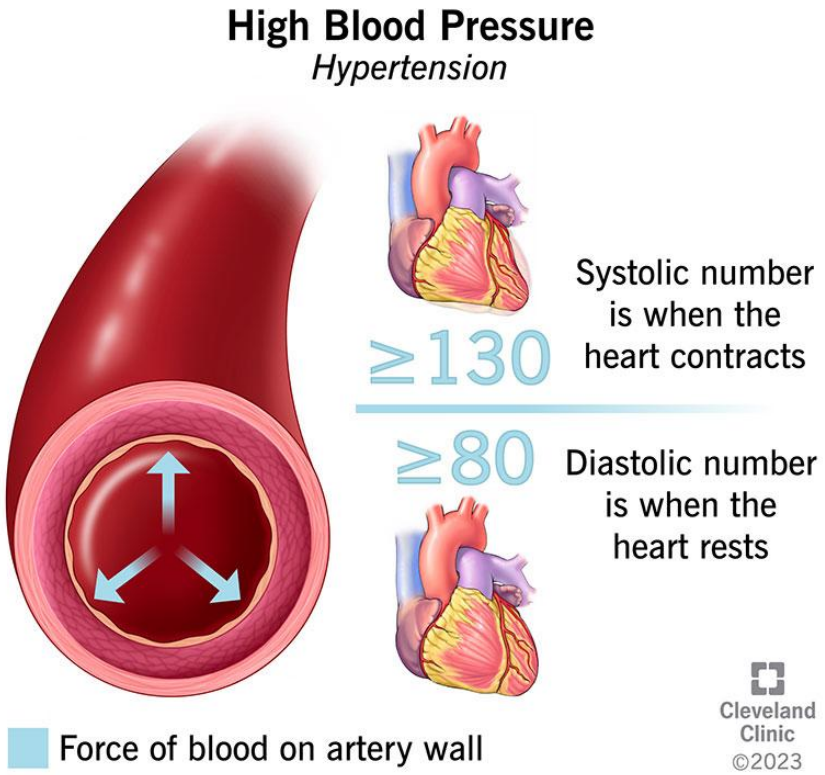
https://www.youtube.com/watch?v=Ms4_6-__KRc

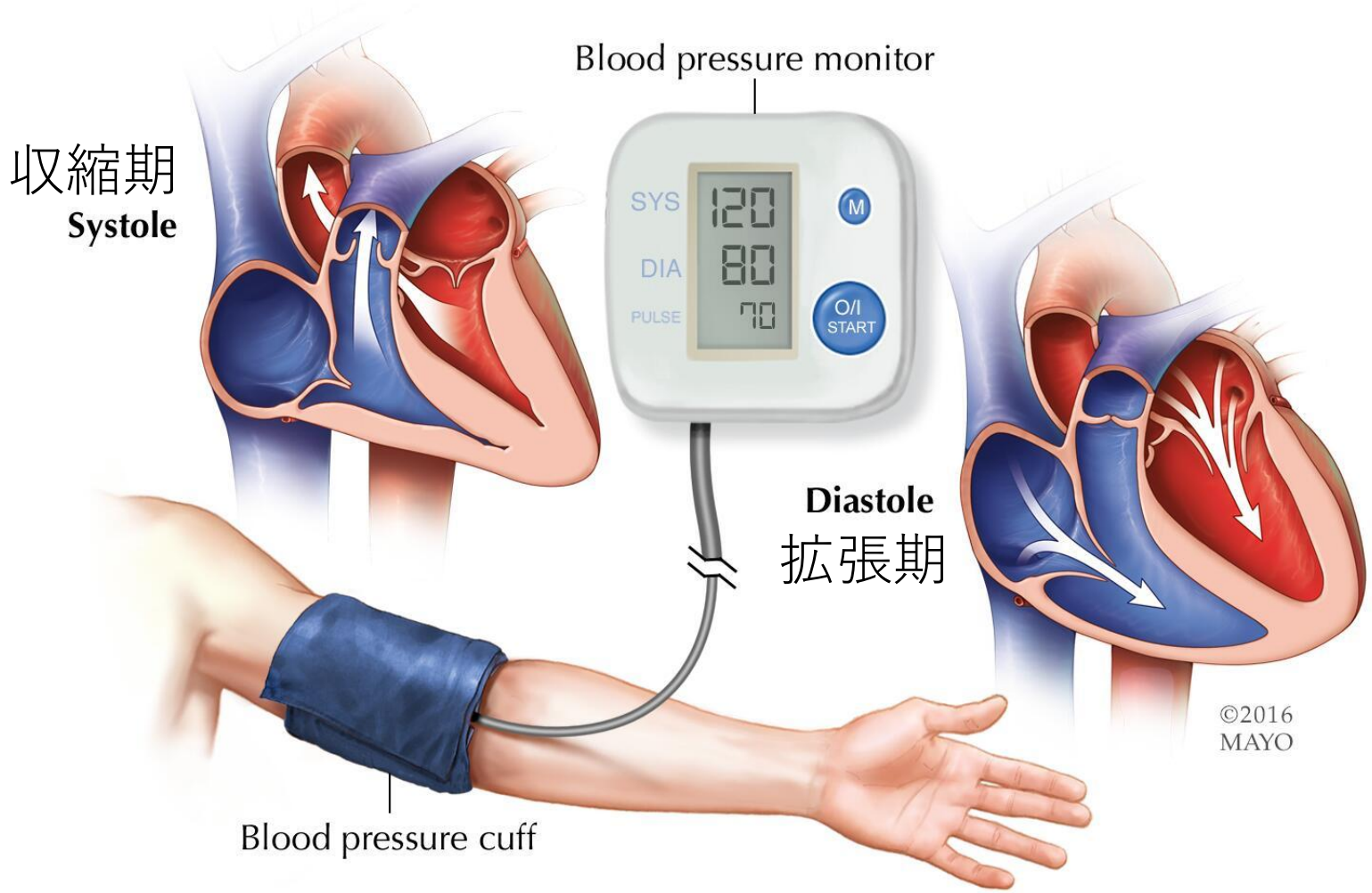
Biosignal – mechanical signals 機械的信号

Blood pressure (BP) 血圧

BP is the pressure of circulating blood against the walls of blood vessels.

- ✓ Cerebrovascular disorder
- ✓ Heart disease
- ✓ Kidney disease
- ✓ Arteriosclerosis





https://www.mayoclinic.org/diseases-conditions/high-blood-pressure/diagnosis-treatment/drc-20373417

https://my.clevelandclinic.org/health/diseases/4314-hypertension-high-blood-pressure

Biosignal - chemical signals 化学的信号

Blood test item

Hematology （血液学的検査）

CBC (complete blood count)

RBC･WBC･Platelets･MCV･MCH･MCHC･Hemoglobin･Hematocrit

RBC: Red blood cell number
WBC: White blood cell number
MCV: mean corpuscular volume
MCH: mean corpuscular hemoglobin

blood biochemistry items （血液生化学的検査）

Liver function （肝機能）
GOT・GPT・γGTP・LDH・ALP・LAP・ChE

Kidney function （腎臓機能）
BUN・Creatinin

Diabetes （糖尿病）
Fast blood glucose・HbA1c

Lipidemia （高脂血症）
HDL・LDL・Triglyceride

Gout （痛風）
Uric acid

Allergy（アレルギー）
Non-specific IgE (RIST)
Specific IgE（RAST）

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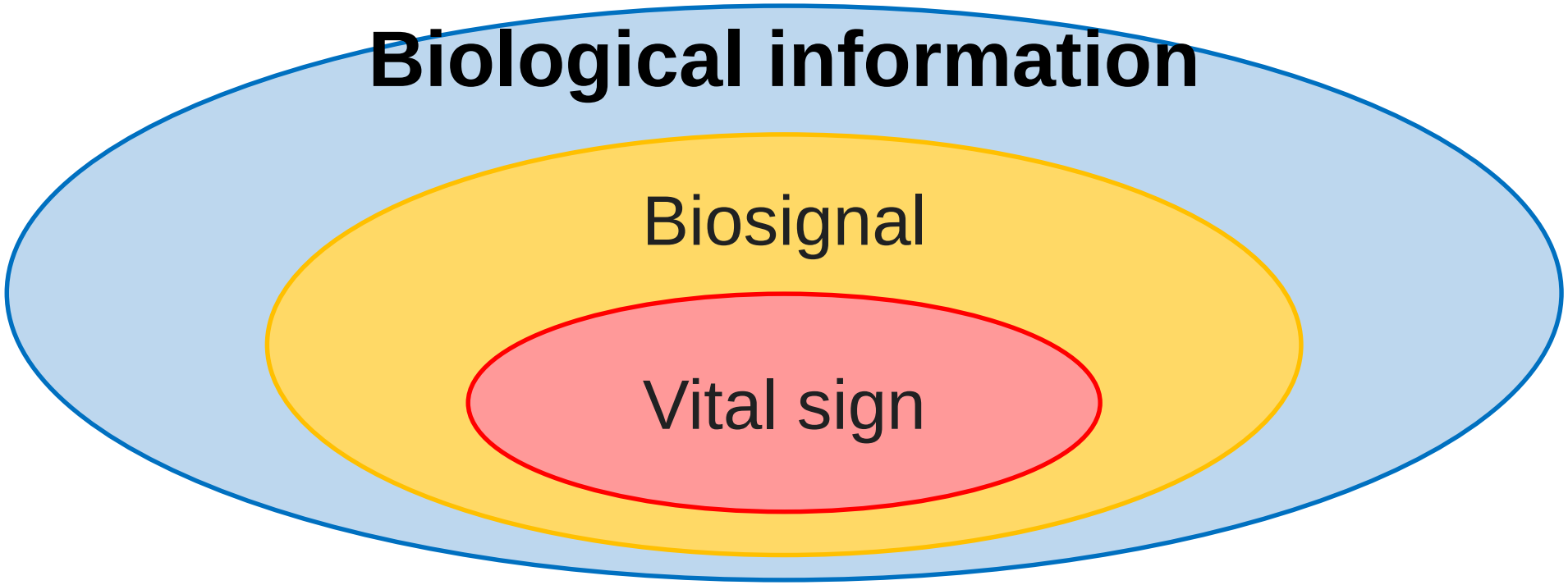
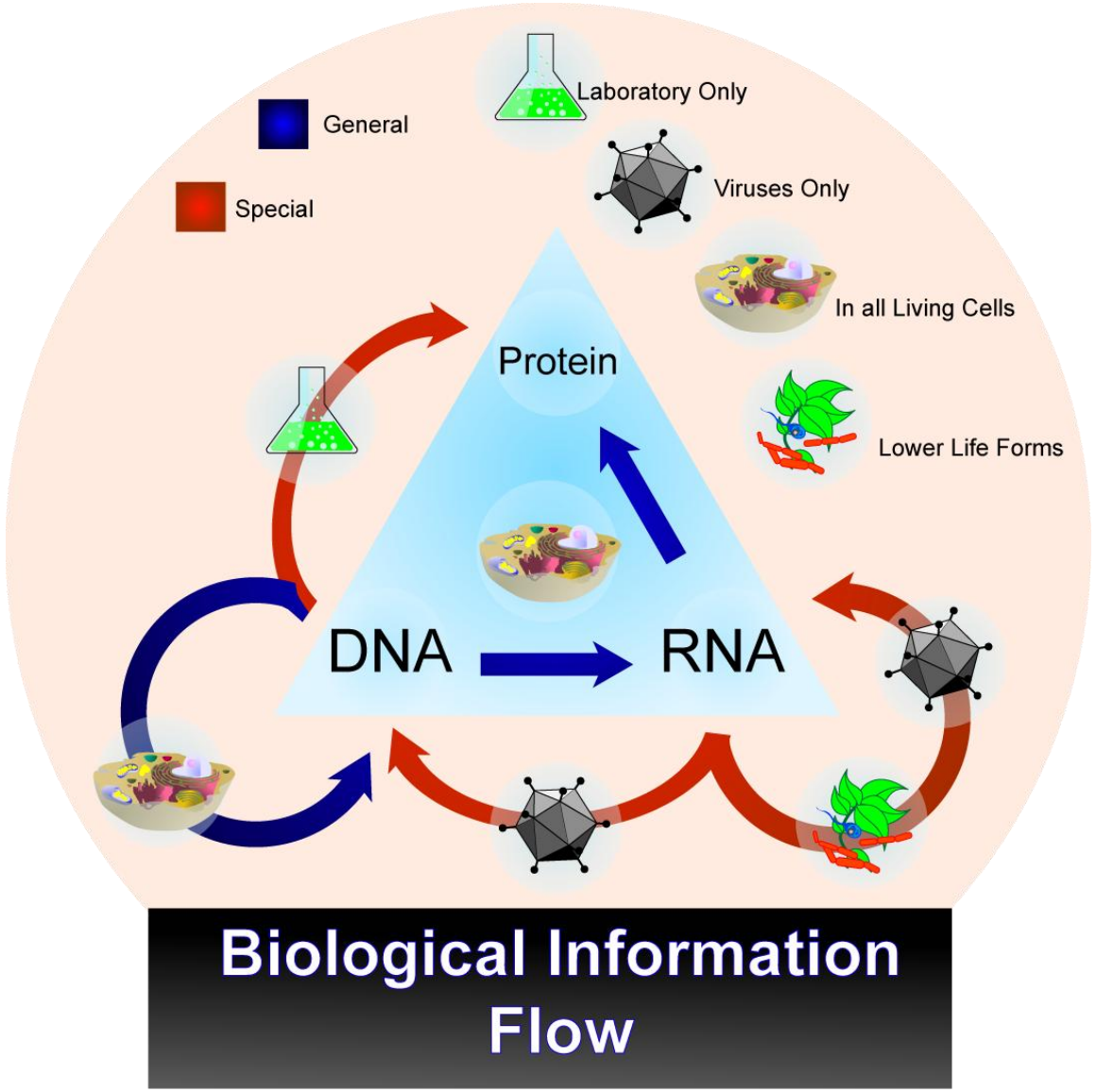
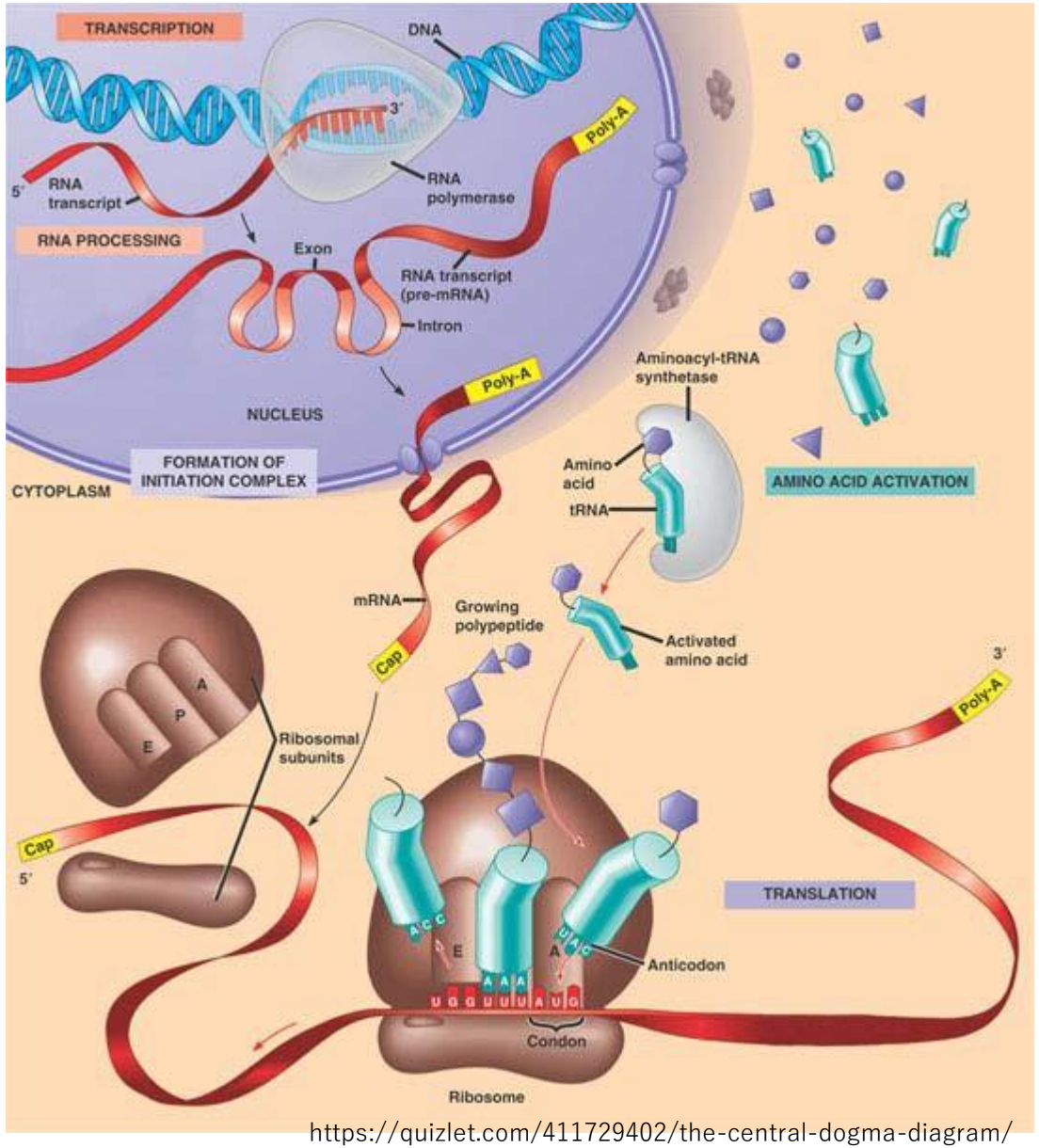


Biological information



https://www.wikidoc.org/index.php/Central_dogma_of_molecular_biology



https://quizlet.com/411729402/the-central-dogma-diagram/

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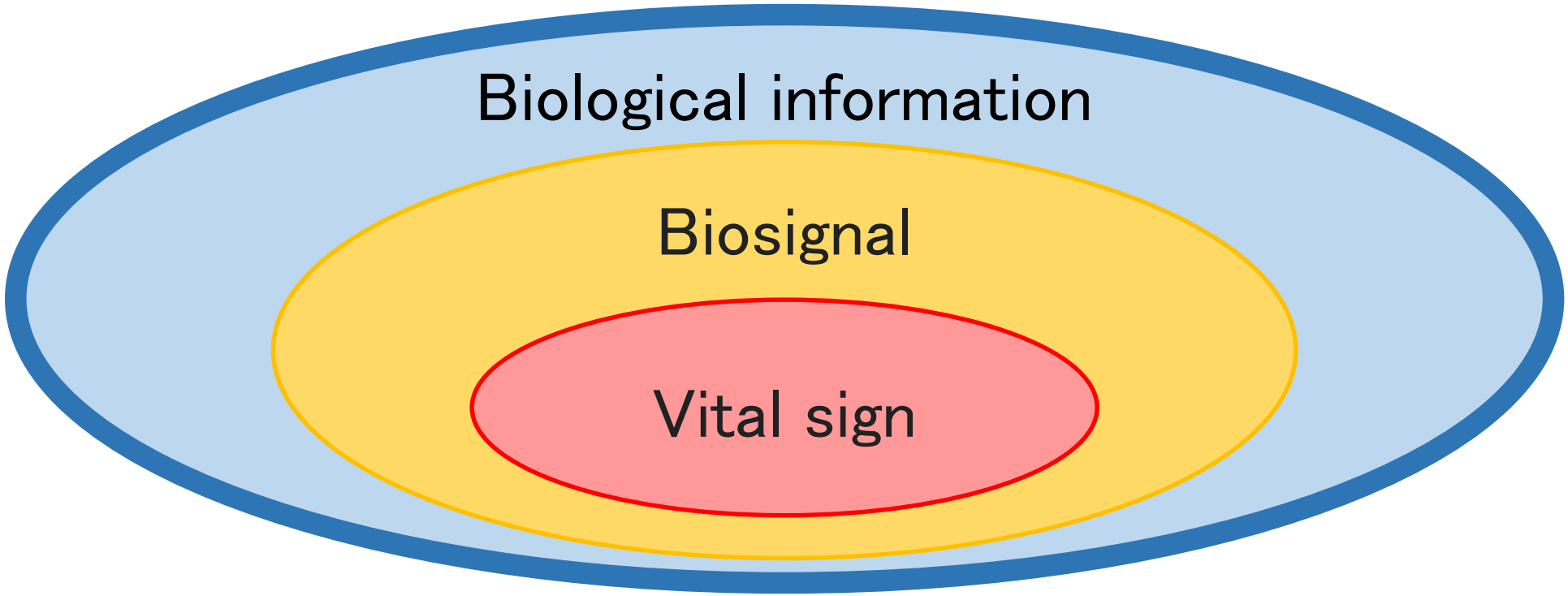
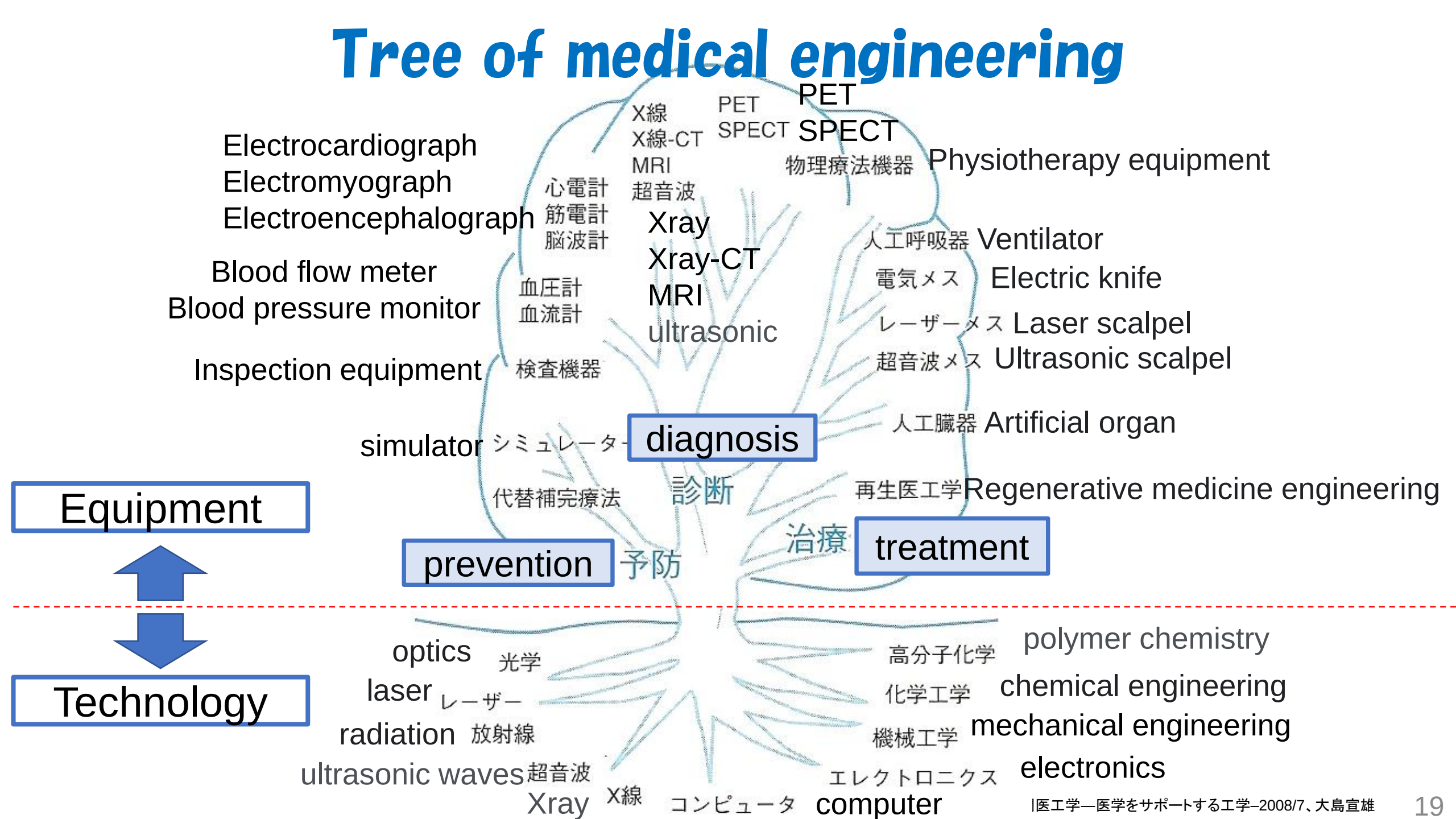


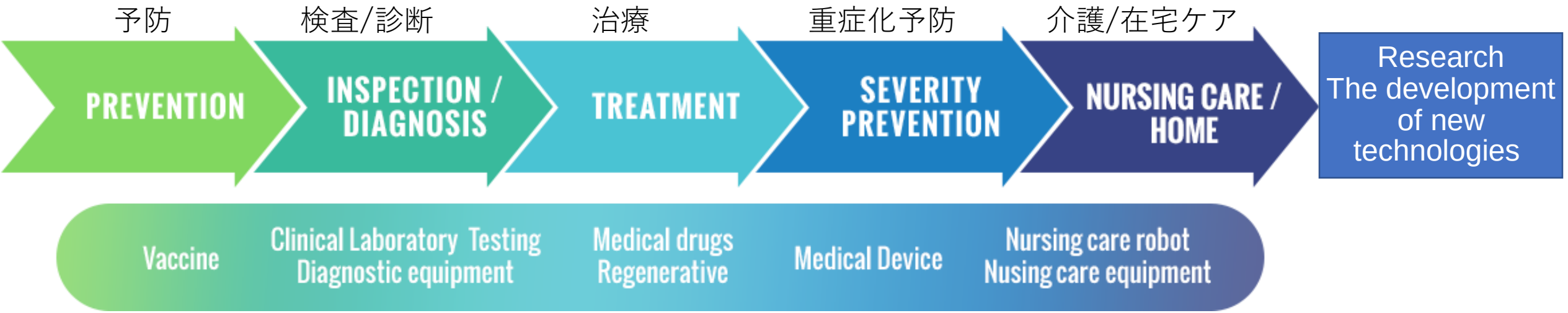
Part 2.
Classification of methods for collecting biological information

生体情報の収集方法の分類

Tree of medical engineering



Medical stage and medical equipment of biological information
生体情報に関する治療ステージと医療機器



https://quizlet.com/411729402/the-central-dogma-diagram/

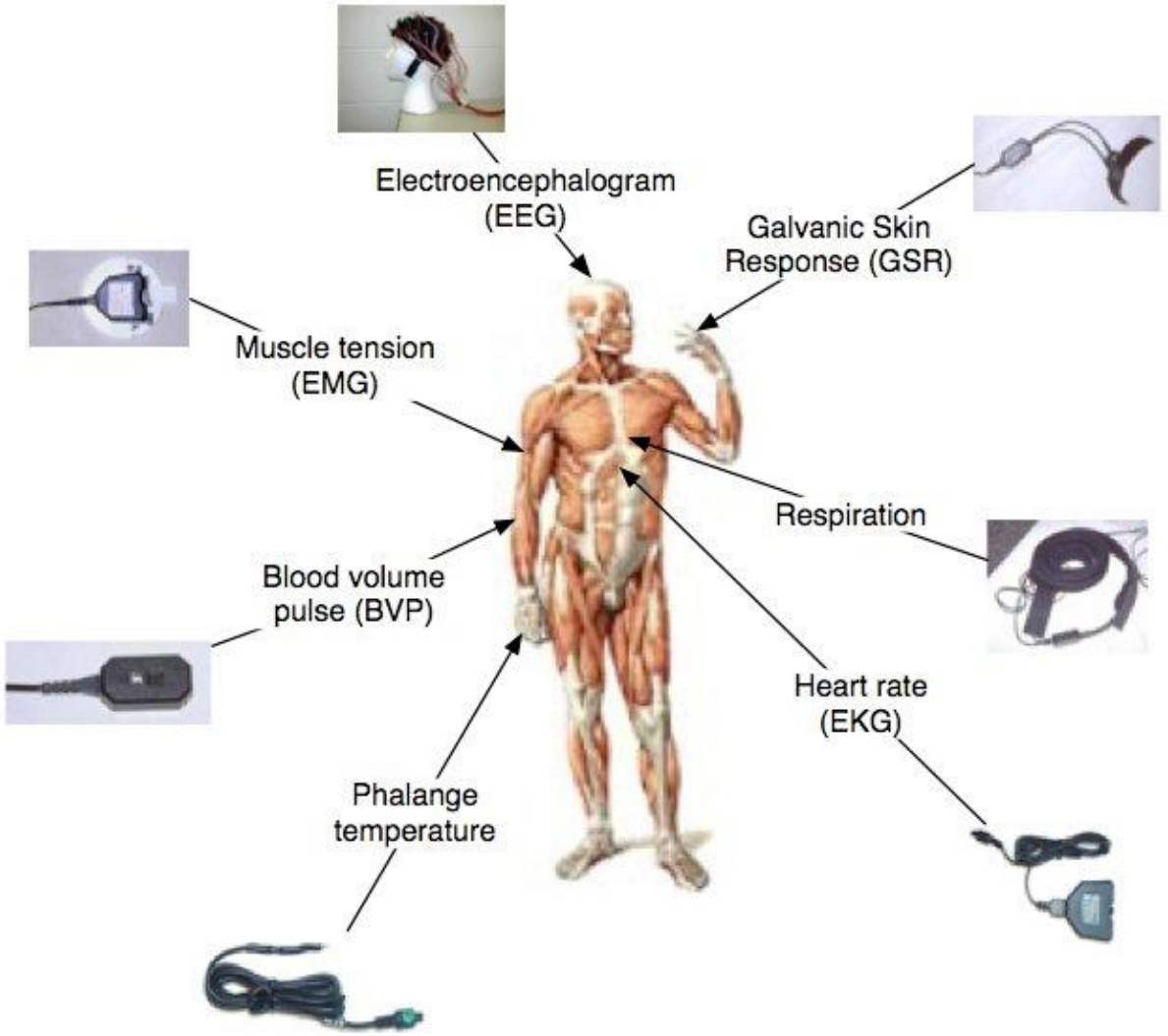
✓ Biochemical examination of blood ✓ Electrocardiogram ✓ Chest X-ray ✓ Mammography	✓ MRI ✓ Gastrointestinal fiberscope ✓ X-ray CT ✓ Serial angiography ✓ Diagnostic imaging ultrasonic apparatus	✓ Electrical scalpel ✓ Laser scalpel ✓ Ventilator ✓ Defibrillator ✓ Radiation therapy equipment	✓ Electrocardiograph ✓ Electroencephalo-graph ✓ EMG ✓ Artificial kidney ✓ Artificial cardiopulmonary device	✓ Bood gas analyzer ✓ Blood pressure monitor	✓ DNA microarray ✓ Next generation sequence ✓ GC-MS ✓ HPLC-MS ✓ Bioinformatics

Signal types of biological information

	自発信号/Spontaneous signals	誘発信号/Trigger signals
電気信号 Electoronic signals	脳波/Electroencephalogram：EEG 心電図/Electrocardiogram, ECG 筋電図/Electromyography - EMG 眼電位図/EOG 神経活動電位	視覚誘発電位、体性感覚誘発電位、聴覚誘発電位、嗅覚誘発電位、網膜電位、温度眼振、視性運動眼振など
機械的信号 Mechanical signals	血圧変動/Blood pressure 筋音図/Mechanomyogram-MMG 心音図/Phonocardiogram, PCG 歩行パターン/Walking pattern 眼瞼運動 重心動揺	腱反射/Tendon Reflex TVR（Tonic Vibration Reflex） GBST（Galvanic Body Sway Test）
化学的信号 Chemical signal	血糖値/Blood glucose 血中ホルモン変動/Blood hormone 神経伝達物質/Neurotransmitter RNA タンパク/protein	遮断剤、分解酵素等の投与
電磁波･磁気･その他 Electromagnetic waves, magnetism, etc.	脳磁図/Magnetoencephalography-MEG、心磁図/Magnetocardiography、体温変動/body temperature, BT、発汗/Perspiration,、嘔吐/vomiting、自覚症状（痛み、耳鳴り/pain, tinnitus）	反応時間計測 瞳孔反射

生体情報工学 (電子情報通信工学シリーズ) (日本語) 単行本 – 2000/5/1
小杉 幸夫 (著), 武者 利光 (著)

Classification of biosignal by biologicql function



Cranial nerve system
Electroencephalogram (EEG)
EvokedEEG
Spinal cord evoked potential

Auditory system
Electrocochleogram(ECochG)
Electronystagmography (ENG)
Stabilometry

Visual system
Retina potential
Electrooculogram(EOG)
Visual evoked potential

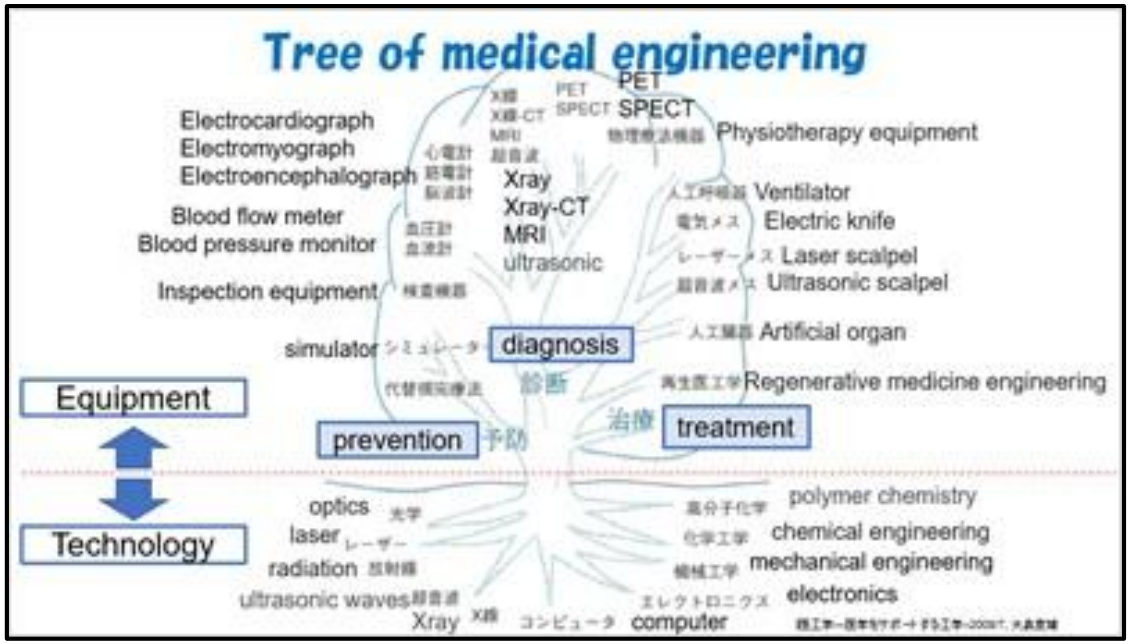
Blood circulating system
Electrocardiogram(ECG)
Phonocardiogram (PCG)
Heart rate
Atrial pressure
Ventricular pressure
Arterial blood pressure
Central venous pressure
Cardiac output
Finger plethysmogram
Body temperature

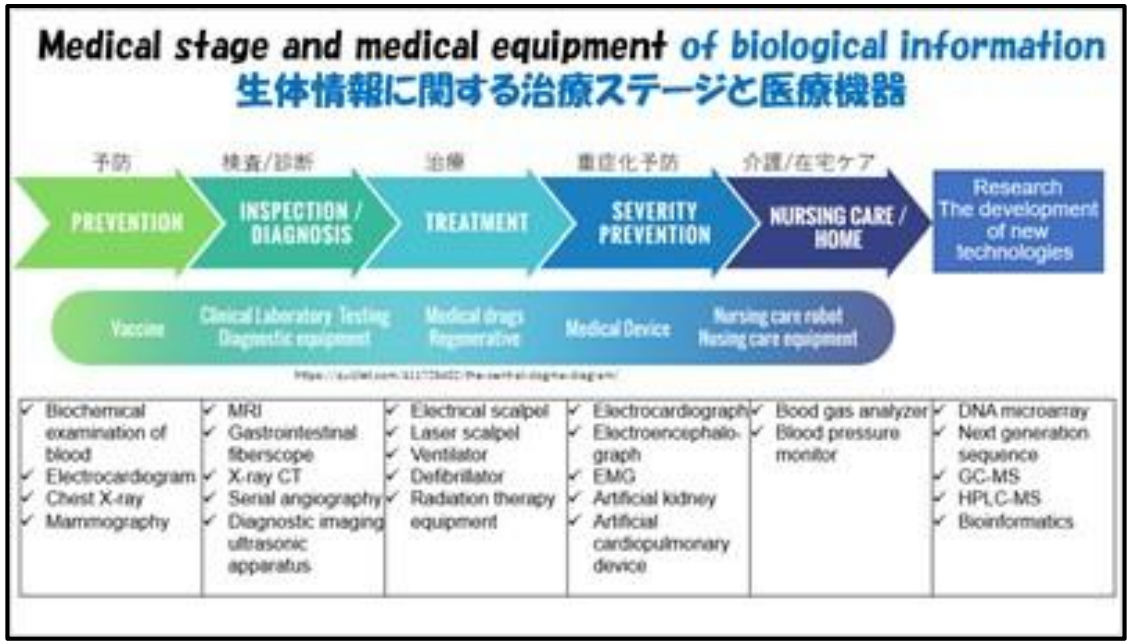
Respiratory system
Alveolar pressure
Intrathoracic pressure
Breathingflowrate
Residual volume
Vital capacity
Airway resistance
Tidal volume
Blood oxygen saturation level(SpO_2)

urogenital system
Intrauterine pressure
Fetal ECG
Tocodynamometer
Intravesical pressure
Ureter internal pressure
Urineflow

Neuromuscular system
Electromyogram (EMG)
EvokedEMG
Nerve conduction velocity

https://www.researchgate.net/figure/Overview-of-the-biosignals-handled-in-the-Bio-Music-platform_fig9_255435950





Signal types of biological information

	自発信号/Spontaneous signals	誘発信号/Trigger signals
電気信号 Electoronic signals	脳波/Electroencephalogram: EEG 心電図/Electrocardiogram, ECG 筋電図/Electromyography - EMG 眼電位図/EOG 神経活動電位	視覚誘発電位、体性感覚誘発電位、聴覚誘発電位、嗅覚誘発電位、網膜電位、温度眼振、視性運動眼振など
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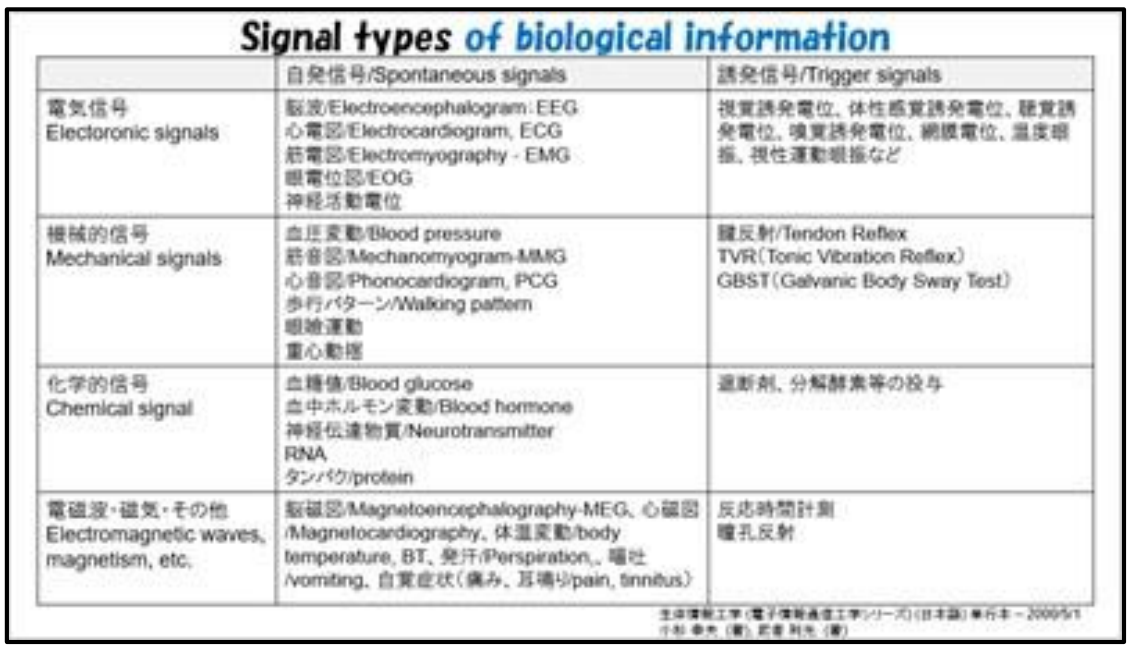
電磁波・磁気・その他 Electromagnetic waves, magnetism, etc.	脳磁図/Magnetoencephalography-MEG、心磁図/Magnetocardiography、体温変動/body temperature, BT、発汗/Perspiration、嘔吐/vomiting、自覚症状（痛み、耳鳴り/pain, tinnitus）	反応時間計測 瞳孔反射



Classification of biosignal by biologicql function

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Auditory system
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Stabilometry

Visual system
Retina potential
Electrooculogram(EOG)
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Blood circulating system
Electrocardiogram(ECG)
Phonocardiogram (PCG)
Heart rate
Atrial pressure
Ventricular pressure
Arterial blood pressure
Central venous pressure
Cardiac output
Finger plethysmogram
Body temperature

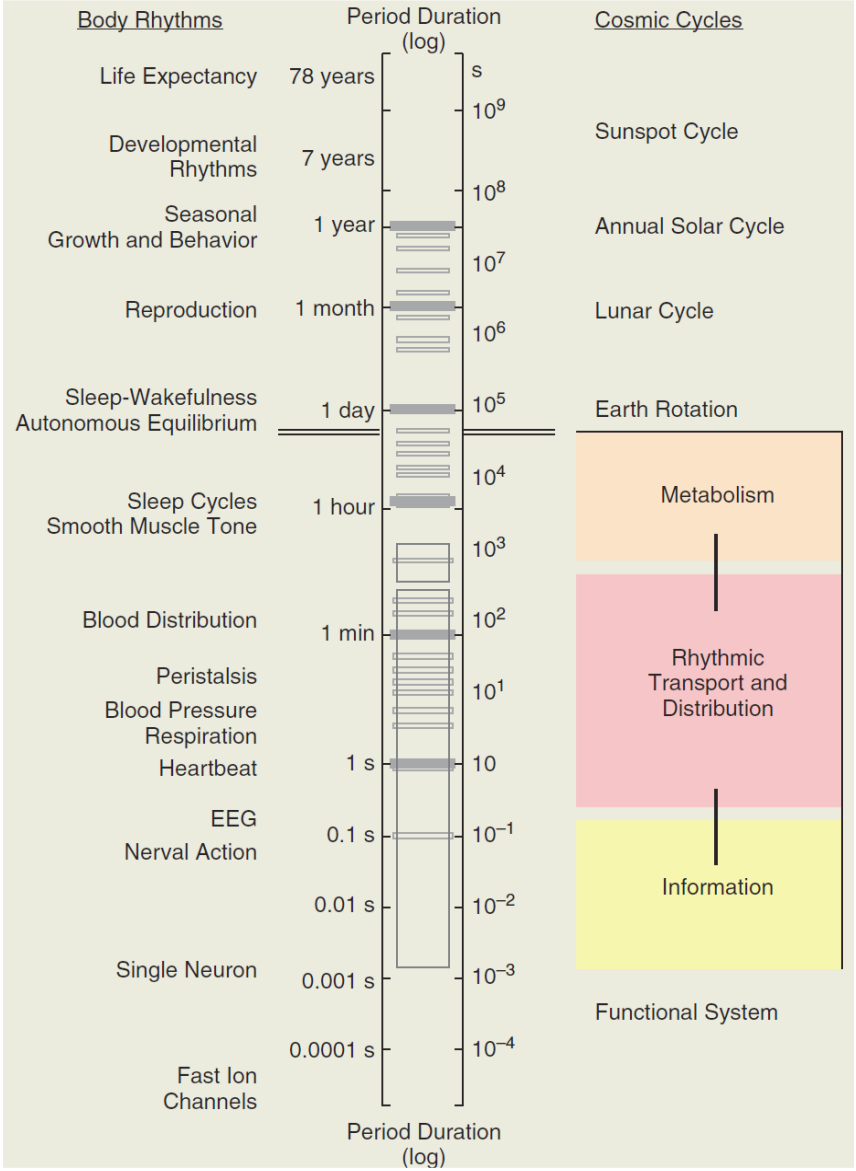
Respiratory system
Alveolar pressure
Intrathoracic pressure
Breathingflowrate
Residual volume
Vital capacity
Airway resistance
Tidal volume
Blood oxygen saturation level(SpO2)

urogenital system
Intrauterine pressure
Fetal ECG
Tocodynamometer
Intravesical pressure
Ureter internal pressure
Urineflow

Neuromuscular system
Electromyogram (EMG)
EvokedEMG
Nerve conduction velocity

Duration of biosignals 生体信号の持続時間

平均寿命	Life expectancy	78 years
生殖周期	Reproduction	1 month
睡眠覚醒周期 自律神経平衡	Sleep wakefulness cycle Autonomous equilibrium	1 day
睡眠周期 平滑筋緊張	Sleep cycles Smooth muscle tone	1 hour
血液分布	Blood distribution	1min
蠕動 血圧 呼吸 心拍	Peristalsis Blood pressure Respiration Heartbeat	1 s
脳波 神経活動	EEG Nerval Action	0.1s
単一ニューロン応答	Single neuron	0.001 s
高速イオンチャネル応答	Fast ion channels	0.0001 s



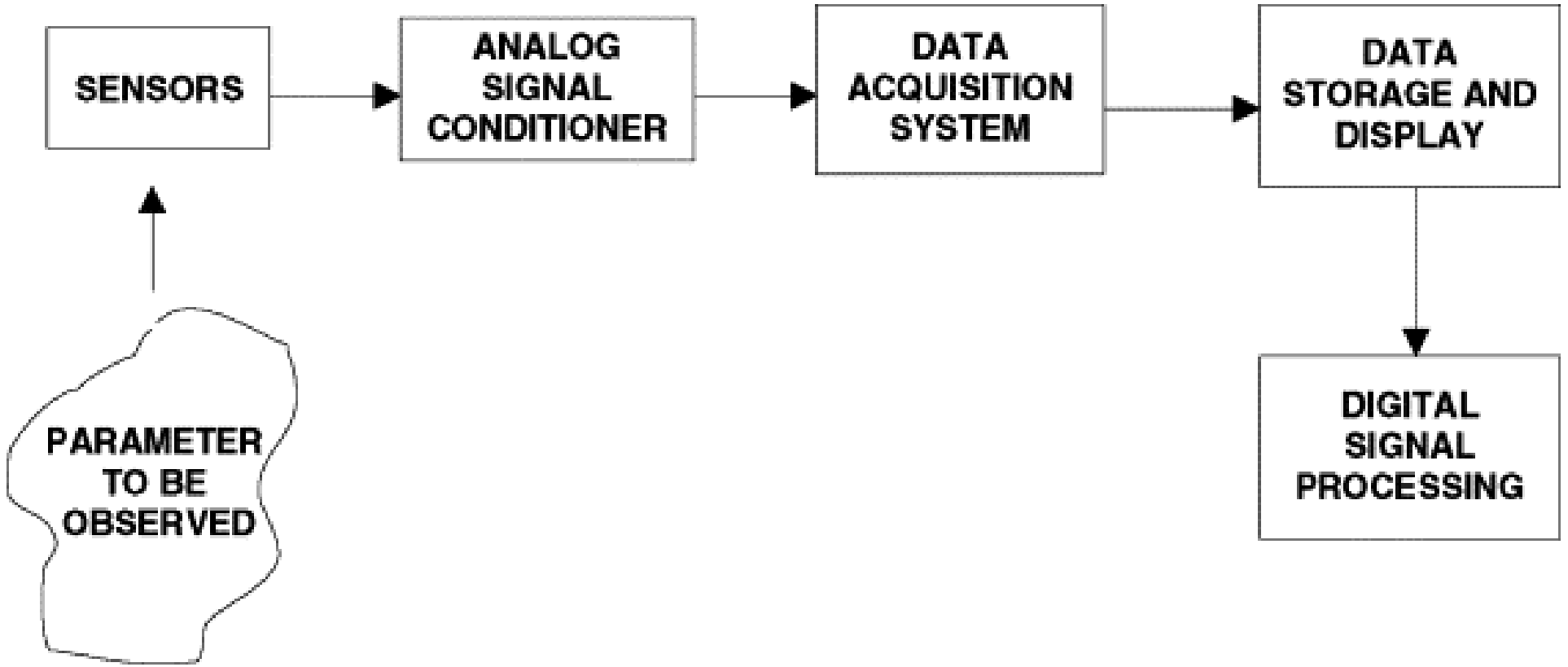
http://web-ext.u-aizu.ac.jp/course/bmclass/Lec-2-1.pdf

Range, frequency and sensors of the various biosignals

Biosignal	Range	Frequency (Hz)	Sensor
Electroencephalogram (EEG 脳波計	10-5000 μV	0-150	Brain-surface or depth electrodes
Electromyogram (EMG) 筋電図	0.1-5 mV	0-10.000	Needle electrodes
Electrooculogram (EOG) 眼電図	50-3500 μV	0-50	Contact electrodes
Electroretinogram (ERG) 網膜電図	0-900 μV	0-50	Contact electrodes
Galvanic skin response (GSR) 皮膚電気反応	1-500 kΩ	0.01-1	Skin electrodes
Electrogastrogram (EGG) 胃電図	10-1000 μV	0-1	Skin-surface electrodes
	0.5-80 mV	0-1	Stomach-surface electrodes

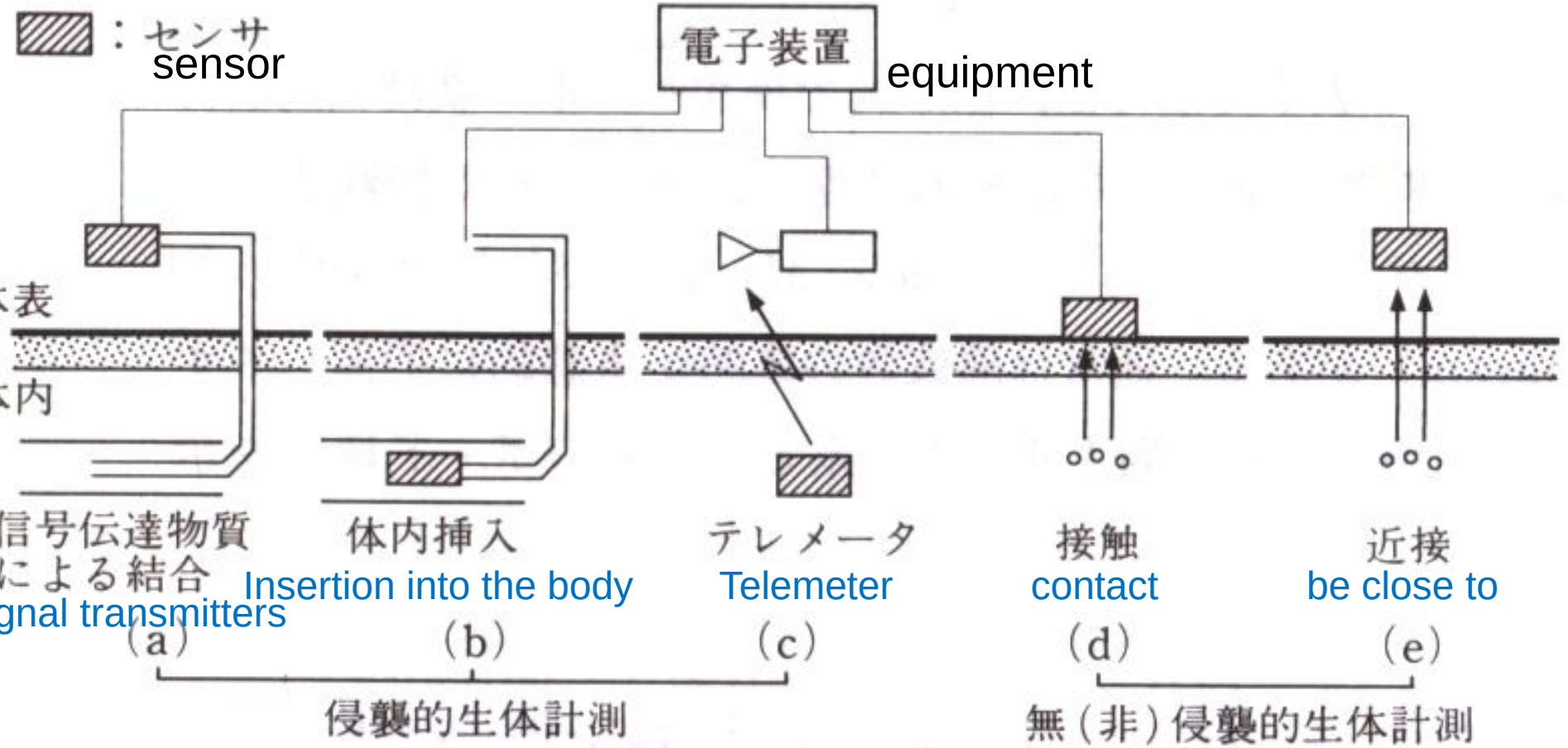
Dindorf, Ryszard & Takosoglu, Jakub & Wos, Piotr. (2018). DEVELOPMENT OF PNEUMATIC CONTROL SYSTEMS.

Biosignal processing



https://www.sciencedirect.com/science/article/pii/B9780122386626500124#!

Measurement methods of biosignals
生体信号の測定方法



Invasive biological measurement

non-invasive biological measurement

Classification of methods for collecting biological information
生体情報の収集方法の分類

- ✓ Medical stage and equipment of biological information
- ✓ Signal types and detection of biological information
- ✓ Position of biosignal in the body
- ✓ Duration of biosignal
- ✓ Range, frequency and sensors of the various biosignals

Part3.
Examples of biological information collection
Bioelectrical signal measurement
生体電気信号の計測

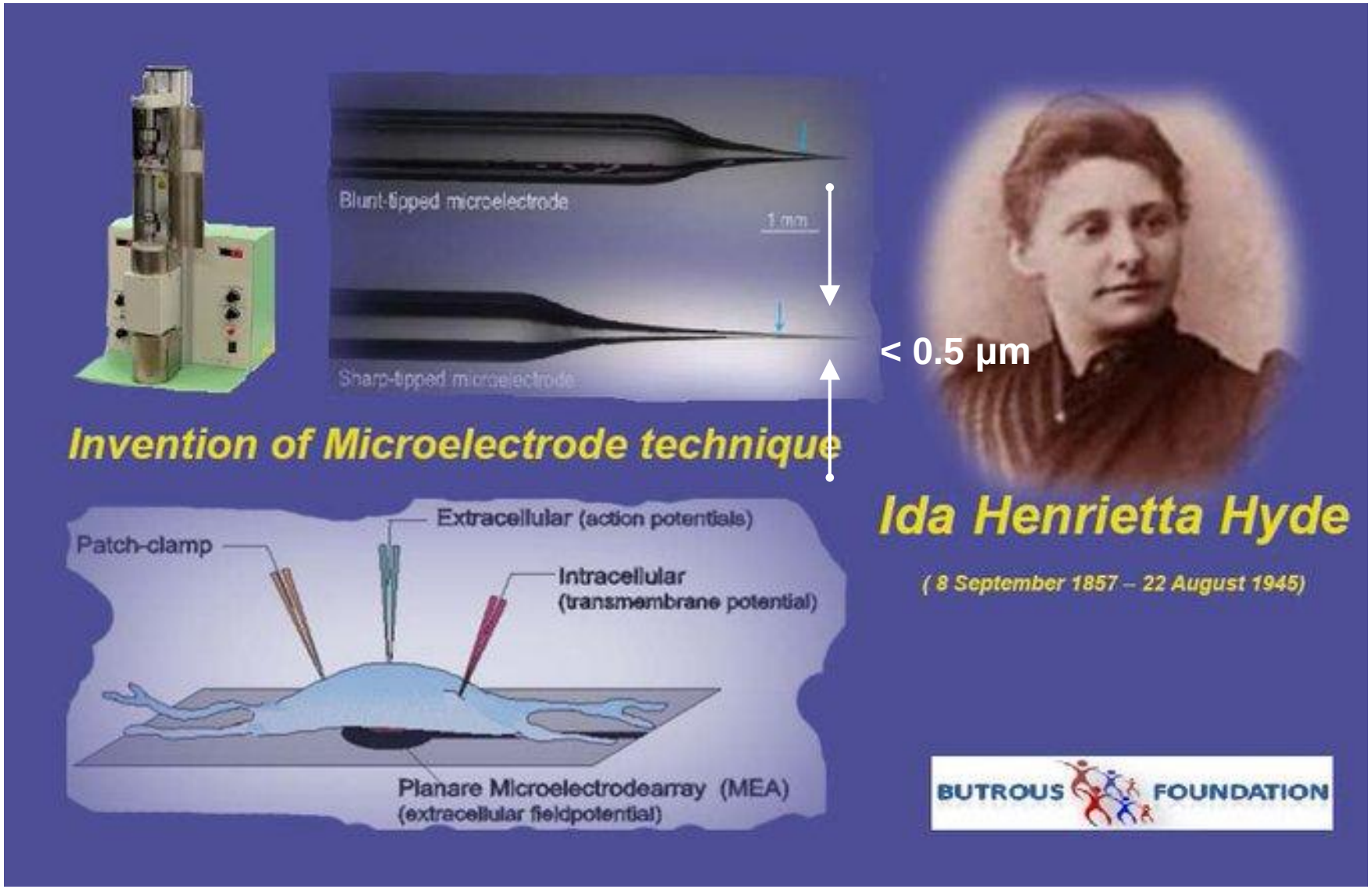
- Electroencephalogram, EEG 脳波計
- Electrocardiogram, ECG 心電図

The first forays into the study of bioelectricity
生体電気信号の研究のはじまり

Laboratory of Luigi Galvani, 9 September 1737 – 4 December 1798

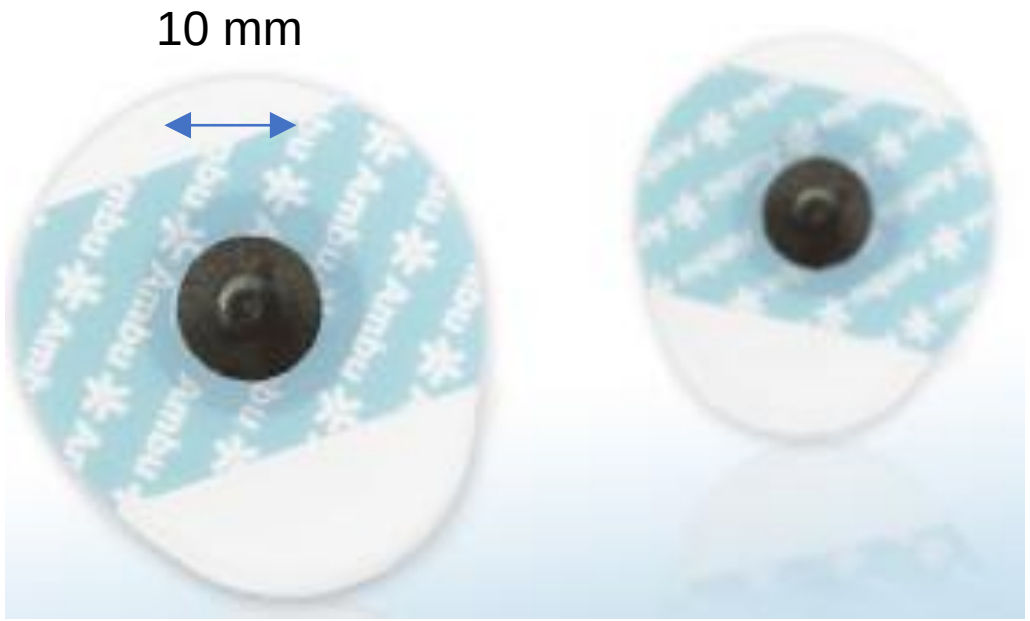
http://www.kaeruclub.jp/report/galvani/galvani.html

Electrodes for single cell – microelectrodes
単細胞用電極 – 微小電極



https://twitter.com/butrousfound/status/767499911415861248

Electrodes for cell population activity
細胞集団活動を検出する電極



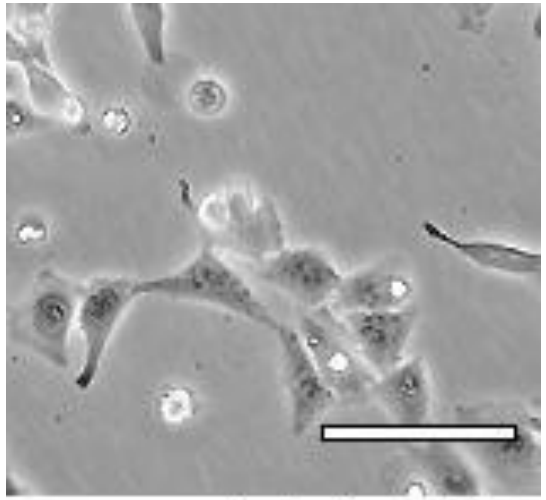
Disposable electrodes for electrocardiogram

https://www.mets-tokyo.jp/products/electrode.html

For Electroencephalogram (EEG) measurement

http://www.intercross.co.jp/product/ix-810/

Electrode and cell size
電極と細胞の大きさ



Electrocardiogram electrodes
10mm

Cells
10 µm

Diameter 1000 times
Area 10000000 times

Histroy of Electroencephalogram:EEG
脳波計測の歴史

1875	Richard Caton. First report of electrical phenomena in the living brain of animals.
1890	Beck & Cybulski expanded on Caton's research
1912	Pravdich Neminsky. First photographic picture of EEG and EP of dog.
1924	Hans Berger. Father of Human EEG,
1931	Kaiser-Wilhelm Institute of brain research,
1932	Jan F Tonnies. First ink writing electroencephalograph,
1936	Model 1 EEG,
1947	American EEG Society
1958	JIS standard「脳波計」(JIS T1203)
2020	EEG TODAY,

https://www.preceden.com/timelines/634281-history-of-eeg

EEG Testing and Monitoring - What to Expect

脳波検査とモニタリング - 期待できること

https://www.youtube.com/watch?v=p38nzOGJZtI

Electroencephalogram：EEG　脳波検査

Diagnosing brain disorders,

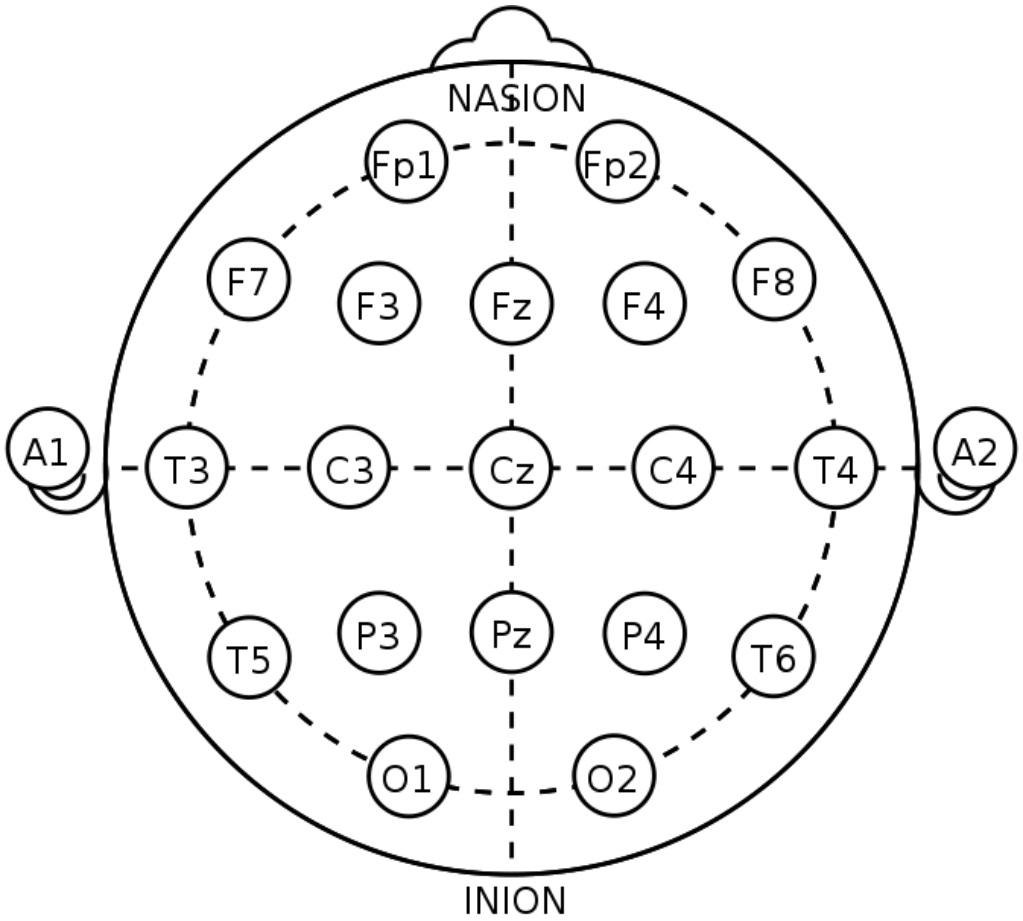
- Epilepsy / てんかん
- Brain tumor / 脳腫瘍
- Brain damage from head injury / 脳損傷
- Brain dysfunction that can have a variety of causes Inflammation of the brain / さまざまな原因による脳の機能障害 脳の炎症
- Stroke / 脳卒中
- Sleep disorders / 睡眠障害

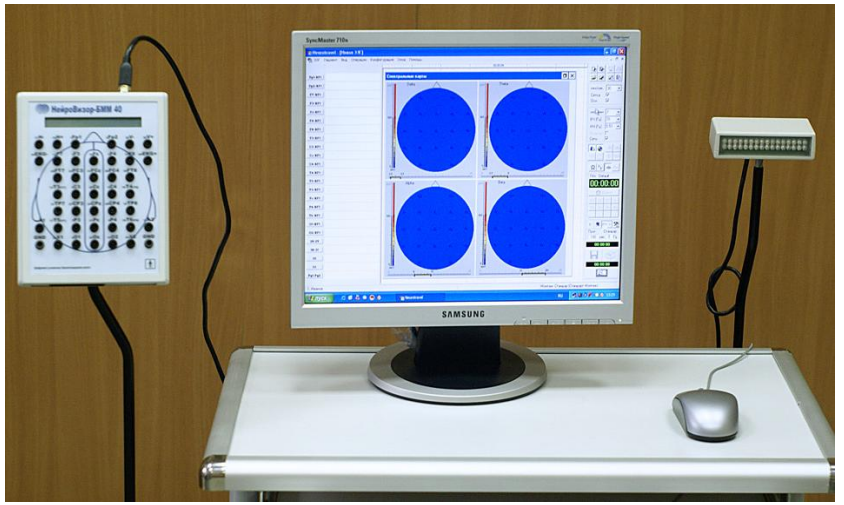
Evoked potentials (EP) : Derivatives of the EEG, averaging the EEG activity time-locked to the presentation of a stimulus

- Cognitive science / 認知科学
- Cognitive psychology / 認知心理学
- Psychophysiological research / 精神生理学

http://www.shizuoka-pho.jp/sogo/labpratory/department/physiological/eeg/index.html

Electroencephalogram：EEG　脳波検査





Amplifier　1000-1000000 times
Sampling 256–512 Hz
High-pass filter　0.5–1 Hz
Low-pass filter　35–70 Hz

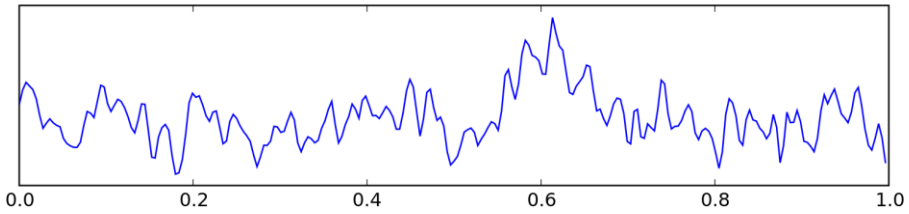
A highly conductive gel that connects the electrode and the skin
電極と皮膚をつなぐ高い導電性をもつ**ゲル**

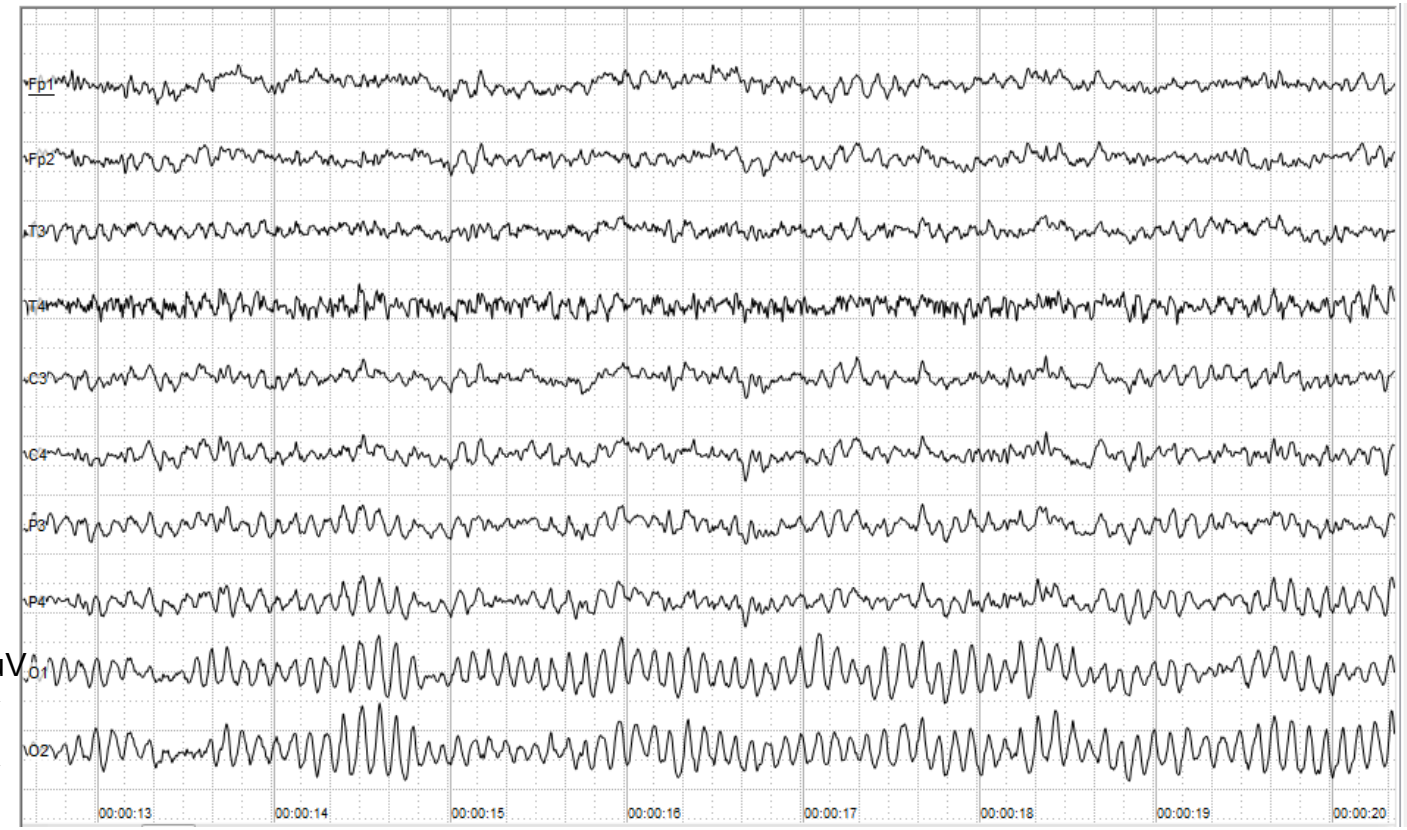
https://guides.lib.kyushu-u.ac.jp/c.php?g=775027&p=5560154

https://en.wikipedia.org/wiki/Electroencephalography

Electroencephalogram：EEG 脳波

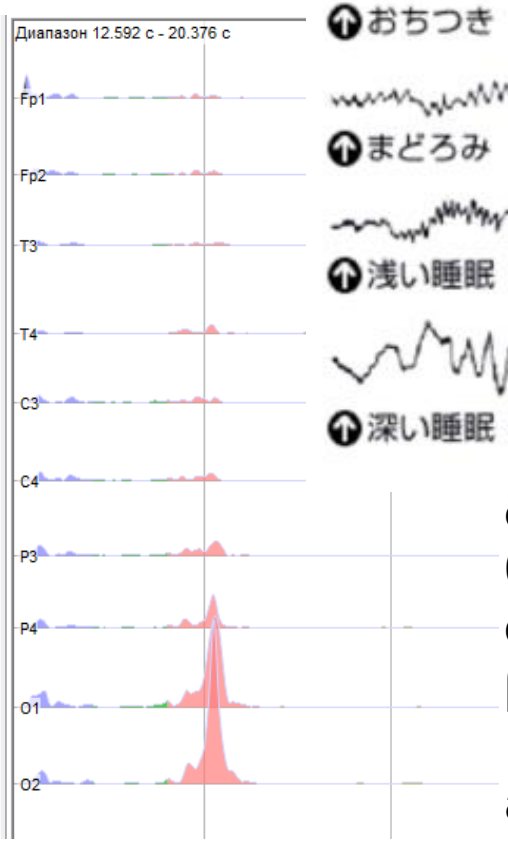
One second of EEG signal

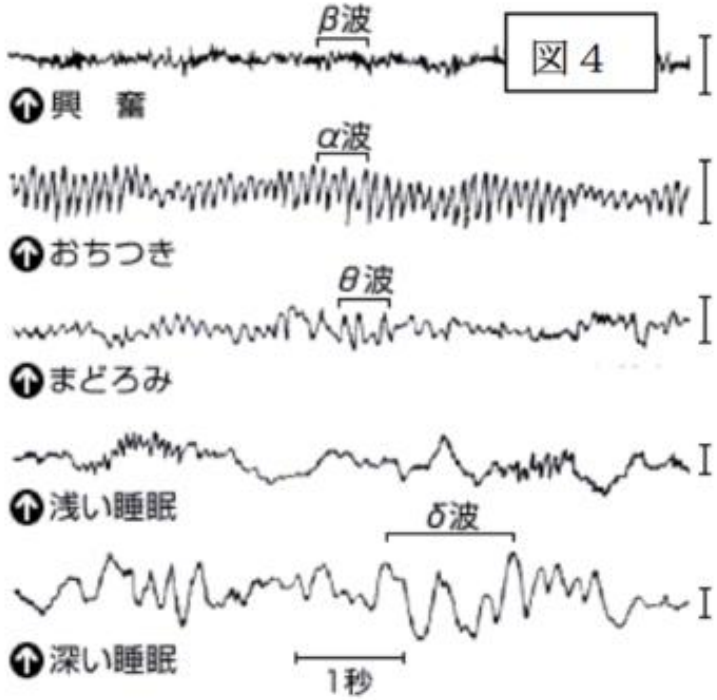




100μV

Time (sec)





δ waves（0.5～4Hz）
θ waves （4～7Hz）
α waves （8～13Hz）
β waves （14～30Hz）

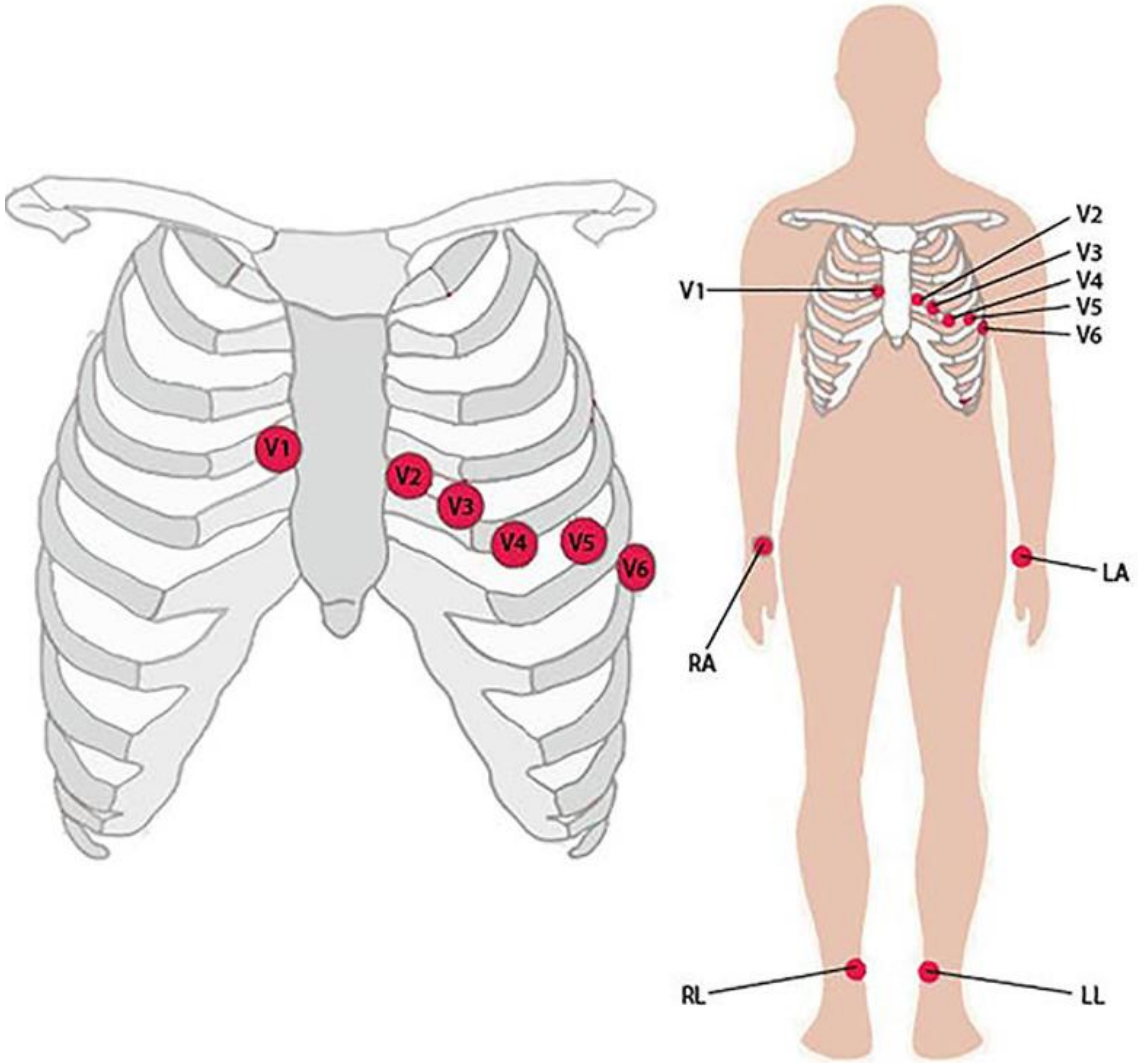
associated with brain activity and mental state

α waves 8－13Hz

https://www.iidabashi-mental.jp/treatment/electroencephalography.html

Electrocardiogram, ECG 心電図

https://www.e-mcast.co.jp/shop/g/g107869/



https://jakenmedical.com/blog/12lead-resting-ekg-electrode-placement/
Mikael Häggström - https://commons.wikimedia.org/w/index.php?curid=20064294による

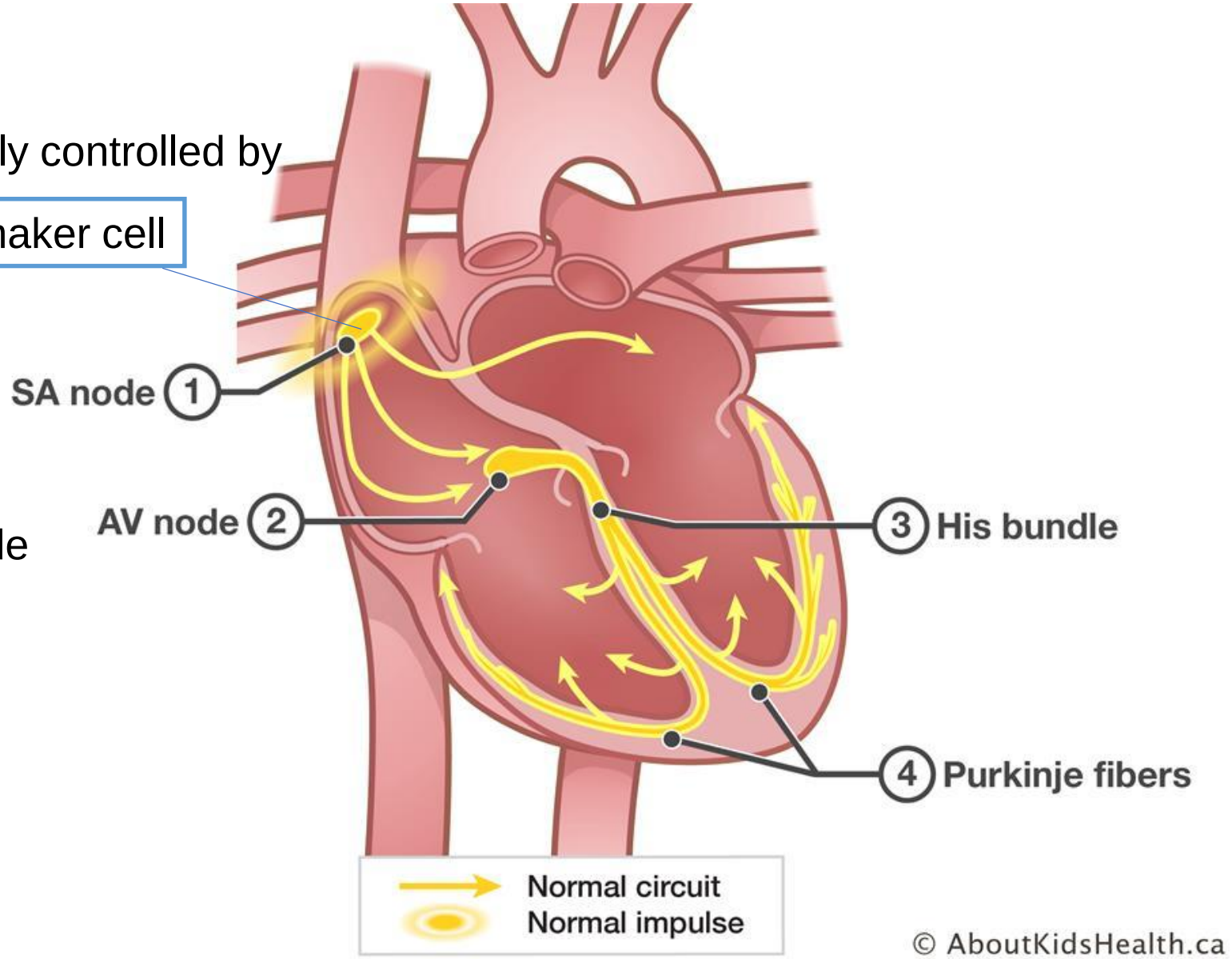
The heart's electrical system 心臓の電気システム

Heartbeat is electrically controlled by

Pacemaker cell

Sinoatrial node

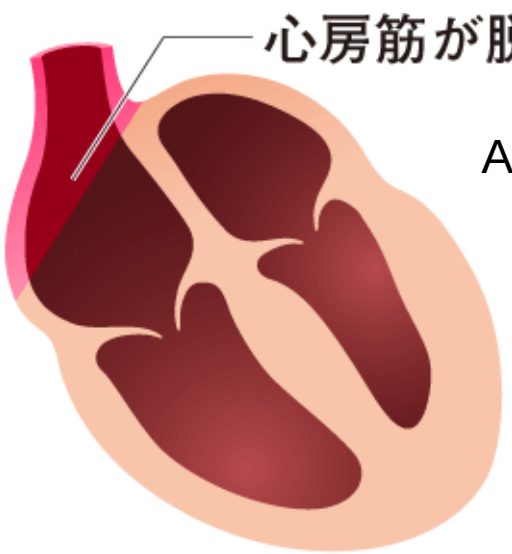
Atrioventricular node



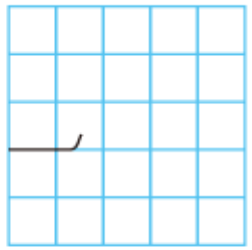
https://www.aboutkidshealth.ca/article?contentid=890&language=english

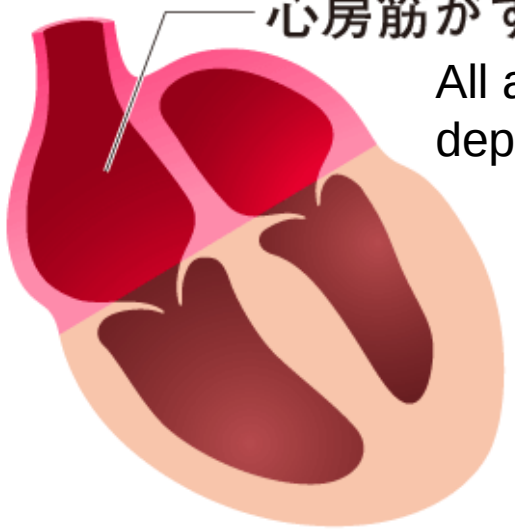
Sequence of cardiac excitation 心臓の興奮の機序

ECG observe as the activity of the heart is the action potentials of the atrium and ventricles.

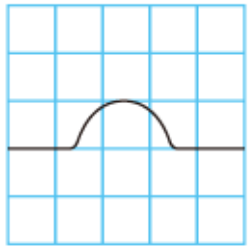


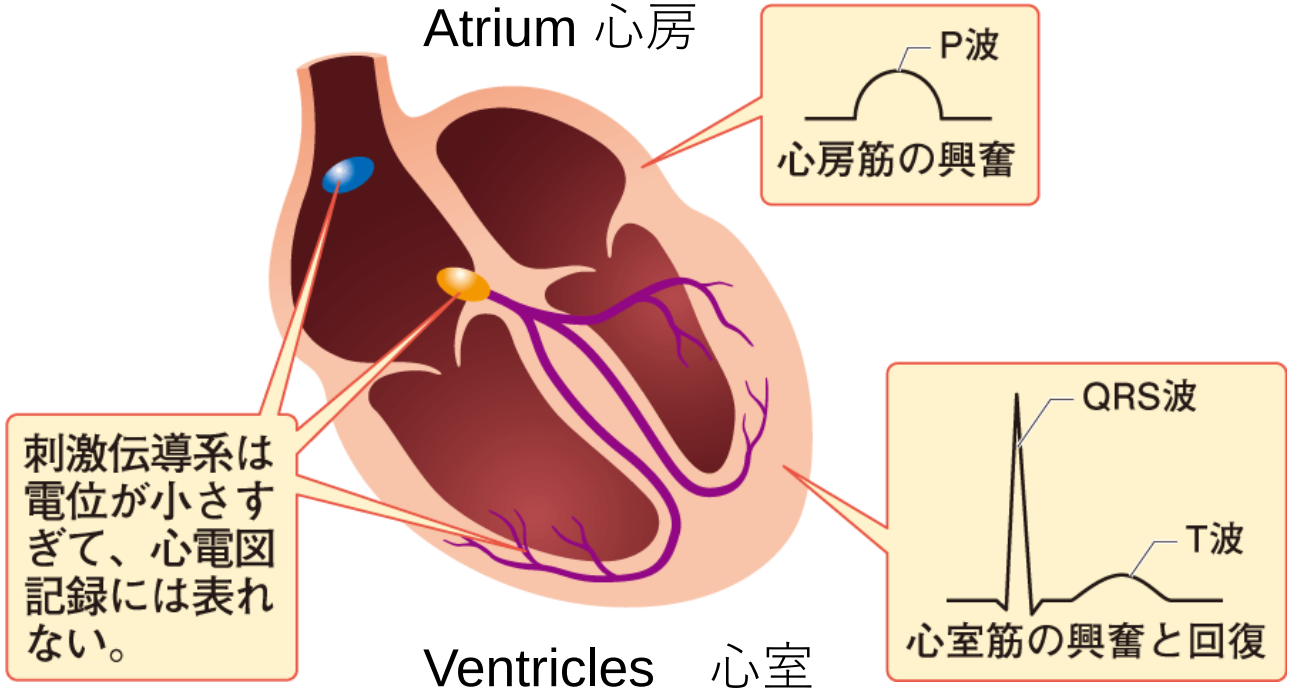
Atrial muscles begins to depolarize





All atrial muscles are depolarized

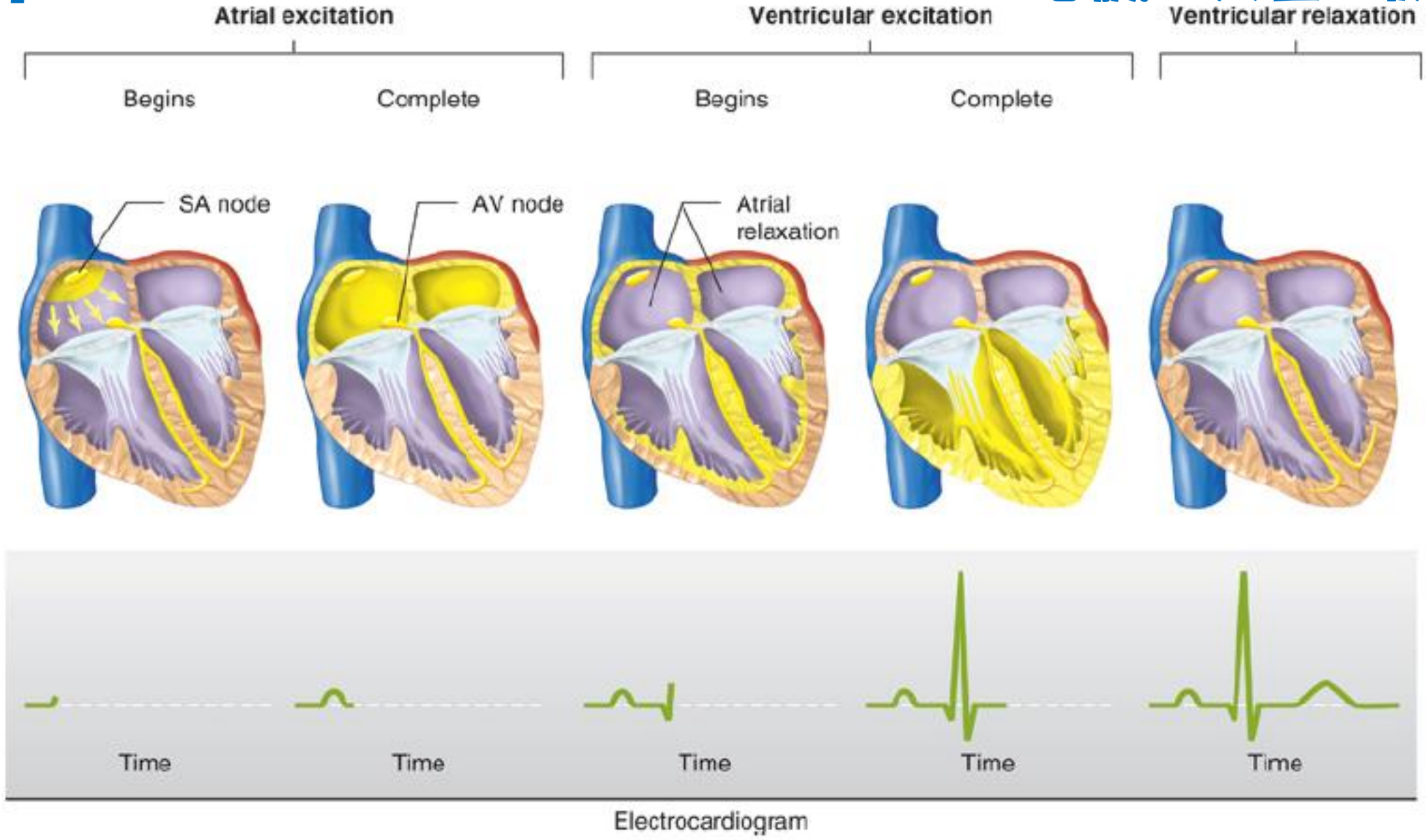




The conductions system do not appear in electrocardiography because there are few cells that excite

https://www.kango-roo.com/learning/1705/

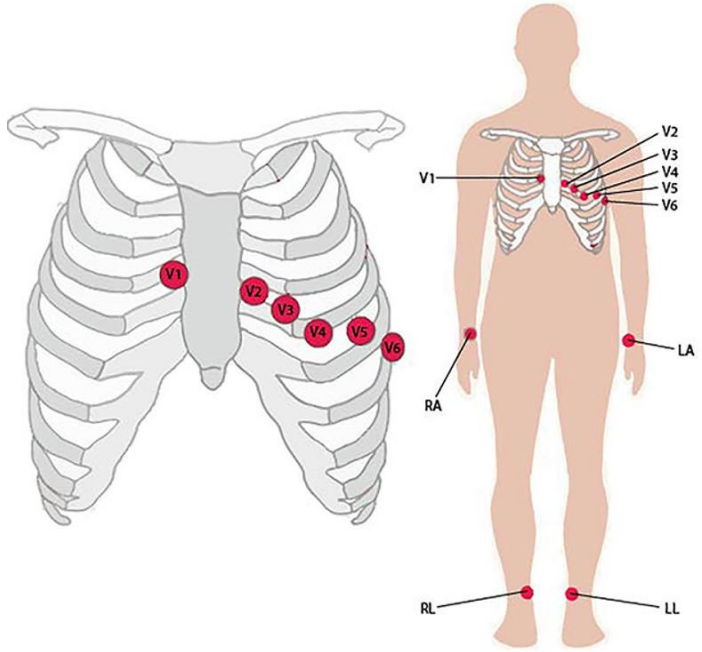
Sequence of cardiac excitation 心臓の興奮の機序



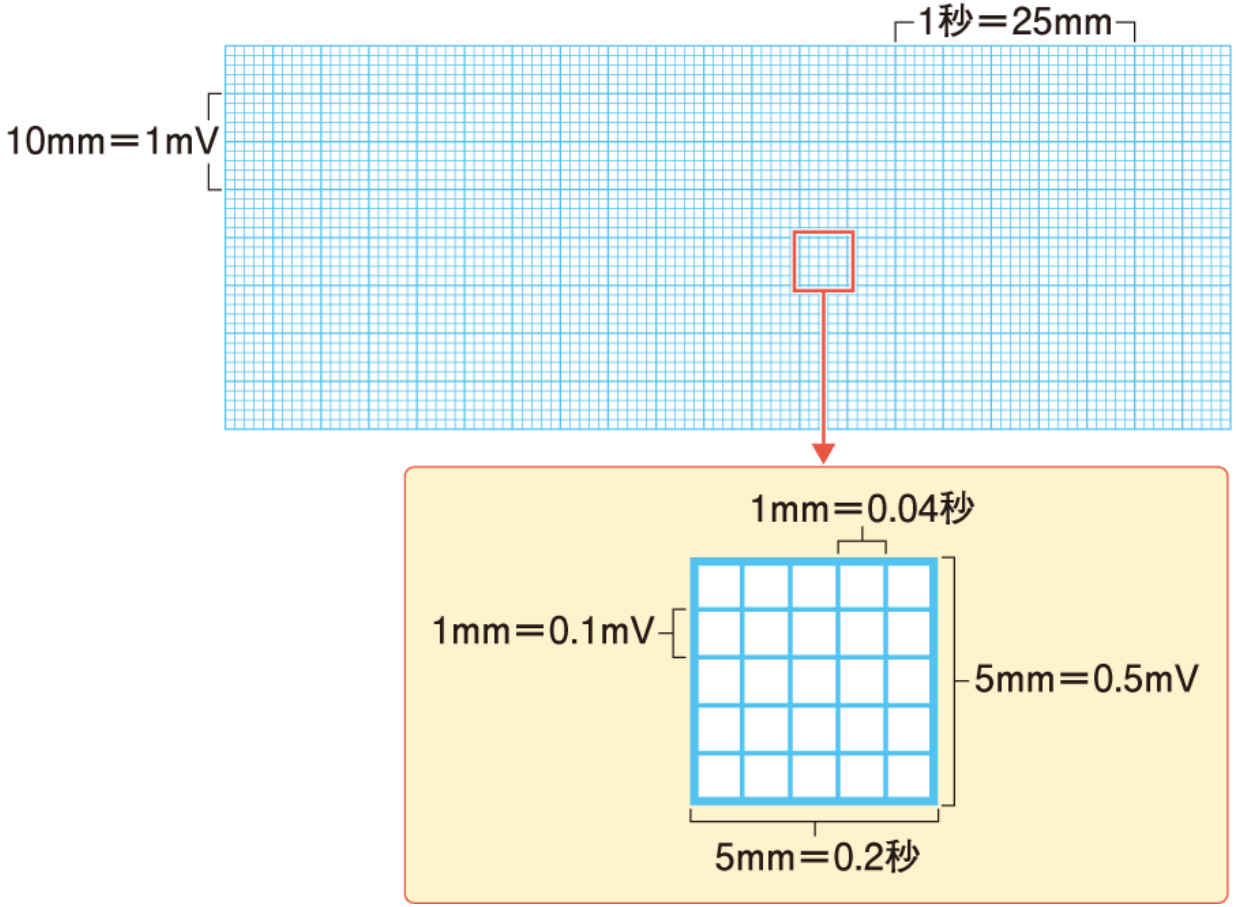
http://www5.zzu.edu.cn/__local/D/15/15/BFA906178BE38CCEB9888ADB328_9B0CBE4C_6BF445.pdf

Electrodes of ECG 心電計の電極

Electrode name	Electrode placement
RA	On the right arm, avoiding thick muscle.
LA	In the same location where RA was placed, but on the left arm.
RL	On the right leg, lower end of inner aspect of calf muscle. (Avoid bony prominences)
LL	In the same location where RL was placed, but on the left leg.
V_1	In the fourth intercostal space (between ribs 4 and 5) just to the right of the sternum (breastbone)
V_2	In the fourth intercostal space (between ribs 4 and 5) just to the left of the sternum.
V_3	Between leads V_2 and V_4.
V_4	In the fifth intercostal space (between ribs 5 and 6) in the mid-clavicular line.
V_5	Horizontally even with V_4, in the left anterior axillary line.
V_6	Horizontally even with V_4 and V_5 in the mid-axillary line.

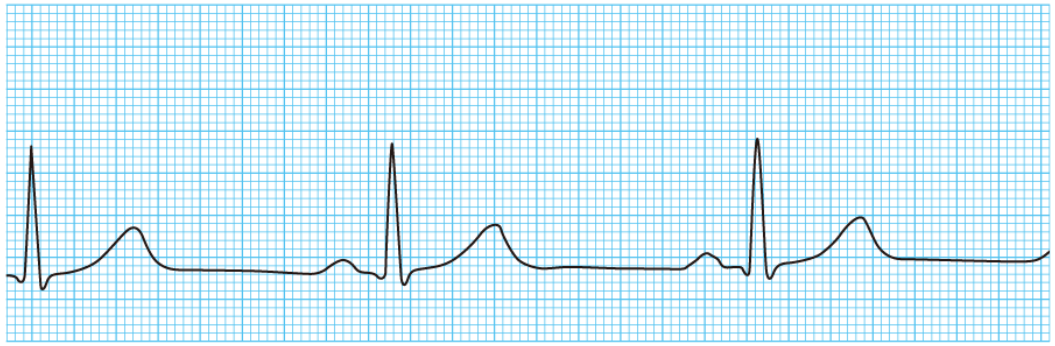


ECG recording paper 心電計記録用紙



■紙送り速度　25mm／秒（通常）

■紙送り速度　50mm／秒



■紙送り速度　10mm／秒

https://www.kango-roo.com/learning/1705/

Part 1. What is biological information engineering?

Part2. Classification of methods for collecting biological information

Part3. Examples of biological information collection

- Electroencephalogram, EEG
- Electrocardiogram, ECG