Module 3

Chapter 5 – Microbial Metabolism

Catabolic and Anabolic Reactions

- Metabolism – ____________________________________
- Two general types of metabolic reactions:
  - _____________________: ____
  - _____________________: ____
- Recall from Chapter 2:
  - Energy can be _____________________ when ______________ bonds ________
  - Energy can be _____________________ when ______________ bonds ________
- Catabolism –
  -
  -
  -
  - Purpose is to ____________________________
    - ______________________________________
    - ______________________________________
- Anabolism –
  -
  -
  -
  - Requires ___________________ to form bonds
  - Purpose is to ________________________________
- Catabolic reactions are "coupled with" anabolic reactions
  - Coupled by __________
- A metabolic pathway is a ________________ of chemical ________________ in a cell
- Metabolic reactions are controlled by proteins – ________________________

Enzymes

- Enzymes are biological catalysts
  -
  -
- ___________________ for a _____________ chemical reaction
- Specificity is due to ______________ of enzyme
  - Proteins (enzymes) have characteristic __________________
  - Structure is ________________ for ____________________
- If enzyme ______________, enzyme doesn't ______________
  - ____________________________
- Enzymes act on one or more _________________
  - ____________________ bind at ___________

- Each enzyme is specific
    -
    -
- Names of enzymes end in "____________"
    - Suc*rase*, catal*ase*, DNA polymer*ase*

Enzyme components

- Many enzymes are made entirely of _________________
- Some consist of 2 components
    - Apoprotein:
    - Cofactor:
        - __________________: organic cofactor
- Holoenzyme:
    -

Enzyme Mechanism

- The general sequence of events in an enzymatic reaction
    - Substrate(s) binds to ________________
        - This is called ______________________
    - The substrate(s) is transformed
    - Transformed molecule(s), the ______________, released from enzyme
        - No longer ____________________
        - Enzyme only ___________ to _____________
    - Enzyme is free to ___________________________________
- Sequence continues until enzyme is ____________, or enzyme _______________

Factors influencing enzymatic activity

- Enzymes require _____________________ to function
- Hostile environments can cause proteins to _______________
- Temperature
    - In general, chemical reactions speed up as temp ________________
    - For enzymes, too __________ temperature causes ___________
- pH
    - pH is ____
    - All enzymes have __________________ pH
    - ___________ from preferred pH will ______________
- Inhibitors
    - Certain chemicals that bind to enzymes
        -
- Two classes of inhibitors:
    - Competitive inhibitors – bind _____________________________
        - ______________ with substrate for the _____________ of the enzyme
        - _________ drugs inhibit _____________ (an essential ________________) synthesis via competitive inhibition
        - _________ drugs were the first effective antibacterial drugs
    - Noncompetitive inhibitors – bind ______________________________
        - Aka ___________________ inhibition
        - _________________ prevents replication of HIV via noncompetitive inhibition

Feedback inhibition
- Control of enzymatic activity by use of ___________________________________
  -

Energy Production
- Energy is stored in ________________
  - Recall, covalent bonds form by _______________________
- Energy is stored in ____________________ covalent bonds
- Catabolism involves stripping “high energy” __________ from molecules and concentrate them in the bonds of ATP
- Reactions that involve removing and adding electrons are called “_____________________” reactions

Oxidation-Reduction reactions
- Oxidation:
- Reduction:
- __________ reaction: an oxidation reaction _________ with a __________ reaction
- Catabolism is the _______________ of highly _______________ molecules

The Generation of ATP
- Energy released by redox reactions “trapped” by __________
- ________ is generated by the ______________________ of __________
  - Addition of a __________________
  - Requires energy
- 3 types of ________________________ to generate _______

Substrate-level phosphorylation
- _________________________ of a PO4- to _______ generates ________
- _________________ process
- ______________ and __________

Oxidative phosphorylation
- ____________________________ from organic molecule (_______________) used to generate ___________________ (_________________) gradient
  - Gradient used to ________________________ production

Photophosphorylation
- Occurs only in ________________ cells
- _______ transfers energy to _______________ electrons
  - _________ get excited
- Excited _____________ used to generate _________________ gradient, drive ________ production
  - Similar to _________________ phosphorylation, using ________ instead of _______ to build dam

Metabolic pathways of energy production
- Catabolism involves series of controlled reactions
  - Releasing energy in one reaction generates too much heat
  - Energy cannot be harnessed efficiently
- Catabolism involves a series of ___________________ reactions
  - ___________________ extracted to _______________________
  - Sequence of reactions called a ____________

- Every reaction in a pathway is performed by ___________

Carbohydrate catabolism

- Carbohydrates are _________________ of energy
    - ______________ is most common energy source
- Glucose is broken down via two general processes:
    - Cellular respiration
        -
    - Fermentation
        -

Cellular Respiration

- ______________________ (catabolism) of glucose
    - Waste products are _______________
- Most of the _____________ is produced via ________________ phosphorylation
- Two types of respiration
    - _____________ Respiration – with _____________
    - _____________ Respiration – without _____________
- Multiple pathways involved

Glycolysis

- The __________ of glucose molecule (6 Carbons) to 2 pyruvic acid molecules (3 C)
- Main end-products
    - 2 ____________________
    - 2 ____________________
    - 2 ____________________ via __________
- Electron Carriers
    - ________ (empty electron carrier) removes electrons from _________________ (______________________)
        - Becomes _____________ (full electron carrier)
    - __________ takes electrons to their final destination

The pathway

- Requires 2 _______ to get started
- _________ is __________ to ____________
- Overall _________ produced by glycolysis

  Glycolysis _________________ require oxygen

Alternatives to glycolysis

- Pentose-phosphate pathway
    - Uses ______________ and ____________ (__________________________)
    - Operates ____________ with glycolysis
- Entner-Doudoroff pathway
    - Produces _____________ and _________
    - Does ____________________ glycolysis

Intermediate Step

- Pyruvic acid (from ________________) is ___________ and _____________
- __________ is produced
- ________ waste

The Krebs Cycle

- Aka ________________________ or citric acid cycle
- A series of 8 reaction steps
- Completely catabolizes organic molecule to _______________
    -
- Main products are ____________, ___________, 1 ATP
    - ______________ carriers
- Final end-product is same as starting reactant; a cycle

The pathway

- _______________ enters Krebs cycle
- Generates ________________________
- 1 ATP produced by _______________
- ________ generated as waste

The Electron Transport Chain

- A series of __________________________________
- _____________________ pass electrons to ETC
    - Become _______________
    - Return to glycolysis, Krebs cycle
- Energy released from _____________ used to drive __________________ from inside cell to ____________ cell
    - Produced ________ concentration gradient – _______________
    - Electrons end up on ____________________________ -
- ETC generates _________________ gradient
- ___ gradient favors ________________ into cell
    - ___________________ diffuse across membrane freely
- _______ re-enters cell via _________________
    - Through transporter called ___________________
- ________________ captures energy in gradient
    - Produces _________ → _______________________

Summary of Respiration

- Aerobic respiration: the final electron acceptor in ETC is _____________________
    - Organism is an _________________
    - Oxygen is converted to ______________ → _____________
- Anaerobic respiration: the __________________________ in the ETC is _________
    - Usually an ________________________
    - Yields ____________ than aerobic respiration because only part of the Krebs cycle operates under ___________________ conditions
- _____________ sources can be used
    - Eg, can oxidize lipids, _____________
- Polymers broken down by enzymes
- Smaller subunits enter catabolism at various points of glycolysis, Krebs cycle

Fermentation

- Scientific definition:
    - Releases energy from _____________ of ____________ molecules (food)
    - Does _____________ oxygen

- Does not use the ________________________
    - Uses an _______________________ as the final electron acceptor
- ATP generated only via ______________
- ____________ converted into organic molecule end-product → _______________
    - Main purpose is to regenerate __________ (from ___________) for _____________
    - __________ can participate in ____________ again
- Produces ______________________ of energy - ____________ left in end-product

The Pathway

- _________________ produces _________
- ______________________ glucose during glycolysis
- ______________ produced during glycolysis
- _________________ pyruvic acid; regenerates ____________
- Lactic Acid fermentation produces _______________
- Ethanol fermentation produces _____________

Chemotherapy

- ___________ → highly toxic
    - Inhibit Cytochrome c Oxidase, enzyme in ____________
- ______________ ETC
    - Cell cannot ______________
    - Cell cannot ______________
    - Cell ______________
- _________________ not affected by cyanide

Photosynthesis

- Photo: conversion of __________ energy into ___________ energy (_____)
    - ____________**-dependent (light) reactions**
- Synthesis:
    - **Carbon** _____________: fixing carbon into __________ molecules
- Light energy is absorbed by _____________
    - In _________________ of chloroplasts in eukaryotes
    - In _________________ of prokaryotes
- Light energizes or "__________" ___________ in ______________
- Excited electrons are passed on to ______________
    - ATP is generated
- Occurs in two ways:
    - ______________ (_________________)
    - ______________ (_________________)

Cyclic photophosphorylation

- ____________________ electrons
- ____________ passed on to _______________
- ATP generated by ______________________
- Electrons _______________________

Noncyclic photophosphorylation

- ____________________ electrons
- ____________ passed on to _______________

- ATP generated by ______________________
- Electrons placed on ____________ → forms ______________
- Electrons in chlorophyll replaced by electrons from _____________ → ________ produced as waste

Light-independent (Dark) reactions

- Aka The __________________ cycle
- Uses ATP, NADPH produced by noncyclic photophosphorylation to "________" __________
- _________ from __________
- Process requires lots of ___________
- _____________________ produced

Metabolic diversity among organisms

- Organisms classified according to ______________
    -
- Specifically, look at basic requirements to sustain life
    -
    -
- Two classifications based on ___________ sources
    - Phototrophs –
    - Chemotrophs –
- Two classifications based on ___________ sources
    - Autotrophs –
        - Aka ____________________________
    - Heterotrophs –
        - Aka _______________________________

Classification can be combined

- Photoautotroph
    -
- Photoheterotroph
    -
- Chemoautotrophs
    -
- Chemoheterotrophs
    -

Chemoheterotrophs

- Heterotrophs classified according to their source of organic molecule
    - Saprophytes –
    - Parasites –
- Metabolic diversity of great interest
    - Can cause problems, provide potential solutions
        - Rubber degrading bacteria can destroy gaskets in machinery
        - BUT, can be used to degrade discarded tires
        - *Rhodococcus erythropolis* can cause disease in humans, animals
        - BUT, can remove sulfur from petroleum