1 ☐ EVPP 110 Lecture Dr. Largen - Fall 2002

# Life: Cell Structure and Major Processes for Fueling Life's Activity

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# Structure of the Cell

- 3 ☐ Introduction to the cell
  - ✓ Before microscopes (first used in 17th century), no one knew living organisms were composed on cells
- 4 🗖
- 5 All cells share fundamental features
  - ✓ Major features common to all cells
    - -plasma membrane
    - -DNA
    - -cytoplasm
    - -carry out metabolism
- 6 ☐ All cells share fundamental features
  - ✓ Major features common to all cells
    - plasma membrane = encloses a cell and separates its contents from its surroundings
      - is a phospholipid bilayer 5-10 nanometers thick
      - contains embedded proteins
- 7 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 the rest of the cell's contents by membrane
      - · eukaryotes
        - **nucleus** double-membrane bound organelle which contains the DNA
- 8 All cells share fundamental features
  - ✓ Major features common to all cells
    - cytoplasm
      - semi-fluid matrix that fills the interior of the cell, exclusive of the nucleoid or

#### nucleus

- contains the chemical wealth of the cell
  - sugars
  - amino acids
  - proteins
- · contains organelles in the eukaryotes

## 9 All cells share fundamental features

- ✓ Major features common to all cells
  - carry out metabolism
    - · the interconversion of different forms of energy and of chemical materials
      - two major metabolic processes
        - » photosynthesis
        - » cellular respiration

#### 10 All cells share fundamental features

### √ the primary tenants of the Cell Theory

- all organisms are composed of 1 or 1+cells
  - · where processes of metabolism & heredity occur
- the cell is the smallest (basic) unit of life
  - · the smallest living thing
- cells arise only by the division of a previously existing cell
  - life evolved spontaneously on early earth
  - all life on earth represents a continuous line of descent from those early cells

## 11 Introduction to the cell

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

#### 12 Introduction to the cell

- ✓ Prokaryotic cell characteristics
  - small, avg. 1/10th size of eukaryotic cell
  - lacks a nucleus
    - DNA contained in **nucleoid region** which is not membrane bound
  - surrounded by plasma membrane
  - most also have bacterial cell wall

- some also have a 3rd layer-the capsule
- some have projections called **pili** (sticky)
- some are propelled by a flagellum
- 13 🗷
- 14 Introduction to the cell

### ✓ Eukaryotic cells

- name eukaryotic, from Greek eu for "true" and karyon for kernal or "nucleus"
- are fundamentally similar to each other
  - profoundly different from prokaryotic cells
- √ characteristics of eukaryotic cells
  - in general
  - comparing animal and plant cell
- 15 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
- 16 Introduction to the cell

#### ✓ Eukaryotic cells

- have 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
- 17 🗷
- 18 Introduction to the cell

#### ✓ Eukaryotic cells

- membranes partition the cytoplasm into compartments called membranous organelles
  - many of the chemical activities known as cellular metabolism
    - occur in the fluid-filled spaces within the membranous organelles

 w/o internal membranes, eukaryotic cells wouldn't have enough membrane surface area to meet metabolic needs

## 19 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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<sup>21</sup> 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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23 Introduction to the cell

## ✓ membranous organelles

- nucleus
- endoplasmic reticulum
- Golgi apparatus
- mitochondria
- lysosome
- peroxisome
- chloroplast
- central vacuole
- 24 Introduction to the cell

#### ✓ non-membranous structures

centriole

- -flagellum
- ribosome
- microtubule
- microfilament
- cell wall

## 25 Energy converting organelles

- ✓ Chloroplasts are the photosynthesizing organelles of plants and protists
  - internal membranes create 3 compartments
    - space between inner and outer membranes
    - · space enclosed by inner membrane
    - · space inside tubules and disks

# <sup>26</sup> Energy converting organelles

#### √ Chloroplasts

- space between inner & outer membranes
  - called intermembrane space
- space enclosed by inner membrane
  - · contains thick fluid called stroma
  - network of tubules and hollow disks
- space inside tubules and disks
  - · disks occur in stacks, called grana
    - grana are the chloroplasts solar power packs

- 27 🗷
- 28 🗷
- <sup>29</sup> Energy converting organelles

#### ✓ Mitochondria

- organelles that convert chemical energy from one form to another
- carryout **cellular respiration**, in which
  - chemical energy of foods such as sugars

- converted to chemical energy of a molecule such as ATP (adenosine triphosphate)
  - » ATP is main energy source for cellular work

## 30 Energy converting organelles

#### ✓ Mitochondria

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

## 31 Energy converting organelles

#### ✓ Mitochondria

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

#### 32 🗷

# 33 Tueling the activities of life

√ two main mechanisms by which organisms obtain food for the activities of life

- autotrophs (self-sustaining)
- heterotrophs (not self-sustaining)

# 34 Fueling the activities of life

✓ two main mechanisms by which organisms obtain food for the activities of life

- autotrophs (self-sustaining)
  - · plants and other photosynthetic organisms
  - can produce from inorganic compounds the organic molecules they need for life

# 35 Tueling the activities of life

- ✓ two main mechanisms by which organisms obtain food for the activities of life
  - heterotrophs (not self-sustaining)
    - animals
    - must obtain the organic molecules that they need by consuming organic molecules already produced by other organisms

## 36 Tueling the activities of life

- √ heterotrophs have two main methods of feeding
  - absorptive feeders
    - lack mouth or digestive tract
    - absorb nutrients through their body surface
    - example, tapeworms
  - ingestive feeders
    - ingest living or dead organisms (plant or animal) through a mouth

# 37 ☐ Fueling the activities of life

- ✓ Ingestive feeders are divided into three groups on the basis of their food sources
  - omnivores
  - herbivores
  - carnivores

# 38 Tueling the activities of life

- ✓ Inaestive feeders
  - omnivores
    - · ingest both plants and animals
    - ex., humans, crows, cockroaches,
  - herbivores
    - · ingest plants and algae
    - · examples, cattle, deer, gorillas
  - carnivores
    - · ingest animals
    - examples, lions, hawks, spiders, snakes

# 39 ☐ 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 the energy from the food molecules
  - autotrophs
    - manufacture their own food via photosynthesis
    - cellular respiration harvests the energy from the food molecules

## 40 Cellular Respiration

- 41 Introduction to Cellular Respiration
  - ✓ Respiration often used as synonym for breathing
    - respiration refers to an exchange of gases
      - organism obtains O<sub>2</sub> from its environment & releases CO<sub>2</sub>

#### √ Cellular respiration

- the aerobic harvesting of energy from food molecules by cells
- 42 Introduction to Cellular Respiration
  - ✓ Breathing and cellular respiration are related
    - organism takes in O2 from its environment
      - distributes O<sub>2</sub> to its cells
        - mitochondria in cells use O<sub>2</sub> in cellular respiration
          - » to harvest energy that cell uses to do work
          - » CO<sub>2</sub> waste produced by cellular respiration in cells is removed to external environment
- 43 🗷
- 44 Introduction to Cellular Respiration
  - ✓ Harvesting energy from food molecules is a fundamental function of cellular respiration
    - glucose is usually used as a representative food molecule
      - cells may use many organic molecules in cellular respiration
  - ✓ 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 the chemical bonds of ATP
- 45 🗷
- 46 Introduction to Cellular Respiration
  - ✓ Efficiency of cellular respiration
    - glucose contains a lot of chemical energy
      - but each ATP molecule made by cellular respiration contains only about 1% of the amount of chemical energy present in one glucose molecule
    - cellular respiration is not able to harvest all the energy of glucose in a usable form
      - · a typical cell banks about 40% of glucose's energy in ATP molecules
        - most of other 60% is converted to heat
- 47 Introduction to Cellular Respiration
  - ✓ Efficiency of cellular respiration
    - comparison
      - · glucose burned in lab converts 100% of its energy to heat and light

- glucose "burned" in cell converts about 40% its energy into stored energy in ATP molecules
- gasoline engine converts about 25% of the energy in gasoline into the kinetic energy of movement
- 48 ☑
  49 ☐ Introduction to Cellular Respiration
  - ✓ Cellular respiration is more efficient than any other process a cell can perform without oxygen
    - a yeast cell in an anaerobic environment harvests only about 2% of the energy in glucose
- 50 🗖 Basic Mechanisms of Energy Release & Storage
  - ✓ Underlying mechanisms of energy release and harvest in the cell
    - energy available to a cell is contained in the specific arrangement of electrons 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
- 51 Basic Mechanisms of Energy Release & Storage
  - ✓ cellular respiration shuttles electrons through a series of energy releasing reactions
    - at each step, electrons start out in a molecule where they have more energy & end up in molecule where they have less energy
      - thus, 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
- 52 Basic Mechanisms of Energy Release & Storage
  - ✓ cellular respiration shuttles electrons through a series of energy releasing reactions
    - movement of hydrogen atoms in chemical equation for cellular respiration can illustrate 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 in cellular respiration
- 53 🗷
- 54 Mechanisms of Energy Release & Storage
  - ✓ Movement of electrons from one molecule to another is an oxidation-reduction reaction (redox)
    - oxidation is the loss of electrons from one substance (molecule is oxidized)

- reduction is the addition of electrons to another substance (molecule is reduced)
- oxidation-reduction reactions always go together because an electron transfer requires both a donor and an acceptor

## 55 Mechanisms of Energy Release & Storage

- ✓ Movement of electrons from one molecule to another is an oxidation-reduction reaction (redox)
  - glucose gives up energy as it is oxidized
    - enzymes remove electrons from(oxidize) glucose and transfer them to (reduce) a coenzyme
  - electrons are moved about by moving hydrogen atoms (along with their electrons)

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- 57 Mechanisms of Energy Release & Storage
  - ✓ electron cascade in which electrons "fall" down an energy "hill" of electron carriers
    - each electron carrier is a different molecule
    - electrons move "downhill" because each carrier molecule has a greater affinity for electrons than its uphill neighbor
    - at each step, the redox reactions release energy in small amounts, useful to the cell
    - last molecule at the bottom of the hill is O2
      - with greatest electron affinity of all the carriers

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59 Mechanisms of Energy Release & Storage

#### ✓ Electron transport chains

- series of electron carriers
- ordered groups of molecules embedded in the membranes of a eukaryotic cell's mitochondria
  - in prokaryotes, they are located in the plasma membrane
- as electrons pass along chain, they lose energy
  - which the cell can use to make ATP

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- 62 Stages of Cellular Respiration
  - ✓ Cellular respiration is a continuous process but it can be divided into
    - three main stages
      - 1st & 2nd stages are exergonic
        - glycolysis
        - Krebs cycle
      - 3rd stage is endergonic

#### - electron transport chain & chemiosmosis

## 63 Stages of Cellular Respiration

#### √ Glycolysis

- first stage of cellular respiration
- occurs outside the mitochondria in the cytoplasm of the cell
- means "splitting of sugar"
- universal energy-harvesting process of life
  - · occurs in all cells
  - because of its universality, it is thought to be an ancient metabolic system
- starts with glucose

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## 65 Stages of Cellular Respiration

#### √ Krebs cycle

- 2nd stage
- takes place in the mitochondria
- completes breakdown of glucose
  - by decomposing a derivative of pyruvic acid to carbon dioxide
- contributes electrons to 3rd stage
- produces 2 molecules of ATP
  - by substrate-level phosphorylation
- produces other energy-rich molecules

66 🗷

## 67 Stages of Cellular Respiration

#### ✓ Electron transport chain

- 3rd stage
- takes place in the mitochondria
- chain uses downhill flow of electrons from electron carriers to oxygen
  - · uses that energy to pump hydron ions across membrane
    - which provides energy for ATP synthase to make ATP by chemiosmosis

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# Photosynthesis: Using Light to Make Food

70 ☐ Photosynthesis uses light energy to make food molecules
✓ Photosynthesis

- most of living world depends on the food-making machinery of this process
  - on a global scale billions of tons of organic matter are produced each year by this process
  - no other chemical process of Earth matches this output
- consists of two stages that occur in the chloroplast

# 71 Autotrophs are the producers of the biosphere

- ✓ Plants are autotrophs
  - "self-feeders"
    - · make own food
      - sustain themselves
        - » without eating other organisms or organic molecules
  - chloroplasts capture energy in sunlight
    - · and with water and carbon dioxide convert sun's energy to chemical energy
      - stored in form of glucose and other organic molecules

### 72 🗷

## 73 Autotrophs are the producers of the biosphere

- ✓ Producers are the organisms that produce the food consumed by heterotrophs
  - all organisms that use light energy to make food molecules from inorganic molecules are
    - · producers
    - · photosynthetic autotrophs
  - producers include
    - plants
    - · certain archaea
    - · certain bacteria
    - · certain protists

# 74 Autotrophs are the producers of the biosphere

#### ✓ Predominant producers

- terrestrial
  - plants such as trees
- aquatic
  - photosynthetic protists (algae)
  - · photosynthetic bacteria

# <sup>75</sup> Photosynthesis occurs in chloroplasts

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

# <sup>76</sup> Photosynthesis occurs in chloroplasts

- ✓ Green tissue in interior of leaf is called mesophyll
  - each mesophyll cell has numerous chloroplasts

- membranes in the chloroplast form the structural framework where 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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# 78 ☐ Plants produce O₂ gas by splitting water

✓ Photosynthesis equation

 $-CO_2 + H_2O \rightarrow light \rightarrow C_6 H_{12}O_6 + H_2O + O_2$ 

# <sup>79</sup> Photosynthesis is a redox process, as is cellular respiration

- ✓ Photosynthesis is a redox process
  - water is oxidized to O<sub>2</sub>
    - · when water molecules are split apart
      - they lose electrons & hydrogen ions
  - CO<sub>2</sub> is reduced to sugar
    - · when electrons & hydrogen ions are added to it

# <sup>80</sup> □ 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
- 81 🗷

# 82 Photosynthesis occurs in two stages

- ✓ Photosynthesis is not a single process
  - has two stages, each with multiple steps
    - · light reactions
      - first stage
      - converts light energy to chemical energy and oxygen gas
    - · Calvin cycle
      - second stage
      - assembles sugar molecules using CO<sub>2</sub> and energy-containing products of the light reactions
- 83 Photosynthesis occurs in two stages
  - √ Light reactions
    - occur in thylakoid membranes

- absorb solar energy & convert it to chemical energy by
  - making ATP from ADP + P
  - transferring electrons from H<sub>2</sub>O to NADP+ to form NADPH
    - electron carrier similar to NAD+
  - notice that no sugar is produced during these reactions
- requires light

# 84 Photosynthesis occurs in two stages

- √ Calvin cycle
  - occurs in stroma of chloroplasts
  - carries out process of carbon fixation
    - incorporation of the C from CO<sub>2</sub> into organic compounds
  - enzymes of the cycle then make sugars by further reducing the 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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## 86 Photosynthesis uses light energy to make food molecules

- √ light reactions
  - occur in thylakoid membrane
  - photosystems I & II capture solar energy and energize electrons
  - water is split and O2 is released
  - photosystems transfer electrons to ETCs
    - where energy is harvested and used to make NADPH and ATP

## 87 Photosynthesis uses light energy to make food molecules

- ✓ Calvin cycle
  - occurs in stroma
  - incorporates carbon from CO<sub>2</sub> in the air into the 3 carbon 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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