1

The Working Cell

Bio 103 Lecture
GMU
Dr. Largen

2 Sections

✓Energy and the cell
✓Enzymes
✓Membrane structure and function

3

Energy and the Cell

4 Energy and the Cell
Energy is the capacity to perform work

✓**Energy**
– capacity to do work
•
– all organisms require energy to stay alive
– exists in two states
• **kinetic energy**
• **potential energy**

5 Energy and the Cell
Energy is the capacity to perform work

✓**Energy** exists in two states
– **kinetic energy**
• energy of motion
–
– **potential energy**
• stored energy
–

6 Energy and the Cell
Energy is the capacity to perform work

✓**Energy** exists in two states

- **potential energy vs kinetic energy**
  - consider boulder perched on a hilltop
    -
  - as it rolls down hill potential energy is converted into kinetic energy
-

7 Energy and the Cell
Energy is the capacity to perform work

✓energy exists in many forms
- mechanical energy
- heat
- sound
- electric current
- light
- radioactive radiation
- **chemical energy**
  - potential energy of molecules
    -

8 Energy and the Cell
Energy is the capacity to perform work

✓many ways to measure energy
- most convenient is in form of **heat**
  - measure of random motion of molecules
  -

9 Energy and the Cell
Two laws govern energy conversion

✓Life depends on fact that energy can be converted from one form to another

✓thermodynamics
- study of energy transformations
  -

✓**Laws of Thermodynamics**
- set of universal laws that govern all energy changes in universe
  -

10 Energy and the Cell
Two laws govern energy conversion

✓**First Law of Thermodynamics**
- concerns amount of energy in universe
- states that energy can be changed from one form to another but can neither be created or destroyed
- total amount of energy in universe remains constant

11 Energy and the Cell
Two laws govern energy conversion

✓**First Law of Thermodynamics**
- potential energy can be shifted to other molecules, stored in different chemical bonds, convert into other forms

- during each conversion some of energy dissipates into environment in form of heat
-
- energy available to do work decreases
  -

12 Energy and the Cell
Two laws govern energy conversion

✓**Second Law of Thermodynamics**

– concerns transformation of potential energy into heat
-

– states that disorder (or **entropy**) in universe is continuously increasing
-
- **entropy**
  – measure of disorder of a system
  – heat is one form of disorder

13 Energy and the Cell
Two laws govern energy conversion

✓**Second Law of Thermodynamics**

– entropy increases
– when universe was formed it had all potential energy it will ever have
- has become more disordered ever since
- every energy exchange has increased entropy in universe

–

14 Energy and the Cell
Chemical reactions either store or release energy

✓Chemical reactions are of two types

– **endergonic reactions**
- “energy in”
- requires net input of energy

– **exergonic reactions**
- “energy out”
- releases energy

15 Energy and the Cell
Chemical reactions either store or release energy

✓**endergonic reactions**

– yield products rich in potential energy
-
-
-

– don’t proceed spontaneously
- requires input of energy

– example is **photosynthesis**

16

17 Energy and the Cell
Chemical reactions either store or release energy

✓**exergonic reactions**

– reactants store more energy than products
  • energy is released
– tend to proceed spontaneously
  • does not require an input of energy
– example is **cellular respiration**
  •
  •

18

19 Energy and the Cell
Chemical reactions either store or release energy

✓**Cellular metabolism**

– sum of exergonic and endergonic reactions carried out by working cells

20 Energy and the Cell
ATP shuttles chemical energy within the cell

✓**Energy coupling**

– using energy released from exergonic reactions to drive essential endergonic reactions
– usually
  • usable energy stored in ATP
  • energy used comes from ATP

✓**ATP** powers nearly all forms of cellular work

21 Energy and the Cell
ATP shuttles chemical energy within the cell

✓**ATP (adenosine triphosphate)**

– has 3 parts, connected by covalent bonds
  • **adenine**
    – nitrogenous base
  • **ribose**
    – 5-carbon sugar
  • **phosphate group**
    – chain of 3 phosphate groups

22

23 Energy and the Cell
ATP shuttles chemical energy within the cell

✓**Hydrolysis of ATP**

– exergonic reaction
– covalent bond btwn 2nd and 3rd phosphate groups is unstable
  •
  •
– when 3rd bond breaks
  • phosphate is removed
  • ATP becomes ADP (adenosine diphosphate)
  • energy is released

24

25 Energy and the Cell
ATP shuttles chemical energy within the cell

✓**Phosphorylation**
– transfer of a phosphate group to a molecule
– process by which ATP energizes other molecules
  •
  •
  • 3rd phosphate is used as energy shuttle

26

27 Energy and the Cell
ATP shuttles chemical energy within the cell

✓**ATP cycle (ATP is renewable resource)**
– hydrolysis of ATP to ADP + P
  • removes a phosphate
  • exergonic reaction
    –
– dehydration synthesis of ADP + P to ATP
  • adds a phosphate
  • endergonic reaction
    –

28

29

Enzymes

30 How Enzymes Work
Enzymes speed up reactions by lowering energy barriers

✓**Energy of activation (E_A)**

– amount of energy that reactants must absorb to start a chemical reaction

– can be thought of as an energy barrier

– most reactions require energy to get started

•

31 How Enzymes Work
Enzymes speed up reactions by lowering energy barriers

✓**Energy of activation (E_A)**

– illustrated with "jumping bean" (JB) analogy

•

•

•

32 How Enzymes Work
Enzymes speed up reactions by lowering energy barriers

✓**Enzymes**

–

– protein molecules that serve as biological catalysts

– increase rate of reaction without being changed into different molecule

– do **not** add energy to reaction

• speeds up reaction be lowering **Energy of activation (E_A)**, or energy barrier

–

33 How Enzymes Work
Enzymes speed up reactions by lowering energy barriers

✓In jumping bean analogy

– enzyme lowers energy barrier

–

–

–

34

35

36 How Enzymes Work
A specific enzyme catalyzes each chemical reaction

✓**enzymes**

– lower **E_A**

• holding reactant molecules in a particular position

– are selective

– have a unique 3-dimensional shape

•

– recognize only the **substrate**(s) of reaction it catalyzes
  • **substrate** is substance enzyme acts on

37 How Enzymes Work
A specific enzyme catalyzes each chemical reaction
✓**catalyzing a reaction**
– **enzyme binds to its substrate**
  • at its **active site**
    –
      »
– while joined, substrate changes into product
– enzyme releases products
– enzyme emerges from reaction unchanged

38 How Enzymes Work
A specific enzyme catalyzes each chemical reaction
✓enzyme emerges from reaction unchanged
– active site now ready for another substrate molecule and another cycle
– Single enzyme molecule may act upon thousands or millions of substrate molecules per second

39

40 How Enzymes Work
The cellular environment affects enzyme activity
✓Activity of enzyme is affected by its environment
– enzyme has optimal conditions
  •
– factors that alter enzyme's shape can affect its ability to catalyze a reaction

41 How Enzymes Work
The cellular environment affects enzyme activity
✓Factors affecting enzyme activity
– **temperature**
– **pH**
– **salinity**

42 How Enzymes Work
The cellular environment affects enzyme activity
✓Factors affecting enzyme activity
– **temperature**
  • optimum temperatures (35-40°C)
    –

–

- at high temperatures
  - enzyme can be denatured
    »

43 How Enzymes Work
The cellular environment affects enzyme activity
✓Factors affecting enzyme activity
– **pH and salinity**
- variations in number of salt and hydrogen ions
  - can interfere with chemical bonds that maintain protein structure
  - optimum pH = 6-8
  - optimum salinity = cell salinity

44 How Enzymes Work
The cellular environment affects enzyme activity
✓Factors affecting enzyme activity
– **cofactors**
- required by some enzymes
- may be inorganic molecules, called **cofactors**
  - such as zinc, iron, copper
- may be organic molecules, called **coenzymes**
  - such as vitamins or vitamin products

45 How Enzymes Work
Enzyme inhibitors block enzyme action
✓chemical that interferes with an enzyme's activity is called an **inhibitor**
– two types of inhibitors
- **competitive inhibitor**
- **non-competitive inhibitor**

46

47 How Enzymes Work
Enzyme inhibitors block enzyme action
✓competitive inhibitor
– resembles enzyme's normal substrate
– competes with substrate for enzyme's active site
-
- prevents enzyme from acting

48

49 How Enzymes Work
Enzyme inhibitors block enzyme action
✓non-competitive inhibitor

– does not compete with active site
– binds to enzyme outside of active site
• causes shape change
– active site no longer fits substrate
–

50

51

52

Membrane Structure and Function

53 Membranes organize the chemical activities of cells

✓Many metabolic reactions occur simultaneously in a cell

–
•
•

✓Membranes provide structural basis for metabolic order

54 Membranes organize the chemical activities of cells

✓For all types of cells

– **plasma membrane** is edge of life
• boundary between living cell and its surroundings

✓For most eukaryotic cells

– **membranes** form
• most organelles
• compartments within cells that contain enzymes

55 Membranes organize the chemical activities of cells

✓All membranes are **selectively permeable**

– control passage of molecules into and out of cell (or organelle)
•
•
– allows some substances to cross more easily
– blocks passage of some substances entirely

56 Membranes organize the chemical activities of cells

✓**Plasma membrane** (cell membrane)

– very thin
•
•
–

–

57 Membrane phospholipids form a bilayer

✓**Plasma membrane** (cell membrane) is composed mainly

– phospholipid molecules

- has two parts
- "head"
  - glycerol and phosphate group
  - polar = hydrophilic
- " tail"
  - two fatty acid tails
  - non-polar = hydrophobic

58

59 Membrane phospholipids form a bilayer

✓Phospholipid structure suited to role in membranes

– spontaneously form stable two-layer sheet in water

- **phospholipid bilayer**
  –
  –

–

60

61 Figure 8.1 Artificial membranes (cross sections), Campbell & Reece

62 Membrane phospholipids form a bilayer

✓membranes are **selectively permeable**

– partly due to hydrophobic interior of bilayer

- nonpolar , hydrophobic molecules are soluble in lipids
  –
- polar, hydrophilic molecules are not soluble in lipids
  –

63 The membrane is a fluid mosaic of phospholipids and proteins

✓Structure plasma membrane described as **fluid mosaic**

– mosaic

- many parts
-

– fluid

- moveable
-
-

64 Figure 8.4 The fluidity of membranes (Campbell & Reece)

65 Figure 8.2 Two generations of membrane models (Campbell & Reece)

66 Figure 8.5 Evidence for the drifting of membrane proteins (Campbell & Rece)

67 The membrane is a fluid mosaic of phospholipids and proteins

✓two surfaces of **plasma membrane** are different

– outer surface (exterior of cell)
  •
  •
– inner surface (interior of cell)
  •

68  Figure 8.6 The detailed structure of an animal cell's plasma membrane, in cross section (Campbell & Reece)

69  Figure 8.3 Freeze-fracture and freeze-etch (Campbell & Reece)

70  Figure 8.8 Sidedness of the plasma membrane (Campbell & Reece)

71 Proteins make the membrane of a mosaic function

✓Proteins perform most of functions of membrane
– what roles do membrane proteins play
  • attach membrane to cytoskeleton and external fibers
  • provide cellular identification tags
  • form junctions between adjacent cells
  • **receptors** for chemical messengers
  • help move substances across membrane
  • serve as enzymes

72  Figure 8.9 Some functions of membrane proteins (Campbell & Rece)

73  Figure 8.7 The structure of a transmembrane protein (Campbell & Reece)

74 Passive transport is diffusion across a membrane

✓**Diffusion**
– tendency for particles to spread out spontaneously to regions where they are less concentrated
– requires no work
  • random motion (kinetic energy)
  • universal tendency of order to deteriorate into disorder (entropy)
– **passive transport**
  •

75 Passive transport is diffusion across a membrane

✓**passive transport**
– substance moves from area of higher concentration to area of lower concentration until equilibrium is reached
  • substances diffuse **down** their **concentration gradient**
    –

76  Figure 8.10 The diffusion of solutes across membranes (Campbell & Reece)

77 

78 Passive transport is diffusion across a membrane

✓**Passive transport**
– different substances diffuse independently of one another
  •
– important to all cells
  •

•

79 Osmosis is the passive transport of water

✓**Osmosis**

– special case of passive transport

• involving diffusion of water molecules across a selectively permeable membrane

–

– cells contain and are surrounded by aqueous solution

• solutes also diffuse down their concentration gradient

80 Osmosis is the passive transport of water

✓**Osmosis**

– solution on either side of membrane

• described on basis of conc.of solutes

– **hypertonic**

» solution with higher conc.n of solutes

– **hypotonic**

» solution with lower conc. of solutes

– **isotonic**

» solutions on both sides of membrane have same conc.

81 Osmosis is the passive transport of water

✓**Osmosis**

– as solutes diffuse

•

– water molecules will move via osmosis

•

82 

Figure 8.11 Osmosis (Campbell & Recee)

83 

84 Water balance between cells and their surroundings is crucial to organisms

✓animal cell immersed in

– **isotonic** solution

• volume remains constant

–

– **hypotonic** solution

• gains water (loses solutes), swells, may lyse (pop)

•

– **hypertonic** solution

• loses water (gains solutes), shrivels, may die

•

85 Water balance between cells and their surroundings is crucial to organisms

✓plant cell immersed in
– **isotonic** solution
• cell is flaccid, plant wilts
–

86 Water balance between cells and their surroundings is crucial to organisms
✓plant cell immersed in
– **hypotonic** solution (
• turgid, plant is healthiest
–
– **hypertonic** solution
• loses water (gains solutes), shrivels, may die
–

87 
Figure 8.12 The water balance of living cells (Campbell & Reece)

88 
Figure 8.13 The contractile vacuole of *Paramecium*: an evolutionary adaptation for osmoregulation (Campbell & Reece)

89 
Figure 8.13x *Paramecium (Campbell & Reece)*

90 Specific proteins facilitate diffusion across membranes
✓Many substances do not diffuse freely across biological membranes
– due to
• size
• charge
– can cross by **special mechanisms**
•

91 Specific proteins facilitate diffusion across membranes
✓Special mechanisms
– <u>transport proteins</u>
• located in the membrane
• aid in **facilitated diffusion**
–
–
–

92 Specific proteins facilitate diffusion across membranes
✓**facilitated diffusion**
– passive
– higher to lower conc.
– facilitated by transport proteins
•
•

93 

94 
Figure 8.14 Two models for facilitated diffusion (Campbell & Reece)

95 Cells expend energy for active transport

✓Substances **can** be moved across a membrane against its concentration
– process called **active transport**
• requires cell to expend energy
–
• involves transport protein
–
–

96 Cells expend energy for active transport
✓Active transport systems often couple passage of two solutes
–
–
–
–

97
98
99 Figure 8.15 The sodium-potassium pump: a specific case of active transport (Campbell & Reece)
100 Review: Passive and Active Transport Compared
✓**passive transport**
– diffusion
• osmosis
– facilitated diffusion
✓**active transport**
101 Figure 8.16 Review: passive and active transport compared (Campbell & Reece)
102 Active Transport
✓**electrogenic pump**
– a transport protein that generates voltage across a membrane
– examples
• **sodium-potassium pump**
– major electrogenic pump of animal cells
• **proton pump**
– main electrogenic pump of plants, bacteria and fungi

103 
Figure 8.17 An electrogenic pump (Campbell & Reece)

104 Exocytosis and endocytosis transport large molecules

✓**bulk transport**

– process used to move large & polar molecules into and out of cell

– **exocytosis**

• bulk transport out of cell

– **endocytosis**

• bulk transport into cell

105 Exocytosis and endocytosis transport large molecules

✓**bulk transport**

– **exocytosis**

• bulk transport out of cell

•

•

•

106 

107 Exocytosis and endocytosis transport large molecules

✓**bulk transport**

– **endocytosis**

• bulk transport into cell

• three types

– **phagocytosis**

– **pinocytosis**

– **receptor-mediate endocytosis**

108 Exocytosis and endocytosis transport large molecules

✓**bulk transport**

– **endocytosis**

• bulk transport into cell

•

•

•

109 Exocytosis and endocytosis transport large molecules

✓**bulk transport**

– **endocytosis**

• **phagocytosis**

– “cellular eating”

– material cell takes in iisparticulate
» made up of discrete particles

110 Exocytosis and endocytosis transport large molecules
✓**bulk transport**
– **endocytosis**
• **pinocytosis**
– “cellular drinking”
– material the cell takes in is liquid
» not specific, takes in all solutes dissolved in liquid

111

112 Exocytosis and endocytosis transport large molecules
✓**bulk transport**
– **endocytosis**
• **receptor-mediated endocytosis**
– indented pits in outer plasma membrane
» coated w/ receptor proteins which pick up particular molecules
»
–

113

114 Figure 8.19 The three types of endocytosis in animal cells (Campbell & Reece)

115

The End