Membrane structure and function chapter 7 pdf

1. © 2011 Pearson Education, Inc. LECTURE PRESENTATIONS For CAMPBELL BIOLOGY, NINTH EDITION Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson Lectures by Erin Barley Kathleen Fitzpatrick Membrane Structure and Function Chapter 7 2. Overview: Life at the Edge • The plasma membrane is the boundary that separates the living cell from its surroundings • The plasma membrane exhibits selective permeability, allowing some substances to cross it more easily than others © 2011 Pearson Education, Inc. 3. Figure 7.1 4. Concept 7.1: Cellular membranes are fluid mosaics of lipids and proteins • Phospholipids are the most abundant lipid in the plasma membrane • Phospholipids are amphipathic molecules, containing hydrophobic and hydrophilic regions • The fluid mosaic model states that a membrane is a fluid structure with a “mosaic” of various proteins embedded in it © 2011 Pearson Education, Inc. 5. Membrane Models: Scientific Inquiry • Membranes have been chemically analyzed and found to be made of proteins and lipids • Scientists studying the plasma membrane reasoned that it must be a phospholipid bilayer © 2011 Pearson Education, Inc. 6. Figure 7.2 Hydrophilic head Hydrophobic tail WATER WATER 7. © 2011 Pearson Education, Inc. • In 1935, Hugh Davson and James Danielli proposed a sandwich model in which the phospholipid bilayer lies between two layers of globular proteins • Later studies found problems with this model, particularly the placement of membrane proteins, which have hydrophilic and hydrophobic regions • In 1972, S. J. Singer and G. Nicolson proposed that the membrane is a mosaic of proteins dispersed within the bilayer, with only the hydrophilic regions exposed to water 8. Figure 7.3 Phospholipid bilayer Hydrophobic regions of protein Hydrophilic regions of protein 9. • Freeze-fracture studies of the plasma membrane supported the fluid mosaic model • Freeze-fracture is a specialized preparation technique that splits a membrane along the middle of the phospholipid bilayer © 2011 Pearson Education, Inc. 10. Figure 7.4 Knife Plasma membrane Cytoplasmic layer Proteins Extracellular layer Inside of extracellular layer Inside of cytoplasmic layer TECHNIQUE RESULTS 11. Figure 7.4a Inside of extracellular layer 12. Figure 7.4b Inside of cytoplasmic layer 13. The Fluidity of Membranes • Phospholipids in the plasma membrane can move within the bilayer • Most of the lipids, and some proteins, drift laterally • Rarely does a molecule flip-flop transversely across the membrane © 2011 Pearson Education, Inc. 14. Figure 7.5 Glyco- protein Carbohydrate Glycolipid Microfilaments of cytoskeleton EXTRACELLULAR SIDE OF MEMBRANE CYTOPLASMIC SIDE OF MEMBRANE Integral protein Peripheral proteins Cholesterol Fibers of extra- cellular matrix (ECM) 15. Figure 7.6 Lateral movement occurs ~107 times per second. Flip-flopping across the membrane is rare (~ once per month). 16. Figure 7.7 Membrane proteins Mouse cell Human cell Hybrid cell Mixed proteins after 1 hour RESULTS 17. • As temperatures cool, membranes switch from a fluid state to a solid state • The temperature at which a membrane solidifies depends on the types of lipids • Membranes rich in unsaturated fatty acids are more fluid than those rich in saturated fatty acids • Membranes must be fluid to work properly; they are usually about as fluid as salad oil © 2011 Pearson Education, Inc. 18. • The steroid cholesterol has different effects on membrane fluidity at different temperatures • At warm temperatures (such as 37°C), cholesterol restrains movement of phospholipids • At cool temperatures, it maintains fluidity by preventing tight packing © 2011 Pearson Education, Inc. 19. Figure 7.8 Fluid Unsaturated hydrocarbon tails Viscous Saturated hydrocarbon tails (a) Unsaturated versus saturated hydrocarbon tails (b) Cholesterol within the animal cell membrane Cholesterol 20. Evolution of Differences in Membrane Lipid Composition • Variations in lipid composition of cell membranes of many species appear to be adaptations to specific environmental conditions • Ability to change the lipid compositions in response to temperature changes has evolved in organisms that live where temperatures vary © 2011 Pearson Education, Inc. 21. Membrane Proteins and Their Functions • A membrane is a collage of different proteins, often grouped together, embedded in the fluid matrix of the lipid bilayer • Proteins determine most of the membrane’s specific functions © 2011 Pearson Education, Inc. 22. • Peripheral proteins are bound to the surface of the membrane • Integral proteins penetrate the hydrophobic core • Integral proteins that span the membrane are called transmembrane proteins • The hydrophobic regions of an integral protein consist of one or more stretches of nonpolar amino acids, often coiled into alpha helices © 2011 Pearson Education, Inc. 23. Figure 7.9 N-terminus α helix C-terminus EXTRACELLULAR SIDE CYTOPLASMIC SIDE 24. • Six major functions of membrane proteins – Transport – Enzymatic activity – Signal transduction – Cell-cell recognition – Intercellular joining – Attachment to the cytoskeleton and extracellular matrix (ECM) © 2011 Pearson Education, Inc. 25. Figure 7.10 Enzymes Signaling molecule Receptor Signal transduction Glyco- protein ATP (a) Transport (b) Enzymatic activity (c) Signal transduction (d) Cell-cell recognition (e) Intercellular joining (f) Attachment to the cytoskeleton and extracellular matrix (ECM) 26. Figure 7.10a Enzymes Signaling molecule Receptor Signal transduction ATP (a) Transport (b) Enzymatic activity (c) Signal transduction 27. Figure 7.10b Glyco- protein (d) Cell-cell recognition(e) Intercellular joining (f) Attachment to the cytoskeleton and extracellular matrix (ECM) 28. The Role of Membrane Carbohydrates in Cell-Cell Recognition • Cells recognize each other by binding to surface molecules, often containing carbohydrates, on the extracellular surface of the plasma membrane • Membrane carbohydrates may be covalently bonded to lipids (forming glycolipids) or more commonly to proteins (forming glycoproteins) • Carbohydrates on the external side of the plasma membrane vary among species, individuals, and even cell types in an individual © 2011 Pearson Education, Inc. 29. Figure 7.11 Receptor (CD4) Co-receptor (CCR5) HIV Receptor (CD4) but no CCR5 Plasma membrane HIV can infect a cell that has CCR5 on its surface, as in most people. HIV cannot infect a cell lacking CCR5 on its surface, as in resistant individuals. 30. Synthesis and Sidedness of Membranes • Membranes have distinct inside and outside faces • The asymmetrical distribution of proteins, lipids, and associated carbohydrates in the plasma membrane is determined when the membrane is built by the ER and Golgi apparatus © 2011 Pearson Education, Inc. 31. Figure 7.12 Transmembrane glycoproteins ER ER lumen Glycolipid Plasma membrane: Cytoplasmic face Extracellular face Secretory protein Golgi apparatus Vesicle Transmembrane glycoprotein Secreted protein Membrane glycolipid 32. Concept 7.2: Membrane structure results in selective permeability • A cell must exchange materials with its surroundings, a process controlled by the plasma membrane • Plasma membranes are selectively permeable, regulating the cell’s molecular traffic © 2011 Pearson Education, Inc. 33. The Permeability of the Lipid Bilayer • Hydrophobic (nonpolar) molecules, such as hydrocarbons, can dissolve in the lipid bilayer and pass through the membrane rapidly • Polar molecules, such as sugars, do not cross the membrane easily © 2011 Pearson Education, Inc. 34. Transport Proteins • Transport proteins allow passage of hydrophilic substances across the membrane • Some transport proteins, called channel proteins, have a hydrophilic channel that certain molecules or ions can use as a tunnel • Channel proteins called aquaporins facilitate the passage of water © 2011 Pearson Education, Inc. 35. • Other transport proteins, called carrier proteins, bind to molecules and change shape to shuttle them across the membrane • A transport protein is specific for the substance it moves © 2011 Pearson Education, Inc. 36. Concept 7.3: Passive transport is diffusion of a substance across a membrane with no energy investment • Diffusion is the tendency for molecules to spread out evenly into the available space • Although each molecule moves randomly, diffusion of a population of molecules may be directional • At dynamic equilibrium, as many molecules cross the membrane in one direction as in the other © 2011 Pearson Education, Inc. Animation: Membrane Selectivity Animation: Diffusion 37. Figure 7.13 Molecules of dye Membrane (cross section) WATER (a) Diffusion of one solute (b) Diffusion of two solutes Net diffusion Net diffusion Net diffusion Net diffusion Net diffusion Net diffusion Equilibrium Equilibrium Equilibrium 38. Figure 7.13a Molecules of dye Membrane (cross section) WATER (a) Diffusion of one solute Net diffusion Net diffusion Equilibrium 39. Figure 7.13b (b) Diffusion of two solutes Net diffusion Net diffusion Net diffusion Net diffusion Equilibrium Equilibrium 40. • Substances diffuse down their concentration gradient, the region along which the density of a chemical substance increases or decreases • No work must be done to move substances down the concentration gradient • The diffusion of a substance across a biological membrane is passive transport because no energy is expended by the cell to make it happen © 2011 Pearson Education, Inc. 41. Effects of Osmosis on Water Balance • Osmosis is the diffusion of water across a selectively permeable membrane • Water diffuses across a membrane from the region of lower solute concentration to the region of higher solute concentration until the solute concentration is equal on both sides © 2011 Pearson Education, Inc. 42. Figure 7.14 Lower concentration of solute (sugar) Higher concentration of solute Sugar molecule H2O Same concentration of solute Selectively permeable membrane Osmosis 43. Water Balance of Cells Without Walls • Tonicity is the ability of a surrounding solution to cause a cell to gain or lose water • Isotonic solution: Solute concentration is the same as that inside the cell; no net water movement across the plasma membrane • Hypertonic solution: Solute concentration is greater than that inside the cell; cell loses water • Hypotonic solution: Solute concentration is less than that inside the cell; cell gains water © 2011 Pearson Education, Inc. 44. Figure 7.15 Hypotonic solution Osmosis Isotonic solution Hypertonic solution (a) Animal cell (b) Plant cell H2O H2O H2O H2O H2O H2O H2O H2OCell wall Lysed Normal Shriveled Turgid (normal) Flaccid Plasmolyzed 45. • Hypertonic or hypotonic environments create osmotic problems for organisms • Osmoregulation, the control of solute concentrations and water balance, is a necessary adaptation for life in such environments • The protist Paramecium, which is hypertonic to its pond water environment, has a contractile vacuole that acts as a pump © 2011 Pearson Education, Inc. Video: Chlamydomonas Video: Paramecium Vacuole 46. Figure 7.16 Contractile vacuole 50 µm 47. Water Balance of Cells with Walls • Cell walls help maintain water balance • A plant cell in a hypotonic solution swells until the wall opposes uptake; the cell is now turgid (firm) • If a plant cell and its surroundings are isotonic, there is no net movement of water into the cell; the cell becomes flaccid (limp), and the plant may wilt © 2011 Pearson Education, Inc. 48. • In a hypertonic environment, plant cells lose water; eventually, the membrane pulls away from the wall, a usually lethal effect called plasmolysis © 2011 Pearson Education, Inc. Video: Turgid Elodea Animation: Osmosis Video: Plasmolysis 49. Facilitated Diffusion: Passive Transport Aided by Proteins • In facilitated diffusion, transport proteins speed the passive movement of molecules across the plasma membrane • Channel proteins provide corridors that allow a specific molecule or ion to cross the membrane • Channel proteins include – Aquaporins, for facilitated diffusion of water – Ion channels that open or close in response to a stimulus (gated channels) © 2011 Pearson Education, Inc. 50. Figure 7.17 EXTRACELLULAR FLUID CYTOPLASM Channel protein Solute SoluteCarrier protein (a) A channel protein (b) A carrier protein 51. • Carrier proteins undergo a subtle change in shape that translocates the solute-binding site across the membrane © 2011 Pearson Education, Inc. 52. • Some diseases are caused by malfunctions in specific transport systems, for example the kidney disease cystinuria © 2011 Pearson Education, Inc. 53. Concept 7.4: Active transport uses energy to move solutes against their gradients • Facilitated diffusion is still passive because the solute moves down its concentration gradient, and the transport requires no energy • Some transport proteins, however, can move solutes against their concentration gradients © 2011 Pearson Education, Inc. 54. The Need for Energy in Active Transport • Active transport moves substances against their concentration gradients • Active transport requires energy, usually in the form of ATP • Active transport is performed by specific proteins embedded in the membranes © 2011 Pearson Education, Inc. Animation: Active Transport 55. • Active transport allows cells to maintain concentration gradients that differ from their surroundings • The sodium-potassium pump is one type of active transport system © 2011 Pearson Education, Inc. 56. Figure 7.18-1 EXTRACELLULAR FLUID [Na+] high [K+] low [Na+] low [K+] high CYTOPLASM Na+ Na+ Na+ 1 57. Figure 7.18-2 EXTRACELLULAR FLUID [Na+] high [K+] low [Na+] low [K+] high CYTOPLASM Na+ Na+ Na+ 1 2 Na+ Na+ Na+ P ATP ADP 58. Figure 7.18-3 EXTRACELLULAR FLUID [Na+] high [K+] low [Na+] low [K+] high CYTOPLASM Na+ Na+ Na+ 1 2 3 Na+ Na+ Na+ Na+ Na+ Na+ P P ATP ADP 59. Figure 7.18-4 EXTRACELLULAR FLUID [Na+] high [K+] low [Na+] low [K+] high CYTOPLASM Na+ Na+ Na+ 1 2 3 4 Na+ Na+ Na+ Na+ Na+ Na+ K+ K+ P P P P i ATP ADP 60. Figure 7.18-5 EXTRACELLULAR FLUID [Na+] high [K+] low [Na+] low [K+] high CYTOPLASM Na+ Na+ Na+ 1 2 3 45 Na+ Na+ Na+ Na+ Na+ Na+ K+ K+ K+ K+ P P P P i ATP ADP 61. Figure 7.18-6 EXTRACELLULAR FLUID [Na+] high [K+] low [Na+] low [K+] high CYTOPLASM Na+ Na+ Na+ 1 2 3 456 Na+ Na+ Na+ Na+ Na+ Na+ K+ K+ K+ K+ K+ K+ P P P P i ATP ADP 62. Figure 7.19 Passive transport Active transport Diffusion Facilitated diffusion ATP 63. How Ion Pumps Maintain Membrane Potential • Membrane potential is the voltage difference across a membrane • Voltage is created by differences in the distribution of positive and negative ions across a membrane © 2011 Pearson Education, Inc. 64. • Two combined forces, collectively called the electrochemical gradient, drive the diffusion of ions across a membrane – A chemical force (the ion’s concentration gradient) – An electrical force (the effect of the membrane potential on the ion’s movement) © 2011 Pearson Education, Inc. 65. • An electrogenic pump is a transport protein that generates voltage across a membrane • The sodium-potassium pump is the major electrogenic pump of animal cells • The main electrogenic pump of plants, fungi, and bacteria is a proton pump • Electrogenic pumps help store energy that can be used for cellular work © 2011 Pearson Education, Inc. 66. Figure 7.20 CYTOPLASM ATP EXTRACELLULAR FLUID Proton pump H+ H+ H+ H+ H+ H+ – – – – + + + + 67. Cotransport: Coupled Transport by a Membrane Protein • Cotransport occurs when active transport of a solute indirectly drives transport of other solutes • Plants commonly use the gradient of hydrogen ions generated by proton pumps to drive active transport of nutrients into the cell © 2011 Pearson Education, Inc. 68. Figure 7.21 ATP H+ H+ H+ H+ H+ H+ H+ H+ Proton pump Sucrose-H+ cotransporter Sucrose Sucrose Diffusion of H+ – – – – + + + + 69. Concept 7.5: Bulk transport across the plasma membrane occurs by exocytosis and endocytosis • Small molecules and water enter or leave the cell through the lipid bilayer or via transport proteins • Large molecules, such as polysaccharides and proteins, cross the membrane in bulk via vesicles • Bulk transport requires energy © 2011 Pearson Education, Inc. 70. Exocytosis • In exocytosis, transport vesicles migrate to the membrane, fuse with it, and release their contents • Many secretory cells use exocytosis to export their products © 2011 Pearson Education, Inc. Animation: Exocytosis 71. Endocytosis • In endocytosis, the cell takes in macromolecules by forming vesicles from the plasma membrane • Endocytosis is a reversal of exocytosis, involving different proteins • There are three types of endocytosis – Phagocytosis (“cellular eating”) – Pinocytosis (“cellular drinking”) – Receptor-mediated endocytosis © 2011 Pearson Education, Inc. Animation: Exocytosis and Endocytosis Introduction 72. • In phagocytosis a cell engulfs a particle in a vacuole • The vacuole fuses with a lysosome to digest the particle © 2011 Pearson Education, Inc. Animation: Phagocytosis 73. • In pinocytosis, molecules are taken up when extracellular fluid is “gulped” into tiny vesicles © 2011 Pearson Education, Inc. Animation: Pinocytosis 74. • In receptor-mediated endocytosis, binding of ligands to receptors triggers vesicle formation • A ligand is any molecule that binds specifically to a receptor site of another molecule © 2011 Pearson Education, Inc. Animation: Receptor-Mediated Endocytosis 75. Figure 7.22 Solutes Pseudopodium “Food” or other particle Food vacuole CYTOPLASM Plasma membrane Vesicle Receptor Ligand Coat proteins Coated pit Coated vesicle EXTRACELLULAR FLUID Phagocytosis Pinocytosis Receptor-Mediated Endocytosis 76. Figure 7.22a Pseudopodium Solutes “Food” or other particle Food vacuole CYTOPLASM EXTRACELLULAR FLUID Pseudopodium of amoeba Bacterium Food vacuole An amoeba engulfing a bacterium via phagocytosis (TEM). Phagocytosis 1µm 77. Figure 7.22b Pinocytosis vesicles forming in a cell lining a small blood vessel (TEM). Plasma membrane Vesicle 0.5µm Pinocytosis 78. Figure 7.22c Top: A coated pit. Bottom: A coated vesicle forming during receptor-mediated endocytosis (TEMs). Receptor 0.25µm Receptor-Mediated Endocytosis Ligand Coat proteins Coated pit Coated vesicle Coat proteins Plasma membrane 79. Figure 7.22d Bacterium Food vacuole Pseudopodium of amoeba An amoeba engulfing a bacterium via phagocytosis (TEM). 1µm 80. Figure 7.22e Pinocytosis vesicles forming (indicated by arrows) in a cell lining a small blood vessel (TEM). 0.5µm 81. Figure 7.22f Top: A coated pit. Bottom: A coated vesicle forming during receptor-mediated endocytosis (TEMs). Plasma membrane Coat proteins 0.25µm 82. Figure 7.UN01 Passive transport: Facilitated diffusion Channel protein Carrier protein 83. Figure 7.UN02 Active transport ATP 84. Figure 7.UN03 0.03 M sucrose 0.02 M glucose “Cell” “Environment” 0.01 M sucrose 0.01 M glucose 0.01 M fructose 85. Figure 7.UN04 Figure 7.1 How do cell membrane proteins help regulate chemical traffic? For the Cell Biology Video Structure of the Cell Membrane, go to Animation and Video Files. Figure 7.2 Phospholipid bilayer (cross section). Figure 7.3 The original fluid mosaic model for membranes. Figure 7.4 Research Method: Freeze-fracture Figure 7.4 Research Method: Freeze-fracture Figure 7.4 Research Method: Freeze-fracture Figure 7.5 Updated model of an animal cell’s plasma membrane (cutaway view). Figure 7.6 The movement of phospholipids. Figure 7.7 Inquiry: Do membrane proteins move? Figure 7.8 Factors that affect membrane fluidity. Figure 7.9 The structure of a transmembrane protein. Figure 7.10 Some functions of membrane proteins. Figure 7.10 Some functions of membrane proteins. Figure 7.10 Some functions of membrane proteins. Figure 7.11 Impact: Blocking HIV Entry into Cells as a Treatment for HIV Infections Figure 7.12 Synthesis of membrane components and their orientation in the membrane. Figure 7.13 The diffusion of solutes across a synthetic membrane. Figure 7.13 The diffusion of solutes across a synthetic membrane. Figure 7.13 The diffusion of solutes across a synthetic membrane. Figure 7.14 Osmosis. Figure 7.15 The water balance of living cells. Figure 7.16 The contractile vacuole of Paramecium caudatum. For the Cell Biology Video Water Movement through an Aquaporin, go to Animation and Video Files. Figure 7.17 Two types of transport proteins that carry out facilitated diffusion. For the Cell Biology Video Na+/K+ATPase Cycle, go to Animation and Video Files. Figure 7.18 The sodium-potassium pump: a specific case of active transport. Figure 7.18 The sodium-potassium pump: a specific case of active transport. Figure 7.18 The sodium-potassium pump: a specific case of active transport. Figure 7.18 The sodium-potassium pump: a specific case of active transport. Figure 7.18 The sodium-potassium pump: a specific case of active transport. Figure 7.18 The sodium-potassium pump: a specific case of active transport. Figure 7.19 Review: passive and active transport. Figure 7.20 A proton pump. Figure 7.21 Cotransport: active transport driven by a concentration gradient. For the Cell Biology Video Phagocytosis in Action, go to Animation and Video Files. Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.22 Exploring: Endocytosis in Animal Cells Figure 7.UN01 Summary figure, Concept 7.3 Figure 7.UN02 Summary figure, Concept 7.4 Figure 7.UN03 Test Your Understanding, question 6 Figure 7.UN04 Appendix A: answer to Figure 7.2 legend question

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