U2. Cell Biology

7. Cell Structure and function.

specimen 현미경 표본, 시료

Light microscope (LM) : magnification x 1000, resolution (200 nm), contrast. ($\propto \frac{1}{\text{wavelength}}$)
living cell 가능.

Electron microscope (EM) : resolution (0.001nm)
- SEM (scanning) : 주사전자
- TEM (Transmition) : 투과전자.
- Cyto-EM : Frozen specimen.

Cell Fractionation

differential centrifugation. = Nuclei + cellular debris → Mitochondria, Chloroplast → microsomes → ribosomes
분별 원심분리법 ⇓ 소포체의 물리적 파괴에 의한 인위적 파편.

cell
- eukaryotic - Protist (단세포 원생), fungi, animal, plant
- prokaryotic

> 핵막, 막성 소기관 유무 차이. DNA 형태, 크기.

All cells have selective barrier - plasma membrane (세포막) : ratio of surface area to volume is important. ☆ > ○
∴ microvilli (미세융모) 형성됨.

Cytoplasm (세포질) → 핵 제외 모든것.
Cytosol (세포질용액) → cytoplasm 이서 세포 소기관 제외한 모든 "액체" 성분. (organelle)

Chromosomes → DNA. DNA location
- Eukaryotic : in organelle (nucleus) - double membrane (핵)
- Prokaryotic : just concentrated in a region. (X enclosed)
  - nucleoid (핵양체)

Animal cell.

- Nucleus
  - Nuclear envelope 핵막
  - Nucleolus 핵인 - ribosome factory
  - Chromatin 염색질 - DNA+단백질이 실처럼 풀어진 상태.
    - Euchromatin 진정 (활성상태, 유전자 발현 가능)
    - Heterochromatin 이질 (응축상태, 유전자 발현 거의 X)
- Lysosome : 가수분해
- Peroxisome
- Cytoskeleton : cell shape, cell movement
  - microfilaments 미세섬유
  - Intermediate filaments 중간섬유
  - Microtubules 미세소관
- Centrosome 중심체 : cell's microtubules initiated, pair of centrioles (중심립)
- Endoplasmic Reticulum (ER) 소포체
  - Rough ER
  - Smooth ER
- Plasma membrane
- Ribosome - make protein
  - free in cytosol
  - bound to rough ER / nuclear envelope
- Golgi apparatus
- Mitochondrion : ATP factory
- Microvilli : increase cell's surface area
- Flagellum 편모 - cluster of microtubules

Plant cell. - central vacuole 액포, Chloroplast, cell wall, Plasmodesmata
= cytoplasmic channels through cell wall

▼ Nucleus

Nuclear envelope - perforated by pore structure (pore complex → protein으로 구성)

nuclear lamina (by intermediate filament) : maintain shape of nucleus.

nuclear matrix. : framework of protein fibers extending throughout the nuclear interior (스캐폴드, 골격)

in the nucleus. - DNA organized into chromosomes. (염색체)

one long DNA + proteins (histones + ∝)

DNA + proteins = chromatin (염색질)

nondividing nucleus = nucleolus (핵소) : 둥치(인) 핵.

mRNA : carry information from DNA. (transported to the cytoplasm via nuclear pore)

▼ Ribosomes. (ribosomal RNA + protein) ≠ organelle. (membrane 없음)

- free ribosome : suspended in cytosol → make most proteins.
- bound ribosome. : attached to outside of ER or nuclear envelope.
  - → proteins that insert into membrane
  - → packaging within certain organelles (ex. lysosome)
  - → export from cell (secretion)

▼ Endomembrane system (nuclear envelope, ER, Golgi, lysosome, vacuoles, plasma membrane, vesicle ...) (소낭)

① Endoplasmic Reticulum (ER) (소포체) : network of membranous tubules + sacs (cisternae) (낭)

cisternae < ~~~~ → ER lumen (cisternal space)

→ separate from cytosol

- Smooth ER : Synthesis of lipids (ex. Hormones), metabolism of carbohydrates, storage of calcium ion, detoxification of drugs and poisons. (Hydroxyl group (OH) 붙여서 물에 녹여서 흘려보냄)
- Rough ER : Attached ribosomes only grow polypeptide chain.

  → ER lumen에 들어와서 fold into its functional shape

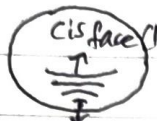
  - most secretory protein. ⇒ glycoprotein (당단백질) [protein + carbohydrates]

    It depart from transition ER by transport vesicles

  - Membrane factory for cells. : Adding membrane protein + phospholipids.

    ER membrane에서 자라고 있다가 떨어져서 다른 endomembrane을 이룸

v Golgi apparatus. - warehouse for receiving, sorting, shipping, +α vicinity 근처.



- specialized for secretion
- Cisternae 가 pile 된 구조. - unlike ER cisternae, not physically connected.

Product of ER modified during transition cis → trans face.

Golgi ≠ static structure.

Cisternal maturation model : cisternae of golgi actually progress forward from cis → trans face carrying + modifying cargo as they move.
Also mature cisternae itself.
vesicles also transport certain proteins backward to less mature golgi cisternae where their functions are needed.

Another model : central region of cisternae remain in place.
outer ends are more dynamic.

Before dispatch its products from trans face.
- sort products and targets them. (Adding molecular identification tags, acting like zip code)
- transport vesicles from golgi may have external molecules on membrane.
that recognize docking sites. (targeting)

v Lysosome. (Digestive compartment) = membranous sacs of hydrolytic enzymes
Lysosomal enzymes work best at acidic Environment. ∴ Lysosome 터져도 cytosol에서 활성도↓
최대한 large number of lysosome distroyment ⇒ self-digestion 발생
Lysosomal membrane + hydrolytic enzymes made from rough ER → Golgi → 따로 떨어져 나옴
Lysosome 의 inner surface protein 이랑 내부 enzymes 피해 안되는 이유
= enzymatic attack 으로부터 안전한 3차원구조.
Phagocytosis (식세포) : 먹은 것을 lysosome 과 융합. (박테리아, 바이러스)
Autophagy (자가포식) : 세포내 청소, 재활용

v Vacuole (액포) : derive from ER + golgi · → unicellular.
Food vacuole - phagocytosis, Contractile vacuole (pump excess water out of cell)
Plant, fungi - certain vacuole carry out enzymatic hydrolysis (ex. Lysosomes)
이외 다양한 역할 수행

central vacuole (plants) - develops by coalescence of small vacuoles.

Mitochondria and Chloroplast

endosymbiont theory (세포내 공생설)

- two membranes not as endomembrane system.
- contain own ribosomes, own DNA (circular)
- autonomous organelles that grow and reproduce in the cell
- mobile (move around)

v Mitochondria.

두 막 has unique collection of embedded proteins.

outer: smooth ← intermembrane space → inner: convoluted (cristae) ← Mitochondrial matrix →

large surface area.
= enhance productivity of cellular respiration
(built in protein, enzymes)

many enzymes
Mitochondrial DNA
Ribosomes

v Chloroplast (chlorophyll)

inner 막도 outer 막처럼 smooth.

thylakoids의 stack = granum (grana (pl))

fluid outside thylakoids = stroma [Chloroplast DNA, ribosome enzymes, ...

intermembrane space → stroma → thylakoids space.

Plastids (색소체) 모든 남세균의 세포내 공생 ∴ 고유 DNA, 리보솜 가짐

(Chromoplast (색색체) : 노, 주, 빨 등의 색소 가짐. / amyloplast : colorless, store starch (amylose))

v Peroxisome - single membrane, oxidation (리방산 분해, 해독 ...)

Contain enzymes that remove H from substrates and transfer to O_2

⇒ H_2O_2 (과산화수소, hydrogen peroxide)

↓

itself also toxic

but also contain enzyme $H_2O_2 \rightarrow H_2O$

Specialize peroxisome ⇒ glyoxysomes

: fat storing tissues of plant seeds.

convert fatty acids to sugar.

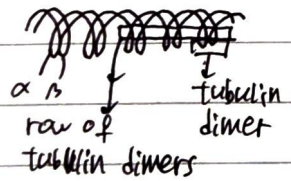
✓ Cytoskeleton : give mechanical support (motility) to the cell, maintain its shape.

Cell motility = interaction of cytoskeleton with motor proteins (ATP powered, ex. myosin --)

- cytoskeletal elements + motor proteins + plasma membrane molecules = cell movement
- Vesicles and other organelles often use motor proteins "feet" to "walk" along cytoskeleton.
  ex) vesicles containing neurotransmitter molecules migrate to the tips of axons (nerve cells that release these molecules)
- manipulates the plasma membrane
  : bending it inward to form food vacuoles or other phagocytic vesicles (식세포)

종류.

- Microtubules (Tubulin polymers)	- Microfilaments (Actin filaments)	- Intermediate Filaments
hollow tubes	Two intertwined strands of actin.	Fibrous protein coiled into cables
25nm, 15nm (center)	7nm	8~12nm
(tubulin dimer consist of α-tubulin and β-tubulin)	Actin	(one of several different proteins including keratins)
(Maintenance of cell shape Cell motility Chromosome movement in cell division (separation) Organelle movements.)	(Maintenance of cell shape Cell motility Changes in cell shape Muscle contraction Cytoplasmic streaming (plant) Cell division (animal))	(Maintenance of cell shape Anchorage of nucleus and organelles formation of nuclear lamina.)



▾ Microtubules

Compression resisting rate.

The two ends of microtubules are slightly different.

- Plus end : accumulate or release tubulin dimers much higher rate. (growing shrinking ↑)

Guide vesicles from ER to Golgi apparatus / Golgi to plasma membrane.

Centrosomes (→ pair of centrioles.) and Centrioles (↘ each composed of 9 sets of triplet microtubules arranged in ring.)

microtubules grow out from it.

flagella (편모, 양↓) and cilia (섬모, 양↑)

Propelled through water.

attached tightly together in a sheet that is part of tissue layer.

can move fluid over the surface of the tissue (이물질 밀어냄, 난소이동 --)

- flagella : undulating motion ex. tail of fish.
- cilia : alternating power stroke and recovery stroke. ex. oars of racing crew boat.
  - ↳ Cilium also act as signal-receiving antenna. = primary cilium.
    이 기능을 하는 cilia는 generally nonmotile, only one per cell.

9+2 : flagella + motile cilia / 9+0 : nonmotile primary cilia.

flagellum and cilium anchored in cell by "basal body" (세포에 고정시킴)
↳ Similar to centriole (9+0)
실제로, 정자가 난자 들어갈때 같이들어가서 중심립으로 쓰임.

Bending ⇒ large motor proteins (dyneins)
↓ attaches along each outer microtubule doublet. kinesins vs dyneins
원리:

• Microfilaments. (Actin filaments)

bear tension.

outer cytoplasmic layer of cell (cortex, semisolid like gel)

bundle of microfilaments makes core of microvilli → increase cell's surface area.

muscle cell contraction → actin filaments and Myosin filament interaction.

Pseudopodia : cell crawls by extending cellular extensions.
by localized contractions by actin and myosin.

cytoplasmic streaming : ~~cellular~~ circular flow of cytoplasm within cells. (Plant)
⇒ speed movement of organelles + distribution of meterials.

v Intermediate filaments → named for their diameter.

(Microtubules, Microfilaments : found in all eukaryotic cells
intermediate filaments : only in cells of some animals, including vertebrates.

specialized for bearing tension

constructed from particular molecular subunit belonging to a family of proteins
whose members include the "keratins"
다른 두개와 다르게 얘는 만들어지면 활성 단백 구조를 유지.

Cell walls of plants. : protects plant cell, maintain shape., prevent excessive uptake of water.

prokaryotes, some protists (원생), fungi also have cell walls.

Cellulose synthase (enzyme) : synthesize microfibrils made of polysaccharide cellulose.
secreted to the extracellular space and embedded in a
matrix of other polysaccharides and proteins.
= strong fibers in a "ground substance"

young plant cells. → matured

Secrete thin, flexible wall (Primary cell wall)

Between primary walls of adjacent cell
= middle lamella (thin layer)
rich in sticky polysaccharides (Pectins)

strengthen wall

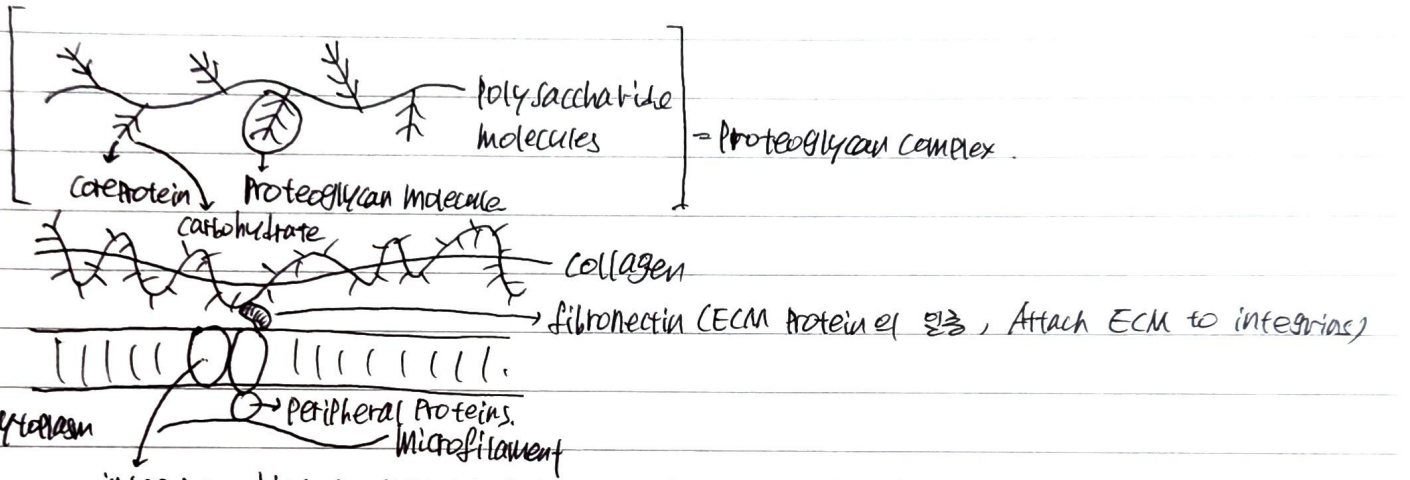
① Just secreting hardening substances into primary wall.

② Adds secondary cell wall between the plasma membrane and primary wall.
(strong, durable matrix,) ex. wood

Extracellular matrix (ECM) of Animal cells.

main ingredients of ECM = glycoproteins + carbohydrate-containing molecules
(ex. collagen)
↳ most abundant, form strong fibers outside the cells.

collagen fibers embedded in network woven out of proteoglycans. secreted by cells.



integrins : binds to ECM on outside and to associated proteins attached to microfilaments
↳ kind of cell-surface receptor protein. : can transmit signal between cell's external and interior.
→ regulate cell behavior (mechanical signaling)

affect extracellular matrix may help "coordinate" behavior of "all" cells of that tissue

coordinate 방법 : Direct connections between cells.

Cell Junction.

Plasmodesmata in plant cell wall (Perforated with Plasmodesmata) : channels that connect cells
Plasma membrane of adjacent cells line the channel of each plasmodesmata.
and thus are continuous ∴ unify most of the plant into one living continuum.

Animal cell : Tight junctions / Desmosome / Gap Junction.

- Tight junctions: bound together by specific proteins. Forming continuous seals around the cells, and prevent leakage of extracellular fluid between epithelial cells (상피세포)
- Desmosome: function like rivets. fastening cells together into strong sheets. (Intermediate filaments) attaches muscle cells to each other.
- Gap Junction: like Plasmodesmata but not lined with membrane. Both membrane proteins extending from membrane of the two cells create pores through which ion, sugar, amino acid, ... pass.

8. cell membranes

Cellular membranes ⇒ fluid mosaics of lipids + proteins.

Phospholipids, most membrane proteins ⇒ amphipathic (친수소수성)

Fluid mosaic model - membrane is mosaic of proteins in fluid bilayer phospholipids.

- 완전 Random X : Group of proteins associated to do functions.

Membrane - hydrophobic interaction 으로 묶임 (very weak)

: lipids - rapidly shift (1초안에 세포 반바퀴), rarely flip-flop 안쪽 ↔ 바깥쪽

Proteins ① immobile : attach to cytoskeleton or ECM ② move driven along cytoskeleton fiber by motor protein.

③ simply drift in membrane

Membrane fluidity - unsaturated hydrocarbon tails ⇑ : 온도 낮아져도 쉽게 pack together X ∴ fluidity ↑

- saturated hydrocarbon tails ⇑ : 쉽게 pack ∴ viscosity ↑ (점성도)

〈Animal〉 Steroid Cholesterol 이 중간중간 끼어있음

T↑ : Phospholipid movement 를 restraining ∴ less fluid. > fluidity buffer 로 작용! 주파수 급변화에 알게 함.

T↓ : Phospholipid 의 packing 을 hinder ∴ much fluid

〈Plant〉 cholesterol 대신 related steroid lipids 가 비슷 역할

역할 : -Ability of membrane proteins to move to where their function needed.

↳ 너무 높아도 다른데 가버리고, 너무 낮아도 필요한 곳이 안감 ∴ adjust 가 중요

-Permeability (투과성)

Membrane proteins (determine most of membrane's function)

Integral Proteins [transmembrane protein
extend only pathway into hydrophobic interior

Peripheral Proteins - bound to surface of membrane or exposed part of integral protein.

Functions : - Transport [span-provided hydrophilic channel (selective)
shuttle by changing shape (some use ATP to pump substances)

- Enzymatic activity - work as enzymes, sometimes organized as team (step-step)

- Signal transduction - hormons 같은 분자 붙으면 신호전달 (대부분) by changing shape.

- Cell-cell recognition - some glycoprotein = identification tag to specifically recognize by membrane proteins of other cell.

- intercellular joining - membrane proteins of adjacent cell hook together (Gap Junc, Tight Junc (long lasting)

- Attach to cytoskeleton and ECM

Membrane carbohydrate's Role in cell-cell recognition.

- Sorting cells into tissue and organs in animal embryo (태아)
- basis for rejection of foreign cells by immune system.

membrane carbohydrate (종, 개체, 세포 종류에 따라 다름) bound to [lipids : glycolipids / proteins : glycoproteins.

- function as marker to distinguish one cell from another.
  ex) 혈액형.

membrane sidedness : 양쪽 side의 lipid composition, protein 다름 (asymmetrical 비대칭)

membrane's selective permeability → 2 factors

① Lipid bilayer
- nonpolar molecule (CH_4, CO_2, O_2) : hydrophobic - lipid bilayer에 dissolve ⇒ cross easily
- polar molecule (Glucose, other sugar) : hydrophilic - hydrophobic interior of membrane impedes direct passage.
  or ions

② Transport Proteins
- Channel proteins : tunnel through membrane (aquaporins)
- Carrier proteins : change shape.

Passive vs active

Passive transport → diffusion (by thermal E) of substances, with no energy investment (spontaneous)
Substances diffuses down its "concentration gradient" (농도 기울기)
Selectively permeable ex. aquaporins

osmosis (삼투) : diffusion of free water across a selectively permeable membrane.

Tonicity : depends in part on its concentration of solutes that cannot cross membrane relative to that inside cell.

- Isotonic solution (등장성) : net movement of H_2O = 0
  - X cell wall : normal shape
  - O cell wall : Flaccid
- Hypertonic solution (고장성) : cell lose H_2O
  - X cell wall : Shriveles
  - O cell wall : plasmolyzed (원형질 분리)
- Hypotonic solution (저장성) : cell gain H_2O
  - X cell wall : Lysed
  - O cell wall : Turgid (팽압) = normal
    - With cell wall : immersed in isotonic
    - Without cell wall : immersed in hypotonic

Plant cell osmosis 로 물 swell, but cell wall expans only so much before it exert back pressure on the cell (turgor pressure 팽압) - oppose water uptake. ⇒ At this point : turgid (healthy state)

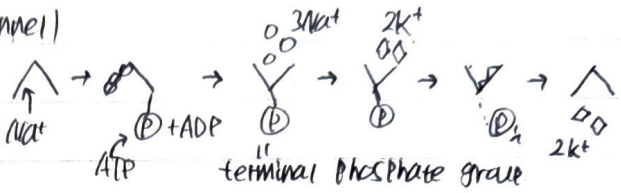
Facilitates diffusion : Passive transport aided by transport proteins (specifically)
- Channel protein : Provide corridors allow specific molecules, ions
- Carrier protein : Change shape that translocates the solute-binding site across membrane
  - triggered by binding / releasing of transported molecules. (Energy x)

Active transport. - use Energy to move solutes against their concentration gradients.

⇒ All carrier proteins (no channel)

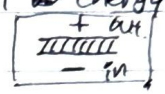
ex) Sodium-potassium pump

Na K



Ion pump : maintain ~~Member~~ membrane potential = electrical potential ~~be~~ energy (voltage)

Voltage across membrane range from -50 ~ -200 mV



electrochemical gradient : chemical force (ion concentration gradient)

+

electrical force (favors the passive transport of cation ~~in~~ into cell (-) and anion out of cell (+))

electrogenic pump : transport proteins that generate voltage across membrane.

ex) sodium-potassium pump : 3+ out, 2+ in, make (-) inner membrane.

Proton pump : transport protons (H^+) out of the cell.

↳ make proton gradient. ⇒ help store energy (ex. ATP synthesis)

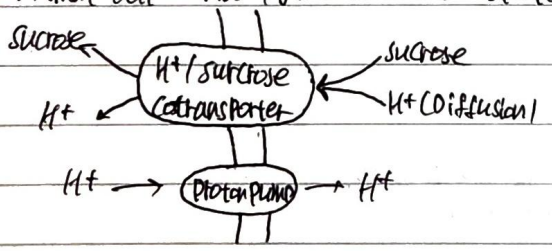
⇒ cotransport.

Cotransport (공동수송) : coupled transport. (ex. water pumped uphill and perform work as it flows back down)

ex. Plant cell uses gradient of H^+ generated by ATP-powered proton pumps to ~~be~~ drive the active transport of amino acids, sugars, several other things into the cell.

Animal cell : Na^+/glucose cotransporters.

[즉, 공동수송이란 한 물질의 농도기울기에 의한 energy 에너지를 이용해 다른 물질을 함께 이동시키는 것.]



Bulk transport - exocytosis / endocytosis

exocytosis : vesicle travels along microtubules to plasma membrane, bind to membrane, secrete.

endocytosis : forming new vesicles from plasma membrane.

- Phagocytosis : cellular eating
- Pinocytosis : cellular drinking - nonspecific
- receptor-mediated endocytosis - partly specific (receptor 에들이 specific 해 뭉쳐있는 vesicle 안에 다른 solutes 포함)

  - receptor 재활용 by same vesicle.

  ex) human take in cholesterol (LDL receptor)

9. cellular signaling

Bacterial cells : secrete molecules that detected by other bacterial cells
monitor own local cell density - by sensing concentration of signaling molecules.
= quorum sensing : allow bacterial populations to coordinate behavior
ex) - biofilm / - secretion of toxins : new antibiotics = disrupt toxin production by interfering signaling pathways.

Yeast's cell signaling. - Identify their sexual mates by chemical signaling.
a Yeast with a factor + α receptor
α Yeast with α factor + a receptor.) fusion ⇒ advantage to the descendants.

Local signaling : Gap Junction, Plasmodesmata, cell-surface molecules, secrete signaling molecules.
⇒ travel only short distance. [Paracrine signaling] ⇒ 주변 cell만 affect.
(Synaptic signaling이 포함)

Long-distance signaling. : Hormones [endocrine signaling] ⇒ hormones travel through circulatory system
ex) ethylene, insulin, ... to other parts of body.

3 stages of cell signaling
Signal reception. ⟶ signal transduction ⟶ cell respond.

: target cell receive signal by receptor
- signaling molecules bind to receptor protein, located at the cell's surface.
- cell 안에 있는 경우도 있음

: signal convert into another form.
- binding of signaling molecule change receptor protein and initiating the process of transduction.
- transduction [one step
signal transduction pathway (by relay molecules)

1) Signal reception. - signal molecules (ligand) bind to receptor → change shape.
Changes shape of receptor protein enable to ~~inter~~ interact with other molecules.
or cause aggregation of 2 or more receptor proteins.

receptors - G protein-coupled Receptors (GPCR)
G protein : binds the energy-rich molecule GTP. ⟨ bind GDP : inactive / bind GTP : active.

Signaling molecule이 GPCR 결합 → GPCR shape change → G protein 활성화시킴 →
active G protein이 membrane 따라 움직다가 enzyme 이상 들어 enzyme 활성화 →
activated cellular response를 trigger함. → G protein이 GTP를 GDP로 만듦 (GTPase function)
다시 비활성화

- Receptor Tyrosine kinase (RTKs) : 두 RTKs 의 signaling Molecule 이 붙어 RTK protein 의 Dimer 화를 유도 → Dimer 된 tyrosine kinase region activate. → 각 tyrosine kinase 가 ATP 에서 Phosphate 를 가져옴 (6 ATP → 6 ADP) → specific relay proteins 들이 각 tyrosine kinase region 에 붙어 활성화 → cellular responses 유도.

- Ion channel Receptors (Ligand-gated ion channel) : Ligand 붙으면 ion channel 열림.

위 3개는 Plasma membrane Receptors.

Intracellular Receptors. - signaling molecules pass through plasma membrane.

ex) (small, hydrophobic molecules)

↓ gases ↓ steroid thyroid hormones.

- hormone-receptor complex : acts as transcription factor.

(turning on/off particular genes)

receptor 혼자 receptor, transducer 역할 다 하는 것!

2) Signal transduction. : Cascade (연쇄반응, 단계적) of molecular interactions.

receptor → relay molecules (proteins, ions, etc) → cellular response

Protein phosphorylation / Dephosphorylation (role of molecular switch)

⇒ commonly used to regulate protein activity.

Protein kinase : enzyme that transfer phosphate group from ATP to protein

(serine, threonine, tyrosine)

Phosphorylation cascade : Protein kinase 활성화 → 다른 protein kinase 활성화 → 다른 Protein kinase 활성화

Protein phosphatase (PP) : enzyme that remove phosphate groups from proteins.

⇒ turn off signal transduction pathway. (신호가 없을때 원래대로 만듦)

형성 protein 인것은 X. : Small nonprotein, water-soluble molecules, ions ⇒ second messengers.

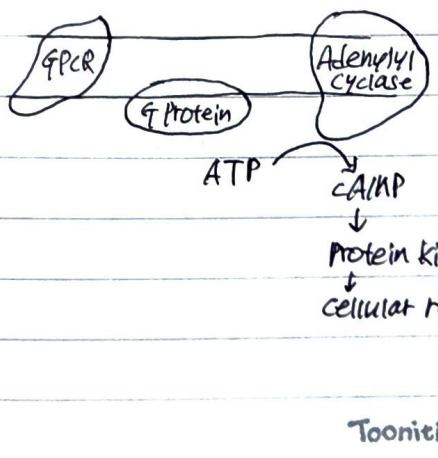
(GPCR, RTK 둘 다 관여)

- Cyclic AMP (cyclic adenosine monophosphate)

ATP —(Adenylyl cyclase)→ [cAMP] —(Phosphodiesterase)→ AMP

Adenylyl cyclase 는 activated by activated G protein 또는 activated by extracellular signal

cAMP → activate protein kinase A.



- Ca^{2+} and Inositol Trisphosphate (IP_3)

주로 ER에 Active transport 해놓은 Ca^{2+}를 세포질로 방출시킴.

GPCR get signal → G protein activate → Phospholipase C activate : PIP_2 < DAG (diacylglycerol), IP_3

IP_3 ↓

Ca^{2+}방출 ← IP_3-gated calcium channel protein

3) Cellular response : regulate transcription or cytoplasmic activities.

Regulation of response.

- Signal Amplification : each catalytic step in cascade, number of activated products can be much greater than in the preceding step.
- specificity of cell signaling and coordination of the response.

Cells exposed to many different hormones < respond → 반응해도 cell마다 반응이 다를 수 있다.
ignore

이유 : different kinds of cell turn on different sets of genes

→ different kinds of cell have different collection of proteins.

Pathway 자체나 다를수도 있다. ⇒ ↓ ⅄ ↓ ↕ different receptor.

- Signaling Efficiency : Scaffolding proteins and signaling complexes

In fact, most of relay molecules not just spread in cytosol (무작위적 확산 느림)

⇒ scaffolding proteins : large relay proteins which several other relay proteins simultaneously attached.

※ permanently hold together networks of signaling pathway proteins 하는 것도 있음.

- Termination of signal (inactivation mechanism)

: 다시 신호 받으려면 다시 빠르게 원상태로 돌아와야함 (reversibility)

Binding of signaling molecules to receptors is reversible.

Relay molecules 도 다시 inactive form 으로 reversible.

- cellular response occur only when concentration of receptors with bound signaling molecules is above certain threshold (역치).

Apoptosis - cellular suicide (when cells ~~that~~ infected, damaged, reach end of life span)

: 내부 구성요소 chop, cell shrink, become lobed (blebbing) → cells parts are packaged in vesicles → engulfed and digested by specialized scavenger cells.

- 이웃 cells 보호하기 위한 것.

trigger [by extracellular signal molecule by other cell.
inner cellular reaction 이 의한 signal pass.

Apoptosis in the soil worm. : ced-3, ced-4 = genes encode proteins essential for apoptosis
Ced-3, Ced-4 = proteins (이미 존재하지만 inactive 상태)

Gene activity 나 protein synthesis 가 아니라 level of protein activity 로 apoptosis trigger.

과정: Death-signaling molecule 을 cell이 receive
→ 미토콘드리아 외막의 ced-9가 수행하던 apoptosis ~~break~~ brake 를 disable
→ ~~ced-4~~ Ced-4 activated → Ced-3 activated. ----> Nucleases, Proteases activated

Mammals Apoptosis : 수많은 pathway 존재.

- ex. certain mitochondrial protein that trigger to form molecular ~~pore~~ pores in the mitochondrial outer membrane. causing it to leak and release ~~other~~ other proteins that promote apoptosis (ex. cytochrome c - 원래는 electron transport 역할 / 세포질로 나오면 cell death factor 로 작용)

Signal originate from outside cell
Signal originate from inside cell
- from nucleus : when DNA suffer ~~irreparable~~ irreparable damage.
- from ER : excessive protein misfolding occurs

Built-in cell suicide - essential to development and maintenance.

[파킨슨 : nerve cell 안에 aggregated proteins 너무 쌓여서 자살.
[암 : 자살 실패.

10. cell Respiration.

Catabolic Pathways (이화작용) : metabolic pathways release stored energy by breaking down complex molecules (exergonic)

Fermentation (발효) : partial degration of fuel, without Oxygen.

aerobic respiration : Oxygen consumed harvests chemical E

anaerobic respiration : no oxygen consumed harvests chemical E

} cellular respiration (aerobic 자체를 의미하는 경우가 대부분)

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + E$ (ATP + Heat) : exergonic, $\Delta G = -686$ kcal/mol

Oxidation and Reduction : Redox Reactions (산화 환원 반응)

electron transfer. [loss electron = oxidation
addition electron = reduction.

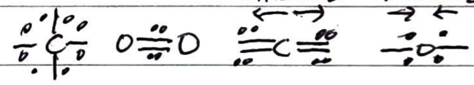
$Na + Cl \rightarrow Na^+ + Cl^-$ (oxidized, reduced)

Na: electron donor. = reducing agent (환원제)
Cl: electron acceptor = ~~oxidize~~ oxidizing agent (산화제)

항상 complete transfer of e^-는 아님. ⇒ change degree of electron sharing in covalent bonds

ex. Methane combustion.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$



⇒ 전자가 덜 electronegative 한 atom 에서 더 electronegative 한 atom 으로 potential↓

꼭 전자가 관여 안해도 됨. - H가 O로 바뀌면서 E 방출하는 관점.

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$.
($C_6H_{12}O_6 \rightarrow 6CO_2$: oxi, $6O_2 \rightarrow 6H_2O$: red)

H는 바로 O_2로 전달되지 않음 → pass first to electron carrier (전자전달체)

: coenzyme ⟨nicotinamide adenine dinucleotide⟩ NAD

dehydrogenase: NAD^+ (oxidation form) ⇄ NADH (reduced form)

NAD^+ ↳ oxidizing agent.
NADH ↳ reducing agent

$NAD^+ + 2H \rightarrow NADH + H^+$
(2H = 2e, 2P; NADH = 2e, P; H^+ = P)

electron transport chain (전자전달계) at 미토콘드리아 내막

NADH (Top of chain) ⟶ O_2 (electron acceptor) bottom of chain.

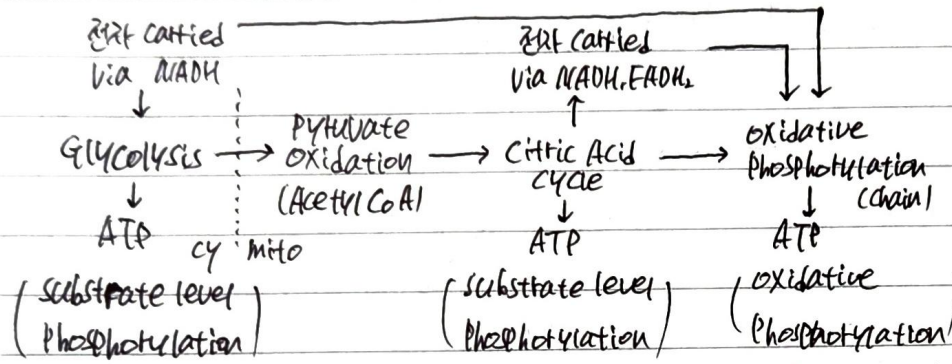
Cascading : chain 따라 점점 electronegative 한 carrier molecule로 내려감.

최종 : O_2.

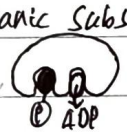
Stage of cellular respiration - preview.

harvesting Energy from glucose by cellular respiration.

Glycolysis Pyruvate oxidation / Citric Acid Cycle Oxidative Phosphorylation (Electron transport, chemiosmosis) 환원 상특



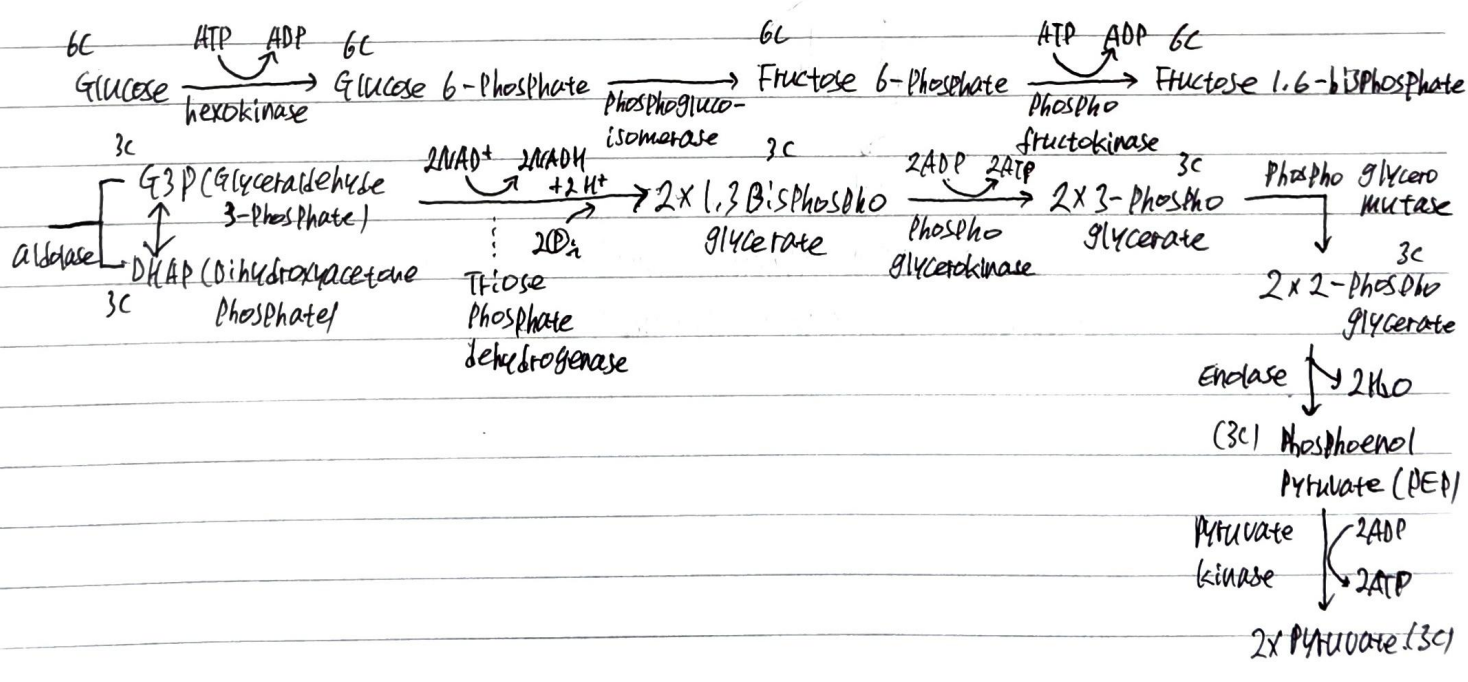
: ATP made by direct transfer of Phosphate group from Organic Substrate to ATP by enzyme



: Inorganic Phosphate.

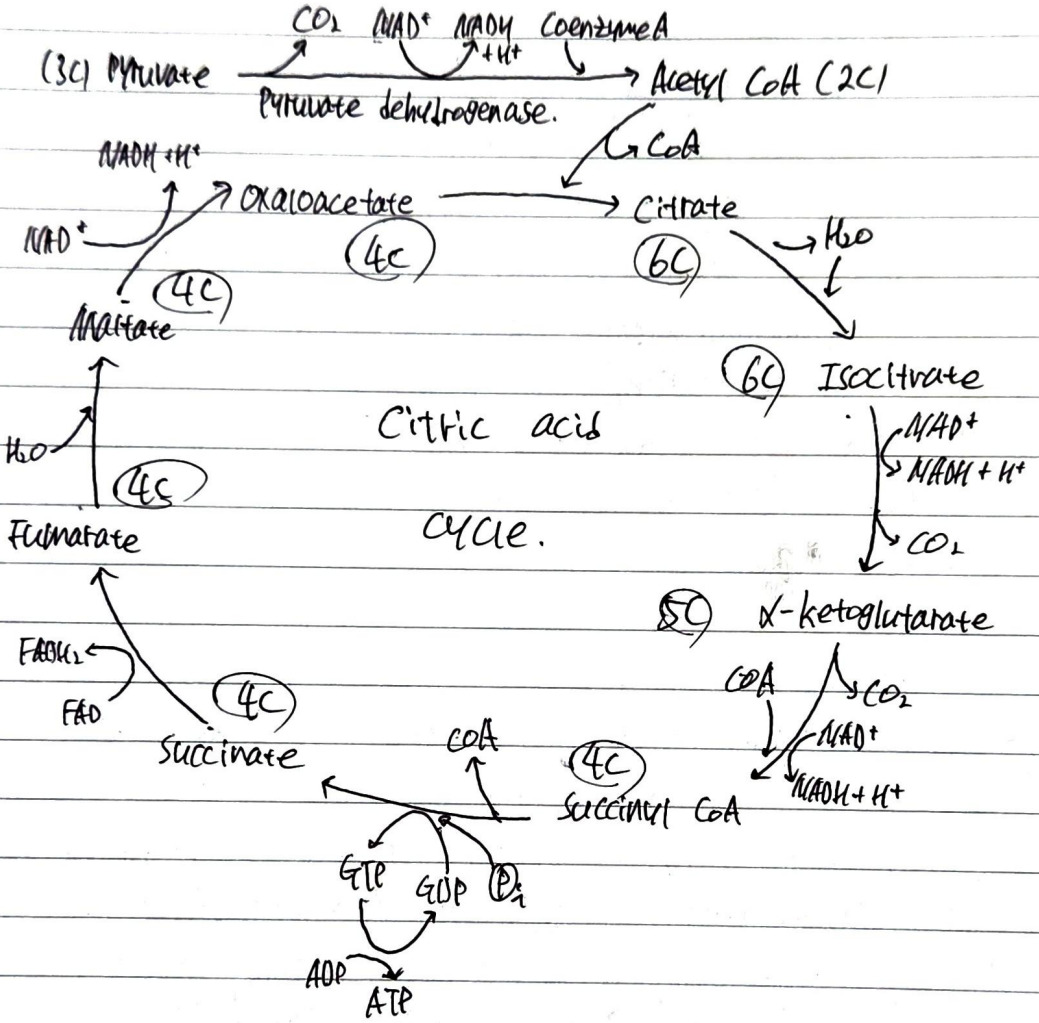
Glycolysis (해당. sugar splitting)

Glucose ← 2ATP → 2 pyruvate, 4ATP, 2NADH, $2H_2O$, $2H^+$ net: 2ATP. 2NADH. 2 pyruvate $2H_2O$. $2H^+$



Citric acid cycle.

산소 있을때 Pyruvate enter mitochondrion (Prokaryotic cell은 cytosol에서)
이후 Pyruvate oxidation. (Pyruvate → acetyl CoA)



Net: 1 Acetyl CoA - 1ATP, 3NADH, 1FADH₂
1 Pyruvate - 1ATP, 4NADH, 1FADH₂
1 Glucose = 4ATP

Oxidative Phosphorylation.

Pathway of Electron Transport chain : collection of molecules embedded in inner-membrane of Mitochondrion (cristae 구조)

- make no ATP directly.

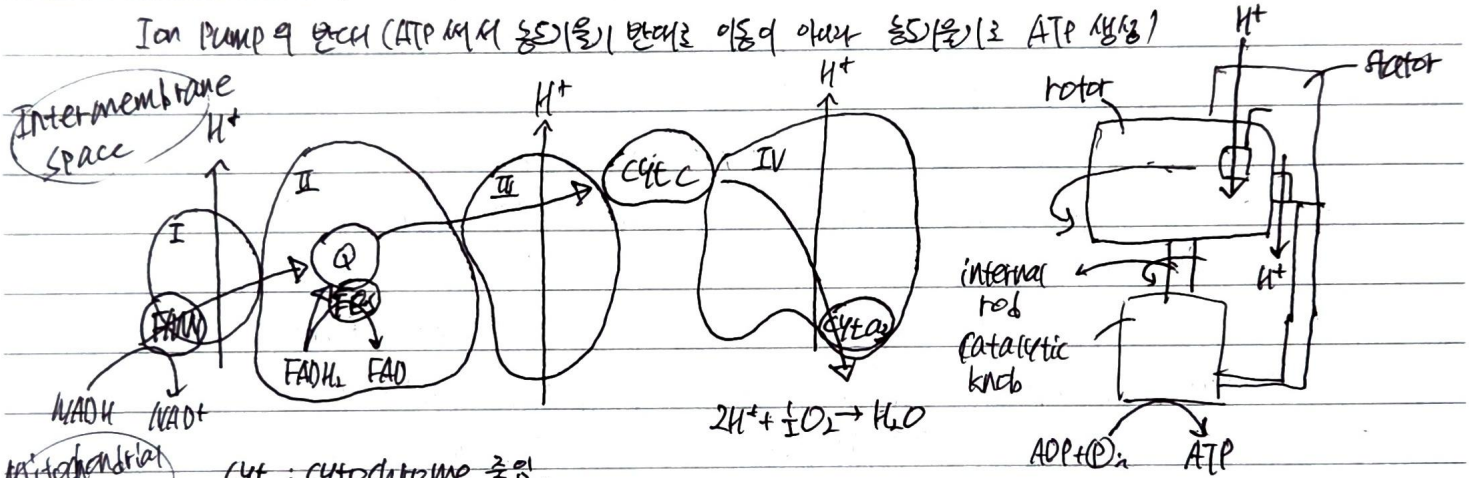
: make of multiprotein complex I ~ IV, 그리고 여기 붙어있는 prosthetic groups (보결분자단)

: nonprotein compounds.

~~Chemiosom~~

chemiosmosis - by protein complex (ATP synthase) : make ATP from ADP and inorganic Phosphate.

Ion pump의 한종류 (ATP 써서 양성자를 반대로 이동해 에너지 농도차로 ATP 생성)



Cyt : cytochrome 줄임.

NADH 대신 $FADH_2$로 ATP 생성시 $\frac{1}{3}$ 수준의 E 생성

Q : Ubiquinone (X protein, mobile)

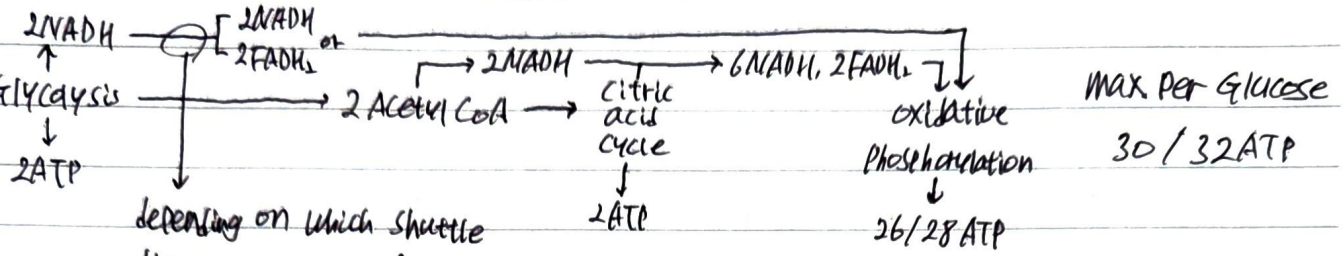
(CoQ. Coenzyme Q 라고도 불림)

Proton-motive force.

: emphasizing the capacity of gradient to perform work.

Energy for gradient formation comes from exergonic redox reactions along electron transport chain.

Accounting ATP production by cellular respiration



NADH : 2.5ATP
$FADH_2$: 1.5ATP.

Shuttle electron: cytosol → Mitochondrion.
NADH 그냥통과 못함 ∴ by electron shuttle system. 따라서
- NAD+ (liver, heart) : 2.5ATP
- FAD (brain) : 1.5ATP

다양한 organism 에서의 정확한 ATP 수율 모름.

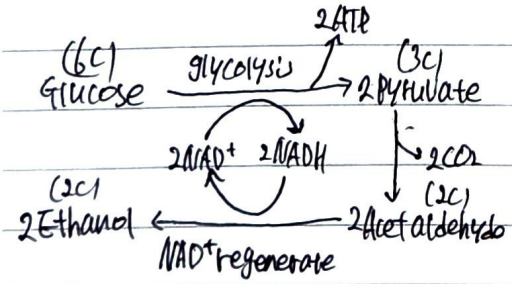
왜냐 all proton-motive force generated by electron transport chain used to ATP synthesis, 1 glucose generate 28ATP (oxidative phosphorylation)
4ATP (substrate level phosphorylation)
= 32ATP (30ATP at brain)

Efficiency estimation : 1 glucose = 686 kcal, ATP stores 7.3 kcal
7.3 × 32 / 686 = 34% (remarkably efficient)
나머지는 heat.

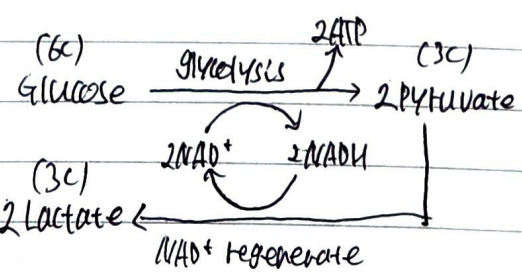
어떤 경우는 efficiency low 가 됨. ex. hibernating mammals.
brown fat : cells contain channel protein (uncoupling protein) that allow protons flow back down without generating ATP.
⇒ generate heat, save fuel.

Fermentation and anaerobic Respiration. (Produce ATP without O_2)
- electron transport chain X.
- O_2 대신 SO_4^{2-} (sulfate ion)
- H_2O 대신 H_2S (hydrogen sulfide)

Alcohol fermentation



Lactic acid fermentation.



Comparing Fermentation with Anaerobic and Aerobic respiration.

key difference - contrasting mechanism for oxidizing NADH back to NAD^+

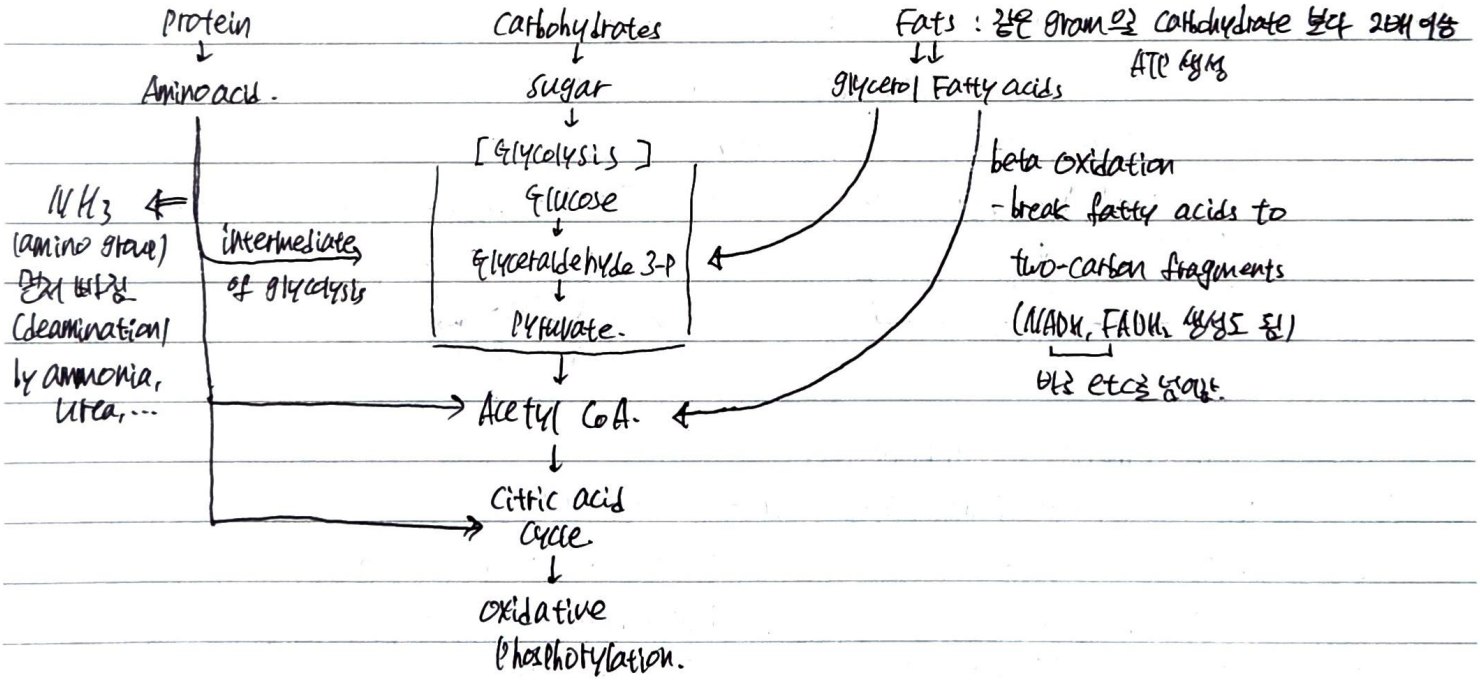
fermentation : final electron acceptor { Pyruvate : Lactic acid fermentation
Acetaldehyde : alcohol fermentation.

aerobic (Cellular respiration.) : NADH transferred to electron transport chain.
final electron acceptor = O_2

amount of ATP produced - fermentation : 2ATP (Substrate level phosphorylation)
- cellular respiration : up to 32ATP.

{ obligate anaerobes : Can't survive in O_2
facultative anaerobes : either fermentation ~~and~~ or respiration (O_2 있을 때 respiration)

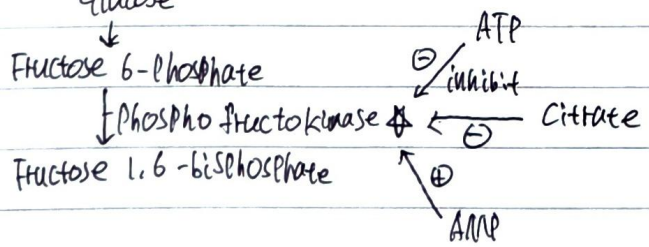
Catabolism of various molecules



Biosynthesis (Anabolic) 으로 필요한 아미노산, glucose, 지방 생성가능!
(필수 아미노산 제외)

Regulation of cellular respiration via Feedback mechanisms.

feedback inhibition : end product of anabolic pathway inhibits enzyme that catalyzes early step of pathway.



* Phospho fructokinase : allosteric enzyme

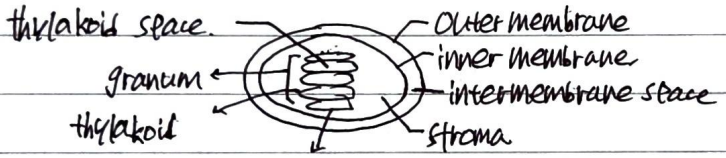
II. Photosynthetic Processes

↳ sunlight Energy ⇒ chemical Energy.

Autotrophs : self-feeders. sustain themselves without eating derived from living beings.
produce organic molecules from CO_2 + inorganic raw materials
- ultimate source of organic compounds. (Plants = Photoautotrophs)

Heterotrophs : live on compounds produced by other organism (consumer)

chloroplast - originated from photosynthetic prokaryote (Endosymbiont theory)
found mainly in mesophyll (엽육조직) < 울타리조직 / 해면조직
CO_2 enter, O_2 out by stomata (기공)



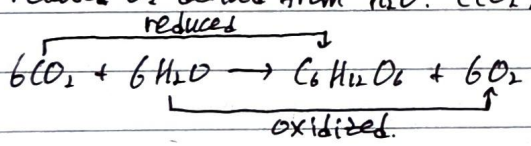
thylakoid membrane : chlorophyll (green pigment) on it

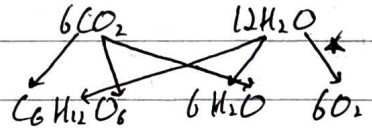
Photosynthesis : $6CO_2 + 12H_2O + \text{Light E} \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$

Net : $6CO_2 + 6H_2O + \text{Light E} \rightarrow C_6H_{12}O_6 + 6O_2$

Simplest : $CO_2 + H_2O + \text{Light E} \rightarrow CH_2O + O_2$

* released O_2 derived from H_2O. (CO_2 X) ⇒ $H_2{}^{18}O$, $C^{18}O_2$ 실험에서, $H_2{}^{18}O$ 형태로 $^{18}O_2$ 방출

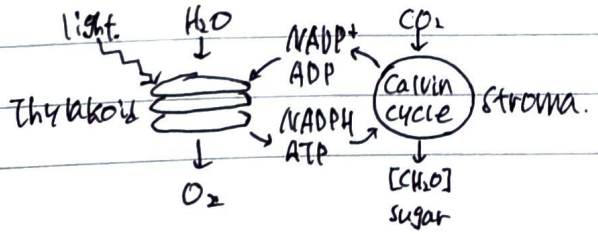




two stages of photosynthesis : preview.

- light reaction : solar E → chemical E. $H_2O \rightarrow H^+ + e^- + O_2$
  generate ATP by chemiosmosis — transfer to acceptor (NADP+)
  (Photophosphorylation) — light E reduce NADP+ to NADPH ($+2e^-, +H^+$ 된것)
  결과적으로 light E → < NADPH → source of e^- : 다른 분을 reduce 시킴. reducing power.
  ATP → 에너지원 (쓰임)

- Calvin cycle : carbon fixation (공기중 CO_2 를 chloroplast 속 organic compounds 에 incorporate)
  이후 fixed carbon 을 carbohydrate 로 reduce (addition of e^- by NADPH)
  Sugar 만듦. but light reaction 의 NADPH와 ATP 없이는 진행 X.
  → dark reaction 으로 불리지만 대부분 낮에 일어남.



Light reactions : solar E → chemical E (ATP, NADPH)

Pigment. - substance that absorb visible light ⇒ see green because chlorophyll absorbs violet-blue, red light.

spectrophotometer , absorption spectrum , action spectrum. (O_2 release, consumption)

chlorophyll a : key light-capturing pigment.] work well on violet-blue & red

chlorophyll b :) accessory pigment (a) - work well on violet-blue.

chlorophyll c :

Engelmann's experiment : using Aerobic bacteria + Filament of algae.

chlorophyll a : CH_3 on functional group , chlorophyll b : CHO on functional group

(blue green color) (olive green color)

chlorophyll d. chlorophyll f

↳ functioning in place of chlorophyll a (work well on very shaded condition)
Higher-wavelength.

Carotenoid : yellow red color, Photoprotection 역할 → absorb and dissipate excessive light E that would damage chlorophyll or interact with oxygen, forming reactive oxidative molecules that are dangerous. (antioxidant properties)

Excitation of chlorophyll by light

molecule absorb photon of light → electrons elevated to orbital that has more potential E.
(ground state) (excited state)

Photon absorb only exactly equal energy difference between ground - excited state.
⇒ unique absorption spectrum 가진 이유.

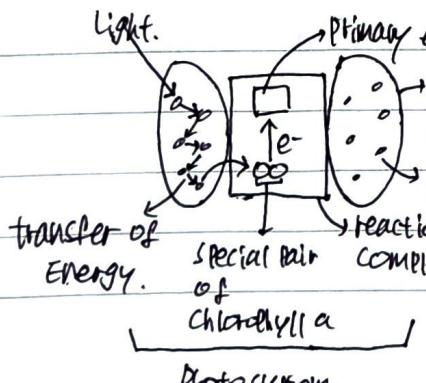
excited state : unstable → drop down to ground state. releasing excess E as heat.
⇒ 햇빛 많으면 더운 이유!

Chlorophyll emit light, heat. ⇒ afterglow called fluorescence (형광)

Photosystem (PS) : Reaction-center complex + Light-harvesting complexes.

- reaction-center complex : Protein holds special pair of chlorophyll a + primary electron acceptor.

- Light-harvesting complex : consist of various pigment molecules. (a, b, carotenoid --) bound to protei

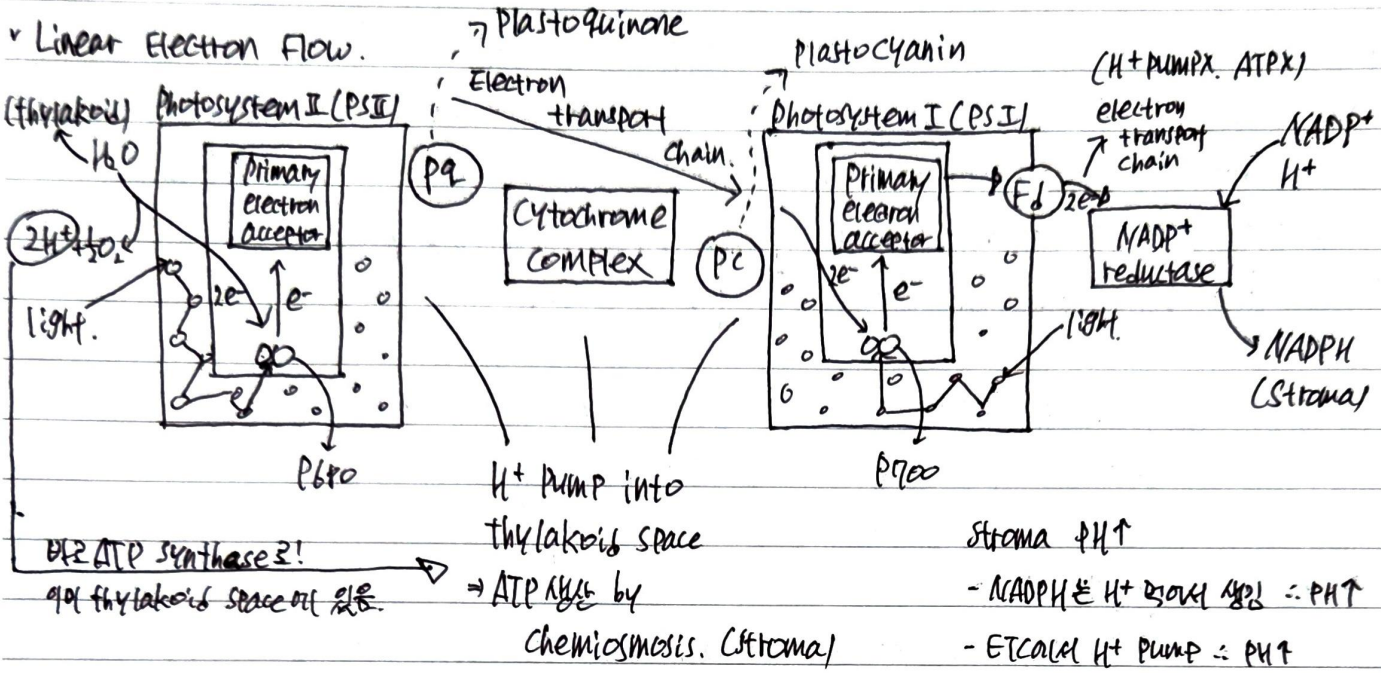


Primary electron acceptor : molecule that capable of accepting electron and reduce

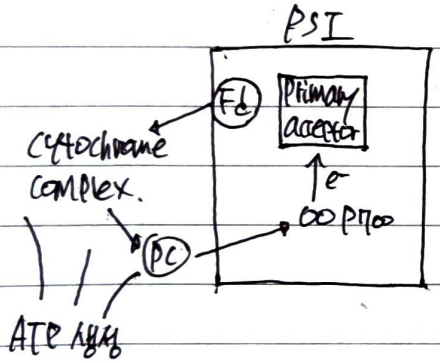
아까 포토스크어서는 primary electron acceptor 없어서 들뜬 전자가 곧바로 ground state로 돌아와서 fluoresces 발생.

Photosystem : light E → chemical E.

Linear Electron Flow.



Cyclic Electron Flow (I에서만)



ATP 생성. NADPH / O_2 생성 X.

Photoprotective 역할. 대부분 I, II 다 있는 식물에서.

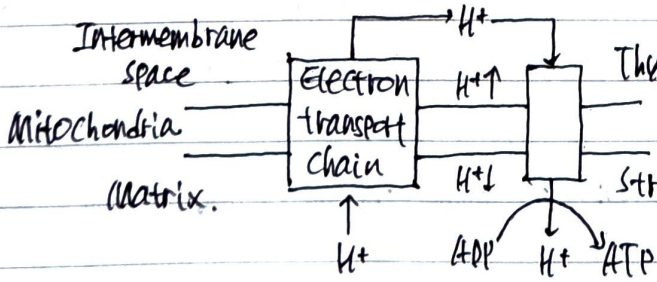
I, II 둘 중 하나만 있는 생물도 있음 ⇒ 무조건 Cyclic Electron Flow.

Comparison of chemiosmosis in Chloroplast / Mitochondria.

- Potential E stored in form of H^+ gradient across membrane.

Chloroplast : high-Energy electron drooped down transport chain come from "water"
Use Chemiosmosis to transform light E to Chemical E (ATP)

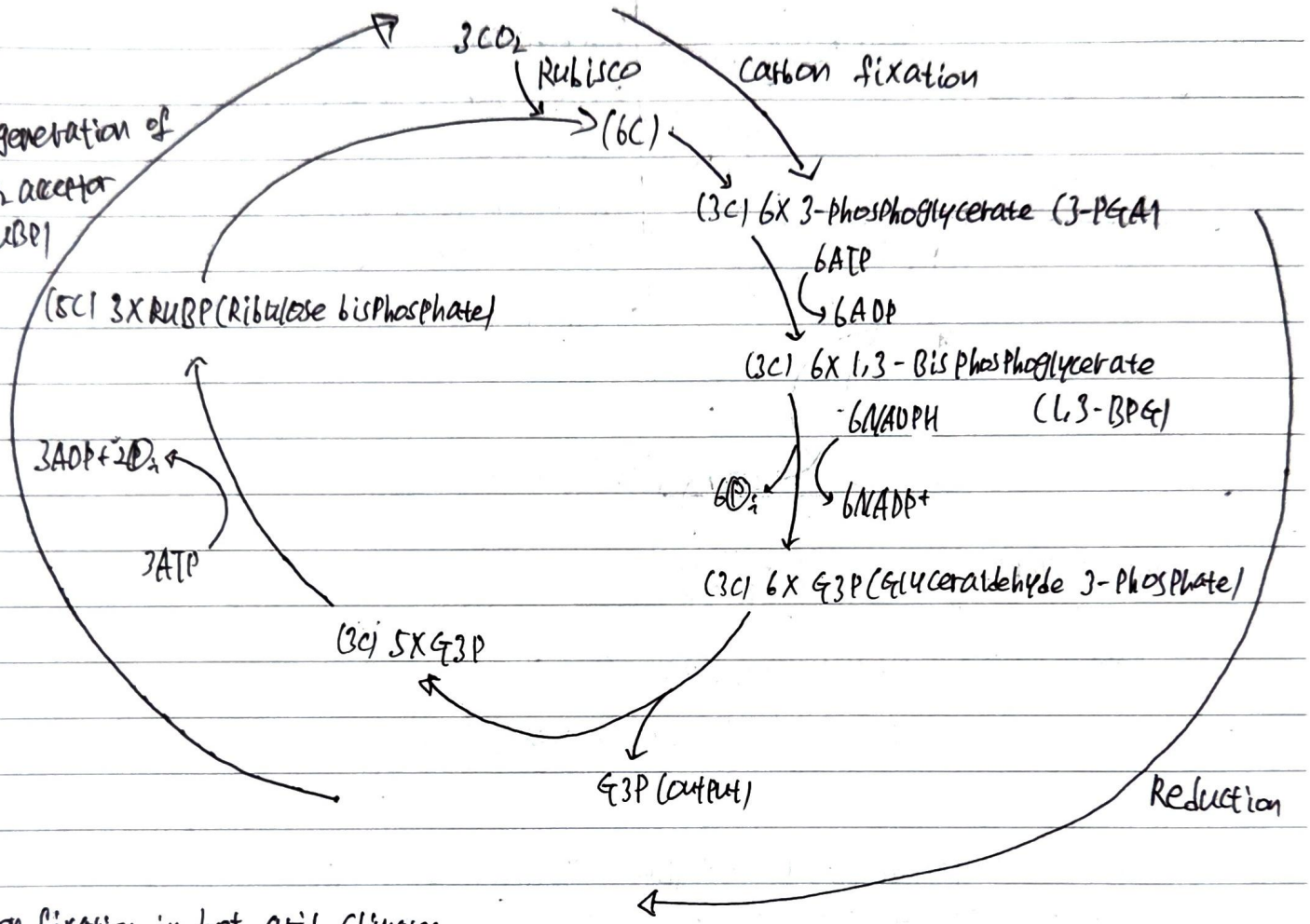
Mitochondria : electron extracted from organic molecules.
Use Chemiosmosis to transfer chemical E from food to ATP.



Chloroplast ⇒ catalytic knob가 stroma에 있음.
ATP가 Calvin cycle에서 쓰임!

Calvin cycle : ATP, NADPH → reduce CO_2 to sugar (stroma) , Anabolic 과정.

Phase → Carbon fixation - Reduction - Regeneration of the CO_2 acceptor (RuBP)



Carbon fixation in hot, arid climates.

stomata → CO_2 얻는 통로, transpiration 통로 (loss water) : 닫히면 CO_2↓, O_2↑ ⇒ photorespiration↑

↳ C_3 plants. - first organic product of carbon fixation = 3 carbon compound (3-PGA) ex. rice, wheat…

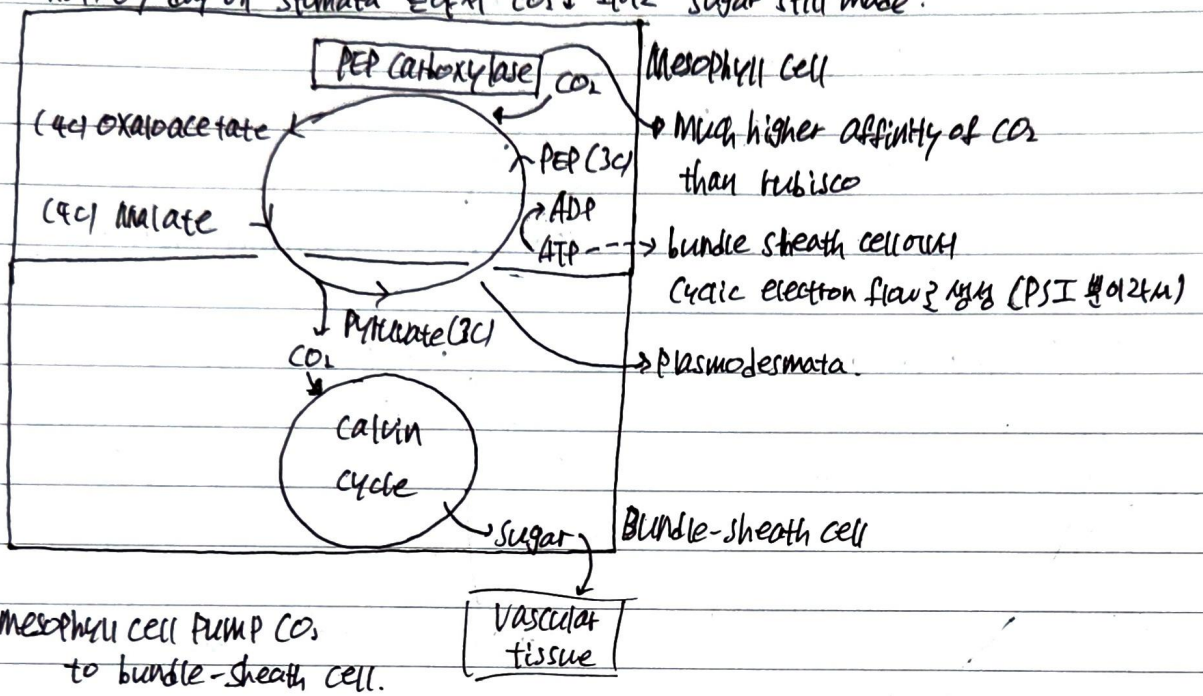
hot, dry day에 stomata 닫힘 → CO_2↓, O_2↑ : Rubisco is capable binding O_2 in place of CO_2.

→ 2C compound 생성 → Mitochondria, peroxisome에서 쓰고 CO_2 방출 ⇒ photorespiration ≠ cellular respiration 과 다르게 ATP 소모. / photosynthesis 와 다르게 decrease photosynthetic output.

생존에 이득: Evolutionary Relic / provide protection against damaging products of light reactio

▾ C_4 plants - 4 carbon compound (oxaloacetate) ex. sugarcane, corn, ···

hot, dry day에 stomata 닫힘시 CO_2↓ 되도 sugar still made.



mesophyll cell pump CO_2 to bundle-sheath cell.

Spend ATP to minimize Photorespiration, enhance sugar production.

산업혁명으로 대기 CO_2↑, T↑로 인해 식물 C_3, C_4 생태에 영향., C_4 rice 개발중.

▾ CAM plants. (Crassulacean acid metabolism) ex. Pineapples, cacti, succulent plants··· (aloe, jade···)

Stomata : open at night (get CO_2) / close at day (conserve water)

↳reverse of other plants. but CO_2↓

CAM's mesophyll cells → store organic acid (made during night before, store in vacuoles)

during day, CO_2 released from organic acids

C_4 : Carbon fixation are separated "structurally" from calvin cycle

CAM : two steps occur in same cell but at "separate times"

- Green cells are only autotrophic parts of the plants.

12 Mitosis (체세포 분열)

cell division.

genome : genetic information (DNA)

Chromosomes (염색체) : DNA packaged into structure

chromatin (염색질)

Somatic cells (체세포) : 46 chromosomes (2x23)

Gametes (생식세포) : 23 chromosomes

during cell division → duplicated chromosome consists of two sister chromatids (염색분체)

- cohesins로 일정히 붙어있다. (Sister Chromatid cohesion)
- centromere : region made up of repetitive sequence in chromosomal DNA where the chromatids are attached most closely.
  - p chromosome arm
  - q chromosome arm

This attachment mediated by proteins that recognize and bind to centromeric DNA.

Mitosis : division in nucleus, followed immediately by cytokinesis (divide of cytoplasm)

Meiosis : Produce gametes.

Phases of cell cycle. - Interphase (간기) (G_1, S, G_2) / Mitotic phase (분열기) (M)

G_2 of Interphase : Two centrosomes formed by duplication of single centrosome

↳ region that organize microtubules of spind (방추사

Prophase (전기) : make chromosomes (visible) / nucleolus disappear.

duplicated chromosome appear as two sister chromatids joined at centromeres., cohesin.

Mitotic spindle (방추사) 생성 시작 / asters 생성.

centrosomes move away from each other, lengthening microtubules between them.

Prometaphase (전중기) : nuclear envelope fragments. / chromosomes more condensed.

kinetochore formed at centromere of each chromatids (2 per chromosome)

some microtubules attach to kinetochore ⇒ kinetochore microtubules (동원체 미세관)

nonkinetochore microtubules interact with opposite pole of spindle, lengthening cell.

Metaphase (중기) : centrosomes are at opposite pole of the cell.

chromosomes all arrived at "metaphase plate" → equidistance between spindle's two poles

Anaphase (후기) : Cohesin proteins cleaves. - each chromatids become independent chromosome

two daughter chromosome move towards opposite side of cell (방추사 shorten)

cell elongates as nonkinetochore microtubules lengthen.

Telophase (말기) : Two daughter nuclei form. / Nuclear envelopes arise. / Nucleolus reappear.
Spindle microtubules depolymerized.
Mitosis complete.

Cytokinesis : formation of cleavage furrow (pinch the cell in two)
(during anaphase or telophase)

Mitotic spindle - Spindle microtubules elongate (polymerize) by incorporating more subunits of tubulin and shorten by losing subunits.

Pair of centrioles located at center of centrosome
During Interphase, single centrosome duplicate → forming two centrosomes.
Aster : radial array of short microtubules. → grown and contact with plasma membrane
kinetochore : chromosome's two kinetochores face opposite directions
kinetochore microtubules (kinetochore 에 붙은 microtubules)
metaphase plate : imaginary plate.
separase = enzyme that chromosome are cleaved.

Way of kinetochore microtubules function in poleward movement of chromosomes
1. motor proteins on kinetochores walks the chromosomes along microtubules which depolymerized at their kinetochore ends after motor proteins have passed.
2. Chromosomes reeled in by motor proteins. at spindle poles and microtubules depolymerized after they pass motor proteins at poles.

nonkinetochore microtubules elongate whole cell during anaphase.
During anaphase, region of overlap reduces as motor protein attached to microtubules walk them away from one another. (using energy of ATP)
- microtubules push ~~along~~ apart from each other - their spindle poles pushed apart.
→ elongate cell.
+ microtubules lengthen by addition of tubulin sub units to overlapping ends.
⇒ overlap 유지.

Cytokinesis : occurs by Process name Cleavage ⇒ first sign of it : appearance of Cleavage furrow.

Cytoplasmic side of furrow : contractile ring of actin microfilaments associated with molecules of protein myosin.

Plant cell : no cleavage furrow.

During telophase, vesicle derived from golgi apparatus move along microtubules to middle of cell, coalesce (합체), Produce cell plate

Binary Fission of Bacteria (circular DNA) : asexual reproduction (무성생식) [Eukaryotes : mitosis ○ / prokaryotes : mitosis ×.

cell division start when DNA begin replicate at specific place on chromosomes called Origin of Replication (Produce two origins)

Each origin moves rapidly toward opposite of cells. + cell elongates.

- two origins end up at opposite poles of cells., anchored by one or more proteins.

Molecular control system of Eukaryotic cell cycle.

cell cycle control system : regulated at certain Checkpoints by internal / external signals
↳ 3개 (G_1, G_2, M phases)

Cyclins and Cyclin-Dependent Kinases (CDK)

Protein kinase : enzyme that activate / inactivate other proteins by Phosphorylating.

CDK initially inactivate → attach to cyclin : activate.

MPF : cyclin-CDK complex. → cyclin concentration 증가에 MPF activity 영향

(Maturation Promoting Factor) : M-Phase Promoting Factor 라고 불리도 무방

trigger cell's passage into M Phase., past G_2 checkpoint.

① MPF Promote Mitosis by Phosphorylating various proteins.

- nuclear lamina 의 protein 을 Phosphorylating 해서 nuclear envelope fragmentation.

② chromosome condensation, Spindle formation 에도 관여.

③ MPF switch itself off by destruction its own cyclin.

④ Give go-ahead signal : G_1 checkpoint, G_2 checkpoint 에서도 regulated by MPF activity.

Stop and go sign - Internal / External signals at checkpoints.

G_1 checkpoint : most important ⇒ G_1 ck 통과시 대부분 G_2, S, M phase 통과함.

go-ahead signal 못받은 G_0 phase 로 (Nondividing state out of cycle)

↳ 대부분 세포는 G_0 단계에서 머문다.

Internal signal

- M checkpoint : Anaphase 에서 separation of sister chromatids 일어나는 것.

some kinetochores 가 unattached to spindle microtubules → delay anaphase by inactivated appropriate regulatory protein complex

안활성화된 activate → activate enzyme separaze (cleaves cohesins)

- S checkpoint : stop cells with DNA damages.
- Between anaphase and telophase : ensure anaphase completed / chromosomes well separated

External signal.

- growth factor : Protein releases by certain cells that stimulates other cells to divide.

ex. Platelet-derived growth factor (PDGF) : Made by blood cell fragments called platelet.

When injury occur, platelets release PDGF.

PDGF is required for division of cultured Fibroblast (type of connective tissue cell)

Fibroblast : has PDGF receptors on plasma membrane (RTKs)

- triggers signal transduction pathway that allows cells pass G_1 ck and divide.

Effect of external physical factor on cell division.

- density-dependent inhibition. : crowded cells stop dividing.

cultured cells normally divide until they form single layer of cells.

Binding of cell-surface protein to counterpart on adjoining cell sends signal to both cells that inhibits cell division.

- anchorage dependence : to divide, cell must attached to something.

↳ 각각은 signal to cell cycle control system.

Cancer : 동작 X. do not stop dividing when growth factors are depleted.
do not need growth factors in culture medium.
- 스스로 gf 만들거나, 항상 작동.
+ cell cycle의 Random한 breakdown 발생 (Checkpoint 이상 X)

Cells in culture that acquire ability to divide indefinitely are said to have undergone a process called "transformation". causing them to behave like cancer cell.

- Cancer cell evade apoptosis.

(benign tumor : 전이 X.
malignant tumor : 전이 O - spread of cancer cell distant from original site (transformed cell) = metastasis

- 방사선 치료 : cancer cell의 low ability to repair 를 활용.
- Cell cycle 관여 chemotherapy. - side effect 있음 (머리빠짐 ...)
  ↳ personalized chemotherapy - side effect 최소화.