Lecture 5, Jan 24, 2023

Mitochondria and ATP

- Mitochondria produce adenosine triphosphate (ATP)
  - A long chain of 3 phosphates attached to a ribose, which is attached to an adenine
- Mitochondria aren't static; they move around within the cell
- Within a mitochondrion:
  - Outer and inner membranes surround the cell
  - The intermembrane space is between them
  - Cristae stick out, increasing surface area
    * Bigger surface area produces more ATP
  - The matrix is inside the mitochondrion
- Glucose goes through glycolysis, producing pyruvate, then undergoes pyruvate decarboxylation, producing acetyl CoA, and undergoes a citric acid cycle and then oxidative phosphorylation, producing ATP at each step
  - Oxidative phosphorylation produces the most ATP (34 ATP vs 2 for most others)
  - Under ideal conditions we can get 38 ATP going through the entire cycle
  - In reality some processes take up ATP, and may be less than 100% efficient, so the real production is 30-32 ATP per glucose
- The production of ATP requires oxygen; without it the process stops at glycolysis, and instead of ATP you get lactic acid

The Cell Membrane

- Thin layer of molecules on the surface of the cell
- The membrane is made of phospholipid molecules
  - One side (head(is hydrophilic and one side is hydrophobic
  - Two lipid tails, one is unsaturated so it has a bend
- The membrane is composed of a bilayer of these molecules; the hydrophobic tails match each other, the hydrophilic head is on the outside and inside of the cell
- For a cell these form a giant sphere, surrounding all the organelles
- There are many structures embedded within the membrane:
  - Various proteins
  - Cholesterol molecules help the membrane be more flexible
  - Channel proteins allow stuff to pass through the membrane

Membrane Transport

- Unassisted membrane transport
  - Passive (simple) diffusion: with enough time molecules like gases naturally diffuse through the membrane, reaching an equilibrium concentration across both sides given enough time
    * Gases like oxygen, carbon dioxide etc can get across the membrane very easily
    * Water gets across less easily due to the polarization, but is still readily available (4 orders of magnitude lower compared to gases)
      - Water travels by osmosis
      - A hypertonic solution has more concentration of solutes outside the cell; isotonic has equal concentration; hypotonic has less concentration of solutes inside the cell
        - In a hypertonic solution, water comes out of the cell and the cell shrivels; in a hypotonic solution water goes in the cell and the cell may burst
    * Glucose is large and uncharged, but slightly polarized, so it does not go across (8 orders of magnitude lower compared to water)
    * Ions are charged, so they are repelled by the lipids and do not get across
    * ATP and amino acids are much bigger and usually charged and do not get across
- Assisted membrane transport

- Channels or carriers facilitate the transport
    * Channel proteins are always open, allowing molecules in
        - There are specific channels for specific ions
    * Carrier proteins are first open, then captures the molecules, and then release them on the other side (these are slower)
        - Bigger molecules like glucose are transported by channel proteins
    * These are still passive processes based on concentration differences (no energy is needed)
- By passive diffusion, the rate of transport is directly proportional to the concentration difference
    * With carrier-mediated transport, there is a maximum rate that after which increasing the concentration difference would not increase the transport rate anymore (limited by number of carriers)
- Sodium and potassium concentrations are important
    * On the order of a hundreds milli-moles per litre outside the cell and tens inside the cell for sodium, and the reverse for potassium
    * This concentration difference is achieved by sodium and potassium pumps that transport sodium ions outside the cell and potassium into the pump
    * These are sodium-potassium ATPase pumps; they require energy (ATP) since the concentration gradient is in the reverse direction
- Primary active transport process:
    1. Cytoplasmic sodium ions bind to the pump
    2. ATP phosphorylates the pump, making it change shape
        * During this process, ATP changes to ADP and releases its energy
    3. The pump changes its shape to open to the outside, so the sodium gets out
    4. Potassium ions on the outside now stick to the cell, causing dephosporylation
    5. The pump returns to the original shape
    6. Potassium is released
- Secondary active transport process:
    * The sodium and potassium concentration differences established by the primary active transport can now be used to bring certain molecules in and outside the cell
    * The sodium outside the cell pulls in molecules and ions; potassium inside the cell pushes them out
        - Importantly the sodium ions can drag glucose in via special carrier proteins