Introduction to Biochemistry

Anatomy of an atom:
An atom has a nucleus (with neutrons, protons) and electrons

Electronegativity of an atom:
Electronegativity is a measure of an atom's attraction for electrons in a bond.

Hydrogen Bond:
Electropositive hydrogen partially shared with two electronegative atoms

Hydrophobic forces:
pushing nonpolar surfaces out of hydrogen-bonded water network

Atomic composition of four building-block elements:

Carbon	☙ Form backbones of organic molecules ☙ Can form four bonds with other atoms
Nitrogen	☙ Component of all proteins and nucleic acids
Oxygen	☙ For Cellular respiration ☙ Found in most organic compound ❖ Food (Be more specific: Glucose)
Hydrogen	☙ Presence in all organic compounds ☙ For acid-base balance

These four elements that make up the human body.

Some Elements / Ion our human body

Na	☙ Major cation in tissue fluid → Vital for **fluid balance** ☙ Vital for **conduction of nerve impulses**
Mg	☙ **Needed in Blood** ☙ Needed in other body tissue ☙ Vital as a **co-enzyme**
P	☙ Part of **nucleic acids** ☙ **Structural part of Bone and Cell walls** ☙ Vital in **energy transfer**
S	☙ Part of **Most proteins** ☙ **Activation of Enzymes**
Cl	☙ Major anion in tissue fluid ☙ **Vital for fluid balance** ☙ Part of NaCl and **gastric juice**
K	☙ Vital in **nerve function** ☙ Affect **muscle contraction** ☙ Fluid and Electrolyte Balance

Ca	☙ Structural Component of Bones and Teeth ☙ Acid-base balance ☙ **Muscle Contraction** ☙ **Nerve Impulse** ☙ **Blood Clotting**
F	☙ **Incorporated into the tooth enamel & bone structure**
Cr	☙ **Maintain blood sugar level /** (Insulin)
Mn	☙ It is a co-factor for enzymes → found in liver, kidney and mitochondria ☙ **maturation of red blood cells**
Zn	☙ needed in saliva for the taste buds ☙ vital for growth → sexual development ☙ Vital in protein synthesis and cell division
I	☙ Part of thyroid hormones

Although those elements are less common in our body, they are essential for body functions and metabolisms

Major feature of Chemical Reaction:

☙ Energy is conserved by first law of **Thermodynamic**
- Energy cannot be created or destroyed → Total Energy of a system and its surroundings is constant
- For any cyclic reaction is no net change in the reaction

Some Example of Important Reaction:

- First reaction in glycolysis is a coupled reaction to ATP conversion to ADP.
  - ✧ Glucose → Glucose-6-phosphate, at the same time ATP is converted into ADP + Phosphate Group

Some Example of Hydrolysis reaction:

- Proteins/Polypeptide are hydrolyzed to amino acids
- Fats are hydrolyzed to fatty acids and glycerol
- Starch and complex sugars (glycogen) are hydrolyzed to simple sugar (glucose/galactose)
- Anions of weak acids dissolve in water to give basic solution.

$$CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$$

☙ Kinetic of a reaction = Rate of the reaction
- Enzymes/Catalyst can change the rate of the reactions → Speed up reaction
  - For Positive Enzymes/Catalyst: It can lower the activation energy of the reaction

☙ Classification of Chemical Reaction:
- By Type of reactants:
  - Redox reaction
  - Acid-base reaction
    - **The Bronsted-Lowry theory**: *An acid is defined as a proton donor and a base as a proton acceptor*
    - The Arrhenius theory
    - The Lewis theory
- By the reaction outcome:
  - Condensation → Water is formed during combination of the reactants
    - Combining 2 molecules (either the same or different) with the elimination of a stable small molecule
  - Hydrolysis → Water is used to break the bond

Introduction to Water:

- The two hydrogen atoms each share a pair of electrons with the oxygen by covalent bonding
  - Uneven distribution of electron density → Water is polar

Oxygen atom in water molecule	Partial negative charge
Hydrogen atom in water molecule	Partial positive charge

  - Hence, the partial positive charge Hydrogen can be attracted by the neighboring partial negative charge oxygen atom. → Hydrogen Bond is formed due to the electrostatic attraction
- When dissolving a solute (e.g: NaCl) into water:
  - Hydration shells surrounding anions and cation
    - Na^+ and Cl^- are hydrated
- When dissolving a solute (e.g: Alcohol) into water:
  - Alcohol form hydrogen bond with the water molecule.
- Unique Physical Properties of water is due to the hydrogen bonding:
  - High heat of vaporization / Specific Heat
  - Strong Surface tension
  - A near universal solvent
  - Hydrophobic effect
  - Ionization of water, pH = pOH = 7
- Important information of solution and solute:
  - A liquid mixture in which minor solute is uniformly distributed within the solvent.
- Important information of suspension:
  - Particles are dispersed throughout the bulk of a fluid.
    - Example: Blood

Building Blocks of Life:

Lipid	Sugar	Nucleic Acid	Proteins

Introduction to Lipids:

Common Type of Lipids:

Triglyceride → Fatty Acid and Glycerol	■ For long term storage (Fuel Molecule) ■ For Making Cholesterol
Phosphoacylglycerols	■ cell membrane (Phospholipids)
Sphingolipids	■ Enriched in the Central Nervous System (CNS) ■ Tissue development ■ Cell recognition ■ Adhesion (黏附) ■ Act as receptors for toxins
Steroid (a cyclical chemical)	■ Energy metabolism ■ Reproduction ■ Homeostasis

Difference between Oil and Lipid:

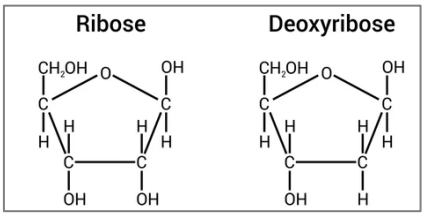
Fat	■ Saturated or fewer double bond ■ Fewer cis structure [No Trans structure] → High MP
Lipidc	■ A large number of double bond → Unsaturated ■ A large number of cis structure → Low MP

Introduction to Phospholipids

$$\text{Phospholipids} = \text{Phosphorus} + 2\text{Fatty Acids} + \text{Alcohol} + \text{Glycerol}$$

Introduction to Sugar (Monosaccharides and Disaccharides):

- Definition of Monosaccharides:
  - Monosaccharides, which cannot be hydrolyzed to simpler compounds, generally have three to six carbons with a carbonyl group at either the terminal carbon or the carbon adjacent to it. Generally, all other carbons have OH groups bonded to them
- More about Monosaccharides:



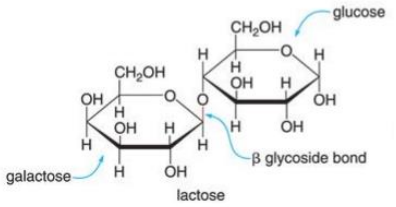
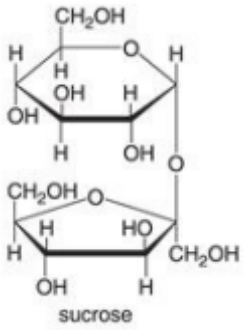
  - Triose = Monosaccharides has 3 Carbons:
    - *L-glyceraldehyde* and *D-glyceraldehyde*, and *dihydroxyacetone*,
  - Tetrose = Monosaccharides has 4 Carbons:
    - *D-Erythrose*, *D-Threose* and *D-Erythrulose*
  - Pentose = Monosaccharides has 5 Carbons:
    - ***Ribose*** (a Petose/核糖) is a constituent of RNA.
  - Hexoses = Monosaccharides had 6 Carbons:
    - Hexoses acts as building blocks of other compounds such as starch.

$$2\ \text{Monosaccharides} \rightarrow \text{Disaccharides} + H_2O\ \ (\text{Linkage is } \mathbf{Glycosidic\ Bond})$$
$$3 \text{ or more Monosaccharides} \rightarrow \text{Polysaccharides}$$

    - Hexoses can form dihexose (like sucrose) by a condensation reaction that makes **1,6-glycosidic bond**.
- Common Example of Monosaccharides:

D-Glucose	D-Galactose	D-Fructose

- Common Example of Disaccharides:

Lactose	Galactose Ring + Glucose Ring Lactose is not appreciably sweet 2 six-membered Ring Joined by 1→4-β-glycosidic bond	
Sucrose	The Disaccharide found in sugarcane Most common in nature One Six-membered and one five membered rings Bonded by 1,6-glycosidic bond	

Introduction to Sugar (Polysaccharides):

- Glycogen:
  - A polymer of glucose containing α-glycosidic bonds
  - As a storage of energy in Liver and Muscle
  - Has an **extensive branched structure**
    - Glucose units are hydrolyzed from the ends of glycogen → Metabolism → Energy
- Cellulose / As a Digestive Fiber for human:
  - Provide Support and rigidity to wood, plant stems and grass
  - Unbranched Polymer (repeating glucose by 1→4-β-glycosidic linkage)
  - Cannot be digested by human
- Amylose / A type of Starch:
  - Has an unbranched skeleton of glucose molecules with 1→4-α-glycoside bonds
  - Numerous of OH groups ⇒ leading to greater water solubility than cellulose.
- Amylopectin / A type of Starch
  - Similar to Amylose
  - Contains Branching along the chain.

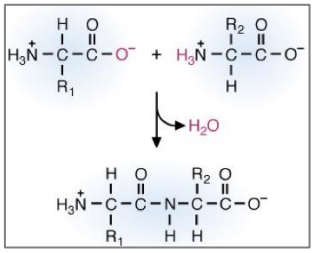
$$\text{Amylose/Amylopectin} + H_2O \rightarrow \text{Glucose (Catalyzed by Amylase)}$$

Introduction to Protein:

General Structure of Amino Acid & Peptide Bond

$$\text{Amino Group} + \text{Carboxyl Group} \rightarrow \text{Amino Acid}$$

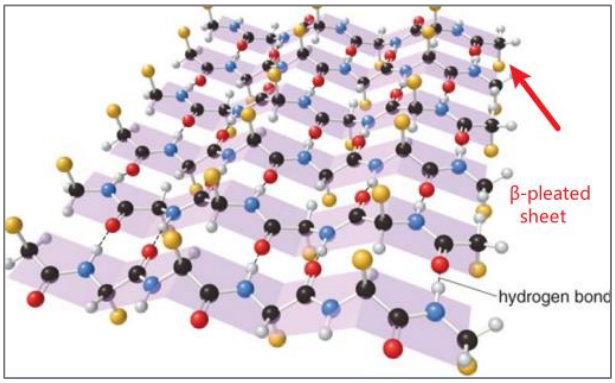
- Do Notice that: One end is COO^- and one end is $R - NH_3^+$
  - By Condensation: A water is removed, and Peptide bond is formed. (Whole compound is neutral.)

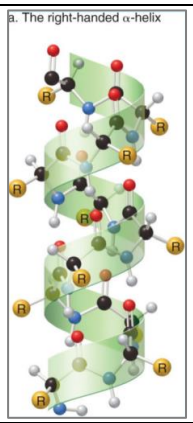


Primary structure of Proteins – Only one poly peptide chain

- Definition:
  - Particular sequence of amino acids that is joined together by peptide bond
- Focus on the structure of Amide Bond

Secondary Structure Proteins – 2 Polypeptide Chains

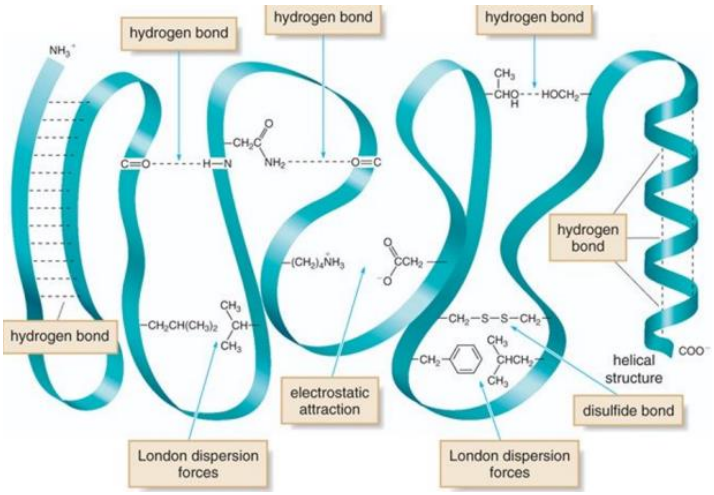




- **α-helix and β-pleated sheet**
- Focus on the NH Bond and CO Double Bond
- The Secondary Structure of Proteins is **formed by the hydrogen bond.**

Tertiary Structure of Proteins – 3 Polypeptide Chains

- Many kinds of intramolecular forces that stabilize polypeptide chains.
  - Including: London Dispersion Forces (Van de Waal's force)



Example:

- Amino acids that contain hydroxyl (OH) and amino groups (NH2) in their side chains ⇒ Hydrogen Bond
- Nonpolar C-C and C-H bonds are stabilized by VDW.

Quaternary Structure of Proteins - More than 3 Polypeptide Chains

- The shape adopted when two or more folded polypeptide chains come together into one protein complex.

n Polypepetide Chains (Subunit) → Quanternary Protein

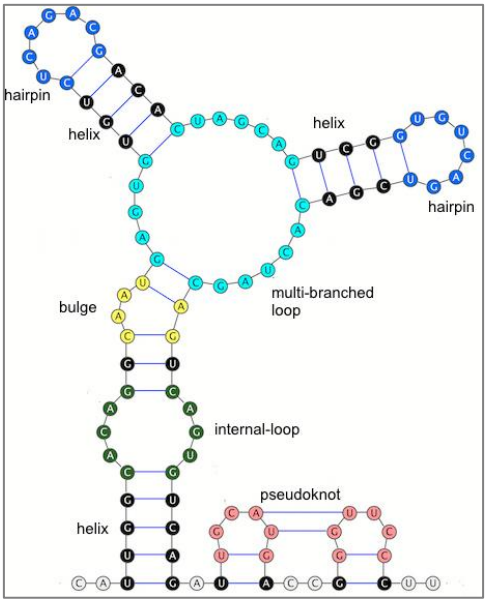
Example: Hemoglobin

Introduction to Protein Complex (Quaternary Structure of Proteins):

Globular	- Coiled into compact shapes - The surface is hydrophilic - Enzymes and Transport Proteins are in this shape - Thus, soluble in blood
Fibrous	- Long, Linear, Compacted Polypeptide Chain - Rod / Sheet Shape - Insoluble in Water - Provide Strength and Protection to tissue or cells

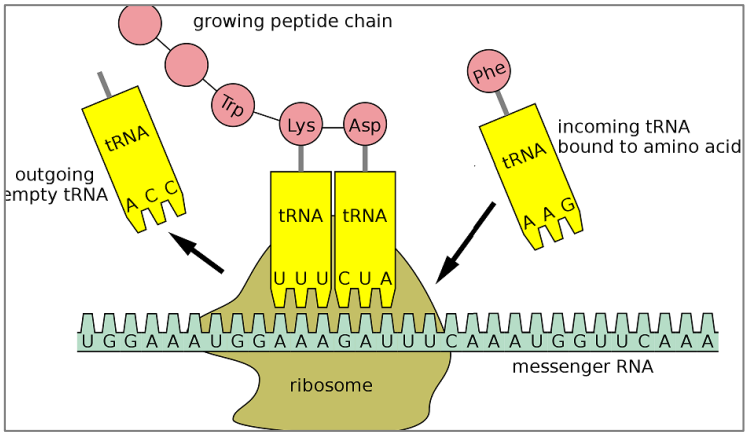
Introduction to RNA (Nucleic Acid):

- Single Strands → Less stable than DNA
- RNA can form secondary structure
  - Hairpin Loops
  - 3D Structure



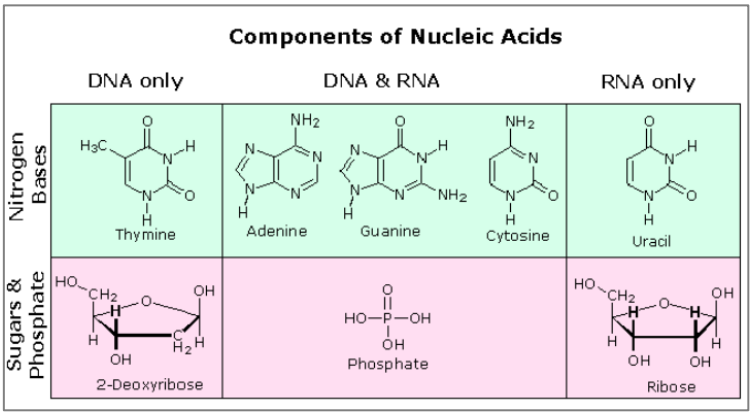
Some common type of RNA:

mRNA (Messager RNA)	★Corresponds to the genetic sequence of a gene ★Read by a ribosome (rRNA) ⇒ synthesizing a protein.
rRNA (Ribosomal RNA)	★Non-coding RNA ⇒ Carries out protein synthesis in ribosomes ★Essential to all cells
tRNA (Transfer RNA)	★Carry an amino acid to ribosome

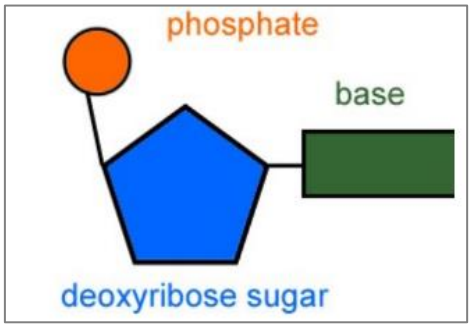


Nucleic Acid – Introduction to Nucleoids and DNA:

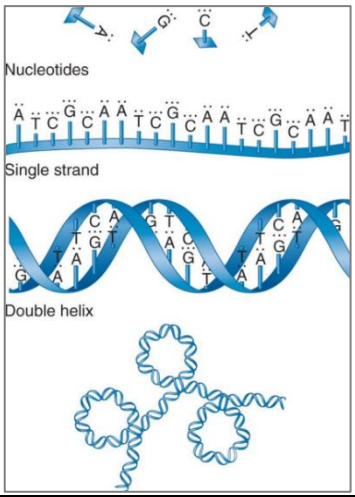
- Component of Nucleic Acid



- Basic Structure of Nucleotides in DNA



- The Bases of Nucleotides:
  - A = adenine
  - G = guanine
  - C = cytosine
  - T = thymine (Only Presence in DNA)
  - U = uracil (Only Presence in RNA)
- Introduction to the relationship between the Nucleoids and the DNA/RNA
  - Nucleotides (monomer) ⇒ linked in linear manner ⇒ a strand of DNA / RNA
  - Two strands of DNA/RNA ⇒ A double helix structure
  - DNA would always interact with another strand of DNA to form double helix.
  - RNA may not interact with another strand to from double helix structure.
- The Complementary base Pairing of DNA / RNA
  - For DNA: A-T, C-G.
    Adenosine must pair with thymine (Paired/Bonded by 2 Hydrogen Bonds)
    Cytosine must pair with guanine (Paired/Bonded by 3 Hydrogen Bonds)
  - For RNA: A-U, C-G
    Adenosine must pair with Uracil
    Cytosine must pair with guanine



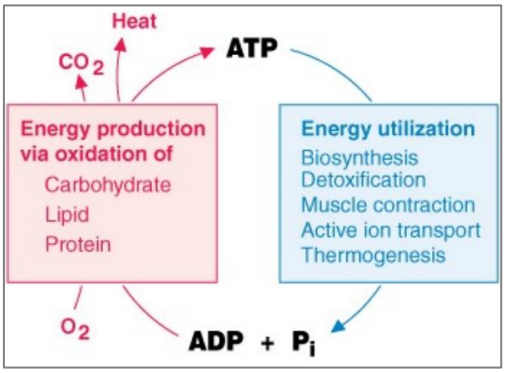
Major Classes of dietary fuels:

Major Fuels from food:

Carbohydrate	Proteins	Fats

oxidation of these fuels to CO_2 and H_2O → Heat + ATP (*adenosine triphosphate*)

How ATP is used:



The energy - generating pathways are shown in red;
The energy -utilizing pathways in blue

Different Forms of Body Fuel Stores:

Fats	☙ Major Fuel Store ☙ Store in Adipose tissues ☙ Accumulate in hips, thighs and abdomens
Carbohydrates	☙ Smaller fuel stores ☙ Stores as Glycogen in liver and muscles
Proteins	☙ From Large muscle masses in particular ☙ Used when we are fasting

Introduction to metabolism:

Metabolism = all chemical reactions involved in maintaining the living state of the cells and the organism.

There are two type of metabolism: **Catabolism** and **Anabolism**

- ☙ Catabolism
  - ■ To break down molecules
- ☙ Anabolism
  - ■ To build up molecules from building blocks

BMSN1601 – 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 **<u>significant short-term regulation</u>**, in other word, t cannot $\rightarrow 0$
* η, l and not subject to **<u>significant regulation</u>** by body, where t cannot $\rightarrow 0$

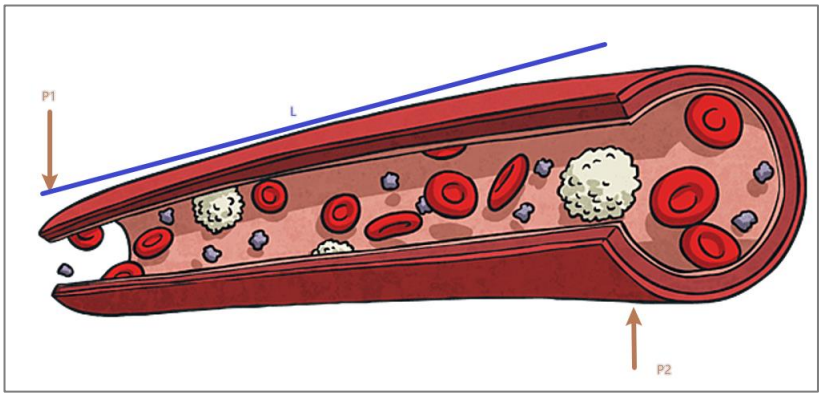
$$Q = \frac{\Delta P}{R} = \frac{\Delta P \pi r^4}{8\eta l}$$

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

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

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

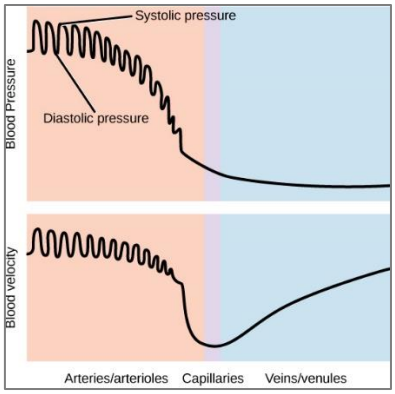
- Do notice that the Blood Pressure decrease over the time
  - From Aorta to Venae Cava
- There is no change in the radius of blood vessel within the length L
- Smaller the radius, Larger the Resistance, Smaller the speed.
  - Do compare this relationship with the above formula $v = \frac{Q}{A}$, where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

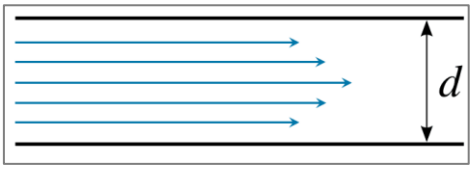
We have $v = \frac{Q}{A} = \frac{Q}{\pi r^2}$, Larger the radius, Lower the Velocity of Fluid.

- Do notice that the ΔP in each region of Arterioles, Capillaries and veins/venules **are not significant.**
- However, it is far apart from the heart, **the resistance cannot be cancelled by the work done by heart**.
  - The Resistance is significant & Lots of Branches
    → Thus, the **Q is not constant** and **Q-v formula cannot be applied.**
- 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
  - **Smaller the Radius, Lower the Velocity of Fluid.**
- Region Venules (小靜脈) ,Veins (靜脈) ,Venae Cava (大靜脈)
  - **Larger the Radius, Higher the Velocity of Fluid.**
  - 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

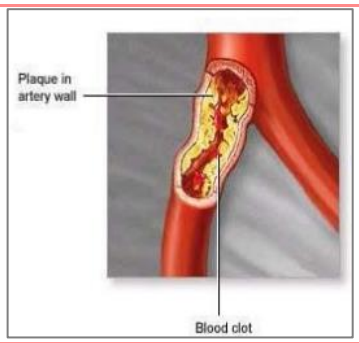
Laminar Flow

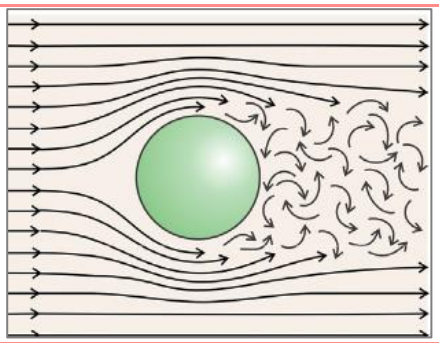


- Requirement:
  - Fluid flows in layers parallel to vessel wall
  - Without disruption between layers
- #Characteristic:
  - **<u>The layer of fluid in contact with the wall has lower velocity</u>**
  - **<u>The layer of fluid that moves along the axis of the tube has maximal velocity</u>**

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

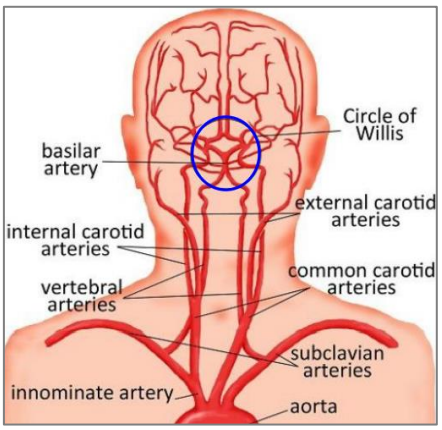
Problematic: Turbulent flow





- 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

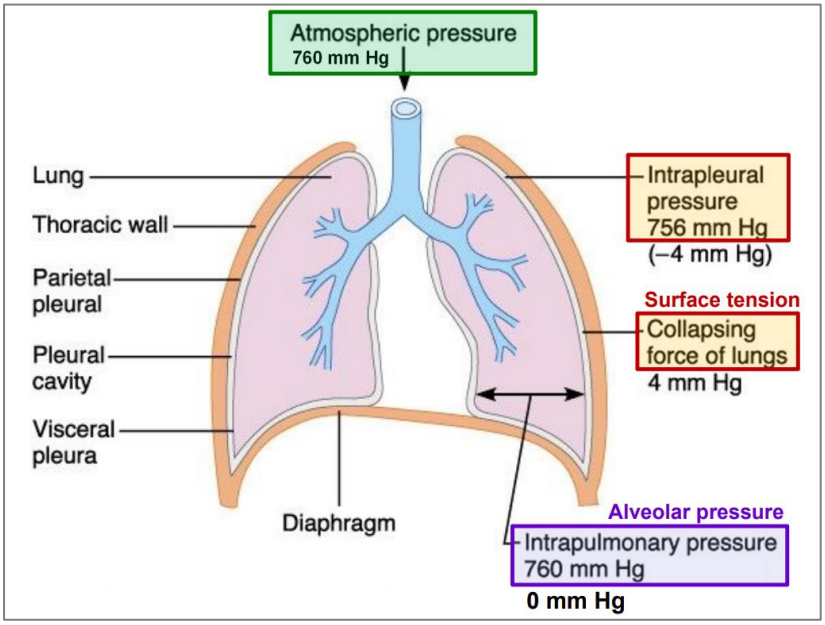
☙ Expiration (exhalation)
- ☋ Gases exit the lungs

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

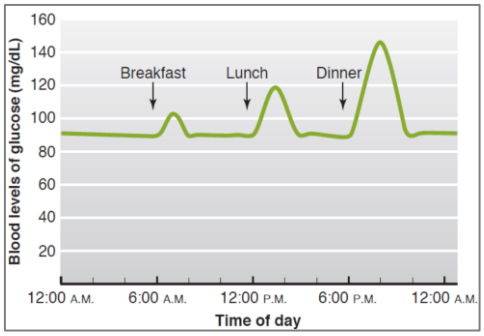
Detailed Summary of Function of Organ System

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

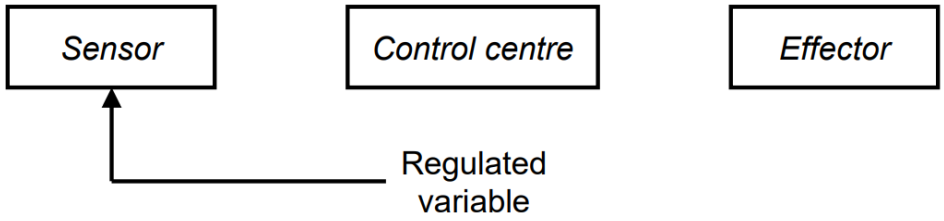
Homeostatic control system - Sensors

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



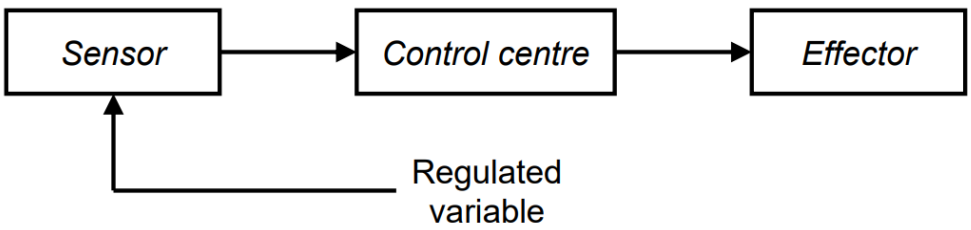
Homeostatic control system – Control Center

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)

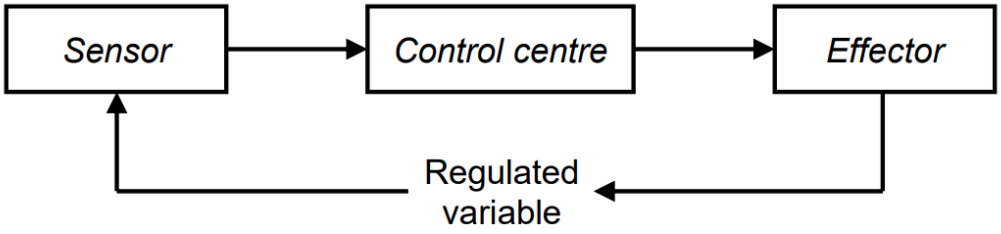
Common Type of Chemical Signals	
Neurotransmitter	Neuron or effector cell in close proximity to (靠近) site of neurotransmitter release
Endocrine agent (hormone)	Target cells in distant places in the body
Paracrine agent	Target cells in close proximity to site of release of paracrine agent
Autocrine agent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

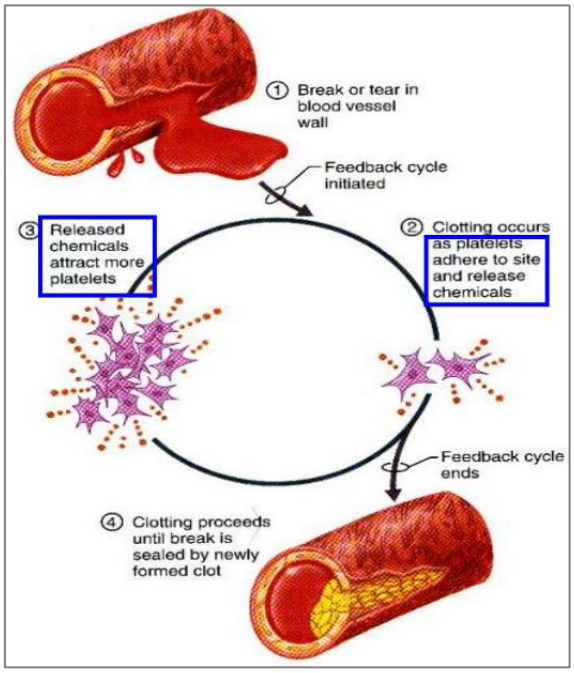
β -cells of pancreatic islet are activated when blood glucose level rises in fed state.

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

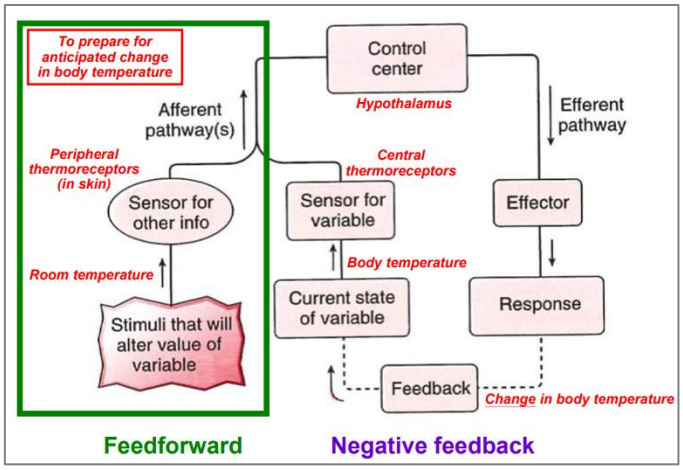
- Non-homeostatic physiological functions are driven by positive feedback loops
  - **Positive feedback loops amplify the input signal**
- Example:
  - Coagulation cascade (blood clotting – activation of clotting factors)



  - 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)

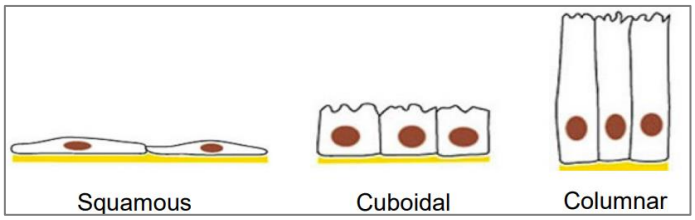
- Has Cell Wall
- Has Cell Membrane
- No Membrane-bounded organelles
- No Nucleus
- Only One DNA, circular DNA in Cytoplasm

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)

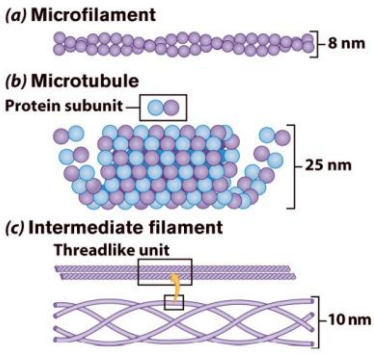
ᔓ Epithelial Cells:



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

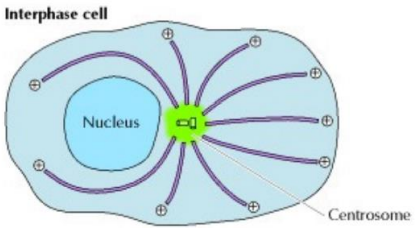
- Intermediate Filament (E.g.: Keratin)
  - Provide structural support for cells to withstand mechanical stress
- Microfilament (E.g.: Actin)
  - Mostly found in the periphery

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

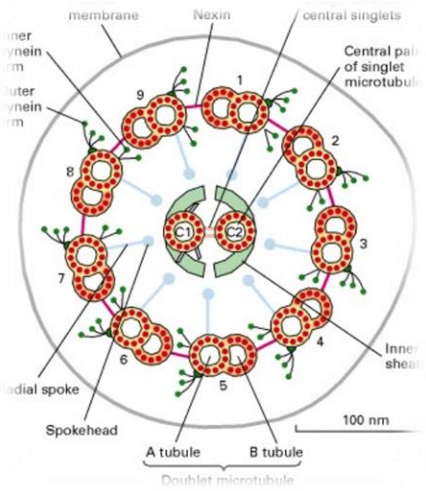
- Rough Endoplasmic Reticulum
  - A network of cisternae, continuous with outer membrane of nucleus
  - Presence of Ribosome
  - Connects to nuclear envelope
  - Abundant in cells that make lots of proteins

- 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

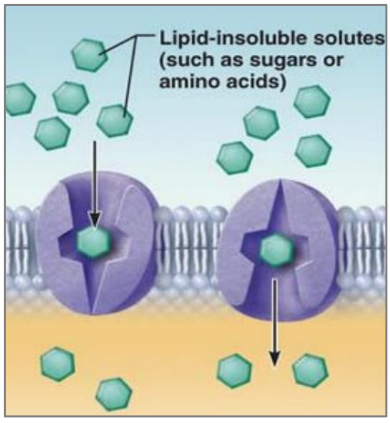
Can Directly Passing Through (Simple Diffusion)	Oxygen	Gas
	Carbon Dioxide	
	Nitrogen Monoxide	

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

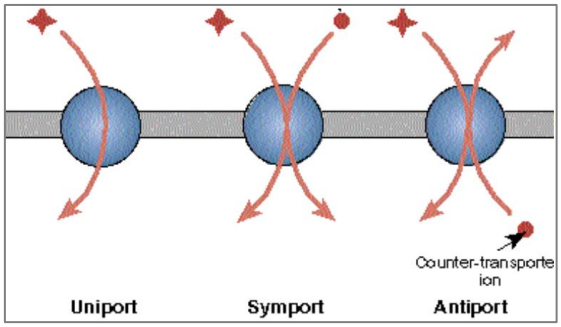
- The Sodium-Potassium Pump is the Active Transport.
    - Active Transport requires ATP

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



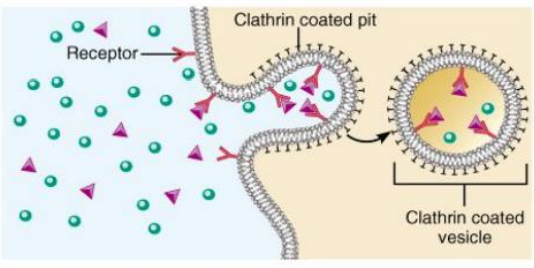
Uniport System	1 Substance is moved across a membrane.
Symport System	2 Substances are moved across the membrane in same direction.
Antiport System	2 Substances are moved across the membrane in opposite direction.

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: ○ The Na^+ is expelled to ECF from ICF by Na^+-K^+ Pump ○ The Na^+ activate the Na^+-Glucose Symport Transporter without the presence of ATP ○ When Glucose is also bind to Na+-Glucose Symport Transporter, conformational change on symport transporter protein is caused ○ 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. 

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Characteristic of an organism

Made of Cell	Growth and Development	Metabolism
Regulation (Maintain Homeostasis)	Reproduction	Responsiveness & Adaption

Definition of Anatomy & Physiology

- Anatomy is study of body structure, including the location, tissue types and associated structure

Surface Anatomy	Regional Anatomy	Systemic Anatomy
Cytology (Study of Cell)	Histology (Study of Tissue)	Radiographic anatomy (X-Ray)

- Physiology is study of body function, including the individual and cooperative functions of anatomical structure.

Composition of Cells

- 3 Main Parts: Cell Membrane, Cytoplasm with organelles, Nucleus

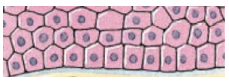
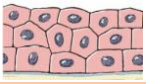
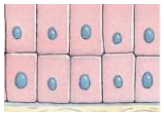
Water	> 70% of the cell mass
Organic Molecule	> 90% of the dry weight of cell
Inorganic Ion Presence in Water/Plasma	< 1% of the cell mass

Introduction of Primary Tissue – Epithelial Tissue

- Epithelial Tissue – (Specializations: Ciliated & Microvilli)

Covering epithelia	Cover Internal & External Surface
Glandular epithelia	Make & Secrete Substance

  - Function:
    - Protection – Skin, Lining of Internal Organs
    - Absorption – Intestines, Skin
    - Filtration – Kidney
    - Sensation – Sensors @ Skin
    - Secretion – Hormones, Mucus, Sweat @ Skin
  - Location of Epithelial Tissue

Simple Squamous	Blood vessel, Air sacs	
Simple Cuboidal	Lines Kidney tubules, Glands	
Simple Columnar (Absorb, Mucus)	Lines most Digestive Organs	
Stratified Squamous	Outer layer of Skin, Mouth, Vagina	
Stratified Cuboidal (Secrete water/ion)	Sweat glands ducts	
Stratified Columnar (Secrete Mucus)	Epididymus, Mammary Glands, Larynx	

  - Characteristic:

Cells fit closely together	Polarity: apical and basal surfaces	Regenerate easily

Avascular (無血管) but has rich nerve supply	Attach via basal lamina to underlying connective tissue	The lateral surface is bound to other epithelial cells

Introduction of Primary Tissue – Connective Tissue

- Structure of Connective Tissue: Cells in Matrix / Vascularized (except cartilage) / Nerve Supply
- As a most abundant tissue in the Body

Adipose tissue	- loose connective tissue with adipocytes (fat cells) - matrix: gelatinous - stores fat (energy) - Insulation
Cartilage	- matrix is rigid, non-vascular - Presence with Chondrocyte (軟骨細胞) - Protects ends of long bones
Osseous tissue (bone)	- Hard tissue (Calcified Matrix) - Presence with Osteocyte, Osteoblast - Metabolically active

Ligament, tendon	- Matrix: dense, regular arrangement of tightly packed protein fibers
	  - Collagen (膠原)
	- Presence with fibroblast
	  - a cell in connective tissue which produces collagen and other fibers.

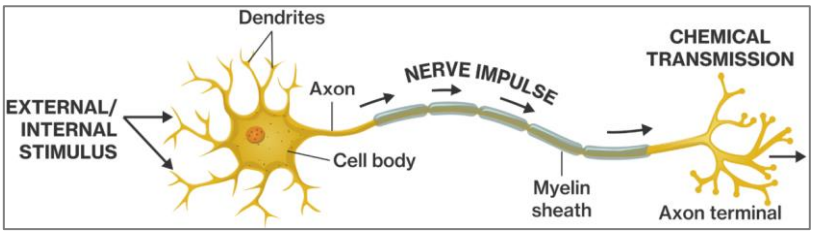
Blood	- Fluid matrix: plasma - Presence with red blood cell, white blood cell and platelet (血小板) - Transports substances throughout the body

Introduction of Primary Tissue – Muscle Tissue

- Excitable, responds to stimulation → Contracts and relaxes to support movement

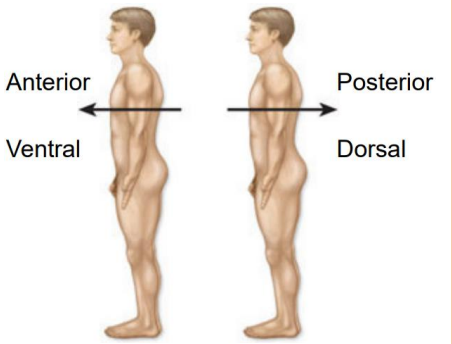
Skeletal Muscle	Smooth Muscle	Cardiac Muscle

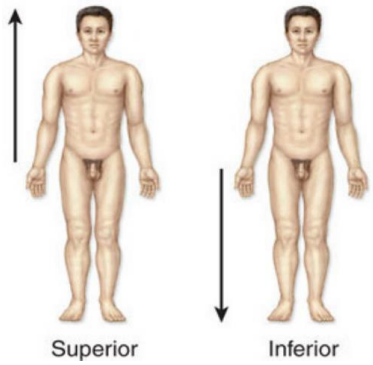
Introduction of Primary Tissue – Nervous Tissue @ Brain, Spinal Cord, Nerves

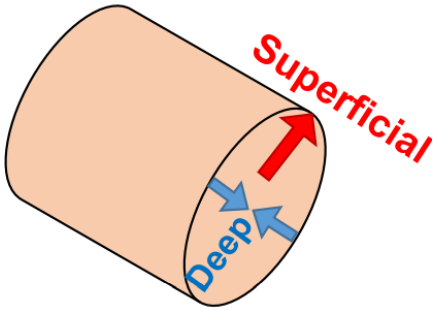


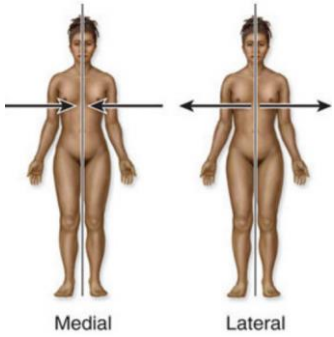
- Excitable
- Transmits and processes information between brain and other part of body
- Controls movement, reflexes, and receives sensory information

Directional terms of Anatomy

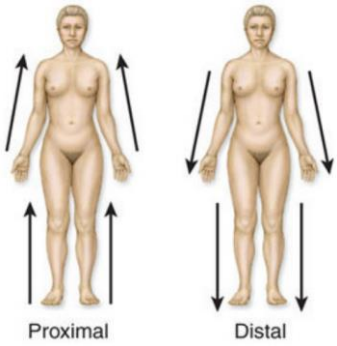






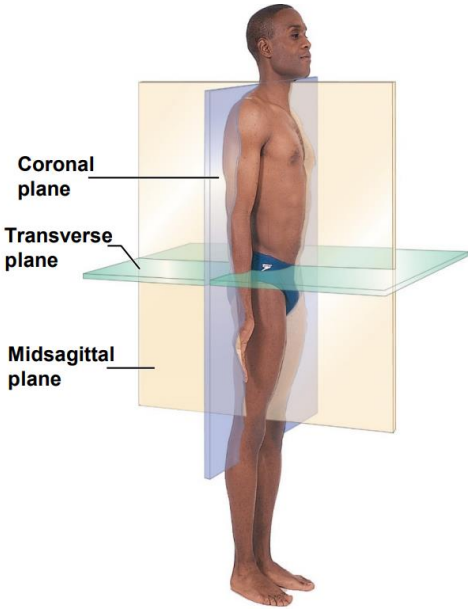


(Medial: Toward the Central Axis)
(Lateral: Away from the Central Axis)

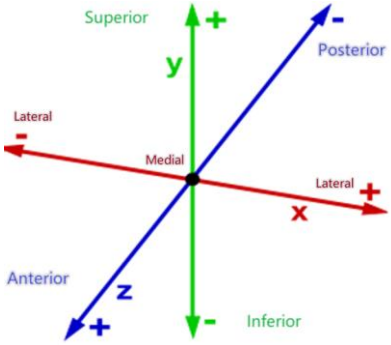


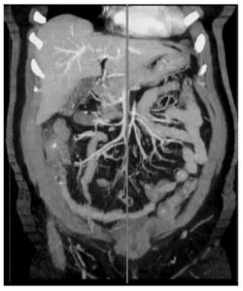
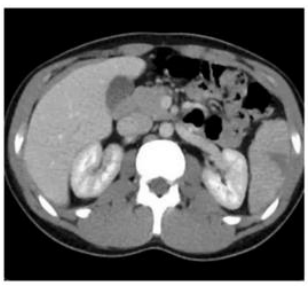
(Proximal: Toward the Joint)
(Distal: Away from Joint)

Body Planes



- Coronal (frontal) plane → Anterior and Posterior
- Transverse (horizontal) plane → Superior and Inferior
- Mid-sagittal (median) plane → (Equal left and right halves)
- Sagittal Plane → (Unequal left and right parts)

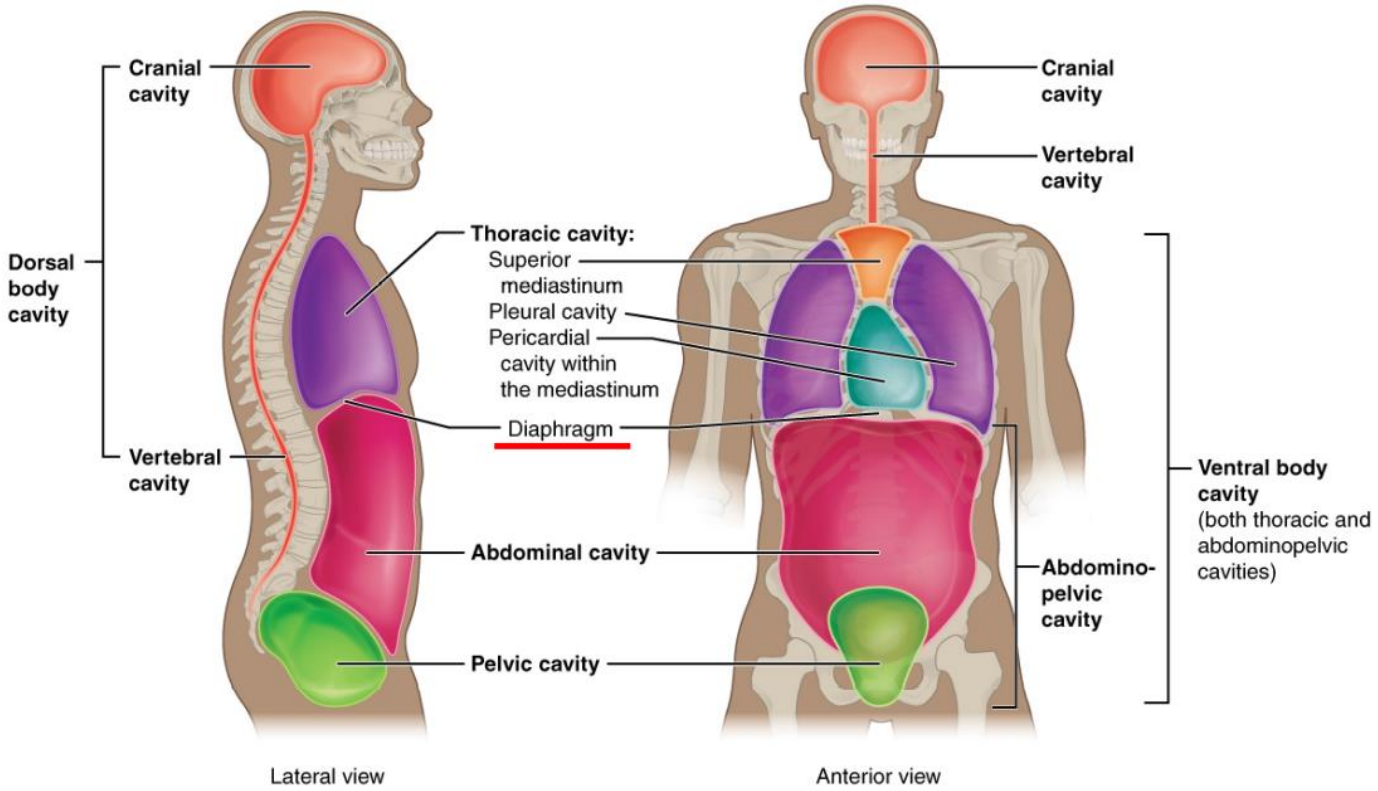


		
Sagittal	Coronal	Transverse

Body Cavity

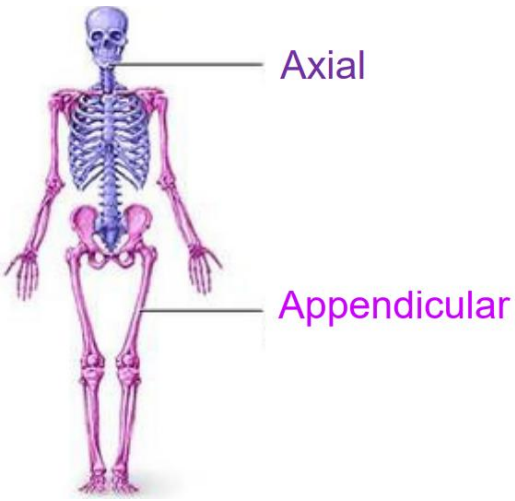
Contain and protect delicate internal organs		
Dorsal (posterior) cavity	Cranial	Brain formed by skull bones
	Vertebral	Spinal cord formed by vertebral column bones

Allows changes in size & shape of organs during their functions		
Ventral (anterior) cavity	Thoracic	Lungs, heart, esophagus and trachea
	Abdominopelvic	Organs of digestion, liver, bladder and internal reproductive organ (Largest)



Regional anatomy

- Axial
  - Head
  - Neck
  - Trunk
- Appendicular
  - Upper Limbs (上四肢)
  - Lower Limbs (下四肢)



Introduction to Circulatory System

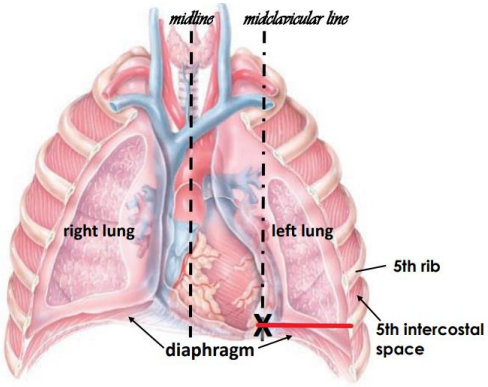
- The circulatory system transports fluids throughout the body.
  - Cardiovascular system (Blood Transportation Network)
    - → **Generates and regulates blood pressure**
    - → Pumps the blood through both pulmonary and systemic circuits

Pulmonary circuit: Carries deoxygenated blood from the heart to the lungs for gas exchange and returns oxygenated blood to the heart **To the Lung**
Systemic Circuit: Carries oxygenated blood from the heart to supply the whole body (including the lungs and the heart themselves) and returns deoxygenated blood back to the heart **Supply Necessity**

  - Lymphatic system (Lymph Transportation Network)
    - → **Maintain Fluid Balance** ⇒ Recover the fluid lost from blood capillaries
    - → **Body Defense** ⇒ Guard against Pathogens
    - → **Fat absorption via intestinal lacteals ⇒ Chyle** (lymph + lipids) is absorbed

Organization of Cardiovascular System

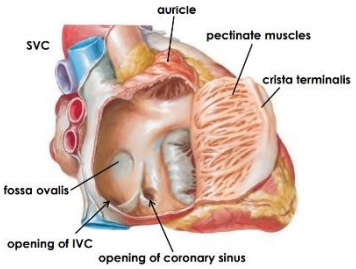
- Shape of the Heart
  - Tilted and inverted pyramid, pointing toward inferior left
  - The apex of the heart is the inferior blunt tip, sit on the diaphragm
  - The base of the heart is the broad superior portion facing the thoracic vertebrae, made up of right and left atrium
- Location of the Heart



  - In the mediastinum
  - Superior to the diaphragm
  - Posterior and to the left of the sternum (胸骨)
  - Apex locates at the left midclavicular line of the 5th intercostal space
- Cardiac Muscle & Coronary Circulation
  - Coronary arteries supply blood to the heart muscle.
    - Right & Left coronary artery
  - Cardiac veins collect and return blood to the right atrium through the coronary sinus
    - Great & Middle & Small cardiac vein
- Conducting System of Heart
  - Specialized cardiac conducting cells (e.g: sinoatrial node) initiate and conduct the electrical signals locally, ensure that the four heart chambers are coordinated with each other.
- Innervation (精神支配) of the Heart
  - The heart is supplied by cardiac plexus (神經) formed of sympathetic and parasympathetic fibers, part of the autonomic nervous system
  - Sympathetic stimulation: **Increase heart rate** & **Dilation of coronary arteries**
  - Parasympathetic stimulation: **Decrease heart rate** & **Constriction of coronary arteries**

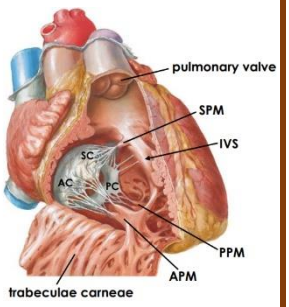
ᘓ Anatomy of the Heart

1. Heart Wall
   - Epicardium (visceral layer of serous pericardium): contains coronary vessels
     - As Lubrication
   - Myocardium: thickest layer, formed by cardiac muscle cells
   - Endocardium: lines the chambers of the heart by **a layer of simple epithelium**
2. Heart chambers
   - Two Atria: Thin-walled, Upper Chambers → As receiving chambers
   - Two Ventricles: Thick-walled, Lower Chambers → As Pumping Chambers
3. Right Atrium @ (forms the right border of the heart)

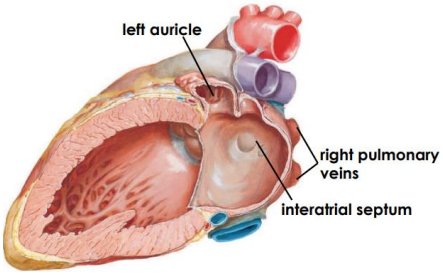


   - A smooth wall posteriorly (後方) containing:
     - Opening of Superior vena cava (SVC)
     - Opening of Inferior vena cava (IVC)
     - Opening of the coronary sinus
   - A rough, muscular wall, which formed by **pectinate muscles**, anteriorly
   - **Crista terminalis** separating smooth and rough wall
   - An oval, thumbprint-sized depression, called **fossa ovalis**, in the **interatrial septum**
   - An ear-like **right auricle** projected superiorly and anteriorly
4. Right Ventricle @ (forms the anterior surface and the inferior border of the heart)
   - Guarded by **tricuspid valve** at **right atrioventricular (AV) orifice**

anterior cusp (**AC**)
posterior cusp (**PC**)
septal cusp (**SC**) → tendinous cords (chordae tendineae) → anterior papillary muscle (**APM**)
posterior papillary muscle (**PPM**)
septal papillary muscle (**SPM**)

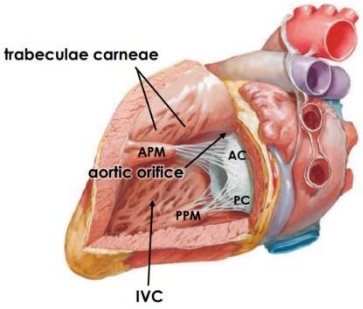


   - Separated from left ventricle by **interventricular septum(IVS)**
   - Communicates with the pulmonary trunk through pulmonary valve(semilunar valve)
   - Contains a rough, muscular wall (**trabeculae carneae**)
5. Left Atrium @ (forms most of the base of the heart.)



   - A large smooth-walled part and a smaller muscular left auricle containing **pectinate muscles**
   - Opening of four pulmonary veins
   - Smooth-walled **interatrial septum**
6. Left Ventricle @ (forms most of the base of the heart)
   - Guarded by bicuspid valve at the left AV orifice

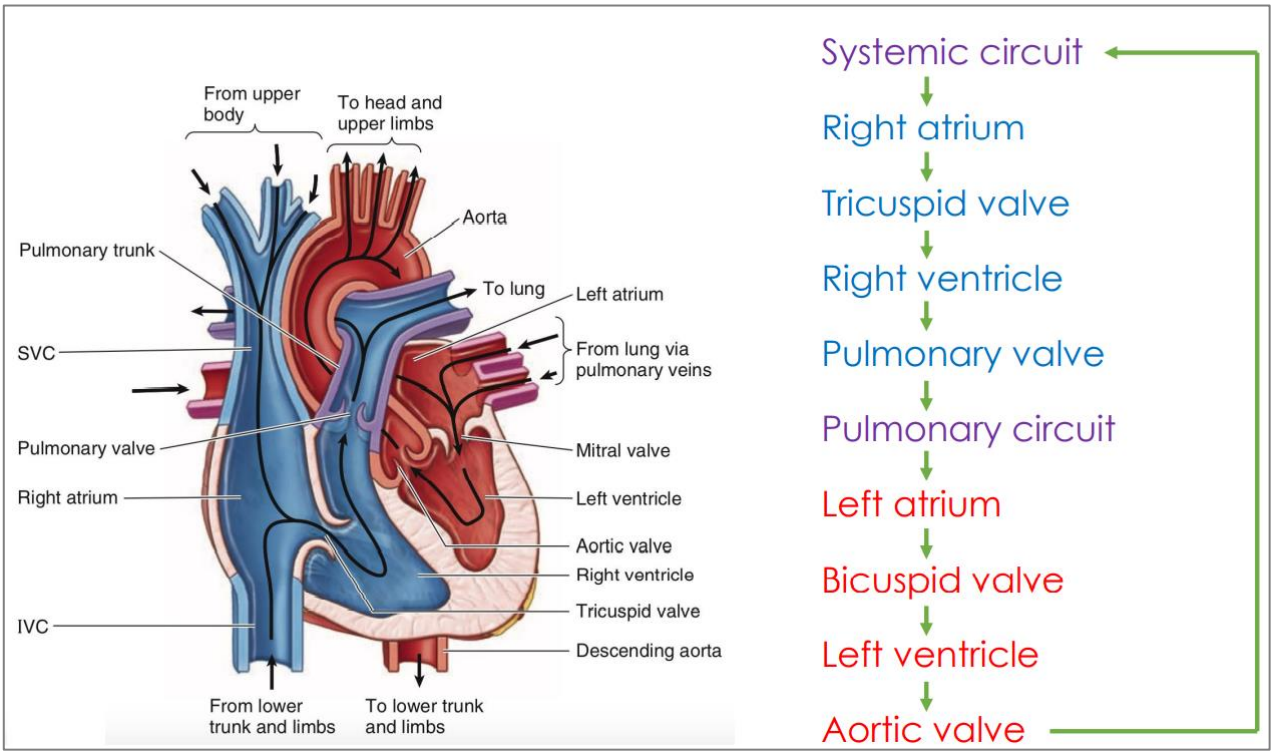
anterior cusp (**AC**)
posterior cusp (**PC**) → tendinous cords (chordae tendineae) → anterior papillary muscle (**APM**)
posterior papillary muscle (**PPM**)



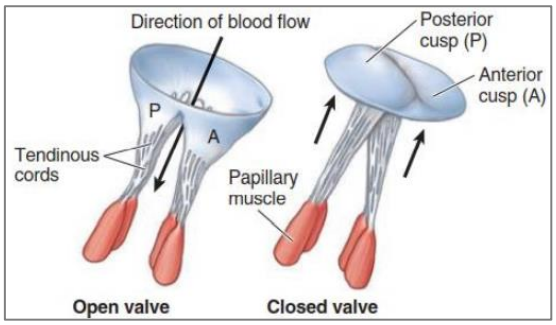
   - Separated from right ventricle by IVS
   - Communicates with the ascending aorta via aortic valve(semilunar valve) at aortic orifice
   - Contains a thick, rough, muscular wall, **trabeculae carneae**

Blood Flow in Heart & Valves

- Blood Flow in Heart



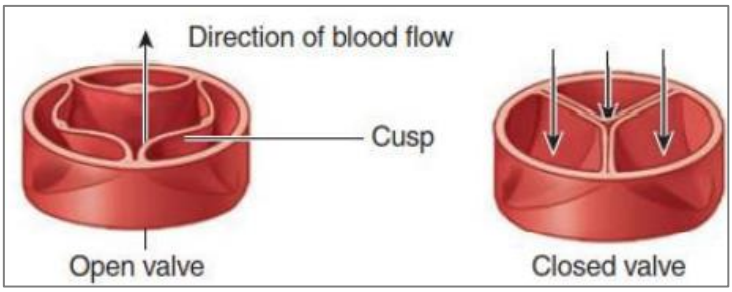
- Blood Flow Through Bicuspid/Tricuspid Valves



Atrial pressure increases (太多血@Atrium) → Blood flow pushes through → Tendinous cords loose → Papillary muscles relax → Valves open

Ventricular pressure increases (流太多血到Ventricle) → Blood flow pushes back → Tendinous cords tighten → Papillary muscles contract → Valves close

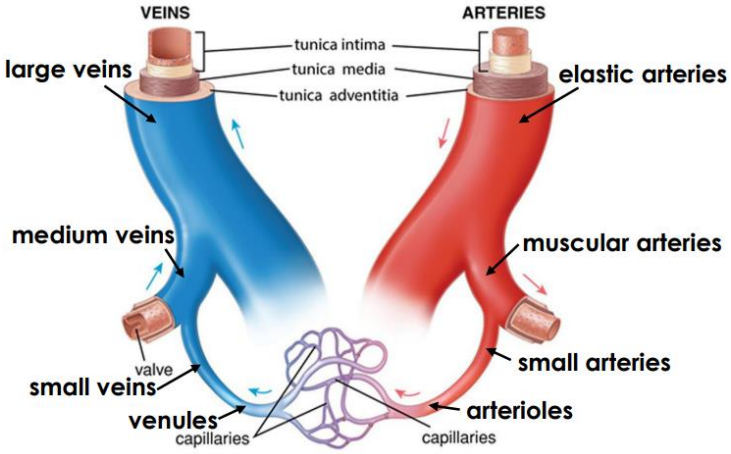
- Blood Flow in Semilunar Valvels



- Ventricular pressure increases → blood flow pushes the cusps aside → valves open
- Ventricular pressure decreases → **reflux of blood enter pulmonary sinuses** → valves close

Structure of Blood Vessels

- The walls of arteries and veins are composed of 3 layers



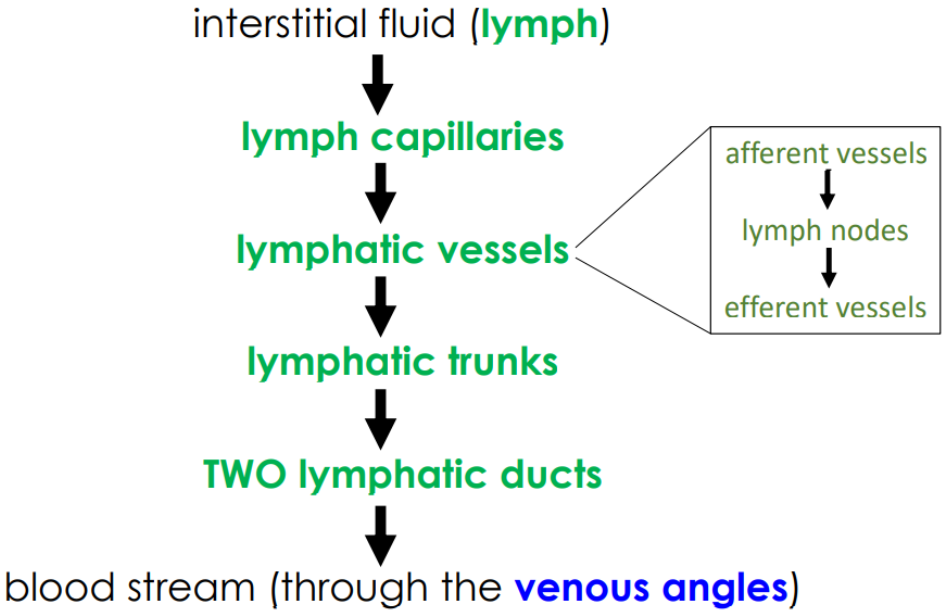
	Tunica intima	Tunica media	Tunica externa
Arteries	most elastic tissue	varies	relatively thick
Veins	very little tissue	thin layer	relatively thick
Capillaries	simple endothelial lining	absent	very delicate

- tunica intima: elastic tissues & endothelial lining
- tunica media: elastic fibers & smooth muscle
- tunica externa (adventitia): connective tissues

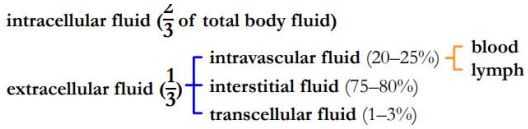
Major lymphatic tissue and organs

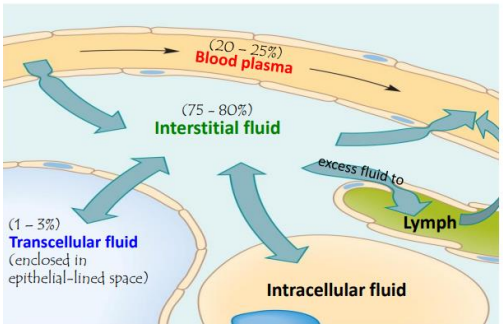
Primary Organs	Sites where lymphoid stem cells are divided and matured into immunocompetent T and B cells	Thymus → (T cells) Bone marrow → (B cells)
Secondary organs	Immunocompetent (免疫活性) cells populate these tissues and initiate immune responses to foreign antigen	lymph nodes / vessel spleen (脾胃) Tonsils

Lymphatic circulation



Body composition





Body Composition: More Fat – Less Water

- Elderly have less body water than the young one
  - A decrease in lean body mass in favor of fat during aging,
- Women contains less water (%) than men.

Man	Women	Elderly
50-60%	~50%	45%-55%

Infusion solutions used for fluid imbalance

Isotonic	Hypertonic	Hypotonic
Maintain the hemeostasis	Let Solute be more concentrated	Let Solute be less concentrated
Example: Bleeding Isotonic Saline	Example: Hyponatremia Hypertonic Saline	Example: Hypernatremia Hypotonic Saline

Definition of:
- Isotonic: solution has the osmolarity the same as that inside the cell & blood
- Hypertonic: solution has the osmolarity higher than that inside the cell & blood
- Hypotonic: solution has the osmolarity lower than that inside the cell & blood

Osmolarity v.s. Osmolality

✅ Osmolality: number of all solute particles per unit weight

0sm/kg

(Weight does not change with environmental temperature) [熱脹冷縮]

❌ Osmolarity: number of all solute particles per unit volume

0sm/L

Crystalloid VS Colloid infusion solution

- Crystalloid: Has solutes which can pass through cell membrane
  - Isotonic crystalloid solution: 0.9% saline, 5% dextrose (glucose)
- Colloid: Has solutes which are too big to pass through cell membrane
  - As volume or plasma expander
  - Example: Albumin (hypertonic [20%] or isotonic [4%]) for hypoalbuminemia (低蛋白血症) or hypovolemia (低血容量)

Introduction to Blood

- Physical Characteristic:
  - Sticky
  - Opaque (Non-transparent)
  - 8% of Body Weight → male: 5 – 6 L ; female: 4 – 5 L
    - 70 kg man, his blood: ~ 5.6 L (density ~1kg/L under 1atm)
  - High Oxygen Level: scarlet red
  - Low Oxygen Level: dark red
  - pH: 7.4
- Composition to Blood
  - Plasma: ~55% of total volume
  - Buffy coat (leukocyte, platelet) <1%
  - **Erythrocytes** ~45% of total volume

Introduction to RBC/erythrocyte

Characteristic of RBC			
biconcave	no nucleus & no organelles	no mitochondria	Flexible
More surface area for gas exchange	More hemoglobin is packed inside cell	Does not consume Oxygen	Change shape when passing through capillaries

- One Hemoglobin has Four Subunits → Four Heme Group → Each Heme Binds to One Oxygen molecule

Introduction to Leukocytes

- Leukocytes: responsible for inflammation, phagocytosis, fever & adaptive immunity

Leukocytes				
Neutrophil	Lymphocyte e.g. B cell, T cell	Monocytes/macrophage	Eosinophil	Basophil

Neutrophil	- Most abundant leukocyte in blood - Bacterial slayer - Phagocytic
Lymphocyte	- non-phagocytic - crucial to adaptive immunity - found in lymphoid tissues [NOT BLOOD CIRCULATION]
Monocytes/macrophage	- largest of all leukocyte - various cellular targets When entering tissue → macrophage → chief phagocytic & prefer to reside in tissue
Eosinophil	- phagocytic - target parasitic worms - **Induce allergies and asthma (哮喘) by stimulating basophils**
Basophil	- Phagocytic - release **heparin** to **counteract (抵消) blood clotting** - release **histamine** (inflammatory chemicals) → induce vasodilation (血管扩张) & **Attract leukocytes to inflamed sites**

Introduction to Cardiovascular System

- Function of Cardiovascular System:
  - To transport O_2 for cellular respiration and remove excess CO_2
  - To transport urea to kidney
  - To transport nutrients
  - To control the body temperature
  - To transport hormone to target organs/tissue
  - To deliver white blood cell & antibodies
  - To deliver clotting factors & platelets
- Component of Cardiovascular System
  - Heart: functions as a pump to systemic & pulmonary circulations
  - Arteries: carry blood away from heart
    - It carries oxygenated blood **except pulmonary arteries & umbilical artery**
  - Veins: carry blood back to heart
    - It carries deoxygenated blood **except pulmonary veins & umbilical vein**
  - Micro-circulation:
    - **composed of arterioles, capillaries & venules** which provide a region of **material exchange** **in every organs**
- Recap: Blood Flow in Heart

right atrium	receives from **superior vena cava** & **inferior vena cava** - SVC receive **venous blood** (deoxygenated blood) from **organs superior the diaphragm** - IVC receive **venous blood** (deoxygenated blood) from **organs inferior the diaphragm**
right ventricle	push the deoxygenated blood to pulmonary arteries → lung
Left atrium	Receive the oxygenated blood from pulmonary veins
Left Ventricle	Push the oxygenated blood to systematic circuit

! : Blood in Ventricle mainly (80%) filled by ventricular relaxation → Only 20% of Blood is pumped by atria

ventricles relax that creates suctional force to draw atrial blood or even blood in vena cava

- Recap: Blood Flow & Valves

atrioventricular valves @ Atria	close to prevent blood backflow **during ventricular contraction** (When Blood is ready to push to the Pulmonary Atria / Atria)
semilunar valves @ Ventricles	close to prevent blood backflow **during ventricular relaxation** (When Ventricle is ready to suck the blood from the atria)

Comparison between Pulmonary Circulation & Systemic Circulation

Pulmonary Circulation	Systemic Circulation
SP/DP: 24/10	SP/DP: 120/80
Lower Resistance	Higher Resistance
Deoxygenated Aterial Blood	Oxygenated Aterial Blood
Oxygenated Venous Blood	Deoxygenated Venous Blood
vasodilation & vasoconstriction mainly depending on blood oxygenation	**vasodilation & vasoconstriction mainly depending on hormone: adrenline**

Same Blood Flow

$Q = \frac{\Delta P}{R}$ Given that R is smaller and P is also smaller → Balanced → Same Blood Flow

Introduction to Blood Circulation – Systemic Circuit

- Blood is supplied to every organ **in parallel**
  - Benefit of **In Parallel**:
    - Same Arterial Composition
    - Similar Arterial Pressure
- Characteristic of different type of blood vessel

Arteries	Muscular for high blood pressure Control the blood flow by vasoconstriction / vasodilation
Capillaries	For Material Exhange
Veins	Less Muscular More Elastic More Distensible (~20x) → As reservior to store 70% of the blood

- Recap: Pulse Pressure / Systolic Pressure / Diastolic Pressure
  - Pulse Pressure = Systolic Pressure – Diastolic Pressure (Respond to the resistance of blood flow against the vessel)
    - (WSD) Wide Pulse Pressure: Increase in Systolic Pressure / Decrease in diastolic Pressure
    - (NDS) Narrow Pulse Pressure: Increase in Diastolic Pressure / Decrease in Systolic Pressure

Type of Pressure	The Normal Range of the Pressure
Systolic Pressure	~120mmHg
Diastolic Pressure	~80mmHg
Pulse Pressure	30~50 mmHg

Implimentation of the Pulse Pressure & Clinic Suituation

- **Aortic regurgitation**
  - When **aortic valve** cannot close properly during **ventricular relaxation**
    - → The Blood Flow Back to the Atria → DP is Decreased & Blood Flow is Decreased
    - → As the Ventricular Contraction is No Change → No Change in SP
    - → Pulse Pressure is Wider (Blood Pressure in the Aorta is Decreased)

Pulse Pressure ≠ Blood Pressure in the Aorta

> ! Pulse Pressure means the Pressure act on the blood by the heart (E.M.F)
> Blood Pressure means the Pressure against the blood vessel by the blood (Potential Difference)
>
> Reference:
> *In aortic insufficiency, the three flaps of the aortic valve, called leaflets, do not close tightly, allowing blood to leak back into the heart. This causes a decrease in blood pressure in the aorta, an increase in pulse pressure, and a decreased forward flow of blood.*
> ***In normal situation, widen the pulse pressure should increase the blood flow, narrow pulse pressure should decrease the blood flow. However, under wide pulse pressure, blood flow will decrease if and only if there is Aortic Regurgitation.***
> ***Thus, it is not a must for the positive relationship between pulse pressure and blood flow. On the other hand, we can find out there must be something wrong if there is no positive relationship between pulse pressure and blood flow.***

- **Aortic Stenosis** (can be spotted by plapation of pulse)
  - **Aortic Valve Cannot open Fully** → The Systolic Pressure is dropping (NDS)
    - → The Pulse Pressure is dropping
    - → The Blood Flow is decreased

Introduction to Anatomy of Respiratory System

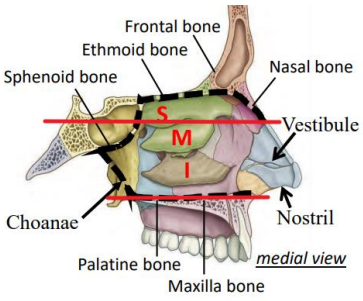
- Recap: Function of Respiratory System
  - Gas Exchange、Oflaction (嗅覺)、Phonation (发声)
- Anatomical Separation of Respiratory System
  - The Respiratory Tract
  - The Lungs
  - The Muscle of respiration

Recap: Components of upper and lower respiratory tracts

- The Components of upper respiratory tracts

The Nose

Nose	Support by bones Support by **cartilages**
Nasal Cavity	There are four boundaries of nasal cavity: ■ Roof ■ Floor ■ Medial Wall ■ Lateral Wall



Notes:
roof (nasal, frontal, ethmoid and sphenoid bones)
floor (maxilla bone and palatine bone)
medial wall (nasal septum)
Ethmoid Bone: superior(S) and middle(M) nasal conchae
Maxilla: inferior(I) nasal conchae

The Nasal Cavity

The Nasal conchae divide the nasal cavity into 4 Passages:

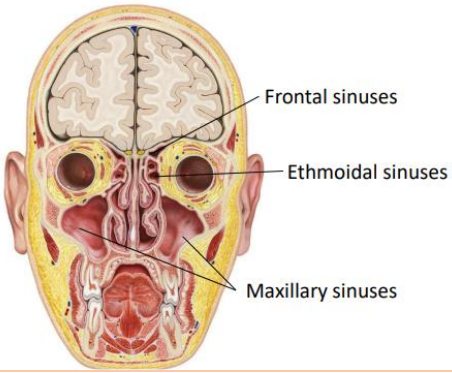
- Spheno-ethmoidal recess
- Superior Nasal meatus
- Middle Nasal Meatus
- Inferior Nasal Meatus

The Paranasal Sinus

There are four sinuses considered as the paranasal sinus:

- **maxillary sinuses**
- **frontal sinuses**
- **ethmoidal sinuses**
- **sphenoidal sinuses**

Notes: Do notice that the sinuses are double-sided,
In total, there are 4 pairs of sinuses



The Pharynx

The **muscular funnel-shaped structure** extending from choanae to the larynx
There are four pharynxes:

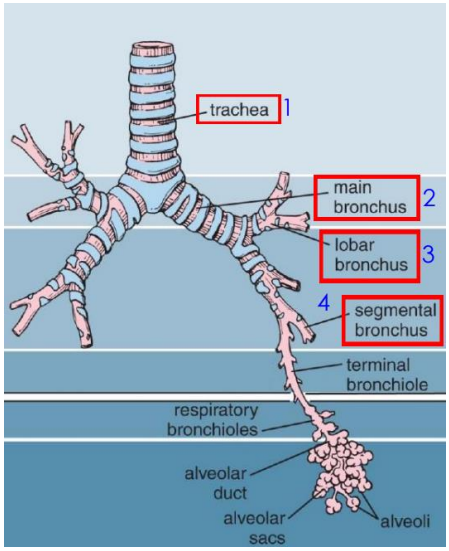
- nasopharynx
- oropharynx
- laryngopharynx

- The Components of Lower Tract of Respiratory System

The Larynx

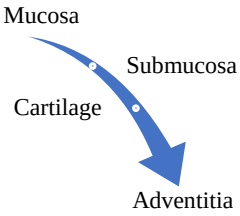
- The **hollow musculoligamentous structure** with **a cartilaginous framework (9 cartilages)** that connects to the trachea
- Functions:
  - Respiration
  - Phonation
  - **Guard the air passage during depression of epiglottis (swallowing)**

Tracheobronchial Tree



Trachea

- The trachea is **supported by C-shaped rings of hyaline cartilage**.
- the **wall of trachea has 4 layers: From Inner to Outermost**



1. Mucosa: consists epithelium **goblet cells and ciliated cells → Mucus-secreting Cell**
2. Submucosa: consists serous and mucous glands
3. Cartilage
4. Adventitia

Main bronchus

Lobar bronchus

Segmental bronchus

- **each supplies a bronchopulmonary segment**

Terminal bronchiole

Respiratory bronchioles

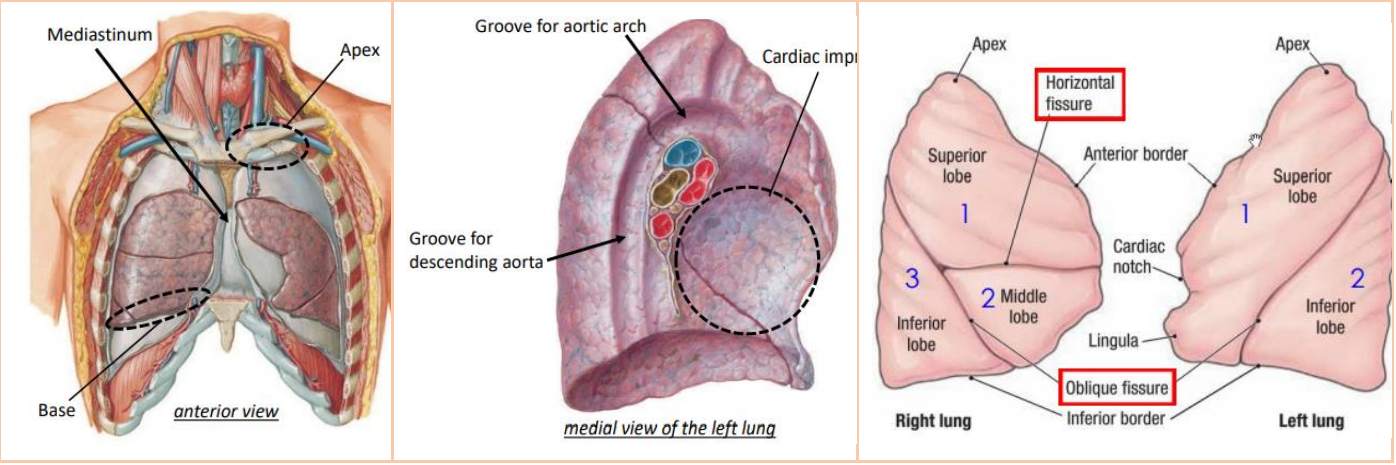
Alveolar duct

Alveolar sacs

Alveoli

- Functional Division of the Tracheobronchial Tress
  - Conducting zone (lined by **respiratory epithelium** / **pseudostratified ciliated columnar epithelium**)
  - Respiratory zone (lining gradually changes to **alveolar epithelium** / **simple squamous epithelium**)

Anatomy features of the Lung



- Apex
  - Superior the level of the 1st rib, ascending into the root of the neck
- Base
  - the concave inferior surface, resting on the diaphragm
- Cardiac impression
  - a depression at mediastinal area for accommodating the heart
- Groove for aortic arch/descending aorta
  - an arched furrow caused by the impression of aortic arch and descending aorta
- Fissures
  - horizontal fissure @ 4th rib
- Oblique fissure
  - Posterior to T4 vertebral
  - Anterior to 6th rib
- Lobes
  - superior and inferior to the Left Lung
  - superior, middle and inferior to the Right Lung

Lungs & Pulmonary artery / veins

- Each Lung Has:

One pulmonary artery: Each pulmonary artery → **secondary lobar arteries** & **tertiary segmental arteries** **running anteriorly along the corresponding bronchus**.
Two pulmonary veins: **Pulmonary veins run independently of arteries and bronchi coursing** between the **adjacent bronchopulmonary segments.**

Introduction to Innervation of the lungs

- The lungs are supplied by **pulmonary plexus formed of sympathetic and parasympathetic fibers**, part of the **autonomic nervous system.**

Sympathetic stimulation	• dilates bronchi • reduces secretion
Parasympathetic stimulation	• constricts bronchi • promotes bronchial secretion

Pleura and Pleural Cavity

- Each lung is enclosed in a pleural sac that consists of two continuous membranes:
  - → **visceral pleura** / adherent to surfaces of the lungs
  - → **parietal pleura** / adherent to the thoracic wall, mediastinum and diaphragm
- The potential space between the layers of pleura is **pleural cavity**, containing **serous pleural fluid.**
- **Costodiaphragmatic recesses** is the lowest area in pleural cavity

Thoracic cage

- The **thoracic skeleton** forms the **thoracic cage** → **protect the heart and lungs** & **provide attachment for muscles**

Introduction to the Hilum of the lung

- **The hilum of the lung** is the area where the structures **form the root**
  - → which connects the lung with the heart and trachea

Pulmonary artery	Superior pulmonary veins inferior pulmonary veins	Main bronchus surrounded with bronchial vessels	lymphatic vessels Lymphatic nerves
The **bronchial arteries** supply the **pleura** near the hilum → **provide oxygenated blood to lung tissues**			

Introduction to the Intercostal space & Diaphragm

Intercostal neurovascular bundles are hidden in the costal groove from superior to inferior: **intercostal Vein** **intercostal Artery** **intercostal Nerve**		
external intercostal muscle	internal intercostal muscle	innermost intercostal muscle

Diaphragm is a **musculotendinous** structure innervated by **phrenic nerve** → As **primary respiratory muscle**		
right dome	left dome	central aponeurotic part

Introduction to Mechanism of Respiration

Quiet inspiration → develops a negative intrathoracic pressure	☙ Diaphragm contracts → increase the vertical diameter ☙ External intercostal muscles contract → increase the transverse → increase AP diameters
Passive expiration → passive recoil of the lungs	☙ diaphragm relaxes → decrease the vertical diameter ☙ external intercostal muscles relax → decrease the transverse → decrease AP diameters
Forced (Active) inspiration → allow additional increase in the AP and transverse diameters	☙ anterior and middle scalene muscles contract → lift the 1 st rib ☙ diaphragm and external intercostal muscles contract → increase the diameter ☙ pectoralis and sternocleidomastoid muscles (SCM) → raise the ribs and sternum
Forced (Active) expiration → allow further increased intrathoracic pressure	☙ internal and innermost intercostal muscles contract → depress ribs → decrease space in the thoracic cavity ☙ abdominal muscles contract → depress lower ribs → compress abdominal contents →push up respiratory diaphragm