Contents

Midterm I

Week 1

- ▷ What are the two central questions of physiology?
  - The mechanism, which refers to how an organism functions.
  - The origin, which asks what the adaptation significance of a mechanisms is.
- ▷ Describe the different sub-disciplines of physiology.
  - Mechanistic(functions)
  - Comparative(diversity)
  - Evolutionary(origins)
  - Environmental(ecology/physiology)
  - Integrative(whole systems).
- ▷ What is the Krogh principle? Explain what it means to physiology.
  - Limited number of animals of convenient study, but enough of the problems can be studied using comparative methods.
  - There is unity in diversity; the differences allow for specialized studies of complex systems due to niche environments, while similarities allow for studies of functions on animals we otherwise couldn't study.
- ▷ Define the terms conformity and regulation and understand how they relate to physiological processes. Discuss examples.
  - Conformity correlates passively with external changes.
  - Regulation holds constant, using cellular mechanisms.
- ▷ Define the term homeostasis. Understand the process of negative and positive feedback regulation.
  - Homeostasis: a coordinated process that maintains a relatively constant state though use of sensors and effectors.
  - Positive feedback: less common, self reinforcing, difficult to regulate, powerful.
  - Negative feedback: more common, self correcting.
- ▷ Describe how physiology changes with time in response to the external environment. Define the terms acclimation, adaptation, natural selection, and evolution.

- Acute: short-term, reversible, and quick to response to the environment, typically minutes–hours.
- Chronic: long term due to prolonged/repetitive exposure, sometimes reversible, can lead to acclimation.
- Evolution acts on changing allele frequencies of a population overtime.
- Natural selection acts to remove the least fit individuals, which influences allele frequencies.
- Adaption is trait that allows for greater fitness compared to other individuals in competition.

▷ Describe the structure and chemical components of lipid membranes.

- Glycoproteins and glycolipids: carbohydrate chains attached to protein or lipids, respectivley.
- Glycocalyx: combination of both.
- Integral proteins: embedded in phospholipid bilayer.

▷ What are the effects of low and high temperatures on membranes? How are membrane properties altered to offset these effects?

- Higher temperature produces more brownian motion which increases membrane fluidity.
- Membranes can have a different proportion of unsaturated/saturated hydrocarbon tails; the more double bounds (unsaturated) creates more fluidity at colder temperatures; more saturation increases stability at higher temperatures.
- Cholesterol acts to both stabilize membrane at higher temperatures and helps increases fluidity at lower temperatures.

▷ Describe the five functional types of membrane proteins and their basic functions.

- Channels: generall for water and used in osmosis.
- Tranporters: used in active transport and facilitated diffusion.
- Enzymes: decreases activation energy of reactions.
- Receptors: mediate responses to chemical messages.
- Structural proteins: used to attached to other molecules, effect cellular flexibility, and other structural relations.

▷ What are the two primary roles of enzymes?

- Accelerating and regulation chemical reactions.

- ▷ Define the terms V_{max} and K_m. Explain the factors that affect these reaction properties.
  - V_{max}: maximum velocity of reaction, determined by relative quantity of enzymes to substrate and catalytic effectiveness of each molecule.
  - K_m: half-saturation constant, inversely related with enzyme-substrate affinity.
- ▷ Define activation energy. Understand the effect of enzyme catalysis on a reaction's energy of activation.
  - The energy required for the substrate to enter the transition (intermediate state between substrate and product).
  - Enzymes lower the activation energy required.
- ▷ What are the effects of substrate concentration on the rate of an enzymatic reaction? How does enzyme-substrate affinity affect the reaction rate?
  - Substrate concentration can increase reaction speed only relative to enzyme concentraion; recactions become saturated when all enzymes are occupied by a substrate, further concentraion increases would have no effect.
  - Affinity affects the shape of the reaction velocity; an rate correlated with affinity.
- ▷ Why are enzymatic rates unresponsive to increases in substrate concentration above a physiologically relevant range?
  - Physiologically relevant range: physiologically possbile (outer limits) or normal bodily concentrations.
  - Enzymes are only functional in relevant ranges mainly due to selection pressure not acting on unusual ranges.
  - Increases in substrates thus would have not any effect if enzymes are not functional.
- ▷ Understand why conformational change is a critical part of enzyme function.
  - The shape of proteins deterins function, so changing the shape is critical for enzymes to influence reactions.
- ▷ Define the term isozyme and understand how they can contribute to natural selection.
  - Isozyme: enzymes that catalyze the same reaction, but differ in amino acid sequence.

- The change in sequence can lead to slight differences in function, which selection pressure can act on, increasing the differences.

▷ Define and understand the process of allosteric modulation.

- Alosteric modulation: the modulation of catalytic properties.
- Allosteric activation and inhibition can increase or decreases affinity, and thus catalytic activity.

Week 2

- ▷ Define the terms transcription, translation, and post-translational processing. Understand the differences between nRNA and mRNA and introns and exons.
  - Transcription: the process of turning DNA into mRNA.
  - Translation: the process of turning mRNA into sequences of amino acids for protein synthesis.
  - nRNA: first product of transcription, before introns have been spliced out, leaving just the exons for the mRNA.
  - Post-translational processing: covalent and enzymatic modification (folding, cutting) of proteins after translation.
- ▷ Understand how to interpret information about the origin of physiological traits from a phylogenetic tree.
- ▷ Define the terms genome and genomics. Describe the methods, challenges, and major goals of genomics research.
  - The study of genomes—the full set of genetic material—of organisms.
  - Mainly uses computational biology that uses various high-throughput methods (analysis of large amounts of data).
  - Major goal: elucidate the evolution of current functioning of genes and genomes.
- ▷ Describe an example for each major mechanism of gene modification, e.g. mutation accumulation, deletions, gene duplication.
  - Gene deleteion: disturbing the function of animal's genes to identify function by revealing deficient phenotypes.
  - Duplication: forced overexpression, inverse of gene deletetion.
  - RNAi: specific mRNA silencing, then compared.
  - CRISPR/Cas: insertion/editing of mRNA that are then tranlasted.
- ▷ What does the phrase "from genotype to phenotype" mean? What are the limitations associated with this phrase?
  - Refers to mapping genes with their functions.
  - Very difficult as there are complex post-translational effects and epigenetics.
- ▷ Define the terms transcriptome and transcriptomics. Describe the methods and challenges of transcriptomics research. How can the function of a gene's expression be tested?

- Transcriptomics: study of which genes are transcribed to make mRNA and the rates at which they are transcribed.
- Transcriptome: full set of mRNA molecules that represent the full complement of genes being transcribed; useful for comparative methods.

▷ Define the terms proteome and proteomics. Why is proteomics treated as a separate discipline rather than being lumped together with genomics and transcriptomics?

- Study of proteins being synthesized by cells and tissues.
- Protein folding is increadily complex; incredibly large number proteins to simultaneously study.

▷ What is two-dimensional gel electrophoresis? What kinds of data does it generate? How is it used in proteomics research?

- Two-dimensional gel: primary method of proteomics that separates complex mixtures of proteins, based on isoelectric points and molecular weights.

▷ Define the term metabolomics. How does it differ from the other "omics" disciplines?

- Study or organic compounds in cell other than the macromolecules coded by the genome.

▷ Define the term epigenetics. Are epigenetic changes heritable from cell to cell? From parents to offspring? Explain.

- Epigenetics: modification of gene expression with no change in DNA sequence that are transmitted when genes replicate.
- Heritable from cell to cell (mitotic) and (meiotic)

▷ Identify the two major mechanisms of epigenetic change and their consequences on gene transcription.

- DNA methylation: addition of methyl groups that generally silences particular genes.
- Histone modification: modifies histones that make DNA more/less accessbile for transcription.
  - Methylation, acetylation, phosphorylation, or other covalent bonding of chemical groups all play specific roles.
  - Also small RNA molecules helps perpetuate changes.

Week 3

- ▷ Define and describe the different types of passive and active solute transport. Understand how and why they differ from each other.
  - Passive transpot: movement of solutes towards equilibrium.
    - Simple diffusion: high solute concentration → low solute concentration.
    - Faciliated diffusion: solute that bind reversibly to tranporter proteins that allow for faster transport that simple diffusion; occurs in direction of electrochemical equilibrium.
    - Temperatue has more of an effect on facilitated diffusion.
  - Active transport: move molecules/solutes against a concentraion gradient using cellular energy.
    - Primary: uses protein pumps to transport mostly metal ions and normally uses ATP.
    - Secondary: uses potential energy through use of transporters to effect the electrochemical gradient.
- ▷ Define: equilibrium, concentration gradient, electrical gradient, electrochemical gradient, electrogenic, and electroneutral.
  - Equilibrium: state of minium capacity to do work under locally prevailing conditions.
  - Cencentration gradient: difference in concentration between two solutions separated by a semipermeable membrane.
  - Electrical gradient: differences in charge.
  - Electrochemical gradient: combination of electrical and chemical gradient.
  - Electrogenic: produces a change in the electrical potential of a cell.
  - Electroneutral: no net change on electric charge.
- ▷ Understand the forces imparted on ion movement as a result of reinforcing and opposing electrochemical gradients.
  - Chemical gradients influence electrial gradients and vice versa; interaction forms an electrochemical gradient.
  - Ions can be moved around with active transport to reinforce or oppose gradient in order to influence passive transport.

- ▷ Define the Fick diffusion equation and be able to use it to calculate a rate of diffusion.
  - $J = D\frac{C_1 - C_2}{X}$
  - J is the net number of solute molecules passing into the low-concentration region from the high-concentration of solute particles, making it a colligative property.
  - **Diffusion coefficient (D)**: proportionality factor determined by the permeability of the membrane or epithelium as well as the temperature.
- ▷ What are the major limitations of diffusion as a transport mechanism?
  - Ion channels: integral membrane protein that permit passive transport; can be gated, allowing for responsive conformational changes.
  - Permeability: ease at which solute can move through membrane by diffusion.
  - Always moves towards equilibrium, so energy must eventually by used to alter gradients to allow diffusion to continue to do work.
- ▷ What is a boundary layer and how does it impact diffusion?
  - The semipermeable layer between gradients.
  - Ion channels and temperature can change permeability of boundary layer.
  - Thickeness of decreases ease of diffusion.
  - Charge and size of ions and molecules impact rates of diffusion.
- ▷ Describe the basic characteristics of the electrochemical environment for a typical animal cell. Na^+ and K^+ ion channels and the Na^+–K^+ ATPase pump affect/regulate these characteristics?
  - Common enzymes use the sodium-potassium pump that moves three Na^+ out for every two K^+ moved into the cell.
  - This can drastically change the electrochemical environment, often drastically impacting rates of diffusion.
- ▷ Describe the different types of gated ion channels and their function in ion transport.
  - Voltage-gated: responds to changes in charge.
  - Stretch-gated: responds to changes in tension.
  - Phosphorylation-gated: responds to changes in protein phosphorylation.

- Ligan-gated: responds to various extracelluar signaling.

▷ Understand the concept of potential energy stored in an electrochemical gradient.

- Cations usually move down the electrochemical gradient using ATP to generate potential energy for passive transport.

▷ What are cotransporters and countertransporters?

- Cotransporters (symporter): two substrates are transported together in the same directions.
- Countertransporters (antiporter): one substrate is transported across while the other in tranporter in the opposite direction.

▷ What are the major mechanisms that generate diversity in transporters and/or modulate their function? Provide examples for each.

- The molecular form can vary considerably which allow for modulation of function and efficiency.
- Channels can be modulated through a lifetime via gene expression responses to environmental circumstances.
- Ligand (typically noncovalent) and phosphorylation (covalent) allow for rapid regulation.
- Insertion-and-retrieval: the location of proteins, and the inerting of removing from the membrane, can allow for relatively quick modulation.

▷ What are colligative properties? List and define the major colligative properties important to physiology.

- Colligative properties: properties of solutions that depend on the ratio between solute particles and solevent molecules.
- Vapour pressure: lowered when non-volatile solute is dissolved.
- boiling and freezing points: additions of solutes increases and decreases points respectivley; both are proportional to lowering of vapour pressure.
- Osmotic pressure: external pressure required to be applied so that there is no net movement of a solvent across the membrane. "Water wants to go where solutes are"

▷ Define osmosis and understand how osmotic pressure is generated and measured.

- Osmosis: primary means by which water in transported into and out of cells using transport of solvent through semipermable membrane towards region of higher solute concentration.

- Formula for osmotic pressure: $K\frac{\Pi_1 - \Pi_2}{X}$
- i.e., the rate at which water crosses the membrane by osmosis.
- Similar to the Fick equation for concentration gradient, except $\Pi_{1\&2}$ are the osmotic pressures of the solutions on each side of the membrane, and K is the osmotic permeability of the membrane + temperature.

▷ Define the terms hyperosmotic, isosmotic, and hyposmotic.

- Isosmotic: when two solutions have the same osmotic pressure.
- Hyperosmotic: when solution A has less solute than B
- Hyposmotic: when B has more solutes than A.
- The direction of net water movement by osmosis is from hyposmotic solution into the hyperosmotic one, i.e., $A \rightarrow B$

▷ Understand the different effects electrolytes and organic molecules have on osmotic pressure.

- Nonpermating solutes create persistent osmotic-gradient components across semipermable membranes.
- Some solute can be dragged along with water, which alters electrochemical gradients, playing a continuous role in rates of passive transport.
- Active transport provdes means of indirect control of the strictly passive water tranport of osmosis through changes in osmotic pressure.

▷ Describe the mechanisms of water transport.

- Aquaporins: main mechanism that uses water channel proteins that greatly increase water transport.

▷ How is cell volume affected by its environment?

- Controlled by osmoregulation, which controls osmolarity, volume, and ionic regulation, all of which have effects on each other.
- Environment change change external pressure and electrochemical gradients, both of which have multiple effects and ultimately cell volume.