

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, triglycerides)

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

- 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

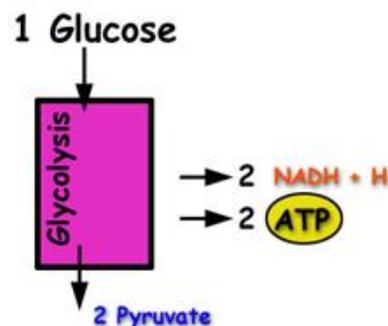
Glycolysis

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

- Occurs in cell cytoplasm

- Conversion of 1 glucose molecule into:

- > _____
- > _____
- > _____

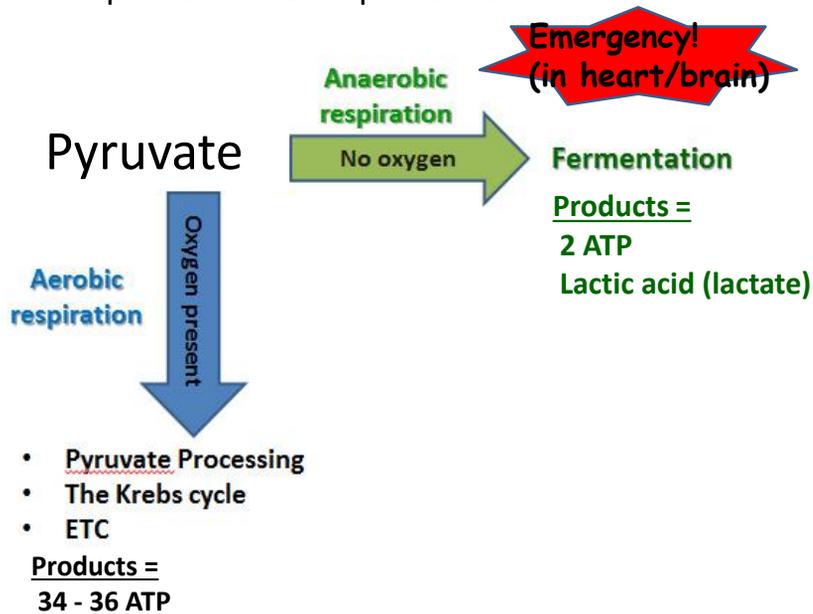


Pyruvate then can go one of 2 ways
- depends on if O^2 is present or not

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



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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 & O_2 heart resorts to anaerobic respiration. Loss of blood & O_2 to heart can cause ...

“angina pectoris” = _____

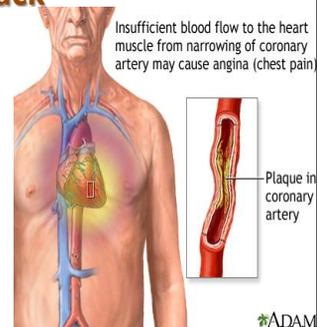
- Prelude to “myocardial infarction” (heart attack)

- 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

Pyruvate

Anaerobic respiration
No oxygen → Fermentation

Aerobic respiration
Oxygen present ↓

- Pyruvate Processing
- The Krebs cycle
- ETC

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 NADH₂, 2 FADH₂ 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 Glycolysi flow chart

Click [HERE](#) for KEY to Glycolysi flow chart

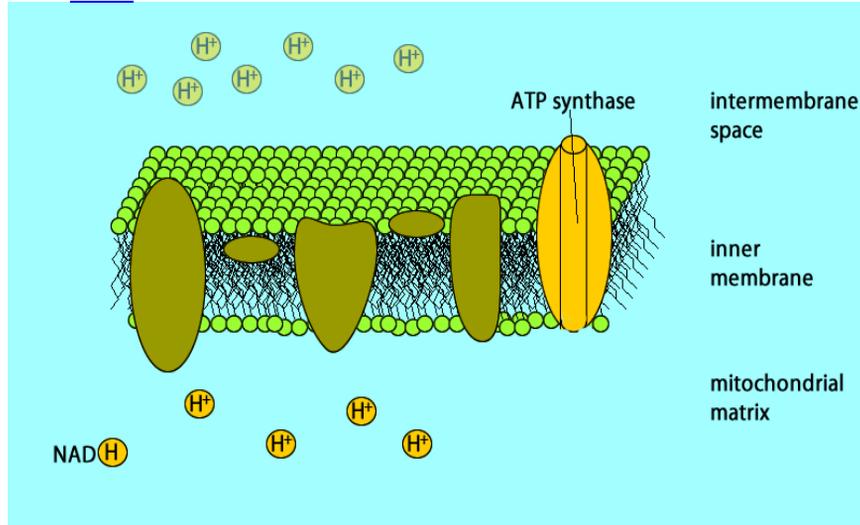
Aerobic Respiration Total = 34-36 ATP

12
image by T. Barbeau

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Electron Transport Chain within the cell mitochondria – ATP production!

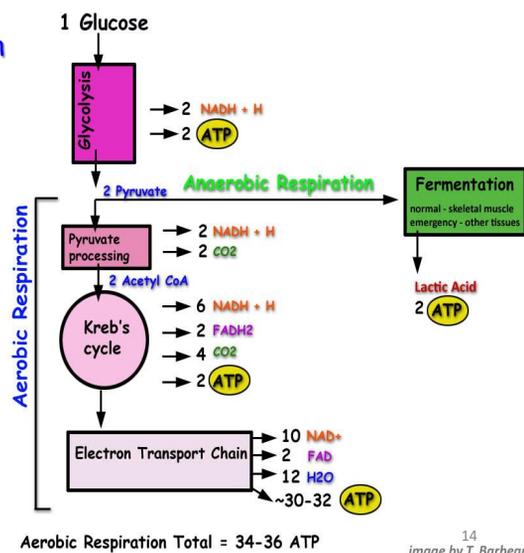
Click [HERE](#) to see GIF online



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Question:
Why do we need oxygen???

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



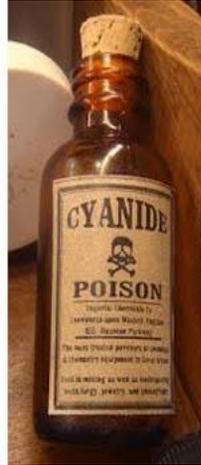
Aerobic Respiration Total = 34-36 ATP

14
image by T. Barbeau

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When aerobic respiration goes wrong!

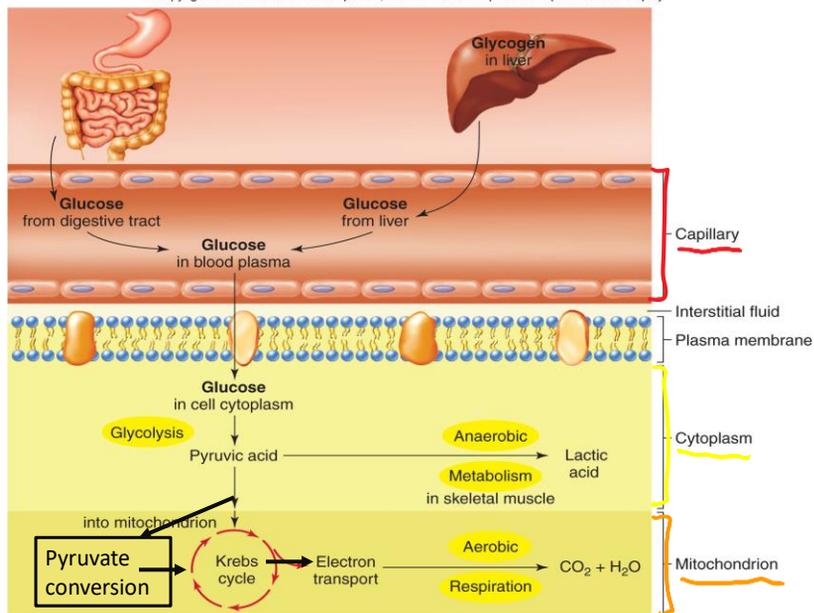
[Read online Clinical App: cyanide](#)



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Where Cell Respiration Occurs

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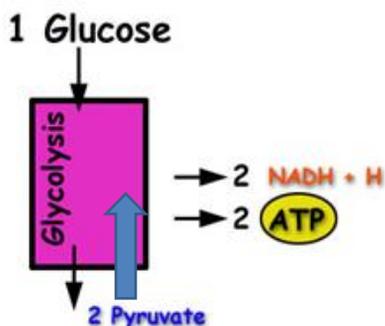
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Review (Whew! That's a lot!)

- 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 CO₂
- **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, Krebs's cycle, and ETC occurs in mitochondria

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Gluconeogenesis = _____



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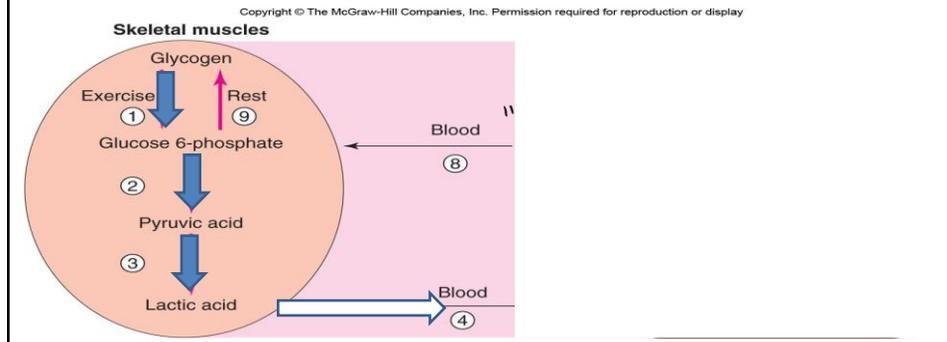
Lactic acid (lactate) metabolism = "The Cori cycle"

= 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

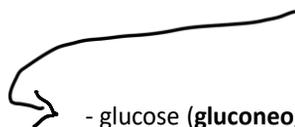
Process of making ketones = _____)

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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SODIUM	21
POTASSIUM	16
CHLORIDE	1.04
CARBON DIOXIDE	15
UREA NITROGEN	6.1
CREATININE	3.0
BUN/CREATININE RATIO	9.7
URIC ACID	
PHOSPHORUS	64
CALCIUM	3.7
CHOLESTEROL, TOTAL	
HDL CHOLESTEROL	112
CHOLESTEROL/HDL RATIO	7.6
LDL CHOL, CALCULATED	8
See footnote 1	
TRIGLYCERIDES	
PROTEIN, TOTAL	

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Lipid Metabolism, contin...

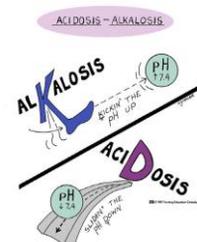
Ketogenesis =

Ketosis =

Click [HERE](#) for clinical app on ketosis.

Ketoacidosis =

Metabolic acidosis =



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Nutritional Ketosis vs Diabetic Ketoacidosis

Nutritional Ketosis

<p>1. Carbohydrates are restricted</p> <p>3. Stored fats enter the bloodstream</p> <p>5. Blood glucose is low and blood ketones are elevated</p>	<p>2. Insulin levels lower</p> <p>4. Fat is broken down in the liver and converted to ketones</p>
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Diabetic Ketoacidosis

<p>1. Insulin is chronically elevated</p> <p>3. The body senses starvation and rapidly produces ketones</p>	<p>2. The cell loses the ability to communicate with insulin to let glucose in</p> <p>4. Blood glucose and ketones are elevated</p>
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ketogenic.com

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Click [HERE](#) for blank flow diagram. Click [HERE](#) for key.

Lipogenesis pathway

"Extra glucose" Liver converts glucose to pyruvate, then Acetyl CoA. Liver then converts Acetyl CoA into: 1. _____

Pancreatic hormone stimulus for liver to take up glucose = _____

2. _____
 3. _____

This molecule the liver can convert into triglycerides (or white fat)

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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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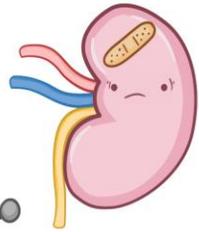
slide added 1/15/25

KIDNEY FUNCTION TESTS (RENAL FUNCTION TESTS)

- BLOOD UREA NITROGEN (BUN)
- SERUM CREATININE
- ESTIMATED GFR
- SERUM ALBUMIN
- URINALYSIS

BACKGROUND

- * PRODUCT of PROTEIN METABOLISM EXCRETED in URINE
- ~ MEASURE of KIDNEY FUNCTION
- ~ SYNTHESIZED in LIVER from AMMONIA, WASTE PRODUCT from AMINO ACID METABOLISM



DIAGNOSIS

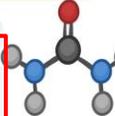
- * BUN TEST
 - ~ MEASURES UREA NITROGEN in BLOOD
 - ~ REFLECTS NITROGEN COMPONENT of UREA (NOT WHOLE UREA MOLECULE)
 - ~ NORMAL RANGE: 5 – 20 mg/dL or 1.8 – 7.1 mmol/L
- * BLOOD TESTS
 - ~ CREATININE MORE PRACTICAL than BUN as UREA PRODUCTION CAN VARY INDEPENDENTLY to KIDNEY FUNCTION

TREATMENT

- * LOW
 - ~ GENERALLY NOT CONCERN
 - ~ ↓↓ PROTEIN INTAKE
 - ~ STOP PROTEIN SUPPLEMENTS
 - ~ UNDERLYING LIVER DISEASE: STOP ALCOHOL or LOSE WEIGHT
- * HIGH
 - ~ ↓↓ PROTEIN INTAKE
 - ~ STOP PROTEIN SUPPLEMENTS
 - ~ ↑↑ HYDRATION
 - ~ UNDERLYING KIDNEY DISEASE: TREATMENT of UNDERLYING DISEASES (e.g. HYPERTENSION or DIABETES MELLITUS) or COMPLICATIONS (e.g. ELECTROLYTE ABNORMALITIES, TOXIN ACCUMULATION, or BONE ABNORMALITIES)
 - ~ SEVERE KIDNEY DISEASE: DIALYSIS or KIDNEY TRANSPLANT

CAUSES

- * LOW
 - ~ OVERHYDRATION, ↓↓ PROTEIN DIET, PREGNANCY
- * HIGH
 - ~ IMPAIRED KIDNEY FUNCTION, ↑↑ PROTEIN DIET, DEHYDRATION, CONGESTIVE HEART FAILURE, ↑↑ PROTEIN BREAKDOWN FROM GI BLEEDING, TRAUMA, or CORTICOID THERAPY



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

“Extra amino acids”

Liver converts to:

pyruvate

Extra amino acids that even the liver can't metabolize, liver converts to:

Kidneys then excrete it in urine.

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 condition 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**. (**Gluconeogenesis**)
- **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 triglycerides 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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