Online Physiology 2130 - Metabolism

Introduction

Dear Student,
Thank you for opening this resource for Physiology 2130, and welcome. This resource has been created by the Education Team at WebStraw. The Education Team consists of students that have previously taken and/or students that are currently taking Physiology 2130.

Purpose

This resource focuses on key concepts that are important for students to understand to succeed within this course. This resource was created by students for other students. Our goal is to help students (1) further develop their understanding of course content and (2) achieve greater academic success. (3) Our resource is also open access meaning there are no financial or legal barriers to students who wish to access and use our resource.

Instructions

These study resources consists of several parts. The first part includes a condensed review of the major takeaways from each physiology module. This is followed by a series of questions and fill in the blank worksheets that should be completed after you have gone through the module and course material, in order to verify your understanding.

Disclaimer

WebStraw is not affiliated with Western University. This resource is supplementary to your course content and is not meant to (1) replace any of the resources provided to you by your instructor nor is it meant to (2) be used as a tool to learn the course material from scratch. We assume that students who use this resource will have a basic understanding of the course content. This resource does not contain everything you need to know for your evaluations. Please refer to the course material provided by your instructors if there are any discrepancies between our resource and your course content.

We wish you the best of luck on your exams!
The WebStraw Team

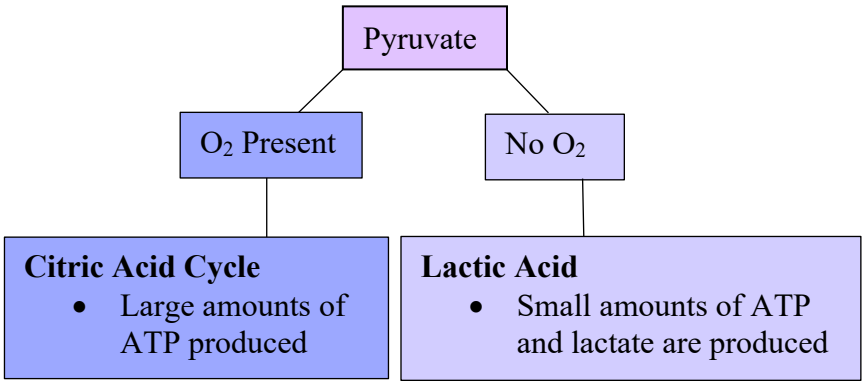
Note to Instructors: If this resource has been created for your course and you would like to collaborate with us, please email us at team@webstraw.ca

Module 16 – Metabolism

Building Blocks		
Carbohydrates	Glucose	Glycogen
Proteins	Amino acids	Cellular protein
Fats	Free fatty acids	Triglycerides

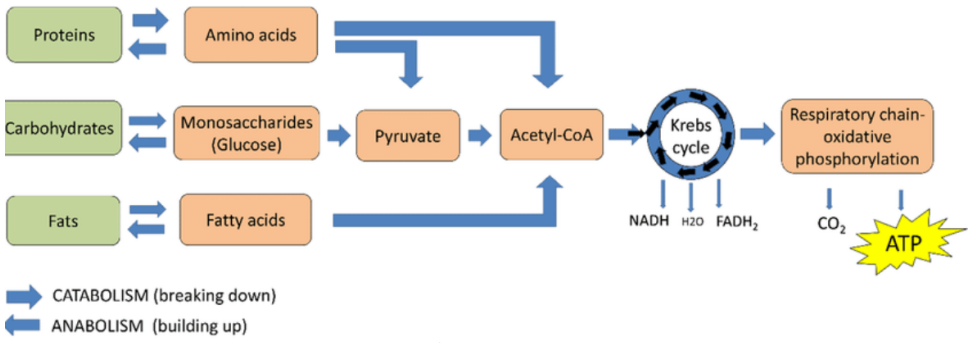
Glucose Metabolism – Glycolysis

- Glucose → Glucose-6-phosphate → Glycolysis (produce ATP) **OR** can be converted to glycogen
  - If necessary, glycogen → glucose-6-phosphate → glycolysis→ produce energy
- Glucose-6-phosphate will undergo reactions and produce pyruvate → leading to ***2*** pathways:



Glucose Metabolism – The Citric Acid Cycle (O_2 present)

- Pyruvate → Acetyl CoA → Citric Acid Cycle
- Citric Acid Cycle & Oxidative Phosphorylation
  - 2 ATP from citric acid cycle
  - 34 ATP from oxidative phosphorylation
  - Produces CO_2 and H_2O
    - CO_2 diffuses into the blood and leaves the body at the lungs



Production of ATP Through Metabolic Pathways

1. **Glycolysis**
   - Occurs in the ***cytoplasm***
   - Anaerobic reaction
   - ***2*** molecules of ATP produced per molecule of glucose
2. **Citric Acid Cycle (CAC)**
   - Occurs in the ***mitochondria***
   - Aerobic reaction
   - ***2*** molecules of ATP produced per glucose molecule
3. **Oxidative Phosphorylation**
   - Occurs in the ***mitochondria***
   - Aerobic reaction
   - ***34*** molecules of ATP produced per glucose molecule

Fuel Sources Entering Metabolic Pathways

- Glucose → Glycolysis
- Pyruvate (converted from amino acids) → Glycolysis
- Glycerol (broken down from fats) → Glycolysis
- Acetyl CoA → Citric Acid Cycle
- Fatty acids (converted from amino acids) → Citric Acid Cycle

Metabolism of Fats & Amino Acids

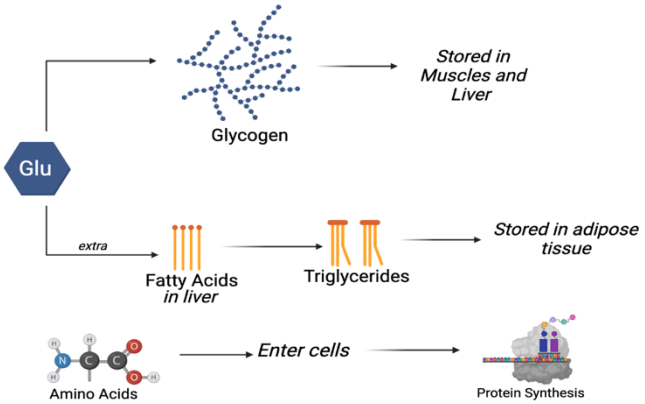
- Amino acids are stored as proteins
  - Amino acids → Pyruvate→ Glycolysis

    OR
  - Amino acids→ Acetyl CoA → Citric acid cycle
- Fats are stored as triglycerides
  - Triglycerides → Glycerol → Glycolysis

    AND
  - Triglycerides → Fatty acids → Acetyl CoA → Citric acid cycle
- Molecules can produce ATP or be stored as glycogen

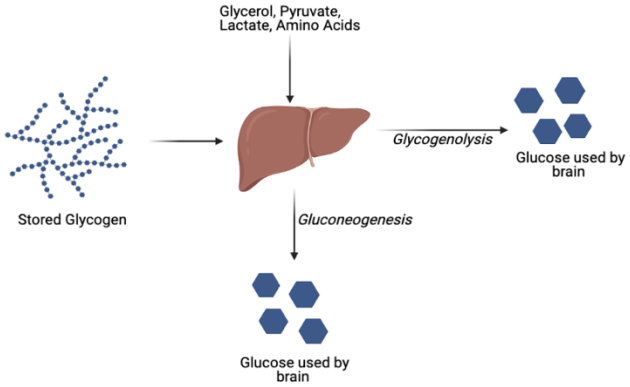
Fed (Absorptive) State

Goal: store all the new fuel (amino acids, fats, and glucose) for later use



Fasted (Post-absorptive) State

Goal: Maintain glucose levels by using stored energy



Other Hormones

1. **Thyroid hormones (T3 and T4)** – increases the breakdown and release of energy stores
2. **Epinephrine (Adrenaline)** – increases glucagon levels and decreases insulin levels
   - Causes release of stored fuel
   - Activated by sympathetic nervous system
3. **Cortisol** – causes release of fuel stores during stressful periods
   - Secreted by adrenal glands

Insulin

- Secreted by ***beta cells in the pancreas*** in response to high glucose levels
- ***Major targets***: muscle, liver, and adipose tissue
  - Has an effect on most cells except brain and red blood cells (RBCs)
- Release of insulin causes:
  - Increased glucose uptake and utilization
  - Increased glycogen formation (glucose storage)
  - Increased triglyceride formation (fat storage)
  - Increased protein synthesis (protein storage)
- ***Decreases glucose, fatty acids and amino acids in blood***

Glucagon

- Secreted by ***alpha cells in the pancreas*** in response to low glucose levels
- ***Major targets***: liver and adipose tissue
- Release of glucagon causes:
  - Increased glycogenolysis (breakdown of glycogen stores)
  - Increased gluconeogenesis (formation of new glucose molecules in the liver)
  - Increased lipolysis (breakdown of fat stores)
- ***Increases glucose, and fatty acids in blood***

Diabetes Mellitus → beta cells of islets are destroyed, and insulin can't be produced

- Blood glucose levels are higher
- Glucose excreted in urine

Review Questions

1. Which of the following is/are TRUE?
    1. Glycerol can enter glycolysis to produce ATP.
    2. 36 ATP molecules can be produced from oxidative phosphorylation.
    3. Triglycerides are broken down into glycerol and fatty acids.
    4. Glycerol can enter the citric acid cycle.

        a) 1, 2, and 3 only
        b) 1 and 3 only
        c) 2 and 4 only
        d) 4 only

2. Although glucose is a common fuel source for cells in the body, it is one of the only fuel sources for the _____.

    a) Kidneys
    b) Lungs
    c) Brain
    d) Liver

3. Food molecules can enter many different metabolic pathways, which of the following is FALSE?
    a) Glucose can enter glycolysis at the end of the reaction.
    b) Amino acids can be converted into pyruvate to enter glycolysis.
    c) Amino acids can be converted into acetyl CoA to enter the citric acid cycle.
    d) Fatty acids can be converted into acetyl CoA to enter the citric acid cycle.

4. Which of the following statements is FALSE?
    a) During post-absorptive state, the liver breaks down glycogen stores to increase blood glucose.
    b) During post-absorptive state, the muscle breaks down glycogen stores to increase blood glucose.
    c) Liver makes glucose using many molecules through a process called gluconeogenesis.
    d) During absorptive state, glucose is stored as glycogen in liver and muscles.

5. Which of the following processes would you expect during times of high stress?
    1. Increased glycogen formation
    2. Increased gluconeogenesis
    3. Increased triglyceride formation
    4. Increased lipolysis

        a) 1, 2, and 3 only
        b) 1 and 3 only
        c) 2 and 4 only
        d) 4 only

Answers
1.B 2.C 3.A 4. B 5.C

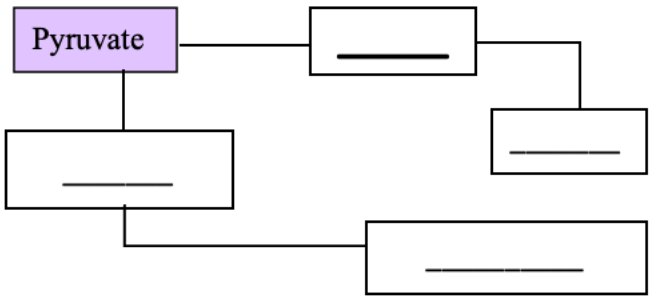
Fill in the blanks.

Production of ATP through Glycolysis

1. Glycolysis occurs in the _____.
2. Glycolysis is a _____ reaction.
3. Glycolysis produces ____ molecules of _____ for every _____ of glucose.

Glucose Metabolism – Glycolysis

- Glucose → _____ → Glycolysis **OR** can be converted to _____
- _____ will produce pyruvate and will have _____ pathways



Production of ATP through CAC & Oxidative Phosphorylation

1. CAC occurs in the _____.
2. CAC and oxidative phosphorylation are _____ reactions.
3. CAC produces _____ molecules of _____ for every _____ of glucose.
4. Oxidative phosphorylation occurs in the _____.
5. Oxidative phosphorylation produces _____ molecules of _____ for every _____ of glucose.

Glucose Metabolism – CAC

- Pyruvate → _____ → _____
- _____ ATP from CAC
- _____ ATP from oxidative phosphorylation
- _____ diffuses _____ the blood and _____ the body at the _____.

Building Blocks		
Carbohydrates		
		Cellular protein
	Free fatty acids	

Fed is the _____ state.

- Its goal is to _____ all the new _____ to use later.
  - New fuel includes _____, fats, and _____.

Fasted is the _____ state.

- Its goal is to _____ glucose levels by using _____.

Insulin

Insulin is secreted by _____ cells in the _____ in response to _____ glucose levels.

- _____ glucose, _____ and amino acids in the blood.

Glucagon

Glucagon is secreted by _____ cells in the _____ in response to _____ glucose levels.

- _____ glucose, and _____ in the blood.

FUN FACT

After 3-4 days of starvation, ketone bodies are created from fats and serve as the primary fuel source for the heart and other organs but NOT the brain (the brain uses glucose).

FUN FACT

The citric acid cycle pathway was one of the earliest pathways to evolve in the metabolism of cells.

Conceptual Questions

1. After finishing an intense HIIT workout, you are given 10 minutes to cool down. Explain what events occur while cooling down. **HINT:** Think about the hormones that are being secreted.

2. Which cell in the human body ONLY uses glycolysis for the production of ATP? **HINT:** Think about the type of reaction.

    a) Erythrocyte
    b) Podocyte
    c) Myocyte
    d) Hepatocyte

3. Which of the following IS produced by glycolysis?
    1. NADH
    2. $FADH_2$
    3. Pyruvate
    4. Lactic acid

    a) 1, 2, and 3 only
    b) 1 and 3 only
    c) 2 and 4 only
    d) 4 only

Answers:
2. A 3. B