aquaporinBMSN1601 – Anatomy – Part I (L6~L10)

What is Cardiovascular System

$$\text{Cardiovascular System} = \text{Heart} + \text{Blood Vessels}$$

- Through Hemodynamics → Deeper understanding in Cardiovascular System
  - Hemodynamics = Study of Blood flow by physical methods
  - Visualization of Hemodynamics can be done by 3D MRI

Introduction to definition of CO, HR, SV, Q and BP

- CO is Cardiac Output
  - Amount of blood pumped by **each ventricle** in **1 minute**
- HR is Heart Rate
  - Number of Heart beat in 1 minute
- SV is Stroke Volume
  - Volume of Blood Pumped out by **a ventricle** with each beat.
- Q is Blood Flow
  - Volume of blood flowing through a vessel, an organ or the entire circulation in each period
- BP is Blood Pressure
  - Force per unit area exerted on the wall of a blood vessel by its contained blood.
    - Like e.m.f → Provide Driving Force to the Blood
  - Unit: mmHg
  - Site of measurement: **brachial artery** (large arteries near the heart)

Blood Flow is not equivalent to the Cardiac Output.
Blood Flow in the entire circulation per minute = Cardiac Output.

Introduction to Blood Pressure

- Difference in BP within vascular system → Driving force to blood → Blood Flows
  - From High Pressure to Low Pressure Area
  - Aorta (大動脈) → Arteries (動脈) → Arterioles (小動脈) → Capillaries (毛細血管) → Venules (小靜脈) → Veins (靜脈) → Venae Cava (大靜脈)
- Arterial Blood Pressure – Systolic Pressure
  - Arterial Pressure **during ventricular contraction**
- Arterial Blood Pressure – Diastolic Pressure
  - Arterial Pressure **during ventricular filling**
- Pulse Pressure

$$\text{Pulse Pressure} = \text{Systolic Pressure} - \text{Diastolic Pressure}$$

- Mean Arterial Pressure
  - Average arterial pressure during **a single cardiac cycle**.

Examination Technique:
Systolic Pressure @ Highest Level in cardiac cycle
Diastolic Pressure @ Lowest Level in cardiac cycle

The Common Formula For Cardiovascular System

Entire Circulation Formula: $Q = \frac{\Delta P}{R} \rightarrow CO = \frac{BP}{\text{Total peripheral resistance}}$

#Blood circulation Formula: $Q = \frac{\Delta P}{R}$

#:The Formula is similar to the Ohm's Law, where $I = \frac{V}{R}$

Formula for velocity of Q: $v = \frac{Q}{A}$, where A is the cross sectional area

* The Formula is assume that there is no resistance in the blood vessel
* Important Idea: Current in = Current Out, when there is no branches, the blood flow will always be the same

Poiseuille's Law: $Q = \frac{\Delta P \pi r^4}{8\eta l}$, where l is the length and η is the viscosity of blood

* Regulation of blood vessel radius
* ΔP is not subject to **significant short-term regulation**, in other word, t cannot $\rightarrow 0$
* η, l and not subject to **significant regulation** by body, where t cannot $\rightarrow 0$

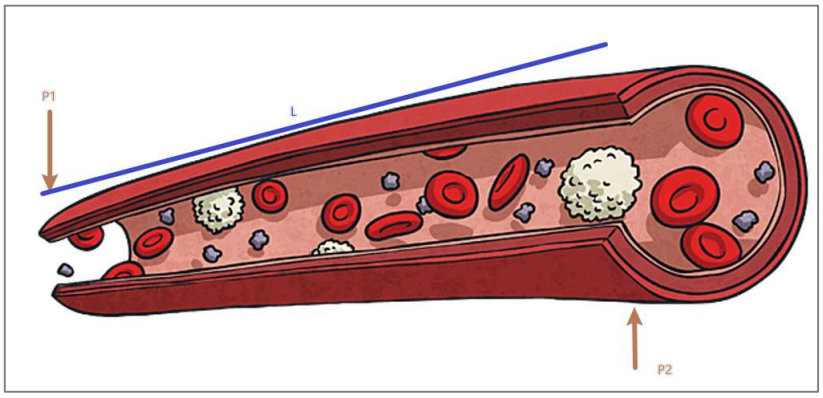
$$Q = \frac{\Delta P}{R} = \frac{\Delta P \pi r^4}{8\eta l}$$

$$R = \frac{8\eta l}{\pi r^4}, \text{we get } Q \propto r^4$$

$$\text{By considering: } va = v(\pi r^2) = \frac{\Delta P \pi r^4}{8\eta l}$$

$$\text{We have: } v = \frac{\Delta P r^2}{8\eta l}$$

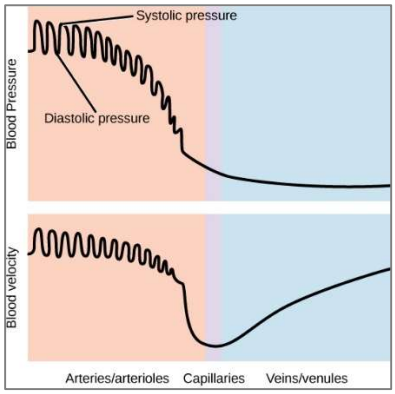
- Do notice that the Blood Pressure decrease over the time
  - From Aorta to Venae Cava
- There is no change in the radius of blood vessel within the length L
- Smaller the radius, Larger the Resistance, Smaller the speed.
  - Do compare this relationship with the above formula $v = \frac{Q}{A}$, where the above formula omit the resistance. – For Detailed Information, Plz Refer to the next page



Poiseuille's Law v.s. Q-v Formula

- Poiseuille's Law can only be applied when ΔP is not significant.
- Q-v Formula can only be applied when there is no resistance

According to the Following Graph:



- Do notice that the ΔP in Aorta (大動脈), Arteries (動脈) are significant.
  - The formula cannot be applied because the heart keeps bumping bloods (keep doing work on the blood flow) to against the resistant.
    → The force acted by resistance on the blood flow is not constant (tends to zero).
    → The Q (Blood Flow) tends to be unchanged.
    → Thus, the velocity of fluid cannot be found by the Poiseuille's Law
- Q-v Formula should be applied in Aorta and Arteries, where the resistance is tends to zero due to the effect of bumping of heart.
- That's why the beginning of velocity of fluid is tends to unchanged.

We have $v = \frac{Q}{A} = \frac{Q}{\pi r^2}$, Larger the radius, Lower the Velocity of Fluid.

- Do notice that the ΔP in each region of Arterioles, Capillaries and veins/venules **<u>are not significant.</u>**
- However, it is far apart from the heart, **<u>the resistance cannot be cancelled by the work done by heart</u>**.
  - The Resistance is significant & Lots of Branches
    → Thus, the **<u>Q is not constant</u>** and **<u>Q-v formula cannot be applied.</u>**
- We should applied Poiseuille's Law in those cases.
  - We have: $Q \propto r^4$ and $v = \frac{\Delta P r^2}{8\eta l}$
- Region Arterioles & Capillaries
  - **<u>Smaller the Radius, Lower the Velocity of Fluid.</u>**
- Region Venules (小靜脈) ,Veins (靜脈) ,Venae Cava (大靜脈)
  - **<u>Larger the Radius, Higher the Velocity of Fluid.</u>**
  - The Blood Flow is gradually increased from Venules to Venae Cava.

❗ There is no direct relationship between velocity of blood, blood pressure and blood flow.

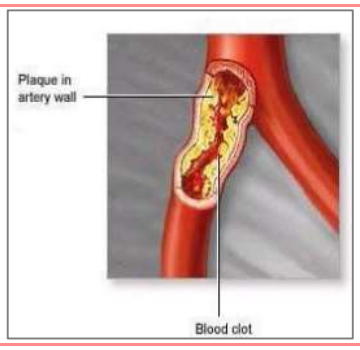
Blood Vessel – Laminar Flow & Turbulent Flow

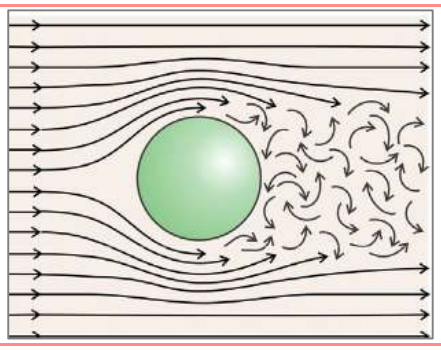
Laminar Flow

- Requirement:
  - Fluid flows in layers parallel to vessel wall
  - Without disruption between layers
- #Characteristic:
  - **<u>The layer of fluid in contact with the wall has lower velocity</u>**
  - **<u>The layer of fluid that moves along the axis of the tube has maximal velocity</u>**

#: This can be explained by the resistance act on the layer of fluid in contact with the wall

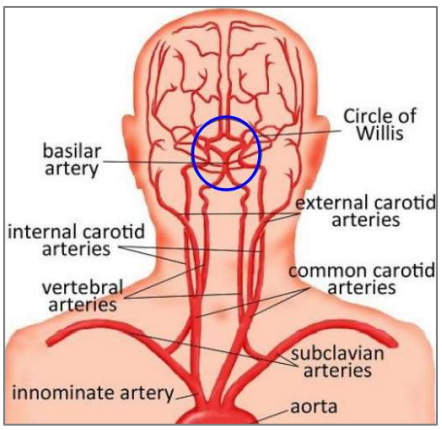
Problematic: Turbulent flow





- Requirement:
  - Irregular Movement
- Characteristic:
  - Q is decreased → Heart Need to Bump more vigorously → Great Work load
  - v is decreased

Some Example to demonstrate the importance of Hemodynamics



- Hypertension / Hypotension
- Stroke
- Aneurysms → Enlargement of an artery → Thin artery wall. → Risk of Apoplexy (内出血) / Intracranial bleed (腦出血)

Introduction to Respiratory System

Upper Tract	☙ **Filter & humidify incoming air**	**Nose**
		Pharynx
		Frontal Sinus
		Sphenoidal Sinus
		Nasal Cavity
		Internal Nares
Lower Tract	☙ **Delicate conduction passages** (精緻的傳導通道) ☙ **Gas Exchange – Refer to Respiratory Zone**	**Larynx**
		Trachea
		Bronchi
		Lung
		Bronchioles
		Diaphragm
		Alveoli

Zone in Respiratory System

Conducting Zone

☙ Provide Rigid conduits for air to reach Respiratory Zone

Nose	Pharynx	Frontal Sinus	Sphenoidal Sinus	Nasal Cavity	Internal Nares
Larynx		Trachea		Bronchi	

Respiratory Zone

☙ Site of Gas Exchange

Bronchioles	Alveolar Ducts	Alveoli	Alveolar Sac

Respiratory muscle

☙ Promote ventilation

Diaphragm

Terms used in Respiratory System

☙ Respiratory System
- ☋ To supply the body with O_2
- ☋ To dispose of CO_2

☙ Pulmonary ventilation
- ☋ Movement of air into & out lungs

☙ Transportation
- ☋ Transport of CO_2 and O_2: Lung & Blood

☙ External Respiration
- ☋ Gas Exchange (GE): lung & blood

☙ Internal Respiration
- ☋ GE: systemic blood vessels & tissues

☙ Inspiration (inhalation)
- ☋ Air flows into the lungs

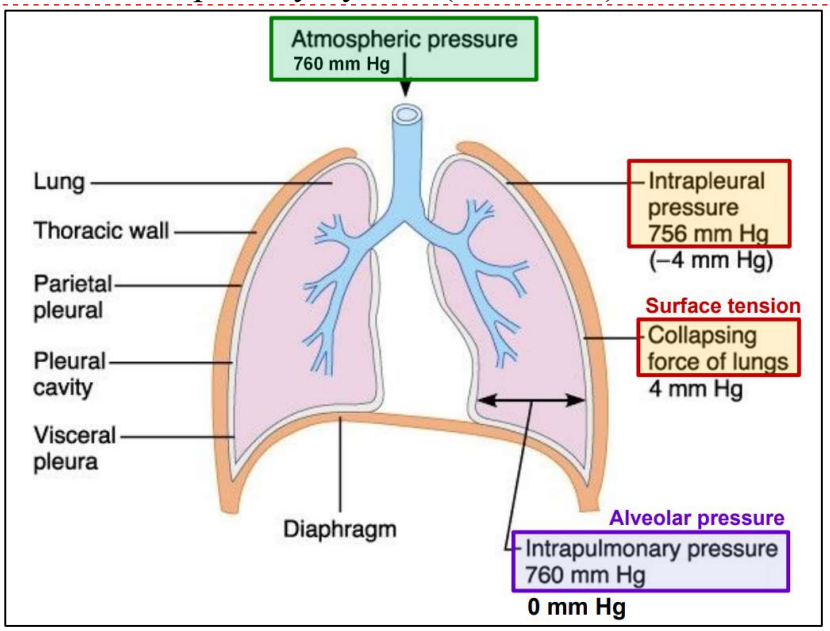
☙ Expiration (exhalation)
- ☋ Gases exit the lungs

Gas Law & Atmospheric Pressure & Unit for Pressure

- 1 mmHg = Pressure generated by a column of mercury 1mm high
- Atmospheric Pressure = 760 mmHg

- Delton's Law
  - Formula: $P_T = \sum_{k=1}^{n} P_k$
  - By this formula, we can calculate the partial pressure by specific gas molecule
- Fick's Law of Diffusion
  - Formula: $R_d = k\frac{A\Delta P}{D}$
    - k: Diffusion Constant (Solubility of Gas & Temperature)
    - A: Area for gas exchange
    - ΔP: difference in partial pressure of gas on either side
    - D: Thickness of barrier to diffusion
- Boyle's Law / Ideal Gas Law
  - Formula: $PV = nTR \rightarrow \frac{PV}{T} = k$, where k is constant

Introduction to Pressure and Respiratory System (Inhalation)



Important Note:

- Intrapulmonary Pressure Always equalizes itself with atmospheric pressure eventually
- The Surface Tension = -1 * Intrapleural Pressure (Pressure within the pleural cavity)
  - Where the surface tension is the collapsing pressure of lungs.
- **Intrapulmonary Pressure is always higher than Intrapleural pressure**

- The Diaphragm contracts (變高)
  → Thoracic cavity increase → Intrapulmonary Pressure (Pressure within alveoli) Decrease
- The Rib Cage elevation (變肥)
  → Thoracic cavity increase → Intrapulmonary Pressure Decrease
- Intrapulmonary Pressure < 1atm / 760mmHg → Air Flows in

Mechanism of Exhalation

- The Diaphragm relaxes (變矮)
  → Thoracic Cavity increase → Intrapulmonary Pressure Increase
- The Rib Cage Lowering (變瘦)
  → Thoracic Cavity Increase → Intrapulmonary Pressure Increase
- Intrapulmonary Pressure > 1atm/ 760mmHg → Air Flow out.

Pulmonary Function Test – Spirometer

- Spirometer: Measure the **volume & rate** of air during inhalation & exhalation

1. A hollow bell is inverted over water
2. Bell is displaced as patient breathes into a connecting mouthpiece
3. A graph is plotted on a rotating drum

Concept of Homeostasis

- Homeostasis = The Maintenance of a stable **internal** environment in the body
  - Internal Environment = Surrounds each living cells in the body / ECF
    - ECF = Interstitial Fluid + Blood Plasma

ICF: Intracellular Fluid / ECF: Extracellular fluid

- Cells undergo most vital biochemical reactions in ICF.
- Substances are moved between ICF and ECF.

Interstitial Fluid: Lies between the cells

Blood Plasma: Liquid Matrix of Blood

Properties of the internal environment

Parameter	Normal range	Short-term non-lethal limit
Body temperature	36.1-37.2 °C	18.3-43.3 °C
Sodium ion	135-145 mmol/L	115-175 mmol/L
Potassium ion	3.5-5.3 mmol/L	1.5-9.0 mmol/L
Calcium ion	1.0-1.4 mmol/L	0.5-2.0 mmol/L
Bicarbonate ion	22-29 mmol/L	8-45 mmol/L
Acid-base (pH)	7.3-7.5	6.9-8.0
Oxygen	25-40 mmHg	10-1000 mmHg
Carbon dioxide	41-51 mmHg	5-80 mmHg
Glucose	70-115 mmol/L	20-1500 mmol/L

Physical Properties	Blood Pressure
	Volume of ECF / Blood
	Body Core Temperature
Chemical Properties	ECF, Concentration of ions
	pH Level of Blood
	Blood Glucose Level
	Blood O_2 and CO_2 level

Summary of Function of Organ System

Nervous and endocrine systems	☙ Regulate body functions.
Integumentary system	☙ Forms a protective boundary around the body ☙ Regulates body temperature
Musculoskeletal system	☙ provides support and body movement ☙ Produces blood cells (Bone marrow)
Circulatory / Cardiovascular system	☙ Distributes materials by pumping blood
Respiratory system	Exchanging materials between the internal and external environment: ☙ Oxygen & Carbon dioxide
Digestive system	Exchanging materials between the internal and external environment: ☙ Nutrients & Water
Urinary system	Exchanging materials between the internal and external environment: ☙ Water and Waste

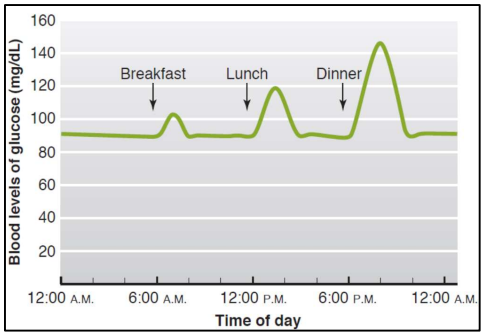
Detailed Summary of Function of Organ System

TABLE 1.1 Organ Systems of the Body

System	Major Organs or Tissues	Primary Functions
Circulatory	Heart, blood vessels, blood	Transport of blood throughout the body
Digestive	Mouth, salivary glands, pharynx, esophagus, stomach, small and large intestines, anus, pancreas, liver, gallbladder	Digestion and absorption of nutrients and water; elimination of wastes
Endocrine	All glands or organs secreting hormones: pancreas, testes, ovaries, hypothalamus, kidneys, pituitary, thyroid, parathyroids, adrenals, stomach, small intestine, liver, adipose tissue, heart, and pineal gland; and endocrine cells in other organs	Regulation and coordination of many activities in the body, including growth, metabolism, reproduction, blood pressure, water and electrolyte balance, and others
Immune	White blood cells and their organs of production	Defense against pathogens
Integumentary	Skin	Protection against injury and dehydration; defense against pathogens; regulation of body temperature
Lymphatic	Lymph vessels, lymph nodes	Collection of extracellular fluid for return to blood; participation in immune defenses; absorption of fats from digestive system
Musculoskeletal	Cartilage, bone, ligaments, tendons, joints, skeletal muscle	Support, protection, and movement of the body; production of blood cells
Nervous	Brain, spinal cord, peripheral nerves and ganglia, sense organs	Regulation and coordination of many activities in the body; detection of and response to changes in the internal and external environments; states of consciousness; learning; memory; emotion; others
Reproductive	Male: testes, penis, and associated ducts and glands Female: ovaries, fallopian tubes, uterus, vagina, mammary glands	Male: production of sperm; transfer of sperm to female Female: production of eggs; provision of a nutritive environment for the developing embryo and fetus; nutrition of the infant
Respiratory	Nose, pharynx, larynx, trachea, bronchi, lungs	Exchange of carbon dioxide and oxygen; regulation of hydrogen ion concentration in the body fluids
Urinary	Kidneys, ureters, bladder, urethra	Regulation of plasma composition through controlled excretion of ions, water, and organic wastes

Fluctuation & Imbalance of Homeostasis

Homeostasis = State of Dynamic Constancy



- Variables stay within a narrow range at all time
- Variables may change quite significantly throughout the day.

  → **If these variables become higher or lower than normal range, body acts to restore them to a "set point"**

All Organ Systems are interdependent

- Some disease can be caused by **Imbalance of Homeostasis**
  - *Diabetes*
  - *Hypertension or Hypotension* （高血壓、低血壓）
- The disease involve failure of more than one organ system → It can be lethal.

Summary of the concept of homeostasis

- Homeostasis is about maintaining stable physical / chemical properties of internal environment (extracellular fluid).
- Homeostatic control systems (sensor, control centre and effector) maintain regulated variable within predictable range.
- Mechanism of control: neural, endocrine and neuroendocrine
- Essential for survival and good health.
- Some abnormalities in physiological variables are tolerated short-term, but are lethal in long run

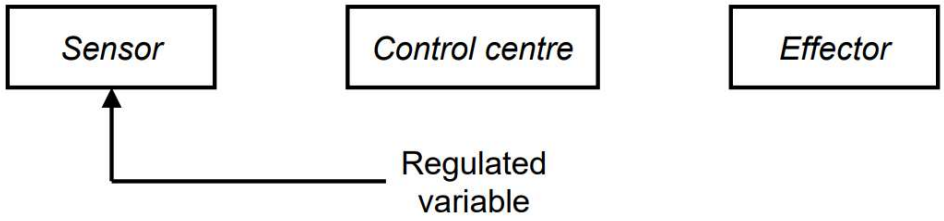
Homeostatic control system - Sensors

Sensors

- Body has several sensors to monitor regulated variable

Sensory Cell	Thermoreceptor	Monitor the absolute/relative change in temperature.
	Baroreceptor	Monitor the blood pressure
	Chemoreceptors	Monitor the O_2 and CO_2 and Blood pH value
	Osmoreceptors	Monitor the **Osmotic pressure** - Detect Hypertonic / Hypotonic
Cellular Component	Cell surface receptors	
	Enzymes	

- Then, The Sensors are sending signals to Control Center / Integrating Center



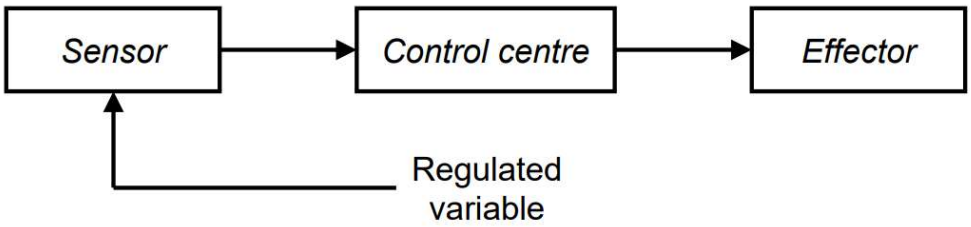
Homeostatic control system – Control Center

Control Center / Integrating Center

- The Control Center (CC) integrate **Signals from Sensors**
- Then, CC use *electrical signals*, *chemical signals*

(Usually both signals send to the effector → Maintain the homeostasis)

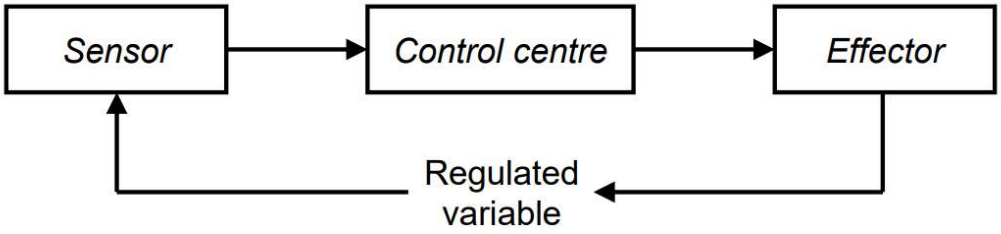
Common Type of Chemical Signals	
Neurotransmitter	Neuron or effector cell in close proximity to (靠近) site of neurotransmitter release
Endocrine agent (hormone)	Target cells in distant places in the body
Paracrine agent	Target cells in close proximity to site of release of paracrine agent
Autocrine agent	**Autocrine agent acts on the same cell** that secreted the agent



Homeostatic control system – Effectors

Effectors

- Effectors are the organs/tissues that determine the regulated variable
  - Liver, Adipose tissue, Skeletal Muscle
    → Blood Glucose Level
  - Kidney, Blood Vessel
    → Blood Volume and osmolarity



Control mechanism -- Neural mechanism & [Endocrine / Neuroendocrine mechanisms]

- Neural Mechanism
  - Sensory cells send signal to the central nervous system (CNS) via afferent neural (sensory neurons)
  - CNS send signal to effector via efferent neural (motor neurons)
  - Signal Transmitted are in the form of:
    - Neurotransmitters
    - electrical signal (action potentials 電勢).
- Endocrine mechanism

Endocrine gland can act as both sensor and control centre.

  - Change in regulated variable → Stimulate endocrine gland → Secrete Hormones → Circulation
    - Through Circulation, hormone reach the target cells / tissues
- Neuroendocrine Mechanism
  - Endocrine Gland Receive signal from efferent neural pathway
    - Secrete Hormones → Circulation → Hormone Reach Target Cell/ Tissues

Neural Mechanism v.s. Endocrine/Neuroendocrine Mechanism

	Speed	Specificity	Duration of Action
Neural	Immediate response	Localized Effects	Usually very short
Endocrine Neuroendocrine	Slower than neural	Global Effect	Last Longer than neural

Negative Feedback Loop

- Homeostasis is driven by negative feedback loop.
  - A disturbance to the internal environment
    - → Effector acts to change the regulated variable towards normal levels
    - → **Eliminates the stimulus detected by the sensor** ⇒ Negative
  - It can reduce the variability of a regulated variable ⇒ Negative feedback loops are self-limited
- Some Example of Negative Feedback Loop:

Baroreceptors are activated when blood pressure rises. This causes them to fire action potentials more frequently along the afferent neural pathway to the medulla oblongata(延髓).

The medulla oblongata reduces the amount of action potentials sent via sympathetic nerve(交感神經), while promoting action potentials sent via parasympathetic nerve(副交感神经).

These together cause the heart to beat slower and contract with less force, decreasing blood pressure

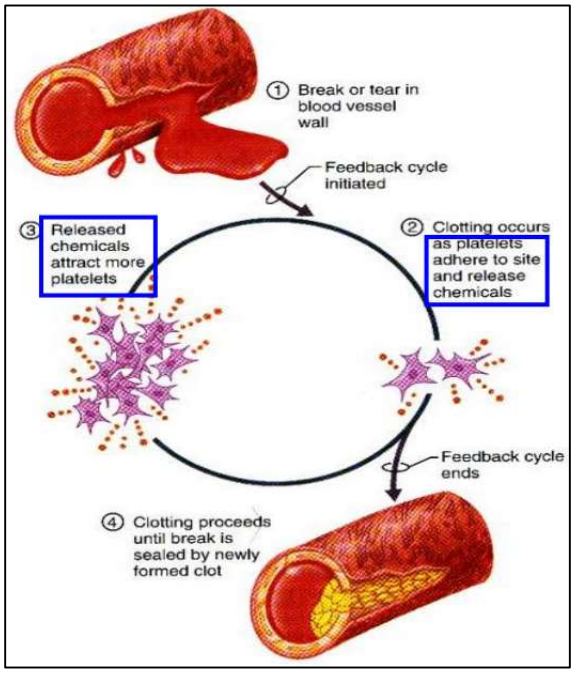
β -cells of pancreatic islet are activated when blood glucose level rises in fed state.

Then, the rate of glycolysis is increased by the increase in the concentration of glucose. As a result, $\frac{[ATP]}{[ADP][Pi]}$ is increased. At the same time, the secretion of insulin is also activated.

The insulin in the blood vessel → Liver / Adipose Tissue (脂肪) / Skeletal muscle increase the glucose uptake. Thus, the blood glucose level is then decreased and back to normal level.

Positive Feedback Loop

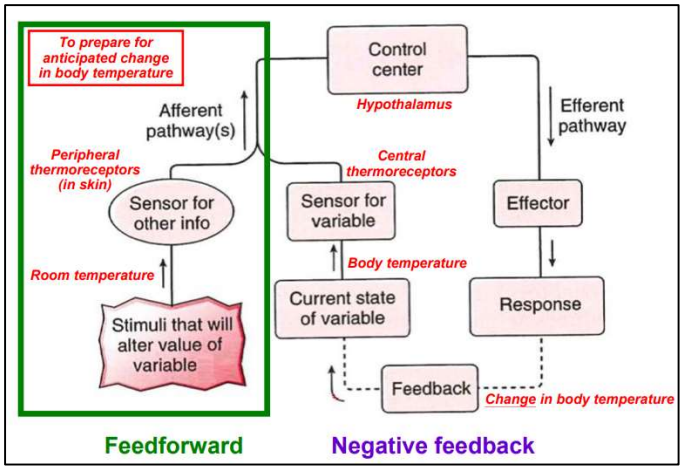
- Non-homeostatic physiological functions are driven by positive feedback loops
  - **Positive feedback loops amplify the input signal**
- Example:
  - Coagulation cascade (blood clotting – activation of clotting factors)



  - Childbirth – oxytocin induces uterine contraction
  - Generation of nerve impulses

Feedforward Control

- Variation of "other variable" directly compensates the anticipated (預計) changes in the controlled variable (independent of a sensor for the controlled variable)



Example: Blood potassium level Regulation

Dietary potassium is sensed by potassium sensors in the gastrointestinal tract in the absence of changes in plasma potassium → Sensor anticipates changes → prompt the system to act in advance

Circadian variation (昼夜节律) of physiological parameters

- Circadian rhythm follows a 24h light-dark cycle
  - Central nervous system receives input from eyes → influence various organ systems.
- Example:
  - Body Temperature
  - Plasma Growth Hormone
  - Plasma Cortisol
  - Urinary excretion of ions

Summary of Cell Summary

- All living things are composed of one or more cells.
- Cells are the basic unit of structure and function in an organism.
- Cells come only from other pre-existing cells (cell division)

Cell Diversity – Comparison of Prokaryotic Cell and Eukaryotic Cell

- Cell are difference in Size, Shape and Cellular Organization (Prokaryotes v.s. Eukaryotes)

Prokaryotes (原核生物-Must Asexual)

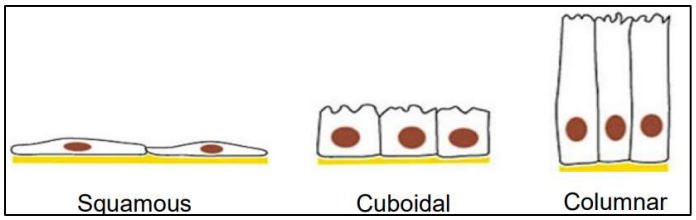
- Has Cell Wall
- Has Cell Membrane
- No Membrane-bounded organelles
- No Nucleus
- Only One DNA, circular DNA in Cytoplasm

Eukaryotes (真核生物)

- No Cell Wall in Animal Cell
- Has Cell Membrane
- Has Membrane-bounded organelles (e.g.: mitochondria)
- Has Nucleus
- More than one DNA, linear DNA in Nucleus

Cell Diversity – Cell Shape (Epithelial Cell As Example)

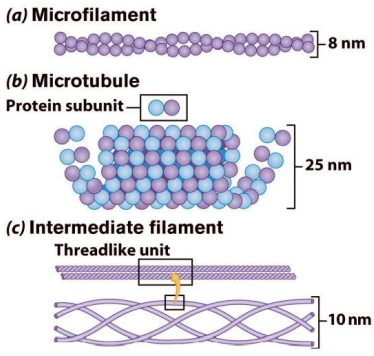
ᔓ Epithelial Cells:



Introduction to the structure of Eukaryotic Cell

All cells take in food, get rid of waste and reproduce.

ᔓ Cell Membrane: o Phospholipid bilayer with Protein o Semipermeable o Molecules within Cell Membrane are highly mobile	ᔓ Function of Cell Membrane: o Separates the cell interior from the env. o Controls molecules that enter or exit the cell. o Consist of Glycocalyx (carbohydrate moieties of membrane glycolipids & glycoproteins) → For Recognition& intercellular adhesion
ᔓ Cell Membrane Protein: o Receptors o Glycoprotein o Channel or Carrier Protein o Enzymes	ᔓ Function of Membrane Protein: o Recognize and interact with ligands to mediate downstream signaling o Markers for cell recognition o For Facilitated Diffusion & Active Transport o For intracellular catalytic reaction
ᔓ Cytoplasm: o Viscous Fluid that lies inside the cell o Constitute 50% of the total volume of cell	ᔓ Function of Cytoplasm: o Holds organelles o Provide a medium for chemical reaction
ᔓ Cytoskeleton: o Network of protein filaments extending throughout the cytoplasm.	ᔓ Function of Cytoplasm: o Provides a structural framework for the cell to maintain the shape of cell o Movement of the entire cell o Intracellular transport



ᔓ Microtubule
- It is **Hollow tubes built from tubulin**
- Transport of organelles and vesicles
- Act as Spindle fibers in mitosis

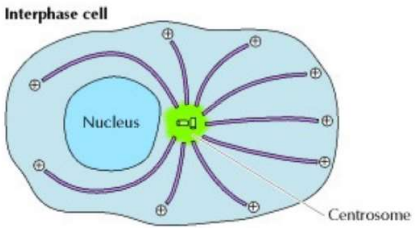
- Intermediate Filament (E.g.: Keratin)
  - Provide structural support for cells to withstand mechanical stress
- Microfilament (E.g.: Actin)
  - Mostly found in the periphery

Microvilli	Increase Surface Area for better diffusion
Stress Fibers	Cell Attachment
Filipodia and Lamellipodia	Cell Movement
Cleavage	For Cytokinesis

- Nucleus
  - The organelle to 'control' the cell
  - Bounded by nuclear envelope
    (2 phospholipid bilayers)
    (Outer membrane is continuous with ER)
    (Contains pores for material entry and exit)
  - Contain nucleolus
    (A cell may have 1 to 3 nucleoli)
    (Produce rRNA)

- Function of Nucleus
  - Storage Center of DNA
  - Ribosome Production (by producing rRNA)

- Centriole (Only Presence in Animal Cell)
  - Locates near nucleus
  - nine sets of triplet microtubules arranged in a ring
  - Exist in pair, at right angles to each other



- Function of Centriole:
  - Helps pulling the duplicated chromosomes to opposite ends of the dividing cell

- Ribosome:
  - Consist of two subunits, each comprised of both proteins and rRNA
  - Consist of two subunits (Large+Small), each comprised of both proteins and rRNA.
  - Free in cytoplasm or attached to rER

- Function of Ribosome:
  - Site of Synthesis of Protein

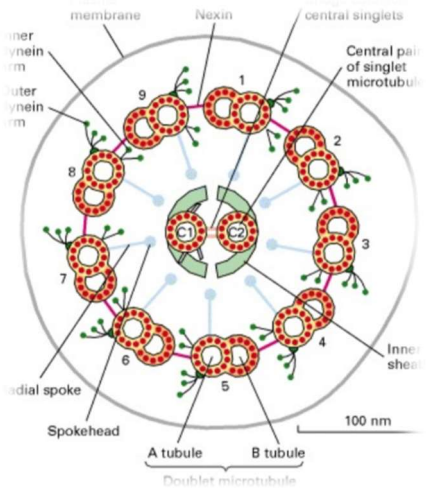
- Rough Endoplasmic Reticulum
  - A network of cisternae, continuous with outer membrane of nucleus
  - Presence of Ribosome
  - Connects to nuclear envelope
  - Abundant in cells that make lots of proteins

- Function of rER:
  - Site of Protein Synthesis
  - From Vesicles to transport protein
    (⇒ Cis-Face of Golgi Apparatus)

☙ Smooth Endoplasmic Reticulum ○ A network of cisternae – Ribosome-free (Membrane that from hollow tubes, flattened sheets and chambers)	☙ Function of SER: ○ Site for Carbohydrate and Protein Systhesis ○ Site of detoxification
☙ Golgi apparatus: ○ A Stack of Cisternae ○ Consist of Cis-Face & Trans-Face & Medial Cis: Receive Protein Trans: Ship Protein & Form Lysosomes Medial: Processing	☙ Function of Golgi Apparatus: ○ Modify, sort, package, and ship to other organelle or export out of the cell by receiving proteins from RER ○ Renew and modify plasma membrane
☙ Mitochondria: ○ Double Membrane ○ Active cells (e.g. muscle cells) have more mitochondria. ○ Contains its own DNA (mtDNA) and synthesis the mitochondrial ribosomes	☙ Function of Mitochondria: ○ Produce energy through Aerobic respiration (Matrix contains enzymes of the TCA Cycle to breakdown sugars to produce ATP) ○ Outer Membrane: Surrounds the organelle ○ Inner membrane: Folds into cristae → Increase surface area → Increase Production of ATP rate
☙ Lysosome: ○ single membrane-enclosed ○ contain enzymes, digests all types of biological polymers (Acid + Enzymes/Acid hydrolases)	☙ Function of Lysosome: ○ destruction of unwanted materials ○ degradation of endocytosed materials ○ destruction of old damaged organelles
☙ Peroxisome: ○ spherical organelles with single membrane	☙ Function of Peroxisome: ○ contains enzymes to break down fatty acid, uric acid, amino acid, hydrogen peroxide (toxic)

Special Organelle: Cilium & Flagellum

- Characteristic of Cilium & Flagellum:
  - Hair-like organelles on cell surface
  - 9 pairs of microtubules arranged around a central pair (2 Pairs of Mircotubules)



Flagella (E.g.: Sperm)	Long One / Few amount in the cell	Move the entire cell
Cilia (E.g.: Cell of Pharynx)	Short Numerous in Number Alone the entire surface of plasma membrane	Move substances along the outer surface of the cell Increase the surface area to facilitate the diffusion rate

Introduction to Membrane Proteins

- Different Type of Membrane Proteins

Integral Protein	Embedded in the membrane
Peripheral Proteins	Loosely bound to the inner or outer surface
Anchored Proteins	A Hydrophobic tail was inserted in the bilayer.

Membrane Permeability

- Phospholipid Bilayer is selectively permeable

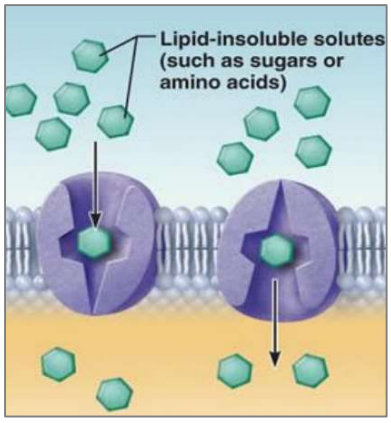
Can Directly Passing Through (Simple Diffusion)	Oxygen	Gas
	Carbon Dioxide	
	Nitrogen Monoxide	

Some can directly passing through (Facilitated Diffusion/Channel Protein)	Ethanal / Ethanol	Polar, Small, Uncharged Molecule
	Water	

Cannot Pass Through	Glucose	Polar, Large, Ion
	Ions	
	Polar, Large Molecule	

Facilitated Diffusion & Protein Carriers

- There is a carrier protein which specific for one chemical.
    - Example: Glucose



- Binding of this Chemical → Change Shape of the Carrier Protein → Release the Glucose → Restore the shape.
- There is no ATP involved in the facilitated diffusion.

Introduction to Osmosis

- Osmolarity: total concentration of solute particles in a solution
- Osmosis occurs when there is **<u>difference in concentration of a solvent (osmolarity)</u>**
    - Osmosis → Diffusion of water across a semi-permeable membrane

❗ Diffusion of water can be both Simple Diffusion / Facilitated Diffusion by Aquaporin (A kind of Channel Protein)

Introduction to Filtration

- Filtration: Passage of water & solutes through a membrane by **<u>hydrostatic pressure</u>**
    - Pressure gradient pushes **<u>solute-containing fluid</u>** from a higher-pressure area to a lower-pressure area

☼ Do notice that is different between Filtration and Osmosis.
- Movement of solute-containing fluid across the layers is involved in Filtration
- Only Movement of Water fluid across the membrane is involved in Osmosis

Introduction to Na-K Pump

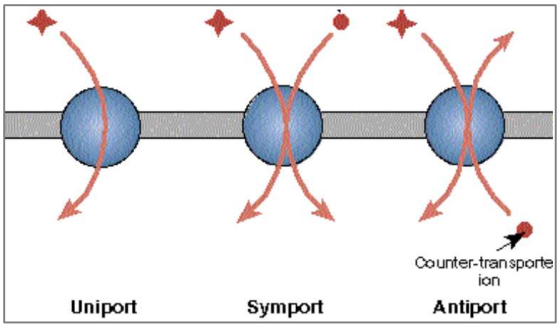
- The Sodium-Potassium Pump is the Active Transport.
    - Active Transport requires ATP

1. Binding of Na^+ in the ICF to the pump protein stimulates phosphorylation by ATP.
2. Phosphorylation causes the protein to change shape of pump
3. The shape change expels Na^+ to ECF and extracellular K^+ binds
4. K^+ binding triggers release of the phosphate group.
5. Loss of phosphate restores the original shape of the Na-K Pump.
6. K^+ is then release to ICF and Na^+ is ready to bind to Na-K Pump Again.

- 3 Na^+ in ICF ⇔ 2 K^+ in ECF
- Do notice that, Na-K Pump against the concentration gradient.
    - Conc. of Na^+ is higher in ECF
    - Conc. of K^+ is higher in ICF

Classification of Membrane Transport System

ᔓ Classify by the Transportation Direction



Uniport System	1 Substance is moved across a membrane.
Symport System	2 Substances are moved across the membrane in same direction.
Antiport System	2 Substances are moved across the membrane in opposite direction.

ᔓ Classify by the cause (Active Transport)

Primary Active Transport	Hydrolysis of ATP phosphorylates the transport protein causing conformational change (構象變化) ᔓ Direct Transport the Particles
Secondary Active Transport	Use of an exchange pump **indirectly** to **drive the other transport** of other solutes. ᔓ Indirect transport the Particles ᔓ For Example: o The Na^+ is expelled to ECF from ICF by Na^+-K^+ Pump o The Na^+ activate the Na^+-Glucose Symport Transporter without the presence of ATP o When Glucose is also bind to Na+-Glucose Symport Transporter, conformational change on symport transporter protein is caused o Thus, Glucose and Na^+ is released to ICF and the shape of symport transporter is restored

Introduction to Vesicular Transport

ᔓ Vesicular Transport = Transport of Large Particles & Macromolecules across membranes

Vesicular Transport	
Exocytosis	Move Substance in secretory vesicle from the **cell interior** to ECF
Endocytosis	Move Substance in (Large: Phagosome / Small: Membranous vesicle) to ICF ᔓ Phagocytosis ᔓ Pinocytosis
Receptor-mediated transport	uses clathrin-coated pits as the major mechanism for specific uptake of macromolecule.