Ch 2, part 1: Cell Respiration & Cell Metabolism

Powerpoint updated January 15, 2025

Objectives:

1. **Understand what molecules our cells metabolize for energy.**
   Carbohydrates (first!)
   Lipids (next)
   amino acids (routine & emergency)
   lactic acid (routine & emergency)
2. **Understand the basics of cell respiration.**
3. **Become familiar with anaerobic & aerobic cell respiration**
4. **Become familiar with metabolism of lipids, carbohydrates, and amino acids.**

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1. Types of Cell Metabolism

i) Carbohydrate metabolism – making or breaking down carbohydrates (ex. Glucose and glycogen).

ii) Lipid metabolism – making or breaking down lipids
(ex. Ketones, fatty acids, trigylcerides)

iii) Protein metabolism (amino acids) – making or breaking down protein.

iv) Lactic acid metabolism – making or breaking down lactic acid.

2

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What conditions occur to make following happen in body?

- Lactic acid metabolism occurs when

  _____

- Lipogenesis occurs when

  _____

- Lipolysis occurs

  _____

- Amino acid metabolism occurs

  _____

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Glucose metabolism:

Glycolysis =

Glycogen metabolism:

Glycogenesis =

Glycogenolysis =

(Ques: what do you remember from Ch 1 about this process?
What pancreatic hormone can stimulate this in the liver?

Lipid metabolism :

Lipogenesis =

Lipolysis =

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Glycogenesis = creation of glycogen from glucose molecules

(enzyme in liver & skeletal muscle)

Glucose + glucose → Glycogen

Glycogenolysis = breakdown of glycogen into glucose

(enzyme in liver & skeletal muscle)

(enzyme in liver only!

glycogen → glucose 6-phosphate → free glucose

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Glycogen metabolism

Click **HERE** for blank flow diagram. Click **HERE** for key.

If insulin is present the liver takes up blood glucose and can undergo glycogenesis.

Glucose + Glucose → Glycogen

What enzyme is needed for this to happen?

_____

If glucagon is present, the liver can breakdown glycogen into free glucose (glycogenolysis)

Glycogen → Glucose 6 phosphate → free glucose

What enzyme is needed for this to happen?

_____

What enzyme does the liver have (but not skeletal muscles) for this to happen?

_____

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Diabetes (Type 2) =

Treatments:
1. Diet & exercise (doesn't always work, especially with genetic predisposition).

2. Pharmaceuticals:
Ex.
Ozempic (semaglutide injection) OR *Rybelsus* (semaglutide pill form)
= increases insulin production AND inhibits glucagon

Click here for Wiki mechanism of action

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2. Basics of Cell Respiration – use of glucose in cell respiration:
Pg 27 – 29 Wiki text

Glycolysis
= 1st step in use of glucose for cell respiration to make ATP

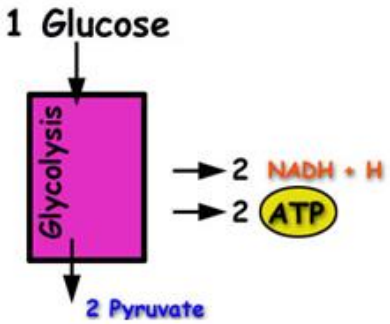
- Occurs in cell cytoplasm

- Conversion of 1 glucose molecule into:

> _____

> _____

> _____



Pyruvate then can go one of 2 ways
- depends on if O^2 is present or not

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Pyruvate from glycolysis then can go one of 2 ways
- depends on if **O^2** is present or not

Pyruvate

Anaerobic respiration

No oxygen

Emergency! (in heart/brain)

Fermentation

Products =
2 ATP
Lactic acid (lactate)

Aerobic respiration

Oxygen present

- Pyruvate Processing
- The Krebs cycle
- ETC

Products =
34 - 36 ATP

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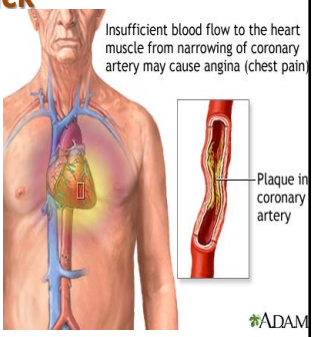
Ischemia, Serum Lactate, and Heart Attack

Ischemia & Angina Pectoris – Click HERE for Clinical App reading.
"Ischemia" = _____



Loss of blood flow to heart:
- without arterial blood & O2 heart resorts to anaerobic respiration. Loss of blood & O2 to heart can cause …

"**angina pectoris**" = _____

_____
- Prelude to "**myocardial infarction**" (heart attack)

- Normal serum lactate = 1- 0.5 mmol/L
- **Hyperlactatemia** = _____= > 4mmol/L

Serum Lactate as a Marker of Acute Myocardial Infarction
http://www.aafp.org/afp/1998/0415/p1993.html

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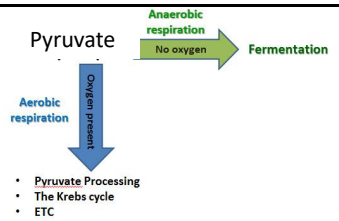
Aerobic respiration



3 Steps of aerobic respiration (AFTER GLYCOLYSIS):

1. Pyruvate processing (pyruvate conversion)

2 pyruvate enter → **2**_____, 2 _____, 2 _____

2. Kreb's cycle (citric acid cycle)

2 Acetyl CoA enter → **2** _____, 6 _____ , 2 _____ , 4 ___

3. Electron transport chain (ETC)

2 NADH2, 6 NADH_2 , 2 FADH_2 enter → **30 – 32 ATP**, 10 ____, 2 ____, 12 ____

Plus 2 NADH2 from glycolysis and

2 NADH2 from pyruvate processing

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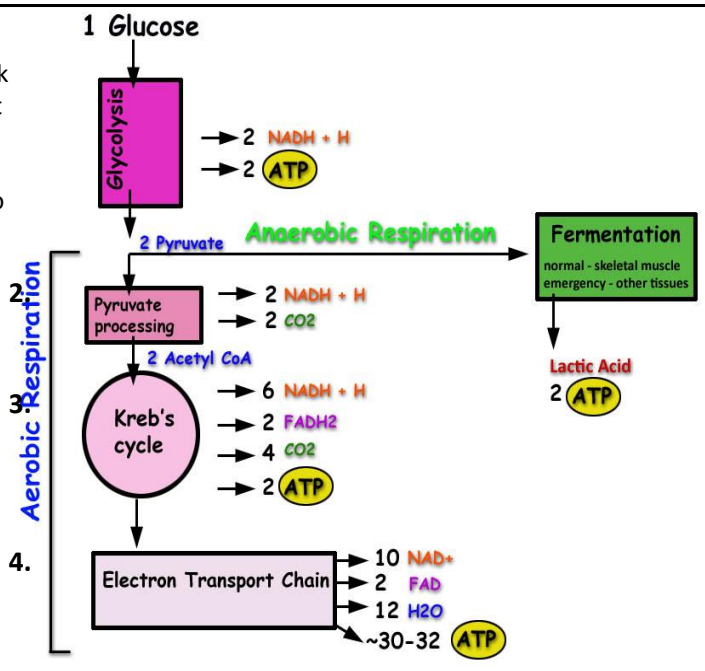
Click **HERE** for blank Glycolysis flow chart

Click **HERE** for KEY to Glycolysis flow chart



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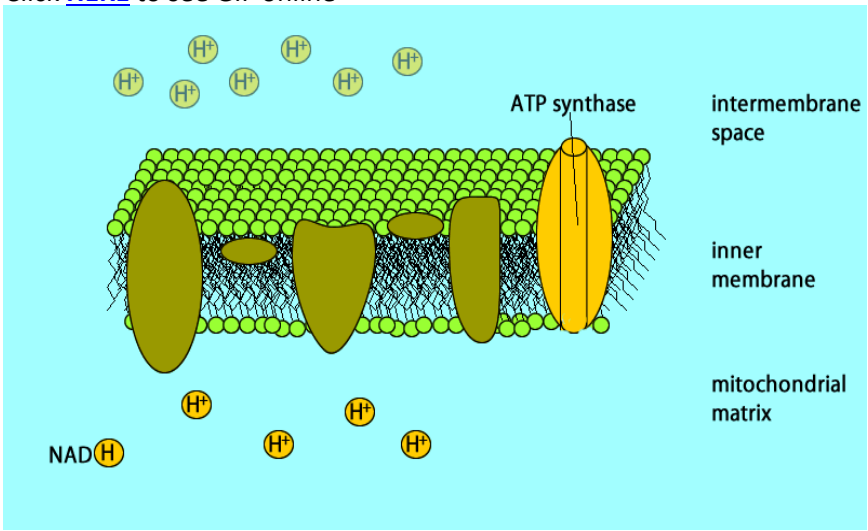
Electron Transport Chain within the cell mitochondria – ATP production!

Click **HERE** to see GIF online



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Question:
Why do we need oxygen???

= As final electron acceptor in ETC in production of ATP!

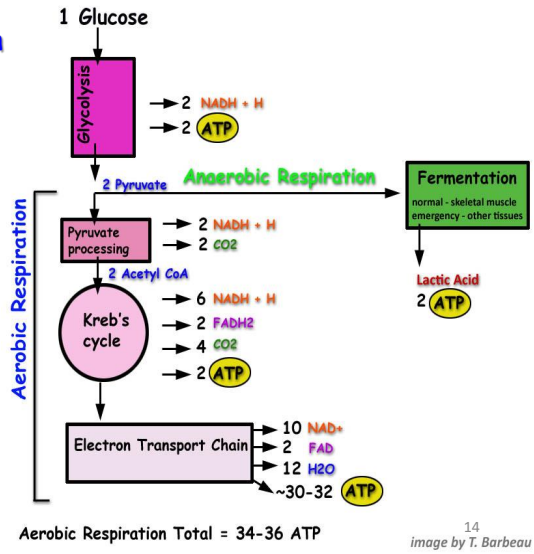

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image by T. Barbeau

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When aerobic respiration goes wrong!

Read online Clinical App: cyanide

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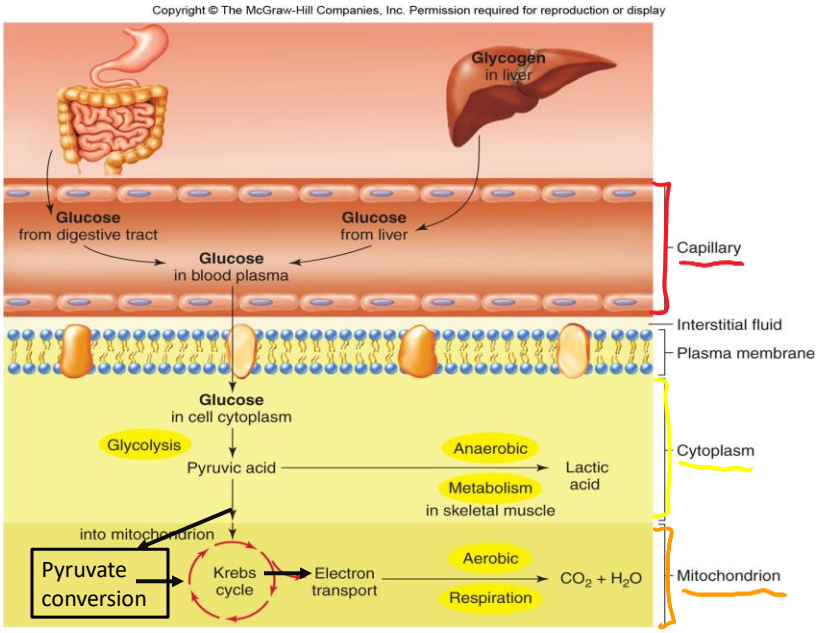
Where Cell Respiration Occurs



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Review (Whew! That's a lot!)

- Our cells can metabolize carbohydrates, lipids, protein, and lactic acid
- Carbohydrate metabolism includes:
  - Glucose metabolism for ATP (glycolysis during cell respiration)
  - Glycogen metabolism
    - Making glycogen (glycogenesis), requires enzyme glycogen synthase
    - Breaking down glycogen (glycogenolysis), requires enzyme glycogen phosphorylase in skeletal muscle & liver, and glucose 6 phosphatase in liver.
- Glycolysis is conversion of glucose into 2 ATP, 2 NADH2, and 2 pyruvate
- Pyruvate can either go through aerobic respiration or anaerobic respiration
- In aerobic respiration, pyruvate goes thru pyruvate conversion to make 2 Acetyl CoA, 2 NADH2, 2 COS
- 2 Acetyl CoA enters Krebs cycle to make 6 NADH2, 2 FADH2, 4 CO_2
- H ions enter electron transport chain to make ~ 30 – 32 ATP, 6 NADH+, 2 NADH+, and 12 H_2O.
- Altogether aerobic respiration of 1 glucose yields 34 – 36 ATP
- Glycolysis occurs in cytoplasm, but pyruvate conversion, Kreb's cycle, and ETC occurs in mitochondria

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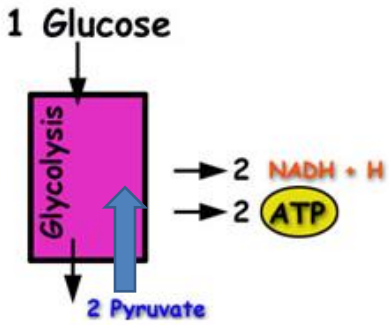
Gluconeogenesis = _____

_____



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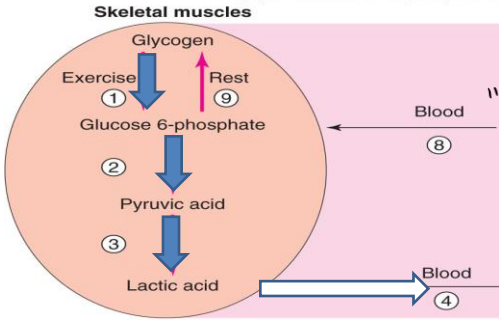
Lactic acid (lactate) metabolism = "The Cori cycle"

= lactic acid (from skeletal muscle activity & anaerobic respiration) can cause "**metabolic acidosis**" and drive blood pH ↓.

Liver "recycles" lactic acid in blood into:

- **Free glucose** (to be returned to blood stream)
  (due to enzyme only in liver – ***glucose 6 phosphatase***)
- Stored **glycogen** (for future need)
- Reverses metabolic acidosis

What is the term for when non-carbohydrate molecules (like lactic acid) are turned into glucose? _____



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Lipid Metabolism:

"**Lipogenesis**" =

"**Lipolysis**" =

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Lipid Metabolism:

"Lipogenesis" = conversion of excess glucose into white fat (triglycerides) in adipose & liver. Stimulus = "insulin"

1. Extra blood **Glucose** enters glycolysis to produce **pyruvate**

2. Pyruvate goes through pyruvate conversion into **Acetyl CoA**

3. Acetyl CoA used by liver to make:

a) cholesterol –

b) ketones –

c) fatty acids –

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Lipid Metabolism:

"Lipolysis" = conversion of white fat (triglycerides) into molecules that can be used for energy (ATP).

A) Triglycerides turned into Ketones by liver

Process of making ketones = _____)

Ketones metabolized for energy (ATP) if no carbs

Process of using ketones for energy, or ketones in blood = _____)

B) Triglycerides turned into fatty acids, if needed, can be converted *back* into Acetyl CoA & enter kreb's cycle to make ATP & H's

OR Acetyl CoA can be converted back into Pyruvate, and then changed into:

- glucose (**gluconeogenesis**)
- glucose can be stored as glycogen (**glycogenesis**)

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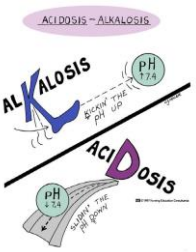
Lipid Metabolism, contin…

Ketogenesis =

Ketosis =
Click HERE for clinical app on ketosis.

Ketoacidosis =

Metabolic acidosis =



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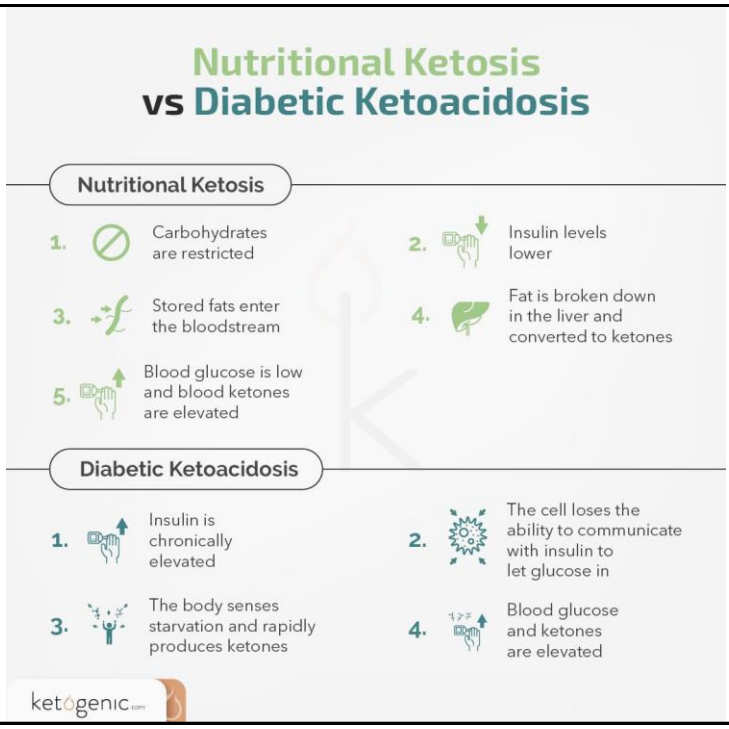

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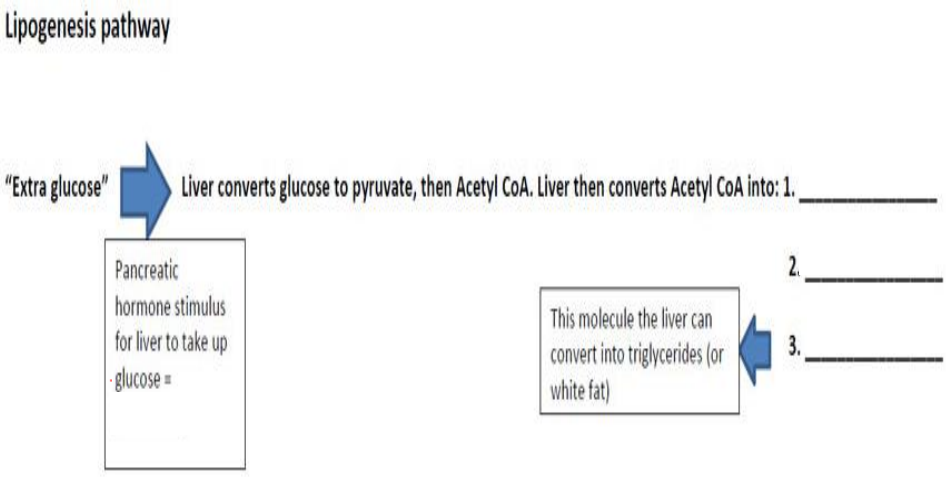
Click **HERE** for blank flow diagram. Click **HERE** for key.



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Amino acid metabolism

- **Amino acids = building blocks of protein**
- **Essential a.a. =** that which we need to consume in diet because body doesn't make
- **Nonessential a.a.** = ones our body can make.
- **Excess a.a. converted by liver into pyruvate or other acids. These can be used:**
  - **1)** in Kreb's cycle for ATP (when pyruvate goes thru conversion to make Acetyl CoA)
  - **2)** a.a. converted into fat (process called _____)

    or a.a. converted into glucose (process called _____)

Un-used a.a. (excess or what body absolutely cannot use)
> liver converts a.a. into ammonia & Urea, which is excreted by kidneys.

- blood panels include **BUN** (blood urea nitrogen) to determine kidney function.
- Normal BUN = 10 – 20 mg/dl. Higher BUN called "**azotemia**" and can indicate excess a.a. metabolism and /or kidney failure. *BUN is NOT the only test for kidney function. If BUN is high, a diagnostic blood and urine creatine test is also run.*

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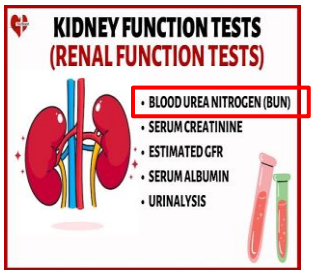
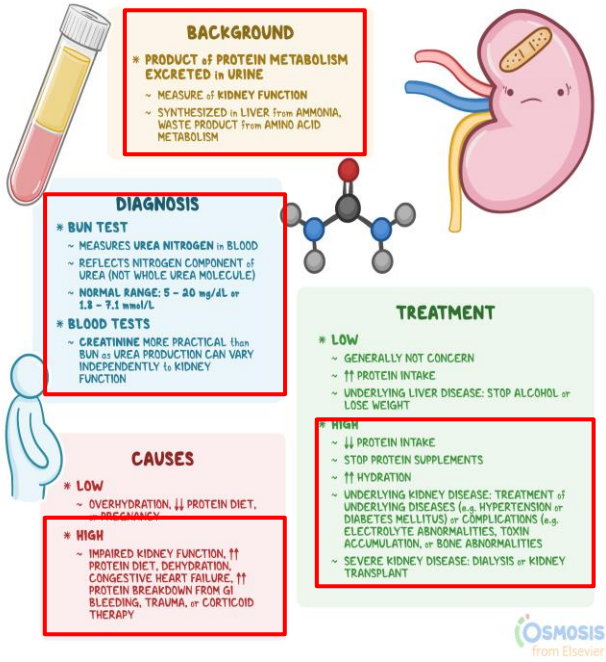
slide added 1/15/25





Click **HERE** to read more about BUN and kidney function.

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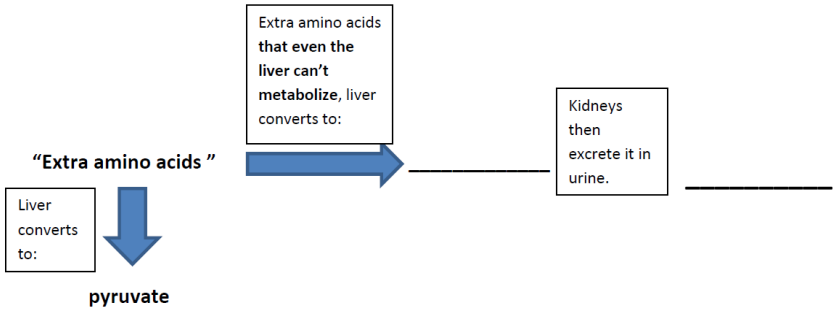
Click HERE for blank flow diagram. Click HERE for key.

Amino acid metabolism pathway



1. How can pyruvate be used to make ATP? _____

2. What else can pyruvate be changed into?

A) _____ (process called _____)

B) _____ (process called _____)

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Ques:
Metabolism of what molecules can lead to metabolic acidosis?

Answer:

>

>

>

>

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Disorder in amino acid metabolism:

Phenylketonuria (PKU) – Read online Clinical App:

Genetic condiction of mutation in gene for enzyme **Phenylalanine hydrolase (PAH)**.

[Need PAH to metabolize amino acid "**phenylalanine**". Without PAH phenylalanine builds up in body and is converted to "**phenylketone**", which is excreted in urine.

Phenylketone is toxic, causes seizures.

Treatment:
Restrict phenylalanine in diet.
(nutrition labels have a warning)

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Review

- Metabolism of lactic acid, lipids, and protein
- **Lactic acid metabolism** occurs all the time due to skeletal muscle activity
  - Lactic acid in blood causes metabolic acidosis.
  - Liver recycles lactic acid into glucose & glycogen thru the **Cori cycle**. (Gluconeogensis)
- **Lipid metabolism** includes making lipids (**lipogenesis**) and breaking them down (**lipolysis**)
  - **Lipogenesis** involves converting excess glucose into pyruvate (thru glycolysis), and then into Acetyl CoA (thru pyruvate conversion)
    - Acetyl CoA used by liver to make: cholesterol, ketones, & fatty acids.
    - fatty acids converted to triglycerides (white fat) for storage
  - **Lipolysis** is simply going backwards biochemically from trigylerides to fatty acids & ketones, which can be metabolized for energy OR converted to glucose (gluconeogenesis)
- **Amino acids** can be converted by liver to urea for excretion by kidneys as ammonia,
  - Liver can also convert excess a.a. into pyruvate and then to glucose (gluconeogenesis)
  - If kidneys not functioning, urea build up in the blood causing **azotemia**.
  - **PKU** = genetic problem metabolizing a.a. phenylalanine. Must avoid phenylalanine in diet because body cannot process it and turns it into toxic phenylketones.

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