1 EVPP 110 Lecture
Dr. Largen - Fall 2003

Life: Levels of Organization, Cell Structure & Function, Major Processes for Fueling Life's Activity

2 Levels of Organization of Life

✓ Levels of organization of life
- – non-living components of life
  - atom
  - molecule
- – within cells
  - macromolecule (biological)
  - organelle
  - cell

3 Levels of Organization of Life

✓ Levels of organization of life
- – within multicellular organisms
  - tissue
  - organ
  - organ systems

4 Levels of Organization of Life

✓ Levels of organization of life
- – among organisms
  - species
  - population
  - community
  - ecosystem
  - biosphere
  - ecosphere

5 Levels of Organization of Life

✓ Levels of organization of life
- represent a hierarchy
  - – each level incorporates lower levels of organization

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Structure of the Cell

8 Introduction to the cell

✓ Before microscopes (first used in 17th century), no one knew living

organisms were composed of cells

9 All cells share fundamental features

✓Major features common to all cells

– **plasma membrane**

– **DNA**

– **cytoplasm**

– **carry out metabolism**

10 All cells share fundamental features

✓Major features common to all cells

– **plasma membrane**

- encloses cell
- separates contents from surroundings
- phospholipid bilayer
  - 5-10 nanometers thick
- contains embedded proteins

11 All cells share fundamental features

✓ Major features common to all cells

– **DNA – the hereditary molecule**

- **prokaryotes**
  - **nucleoid**
    - » area near center of cell, contains circular molecule of DNA
    - » **not** differentiated from rest of cell's contents by membrane
- **eukaryotes**
  - **nucleus**
    - » double-membrane bound organelle contains DNA

12 All cells share fundamental features

✓Major features common to all cells

– **cytoplasm**

- semi-fluid matrix
- contains chemicals of cell
  - sugars
  - amino acids
  - proteins
- contains organelles in eukaryotes

13 All cells share fundamental features

✓Major features common to all cells

– **carry out metabolism**

- interconversion of different forms of energy and of chemical materials
  - two major metabolic processes
    - » photosynthesis
    - » cellular respiration

14 All cells share fundamental features

✓**primary tenants** of Cell Theory
- all organisms composed of 1 or 1+cells
- cell is smallest (basic) unit of life
  - smallest living thing
- cells arise only by division of a previously existing cell
  - all life on earth represents continuous line of descent from early cells

15 Introduction to the cell

✓Two kinds of structurally different cells have evolved over time
- prokaryotic cells
  - Archaebacteria
  - Eubacteria
- eukaryotic cells
  - Protista
  - Fungi
  - Plantae
  - Animalia

16 Introduction to the cell

✓**Prokaryotic** cell characteristics
- small (1/10th size of eukaryote)
- lacks a nucleus
  - DNA in **nucleoid region** (not membrane bound)
- **plasma membrane**
- **bacterial cell wall**
- some have **pili** (sticky)
- some propelled by **flagellum**

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18 Introduction to the cell

✓**Eukaryotic cells**
- from Greek *eu* for “true” and *karyon* for kernal or “nucleus”
- fundamentally similar to each other
  - profoundly different from prokaryoes

✓characteristics of eukaryotic cells
- in general
- comparing animal and plant cell

19 Introduction to the cell

✓ **Eukaryotic cells**
- presence vs. absence of **cell walls**
  - animal cells lack cell walls
  - some protists lack cell walls
  - plants, fungi and some protists have cell walls

20 Introduction to the cell

✓ **Eukaryotic cells**
- **complex interior organization**
  - extensive compartmentalization
  - many membrane-bound organelles
  - true, membrane-bound nucleus
  - complex DNA molecule
  - contain vesicles and vacuoles which function in storage and transport

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22 Introduction to the cell

✓ **Eukaryotic cells**
- membranes partition cytoplasm into compartments called **membranous organelles**
  - location of many chemical activities known as **cellular metabolism**
    -

23 Introduction to the cell

✓ **Eukaryotic cells, animal vs. plant**
- **animal** cells
  - cell wall absent
  - chloroplasts absent
  - central vacuole absent
  - mitochondria present
  - centrioles present
  - lysosome present
  - flagella may be present

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25 Introduction to the cell

✓**Eukaryotic cells, plant vs. animal**

– **plant** cells

- cell wall present
- chloroplasts present
- mitochondria present
- central vacuole present
- flagella absent (except in some sperm)
- lysosome absent
- centrioles absent

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27 Introduction to the cell

✓**membranous organelles**
- nucleus
- endoplasmic reticulum
- Golgi apparatus
- mitochondria
- lysosome
- peroxisome
- chloroplast
- central vacuole

28 Introduction to the cell

✓**non-membranous structures**
- centriole
- flagellum
- ribosome
- microtubule
- microfilament
- cell wall

29 Energy converting organelles

✓**Chloroplasts**
- photosynthesizing organelles of plants and protists
  - internal membranes create 3 compartments

30 Energy converting organelles

✓**Chloroplasts**
- space between inner & outer membranes
  - **intermembrane space**
- space enclosed by inner membrane
  - contains
    - fluid called **stroma**
    - network of tubules and hollow disks

- space inside tubules and disks
  - disks occur in stacks, called **grana**
    - grana are chloroplasts' solar power packs

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33 Energy converting organelles

✓ **Mitochondria**
- energy converting organelles of heterotrophs
- carryout **cellular respiration**
  - chemical energy of foods
    - converted to chemical energy of a molecule such as **ATP** (adenosine triphosphate)
      - » ATP is main energy source for cellular work

34 Energy converting organelles

✓ **Mitochondria**
- enclosed by 2 membranes, has 2 compartments
  - space between inner & outer membrane
    - **intermembrane space**
      - » fluid filled compartment
  - space enclosed by inner membrane
    - contains fluid called **mitochondrial matrix**

35 Energy converting organelles

✓**Mitochondria**
- space enclosed by inner membrane
  - contains **mitochondrial matrix**
    - many of chemical reactions of cellular respiration occur here
  - inner membrane has many folds
    - called **cristae**
    - increases surface area
    - contains enzymes that make ATP

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37 Fueling the activities of life

✓two main mechanisms by which organisms obtain food

– **autotrophs** (self-sustaining)

– **heterotrophs** (not self-sustaining)

38 Fueling the activities of life

✓two main mechanisms by which organisms obtain food

– **autotrophs** (self-sustaining)

- plants and other photosynthetic organisms
- can produce from inorganic compounds the organic molecules they need for life

39 Fueling the activities of life

✓two main mechanisms by which organisms obtain food

– **heterotrophs** (not self-sustaining)

- animals
- must obtain organic molecules they need by consuming organic molecules already produced by other organisms

40 How organisms harvest energy from food molecules

✓ Two major processes enable organisms to fuel the processes of life

– hetertrophs

- ingest their food
- **cellular respiration** harvests energy from ingested food molecules

– autotrophs

- manufacture their own food via **photosynthesis**
- **cellular respiration** harvests energy manufactured food molecules

41 Cellular Respiration

42 Introduction to Cellular Respiration

✓ <u>Respiration</u>

– refers to exchange of gases

- organism obtains O_2 from its environment & releases CO_2

✓ **Cellular respiration**

– aerobic harvesting of energy from food molecules by cells

43 Introduction to Cellular Respiration

✓Breathing and cellular respiration are related

– organism takes in O_2 from environment

- distributes O_2 to its cells
  - mitochondria use O_2 in cellular respiration

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45 Fig. 4.8

46 Introduction to Cellular Respiration

✓Harvesting energy from food molecules
– glucose - used as a representative food molecule

✓summary equation for cellular respiration
– $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATPs$
– bond energy from reactants is stored in chemical bonds of ATP

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48 Introduction to Cellular Respiration

✓Efficiency of cellular respiration
– glucose contains chemical energy
• each ATP molecule made by cellular respiration contains ~ 1% of chemical energy in glucose molecule
– cellular respiration is not able to harvest all energy of glucose in a usable form
• typical cell banks ~ 40% of glucose's energy in ATP molecules
– other ~ 60% is converted to heat

49 Introduction to Cellular Respiration

✓Efficiency of cellular respiration
– comparison
• glucose burned in lab
• glucose "burned" in cell
• gasoline engine

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51 Introduction to Cellular Respiration

✓Cellular respiration
– more efficient than any other process a cell can perform without oxygen
• yeast cell in an anaerobic environment harvests only about 2% of energy in glucose

52 Basic Mechanisms of Energy Release & Storage

✓Underlying mechanisms of energy release and harvest in cell
– energy available to cell is contained in chemical bonds of a molecule (glucose)
– cellular respiration dismantles glucose in a series of steps
• taps the energy carried by electrons

– that are rearranged when old bonds break and new bonds form

53 Basic Mechanisms of Energy Release & Storage

✓cellular respiration shuttles electrons through a series of energy releasing reactions
– electrons start in a molecule where they have more energy & end up in molecule where they have less energy
• energy is released in small amounts
• cell stores some of that energy in ATP
✓cells transfer energy from glucose to ATP by coupling exergonic & endergonic reactions

54 Basic Mechanisms of Energy Release & Storage

✓cellular respiration shuttles electrons through a series of energy releasing reactions
– movement of hydrogen atoms illustrates electron transfers
• glucose loses hydrogen atoms as it is converted to carbon dioxide
• molecular oxygen gains hydrogen atoms as it converted to water
– oxygen serves as the ultimate electron acceptor

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56 Mechanisms of Energy Release & Storage

✓ Movement of electrons from one molecule to another is **oxidation-reduction reaction (redox)**
– **oxidation**
• loss of electrons from one substance (molecule is **oxidized**)
– **reduction**
• addition of electrons to another substance (molecule is **reduced**)
– reactions always go together because electron transfer requires donor and acceptor

57 Mechanisms of Energy Release & Storage

✓**oxidation-reduction reaction (redox)**
– glucose gives up energy as it is oxidized
•
– electrons are moved about by moving hydrogen atoms (along with their electrons)

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59 Mechanisms of Energy Release & Storage

✓**electron cascade** occurs
– electrons “fall” down an energy “hill” of carriers
– each carrier is different molecule
– electrons move “downhill”
• increasing electron affinity
– redox reactions release energy in small amounts at each step, useful to the cell
– last molecule at bottom of hill is O_2
• greatest electron affinity of all carriers

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61 Mechanisms of Energy Release & Storage

✓**Electron transport chains**
- series of electron carriers
- ordered groups of molecules embedded in membranes of mitochondria
  - located in plasma membrane in prokaryotes
- as electrons pass along chain, they lose energy
  - which cell can use to make ATP

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63 Stages of Cellular Respiration

✓Cellular respiration
- continuous process
- three main stages
  - 1st & 2nd stages
    - **glycolysis**
    - **Krebs cycle**
  - 3rd stage
    - **electron transport chain & chemiosmosis**

64 Stages of Cellular Respiration

✓**Glycolysis**
- first stage
- occurs outside mitochondria in cytoplasm of
- means “splitting of sugar”
- universal energy-harvesting process of life
  - occurs in all cells
  - because of its universality, is thought to be ancient metabolic system
- starts with glucose

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66 Stages of Cellular Respiration

✓**Krebs cycle**
- 2nd stage
- takes place in mitochondria
- completes breakdown of glucose
  - producing carbon dioxide
- contributes electrons to 3rd stage
- produces 2 molecules of ATP
- produces other energy-rich molecules

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68 Stages of Cellular Respiration

✓**Electron transport chain**

– 3rd stage

– takes place in mitochondria

– chain uses downhill flow of electrons from electron carriers to oxygen

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Photosynthesis: Using Light to Make Food

71 Photosynthesis uses light energy to make food molecules

✓Photosynthesis

– most of living world depends on this process

- on global scale - billions of tons of organic matter are produced each year
- no other chemical process of Earth matches this output

– consists of two stages that occur in chloroplast

72 Fig. 4.7

73 Autotrophs are the producers of the biosphere

✓Plants are **autotrophs**

– “self-feeders”

- make own food
  - sustain themselves

– chloroplasts capture energy in sunlight

- convert sun’s energy to chemical energy using water and carbon dioxide
  - stored in form of glucose and other organic molecules

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75 Autotrophs are the producers of the biosphere

✓**Producers**

– produce food consumed by heterotrophs

– all organisms that use light energy to make food molecules from inorganic molecules

- photosynthetic autotrophs

– producers include

- plants
- certain archaea
- certain bacteria
- certain protists

76 Autotrophs are the producers of the biosphere

- ✓ **Predominant producers**
  - – terrestrial
    - • plants such as trees
  - – aquatic
    - • photosynthetic protists (algae)
    - • photosynthetic bacteria

77 Photosynthesis occurs in chloroplasts

- ✓ All green parts of a plant have **chloroplasts** and can carry out photosynthesis
  - – leaves have most chloroplasts
    - • are major sites of photosynthesis
  - – green color in plants - from **chlorophyll** pigments in chloroplasts
    - • chloroplhyll absorbs light energy from sun

78 Photosynthesis occurs in chloroplasts

- ✓ Green tissue in interior of leaf is called **mesophyll**
  - – each mesophyll cell has numerous chloroplasts
    - • membranes in chloroplast - many reactions of photosynthesis occur
    - • inner membrane encloses a compartment filled with a thick fluid called **stroma**
      - – within the stroma, disklike membranous sacs called **thylakoids** are suspended
        - » thylakoids are concentrated in sacks called **grana**

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80 Plants produce O_2 gas by splitting water

- ✓ Photosynthesis equation
  - – $CO_2 + H_2O \rightarrow light \rightarrow C_6H_{12}O_6 + H_2O + O_2$

81 Photosynthesis is a redox process, as is cellular respiration

- ✓ Photosynthesis is a redox process
  - – water is <u>oxidized</u> to O_2
    - • when water molecules are split apart
      - – they lose electrons & hydrogen ions
  - – CO_2 is <u>reduced</u> to sugar
    - • when electrons & hydrogen ions are added to it

82 Photosynthesis is a redox process, as is cellular respiration

- ✓ Photosynthesis is a redox process
  - – water is oxidized & carbon dioxide is reduced
    - • electrons gain energy by being boosted up an energy hill
  - – converts light energy to chemical energy
- ✓ Cellular respiration is a redox process
  - – sugar is oxidized and oxygen is reduced

- electrons lose energy as they travel down an energy hill

– converts chemical energy from one form to another

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84 Photosynthesis occurs in two stages

✓ Photosynthesis

– two stages

- **light dependent reactions**
  - first stage
  - converts light energy to chemical energy and oxygen gas
- **light independent reactions (Calvin cycle)**
  - second stage
  - assembles sugar molecules using CO_2 and energy-containing products of the light reactions

85 Photosynthesis occurs in two stages

✓ **Light dependent reactions**

– occur in thylakoid membranes

– absorb solar energy & convert it to chemical energy by

- making ATP from ADP + P
- transferring electrons from H_2O to $NADP^+$ to form NADPH
  - electron carrier
- no sugar is produced during these reactions

– **requires light**

86 Photosynthesis occurs in two stages

✓ **Light independent reactions (Calvin cycle)**

– occurs in stroma of chloroplasts

– carries out process of **carbon fixation**

- incorporation of C from CO_2 into organic compounds

– enzymes of cycle then make sugars by further reducing fixed carbon

- by adding high-energy electrons and hydrogen ions to it

– **does not require light directly**

- but occurs during day in most plants

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88 Photosynthesis uses light energy to make food molecules

✓ **light dependent reactions**

– occur in thylakoid membrane

– photosystems I & II capture solar energy and energize electrons

– water is split and O_2 is released

– photosystems transfer electrons to ETCs

- where energy is harvested and used to make NADPH and ATP

89 Photosynthesis uses light energy to make food molecules

✓ **Light independent reactions (Calvin cycle)**

– occurs in stroma

- incorporates carbon from CO_2 into sugar G3P
- G3P is used to make sugars which are
  - used as fuel for cellular respiration
  - used as starting material for other organic molecules such as cellulose
  - stored as starch in chloroplasts, roots, tubers, fruits

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✓ photosynthesis
- location: chloroplasts
- equation
  - $CO_2 + H_2O \rightarrow light \rightarrow C_6H_{12}O_6 + H_2O + O_2$
- manufactures food molecules
- used by: autotrophs

✓ cellular respiration
- location: mitochondria (stage 2-3)
- equation
  - $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATPs$
- harvests energy in food molecules
- used by: autotrophs and heterotrophs

92 The end