The American Physiological Society
Medical Curriculum Objectives Project
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Cell and General

(revised 2011)

Biological Membranes, Solutes and Solutions

CE 1. Understand the general concepts of homeostasis and the principles of positive and negative feedback in physiological systems.

CE 2. Describe the polar structure of water, and explain how the formation of hydrogen bonds permits the dissociation of salts (such as NaCl), saccharides, and other polar molecules. Contrast the definitions of hydrophobic and hydrophilic related to water polarity.

CE 3. Describe the composition of a cell membrane. Diagram its cross section, and explain how the distribution of phospholipids and proteins influences the membrane permeability of ions, hydrophilic and hydrophobic compounds.

CE 4. Using a cell membrane as an example, define a reflection coefficient, and explain how the relative permeability of a cell to water and solutes will generate an osmotic pressure. Contrast the osmotic pressure generated across a cell membrane by a solution of particles that freely cross the membrane with that of a solution with the same osmolality, but particles that cannot cross the cell membrane.

CE 5. Contrast the following units used to describe concentration: mM, mEq/l, mg/dl, mg%. List the typical value and normal range for plasma Na^+, K^+, H^+ (pH), HCO_3^-, Cl^-, Ca^{2+}, and glucose, and the typical intracellular pH and concentrations of Na^+, K^+, Cl^-, Ca^{2+}, and HCO_3^-.

CE 6. Differentiate between the terms osmole, osmolarity, osmolality and tonicity. List the typical value and normal range for plasma osmolality.

CE 7. Understand that the difference in free energy of a solute or solvent between two components can have chemical, electrical and/or hydrostatic pressure components. At equilibrium, for a given component, the free energy difference between the two compartments is zero.

CE 8. Define the Donnan equilibrium and list the resulting characteristics.

CE 9. Describe the linear relationship between forces and flows (e.g., Ohm's Law, Fick's Law of diffusion, and the law of hydrodynamic flow).

CE 10. Write Fick's Law of diffusion, and explain how changes in the concentration gradient, surface area, time, and distance will influence the diffusional movement of a compound.

CE 11. Based on the principle of ionic attraction, explain how a potential difference across a membrane will influence the distribution of a cation and an anion.

CE 12. Define the term "steady state," and differentiate it from "equilibrium." Relate the pump-leak model of steady-state ion content to cell solute gradients and cell volume maintenance.

CE 13. Write the Nernst equation, and indicate how this equation accounts for both the chemical and electrical driving forces that act on an ion.

CE 14. Based on the Nernst equilibrium potential, predict the direction that an ion will take (follow) when the membrane potential a) is at its equilibrium potential, b) is higher than the equilibrium potential, or c) is less than the equilibrium potential. List values in a typical non-excitable cell for the membrane potential, for E_{Na}, E_K, E_{Cl}, and E_{Ca}.

CE 15. Define the concepts of electrochemical equilibrium and equilibrium potential, and give internal and external ion concentrations. Be able to calculate an equilibrium potential for that ion using the Nernst equation. Contrast the difference in E_K (the Nernst potential for K^+) caused by a 5 mEq/l increase in extracellular K^+ with the change in E_{Na} (the Nernst potential for Na^+) caused by a 5 mEq/l increase in extracellular Na^+.

CE 16. Explain how the resting membrane potential is generated and calculate membrane potential by using either a) the Goldman-Hodgkin-Katz equation or b) the chord conductance equation. Given an increase or decrease in the permeability of K^+, Na^+, or Cl^-, predict how the membrane potential would change.

CE 17. Differentiate the following terms based on the source of energy driving the process and the molecular pathway for: diffusion, facilitated diffusion, secondary active transport, and primary active transport.

CE 18. Describe how transport rates of certain molecules and ions are accelerated by specific membrane transport proteins ("transporter" and "channel" molecules).

CE 19. Describe how energy from ATP hydrolysis is used to transport ions such as Na^+, K^+, Ca^{2+}, and H^+ against their electrochemical differences (e.g., via the Na^+ pump, sarcoplasmic reticulum Ca^{2+} pump, and gastric H^+ pump).

CE 20. Understand the role of ATP-binding cassette transporters in, for example, multi-drug resistance and its significance for cancer chemotherapy.

CE 21. Explain how energy from the Na^+ and K^+ electrochemical gradients across the plasma membrane can be used to drive the net "uphill" (against a gradient) movement of other solutes (e.g., Na^+/glucose co-transport; Na^+/Ca^{2+} exchange or counter-transport). Apply this principle to understand oral rehydration procedures.

CE 22. Describe the role of water channels (aquaporins) in facilitating the movement of water across biological membranes.

CE 23. Understand the mechanisms and role of selective transporters for amino acids, neurotransmitters, nutrients, etc.

Excitable Cells

CE 24. Define the following properties of ion channels: gating, activation, and inactivation.

CE 25. State the cell properties that determine the rate of electronic conduction.

CE 26. Differentiate between the properties of electrotonic conduction, conduction of an action potential, and saltatory conduction. Identify regions of a neuron where each type of electrical activity may be found.

CE 27. Contrast the cell to cell spread of depolarization at a chemical synapse with that at a gap junction based on speed and fidelity (success rate). At the chemical synapse, contrast the terms temporal summation and spatial summation.

CE 28. Understand the principle of the voltage clamp and how it is used to identify the ionic selectivity of channels.

CE 29. Contrast the gating of ion-selective channels by extracellular ligands, intracellular ligands, stretch, and voltage.

CE 30. Know the properties of voltage-gated Na^+, K^+, and Ca^{2+} channels, and understand that voltage influences their gating, activation, and inactivation.

CE 31. Understand how the activity of voltage-gated Na^+, K^+, and Ca^{2+} channels generates an action potential and the roles of those channels in each phase (depolarization, overshoot, repolarization, hyperpolarization) of the action potential.

CE 32. Contrast the mechanisms by which an action potential is propagated along both nonmyelinated and myelinated axons. Predict the consequence on action potential propagation in the early and late stages of demyelinating diseases, such as multiple sclerosis.

Cell Volume Regulation, Cytosolic pH, and Organelles

CE 33. Understand how regulation of the concentrations of K^+, Cl^-, and other Na^+ solutes influence cell volume.

CE 34. Understand how various transporters (e.g. Na^+/H^+ exchange, Cl^-/HCO_3^- exchange, Na^+-HCO_3^- co-transport, etc.) contribute to the control of cytosolic pH.

CE 35. Describe Ca^{2+}accumulation in the sarcoplasmic and endoplasmic reticulum, mediated by Ca^{2+} ATPase.

CE 36. Understand the specifics of mechanisms that regulate the luminal composition of organelles (e.g., pH).

Regulation of Cell Function

CE 37. Describe the concept of signaling pathways and their role in determination of cell state and function of proteins.

CE 38. Understand post-translational regulation of protein function in the cell (e.g., phosphorylation)

CE 39. Describe cell surface receptor structure and function (e.g., GPCRs, TRK, etc.)

CE 40. Diagram the intracellular signaling pathways for representative receptor families and the terms agonist and antagonist as related to membrane receptor ligands.

Epithelia

CE 41. Draw an epithelium, labeling the tight junctions, the apical membrane, and the basolateral membrane. Trace the movement of a compound that travels across an epithelium by a transcellular pathway and a compound that travels via a paracellular pathway.

CE 42. Explain the role of the "tight" junctions in leaky and tight epithelia.

CE 43. Explain the functional significance of polarized distribution of various transport proteins to the apical or the basolateral cell membrane.

CE 44. Understand that movement of water is driven by solute movement.

Cell Motors

CE 45. Understand the concept of molecular motors and their structural and functional properties.

CE 46. Explain how the mobilization of calcium initiates contractions in smooth, striated, and cardiac muscle. Explain the sliding filament model of muscle contraction and contrast the cellular and molecular basis of muscle contraction in smooth and striated muscle.

Transcapillary Transport

CE 47. Differentiate the following terms: osmotic pressure, oncotic pressure, and hydrostatic pressure, as they pertain to movement across the endothelium of the capillaries.

CE 48. Predict the permeability of cardiovascular capillaries to small solutes and proteins (albumin) based on the capillary reflection coefficient.

CE 49. Based on the Starling hypothesis, explain how permeability, hydrostatic pressure and oncotic pressure influence transcapillary exchange of fluid.