# Ch 2, part 1: Cell Respiration & Cell Metabolism

Powerpoint updated Aug 20, 2022

## 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.

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**What conditions occur to make following happen in body?**

- Lactic acid metabolism occurs when skeletal muscle activity
- Lipogenesis occurs when making lipids / fats creating consume fats or have excess glucose in cells.
- Lipolysis occurs lipid breakdown / fats breakdown body needs energy (ATP) and carbohydrates not available.
- Amino acid metabolism occurs making or breaking down protein.

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**Glucose metabolism:** done by glycolysis, to make ATP

**Glycolysis =** use glucose to make ATP in body cell

**Glycogen metabolism:**

**Glycogenesis =** making glycogen from glucose (happens in liver & skeletal muscles)

**Glycogenolysis =** breaking down glycogen into glucose

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

**Lipid metabolism :**

**Lipogenesis =** making lipids.

**Lipolysis =** breaking down lipids

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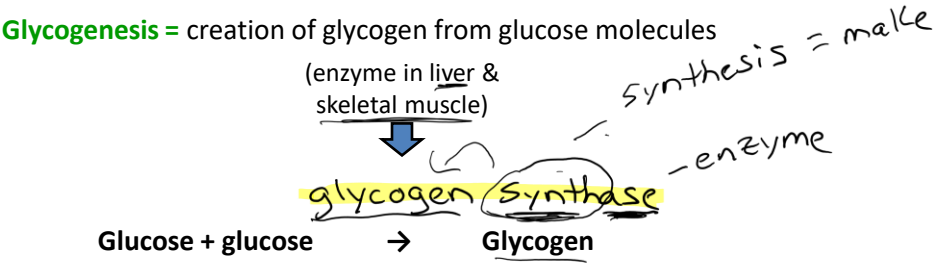
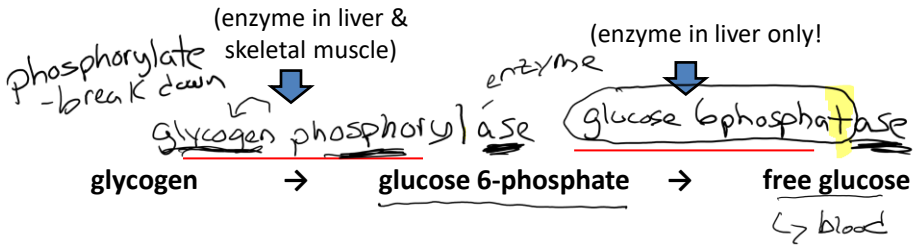
**Glycogenesis =** creation of glycogen from glucose molecules




**Glycogenolysis =** breakdown of glycogen into glucose

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

Glycogen metabolism

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) =** insulin - resistance

**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

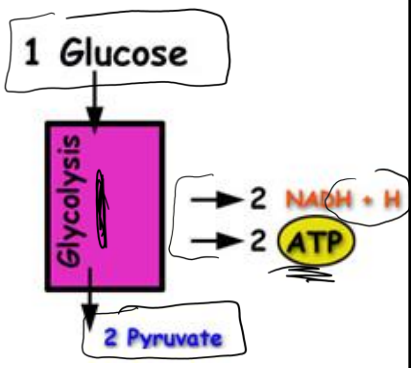
- Occurs in cell cytoplasm

- Conversion of 1 glucose molecule into:

> 2 pyruvate

> 2 ATP

> 2 $NADH_2$




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

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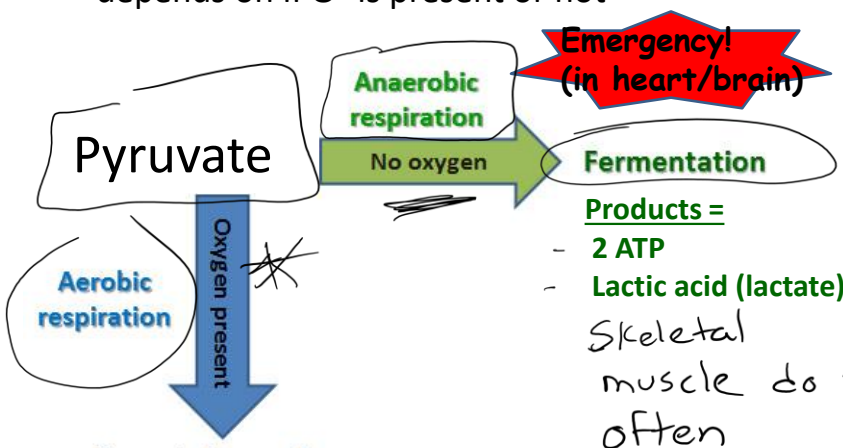
Pyruvate from glycolysis then can go one of 2 ways
- depends on if **$O^2$** is present or not




**Products =**
- 2 ATP
- Lactic acid (lactate)

Skeletal muscle do this often

- Pyruvate Processing
- The Krebs cycle
- ETC

**Products =**
**34 - 36 ATP**

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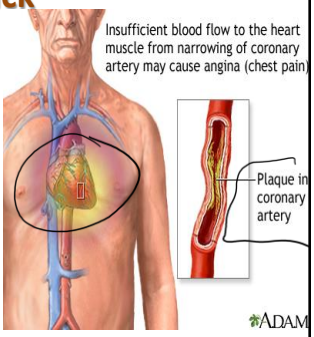
## Ischemia, Serum Lactate, and Heart Attack

**Ischemia & Angina Pectoris – Click HERE for Clinical App reading.**

**"Ischemia"** = interrupted blood flow




**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**" = pain in chest & left arm with ↑ lactate from cardiac ischemia.
- Prelude to "**myocardial infarction**" (heart attack)

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

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

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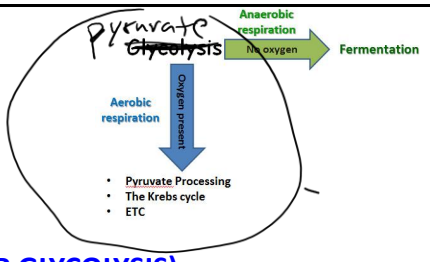
# Aerobic respiration




**3 Steps of aerobic respiration (AFTER GLYCOLYSIS):**

## 1. Pyruvate processing (pyruvate conversion)

2 pyruvate enter → 2 Acetyl CoA, 2 $NADH_2$, 2 $CO_2$

## 2. Kreb's cycle (citric acid cycle)

2 Acetyl CoA enter → 2 ATP, 6 $NADH_2$, 2 $FADH_2$, 4 $CO_2$

Hydrogen ions

## 3. Electron transport chain (ETC)

2 NADH2, 6 $NADH_2$ , 2 $FADH_2$ enter → **30 – 32 ATP**, 10 $NAD^+$, 2 $FAD^+$, 12 $H_2O$

$H^+$

Plus 2 NADH2 from glycolysis and
2 NADH2 from pyruvate processing

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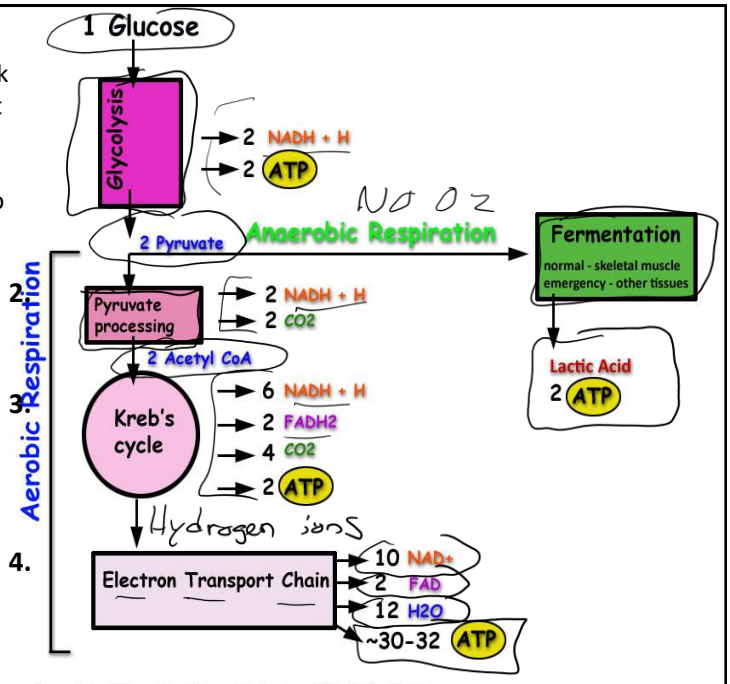
Click **HERE** for blank Glycolysi flow chart

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

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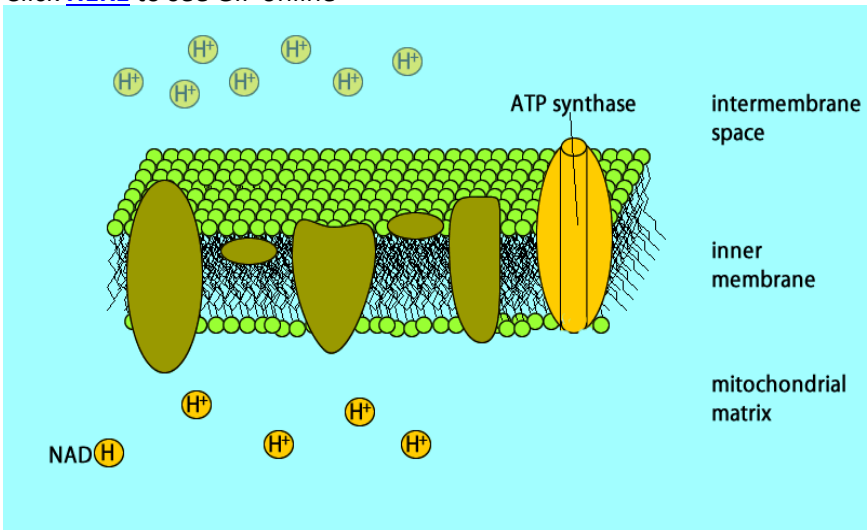
**Electron Transport Chain within the cell mitochondria – ATP production!**

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!

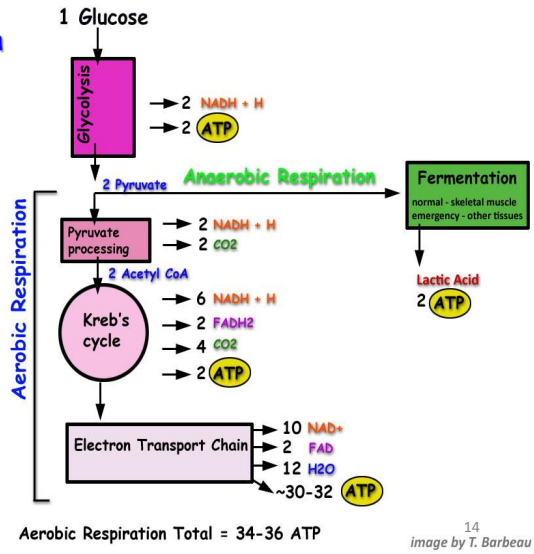


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image by T. Barbeau

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## When aerobic respiration goes wrong!

**Read online Clinical App: cyanide**


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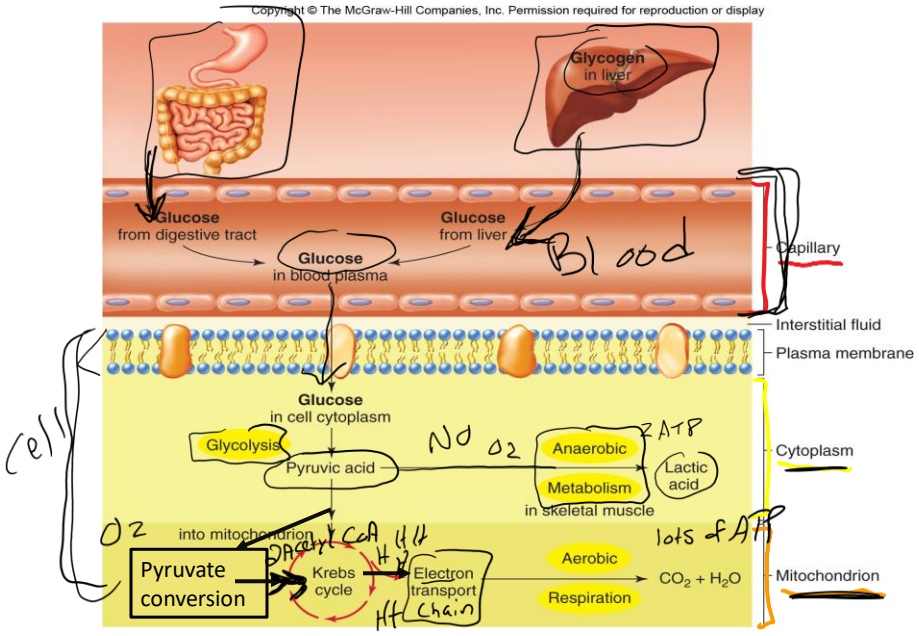
## Where Cell Respiration Occurs

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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 CO2
- H ions enter electron transport chain to make ~ 30 – 32 ATP, 6 NADH+, 2 NADH+, and 12 H2O.
- 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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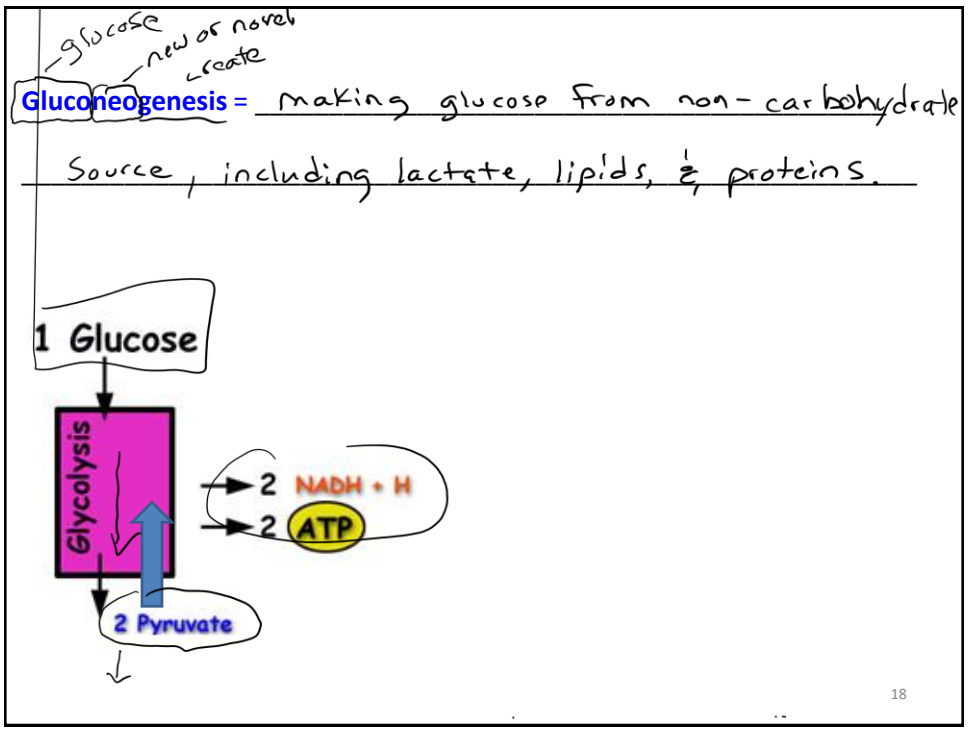


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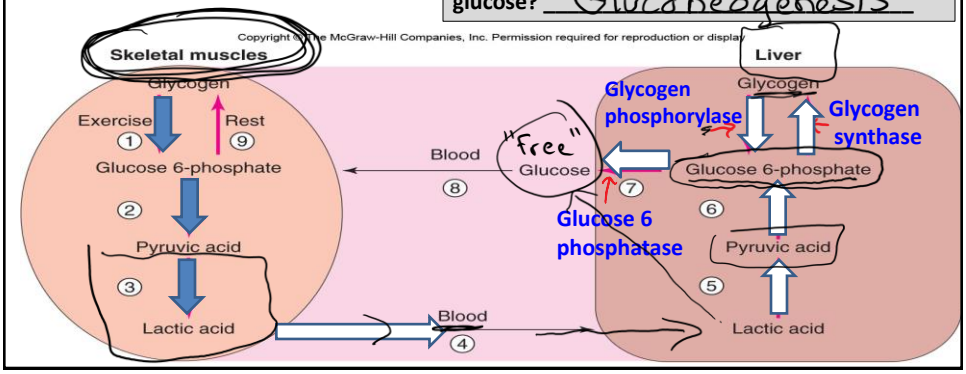
## Lactic acid (lactate) metabolism = "The Cori cycle"

= 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?** Gluconeogenesis

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## Lipid Metabolism:

"**Lipogenesis**" = making lipids

"**Lipolysis**" = breaking down lipids

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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** – for cell membranes, for steroid hormones (estrogen, testosterone), for bile

b) **ketones** – fat used for energy (are acidic)

c) **fatty acids** – precursor to stored white fat (triglycerides)

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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 = (Ketogenesis)

**Ketones** metabolized for energy (ATP) if no carbs

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

**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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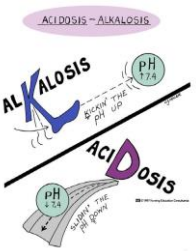
## Lipid Metabolism, contin…

**Ketogenesis** = making ketones

**Ketosis** = ketones in blood for energy source.
Click HERE for clinical app on ketosis.

**Ketoacidosis** = ↓ blood pH from ketosis

**Metabolic acidosis** = ↓ blood pH from metabolism of acidic molecules.

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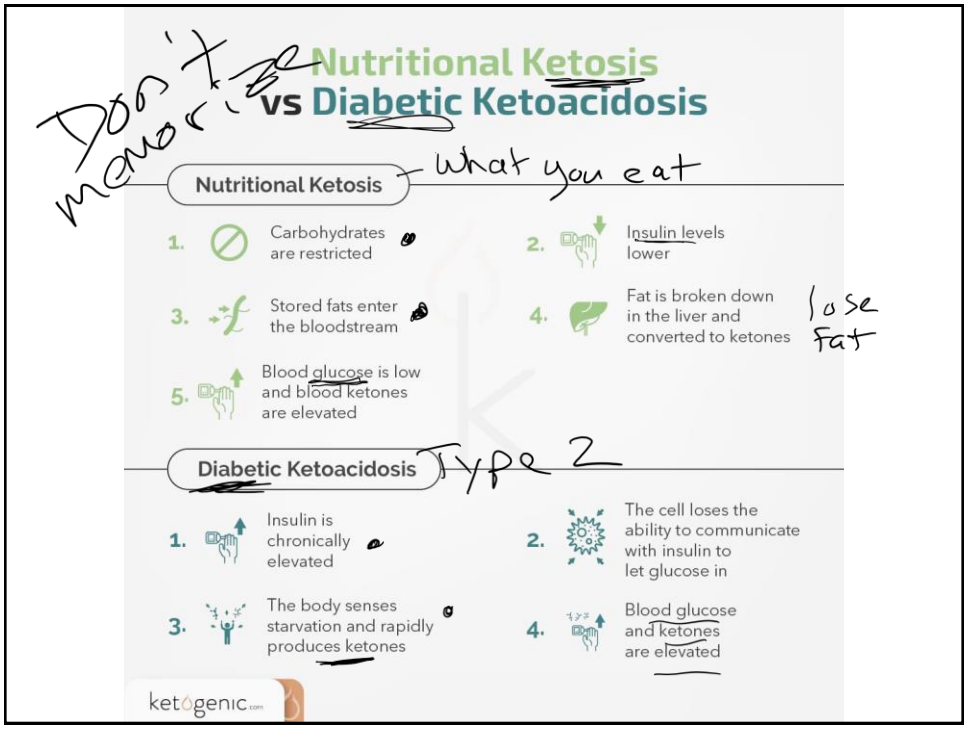


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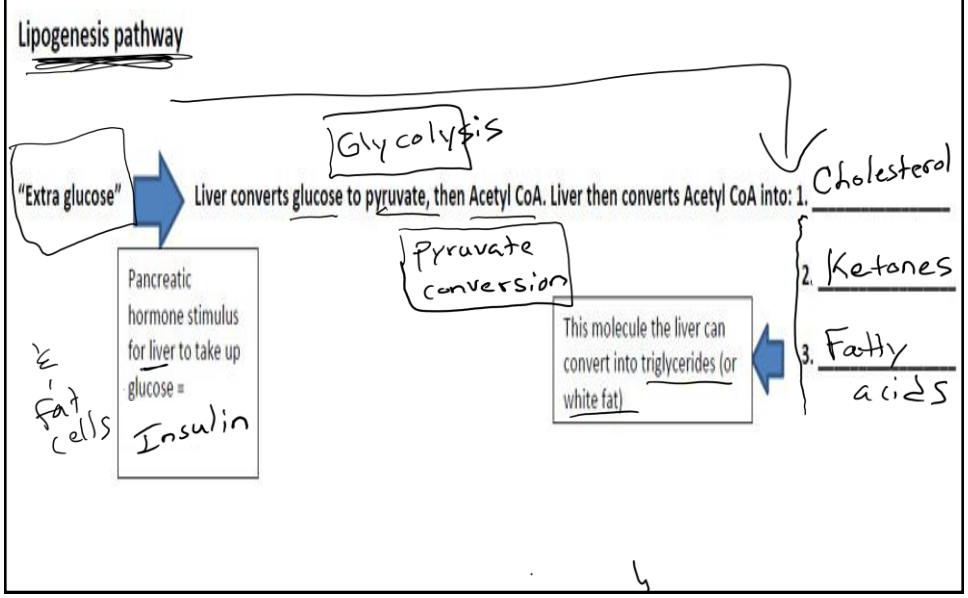


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# Amino acid metabolism

- **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 lipogenesis

    **or** a.a. converted into glucose (process called gluconeogenesis)

**Un-used a.a. (excess or what body absolutely cannot use)** *slide updated 1/15/25*
**> 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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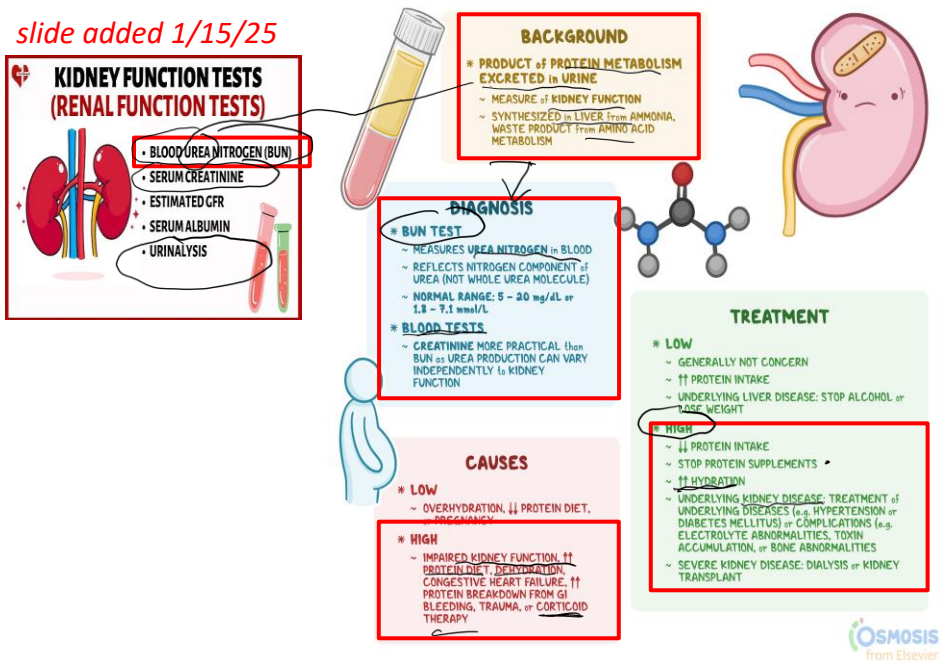
*slide added 1/15/25*




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

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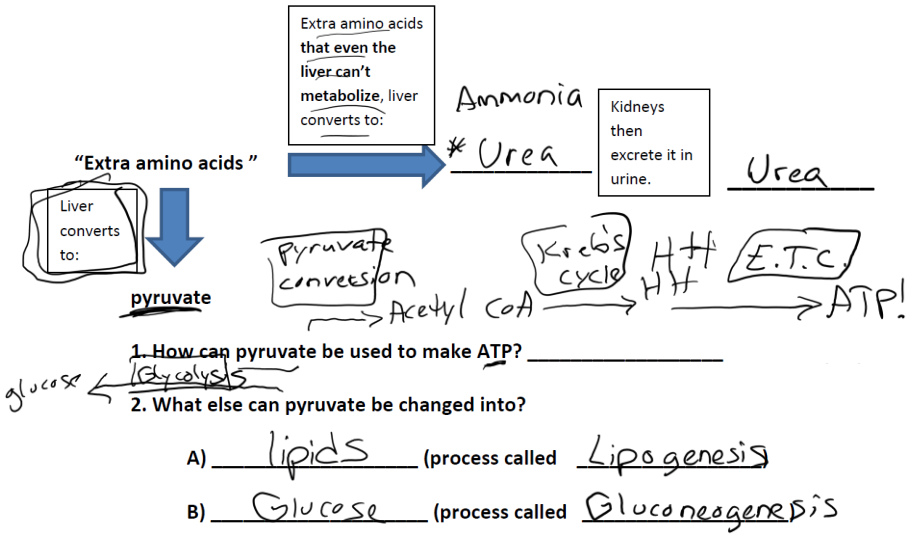
Click **HERE** for blank flow diagram. Click **HERE** for key.

**Amino acid metabolism pathway**




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

**2. What else can pyruvate be changed into?**

A) ___lipids___ (process called ___Lipogenesis___)

B) ___Glucose___ (process called ___Gluconeogenesis___)

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## Ques:

**Metabolism of what molecules can lead to metabolic acidosis?**

**Answer:**

>

>

>

>

Fatty acids
lactic acid
amino acids
Ketones

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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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