**Course Title: Basic Biochemistry**

**Summer Semester**

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 **Max Marks: 50**

**Note: There are FIVE questions, each carry 10 marks with grand total of 50 marks.**

**ATTEMPT all questions.**

**Avoid copy paste material from any source, as it may deduct your marks.**

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**Q1: Define Dickens and Horecker’s Pathway also explain irreversible phase of HMP pathway. Enlist the enzymes used in non-Oxidative phase of HMP Pathway.**

##  **Ans. Dickens,** Frank, English biochemist, 1899–.

Dickens shunt - a secondary pathway for the oxidation of d-glucose (not occurring in skeletal muscle), generating reducing power in the cytoplasm outside the mitochondria and synthesizing pentoses and a few other sugars. Synonym(s): pentose phosphate pathway; [Warburg-Lipmann-Dickens-Horecker shunt](https://medical-dictionary.thefreedictionary.com/pentose%2Bphosphate%2Bpathway)

Warburg-Lipmann-Dickens-Horecker shunt - Synonym(s): [Dickens shunt](https://medical-dictionary.thefreedictionary.com/pentose%2Bphosphate%2Bpathway)

 **--** The pentose phosphate pathway (also called the phosphogluconate pathway and the hexose monophosphate shunt) is a [metabolic pathway](https://en.m.wikipedia.org/wiki/Metabolic_pathway) parallel to [glycolysis](https://en.m.wikipedia.org/wiki/Glycolysis)[[1]](https://en.m.wikipedia.org/wiki/Pentose_phosphate_pathway#cite_note-1). It generates [NADPH](https://en.m.wikipedia.org/wiki/Nicotinamide_adenine_dinucleotide_phosphate) and [pentoses](https://en.m.wikipedia.org/wiki/Pentose%22%20%5Co%20%22Pentose) (5-[carbon](https://en.m.wikipedia.org/wiki/Carbon) [sugars](https://en.m.wikipedia.org/wiki/Sugar)) as well as [ribose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribose_5-phosphate), a precursor for the synthesis of [nucleotides](https://en.m.wikipedia.org/wiki/Nucleotides)[[2]](https://en.m.wikipedia.org/wiki/Pentose_phosphate_pathway#cite_note-2). While the pentose phosphate pathway does involve oxidation of [glucose](https://en.m.wikipedia.org/wiki/Glucose), its primary role is [anabolic](https://en.m.wikipedia.org/wiki/Anabolism) rather than [catabolic](https://en.m.wikipedia.org/wiki/Catabolism). The pathway is especially important in [red blood cells](https://en.m.wikipedia.org/wiki/Red_blood_cell) (erythrocytes).

 There are two distinct phases in the pathway. The first is the oxidative  phase, in which NADPH is generated, and the second is the non-oxidative synthesis of 5-carbon sugars. For most organisms, the pentose phosphate pathway takes place in the ;cytosol in plants, most steps take place in plastids

Similar to the pentose phosphate pathway appears to have a very ancient evolutionary origin. The reactions of this pathway are mostly enzyme-catalyzed in modern cells, however, they also occur non-enzymatically under conditions that replicate those of

 The primary results of the pathway are:

* The generation of reducing equivalents, in the form of NADPH, used in reductive biosynthesis reactions within cells (e.g. [fatty acid synthesis](https://en.m.wikipedia.org/wiki/Fatty_acid_synthesis)).
* Production of [ribose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribose_5-phosphate) (R5P), used in the synthesis of [nucleotides](https://en.m.wikipedia.org/wiki/Nucleotide) and nucleic acids.
* Production of [erythrose 4-phosphate](https://en.m.wikipedia.org/wiki/Erythrose_4-phosphate%22%20%5Co%20%22Erythrose%204-phosphate) (E4P) used in the synthesis of [aromatic amino acids](https://en.m.wikipedia.org/wiki/Aromatic_amino_acid).

Aromatic amino acids, in turn, are precursors for many biosynthetic pathways, including the [lignin](https://en.m.wikipedia.org/wiki/Lignin) in wood

###  **Oxidative phase**

In this phase, two molecules of [NADP](https://en.m.wikipedia.org/wiki/NADP)+ are reduced to [NADPH](https://en.m.wikipedia.org/wiki/NADPH), utilizing the energy from the conversion of [glucose-6-phosphate](https://en.m.wikipedia.org/wiki/Glucose-6-phosphate) into [ribulose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribulose_5-phosphate).



Oxidative phase of pentose phosphate pathway.
Glucose-6-phosphate (**1**), 6-phosphoglucono-δ-lactone (**2**), 6-phosphogluconate (**3**), ribulose 5-phosphate (**4**)

The entire set of reactions can be summarized as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| **Reactants** | **Products** | **Enzyme** | **Description** |
| [Glucose 6-phosphate](https://en.m.wikipedia.org/wiki/Glucose_6-phosphate) + NADP+ | → [6-phosphoglucono-δ-lactone](https://en.m.wikipedia.org/wiki/6-phosphoglucono-%CE%B4-lactone) + **NADPH** | [glucose 6-phosphate dehydrogenase](https://en.m.wikipedia.org/wiki/Glucose_6-phosphate_dehydrogenase) | [Dehydrogenation](https://en.m.wikipedia.org/wiki/Dehydrogenation). The hydroxyl on carbon 1 of glucose 6-phosphate turns into a carbonyl, generating a lactone, and, in the process, [NADPH](https://en.m.wikipedia.org/wiki/NADPH) is generated. |
| [6-phosphoglucono-δ-lactone](https://en.m.wikipedia.org/wiki/6-phosphoglucono-%CE%B4-lactone) + H2O | → [6-phosphogluconate](https://en.m.wikipedia.org/wiki/6-phosphogluconate) + H+ | [6-phosphogluconolactonase](https://en.m.wikipedia.org/wiki/6-phosphogluconolactonase) | [Hydrolysis](https://en.m.wikipedia.org/wiki/Hydrolysis) |
| [6-phosphogluconate](https://en.m.wikipedia.org/wiki/6-phosphogluconate) + NADP+ | → [ribulose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribulose_5-phosphate) + **NADPH** + CO2 | [6-phosphogluconate dehydrogenase](https://en.m.wikipedia.org/wiki/6-phosphogluconate_dehydrogenase) | Oxidative [decarboxylation](https://en.m.wikipedia.org/wiki/Decarboxylation). NADP+ is the electron acceptor, generating another molecule of [NADPH](https://en.m.wikipedia.org/wiki/NADPH), a CO2, and [ribulose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribulose_5-phosphate). |

The overall reaction for this process is:

Glucose 6-phosphate + 2 NADP+ + H2O → ribulose 5-phosphate + 2 NADPH + 2 H+ + CO2

### **Non-oxidative phase**



The pentose phosphate pathway's nonoxidative phase

|  |  |  |
| --- | --- | --- |
| **Reactants** | **Products** | **Enzymes** |
| [ribulose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribulose_5-phosphate) | → [ribose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribose_5-phosphate) | [Ribose-5-phosphate isomerase](https://en.m.wikipedia.org/wiki/Ribose-5-phosphate_isomerase) |
| [ribulose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribulose_5-phosphate) | → [xylulose 5-phosphate](https://en.m.wikipedia.org/wiki/Xylulose_5-phosphate%22%20%5Co%20%22Xylulose%205-phosphate) | Ribulose 5-Phosphate 3-Epimerase |
| [xylulose 5-phosphate](https://en.m.wikipedia.org/wiki/Xylulose_5-phosphate) + [ribose 5-phosphate](https://en.m.wikipedia.org/wiki/Ribose_5-phosphate) | → [glyceraldehyde 3-phosphate](https://en.m.wikipedia.org/wiki/Glyceraldehyde_3-phosphate) + [sedoheptulose 7-phosphate](https://en.m.wikipedia.org/wiki/Sedoheptulose_7-phosphate%22%20%5Co%20%22Sedoheptulose%207-phosphate) | [transketolase](https://en.m.wikipedia.org/wiki/Transketolase) |
| [sedoheptulose 7-phosphate](https://en.m.wikipedia.org/wiki/Sedoheptulose_7-phosphate) + [glyceraldehyde 3-phosphate](https://en.m.wikipedia.org/wiki/Glyceraldehyde_3-phosphate) | → [erythrose 4-phosphate](https://en.m.wikipedia.org/wiki/Erythrose_4-phosphate%22%20%5Co%20%22Erythrose%204-phosphate) + [fructose 6-phosphate](https://en.m.wikipedia.org/wiki/Fructose_6-phosphate) | [transaldolase](https://en.m.wikipedia.org/wiki/Transaldolase) |
| [xylulose 5-phosphate](https://en.m.wikipedia.org/wiki/Xylulose_5-phosphate) + [erythrose 4-phosphate](https://en.m.wikipedia.org/wiki/Erythrose_4-phosphate%22%20%5Co%20%22Erythrose%204-phosphate) | → [glyceraldehyde 3-phosphate](https://en.m.wikipedia.org/wiki/Glyceraldehyde_3-phosphate) + [fructose 6-phosphate](https://en.m.wikipedia.org/wiki/Fructose_6-phosphate) | [transketolase](https://en.m.wikipedia.org/wiki/Transketolase) |

Net reaction: 3 ribulose-5-phosphate → 1 ribose-5-phosphate + 2 xylulose-5-phosphate → 2 fructose-6-phosphate + glyceraldehyde-3-phosphate

 Glucose-6-phosphate dehydrogenase is the rate-controlling enzyme in this pathway. It is allosterically stimulated by NADP+. ... Additionally, NADPH can be used by cells to prevent oxidative stress. NADPH reduces glutathione via glutathione reductase, which converts reactive H2O2 into H2O by glutathione peroxidase.

 **Q2: What are the steps and enzymes involved in Glycolysis.**

**Ans.**  Glycolysis is the central pathway for the glucose catabolism in which glucose (6-carbon compound) is converted into pyruvate (3-carbon compound) through a sequence of 10 steps.

 **Step involve in glycolysis**

###  **Step 1- Phosphorylation of glucose**

* In the first step of glycolysis, the glucose is initiated or primed for the subsequent steps by phosphorylation at the C6 carbon.
* The process involves the transfer of phosphate from the ATP to glucose forming Glucose-6-phosphate in the presence of the enzyme hexokinase and glucokinase (in animals and microbes).
* This step is also accompanied by considerable loss of energy as heat.

###   **Step 2- Isomerization of Glucose-6-phosphate**

* Glucose 6-phosphate is reversibly isomerized to fructose 6-phosphate by the enzyme phosphohexoisomerase/phosphoglucoisomerase.
* This reaction involves a shift of the carbonyl oxygen from C1 to C2, thus converting an aldose into a ketose.

### **Step 3- Phosphorylation of fructose-6-phosphate**

* This step is the second priming step of glycolysis, where fructose-6-phosphate is converted into fructose-1,6-bisphosphate in the presence of the enzyme phosphofructokinase.
* Like in Step 1, the phosphate is transferred from ATP while some amount of energy is lost in the form of heat as well.

### **Step 4- Cleavage of fructose 1, 6-diphosphate**

* This step involves the unique cleavage of the C-C bond in the fructose 1, 6-bisphosphate.
* The enzyme fructose diphosphate aldolase catalyzes the cleavage of fructose 1,6-bisphosphate between C3 and C4 resulting in two different triose phosphates: glyceraldehyde 3-phosphate (an aldose) and dihydroxyacetone phosphate (a ketose).
* The remaining steps in glycolysis involve three-carbon units, rather than six carbon units.

### **Step 5- Isomerization of dihydroxyacetone phosphate**

* Glyceraldehyde 3-phosphate can be readily degraded in the subsequent steps of glycolysis, but dihydroxyacetone phosphate cannot be. Thus, it is isomerized into glyceraldehyde 3-phosphate instead.
* In this step, dihydroxyacetone phosphate is isomerized into glyceraldehyde 3-phosphate in the presence of the enzyme triose phosphate isomerase.
* This reaction completes the first phase of glycolysis.

### **Step 6- Oxidative Phosphorylation of Glyceraldehyde 3-phosphate**

* Step 6 is one of the three energy-conserving or forming steps of glycolysis.
* The glyceraldehyde 3-phosphate is converted into 1,3-bisphosphoglycerate by the enzyme glyceraldehyde 3-phosphate dehydrogenase (phosphoglyceraldehyde dehydrogenase).
* In this process, NAD+ is reduced to coenzyme NADH by the H– from glyceraldehydes 3-phosphate.
* Since two moles of glyceraldehyde 3-phosphate are formed from one mole of glucose, two NADH are generated in this step.

### **Step 7- Transfer of phosphate from 1, 3-diphosphoglycerate to ADP**

* This step is the ATP-generating step of glycolysis.
* It involves the transfer of phosphate group from the 1, 3-bisphosphoglycerate to ADP by the enzyme phosphoglycerate kinase, thus producing ATP and 3-phosphoglycerate.
* Since two moles of 1, 3-bisphosphoglycerate are formed from one mole of glucose, two ATPs are generated in this step.

### **Step 8- Isomerization of 3-phosphoglycerate**

* The 3-phosphoglycerate is converted into 2-phosphoglycerate due to the shift of phosphoryl group from C3 to C2, by the enzyme phosphoglycerate mutase.
* This is a reversible isomerization reaction.

### **Step 9- Dehydration 2-phosphoglycerate**

* In this step, the 2-phosphoglycerate is dehydrated by the action of enolase (phosphopyruvate hydratase) to phosphoenolpyruvate.
* This is also an irreversible reaction where two moles of water are lost.

### **Step 10- Transfer of phosphate from phosphoenolpyruvate**

* This is the second energy-generating step of glycolysis.
* Phosphoenolpyruvate is converted into an enol form of pyruvate by the enzyme pyruvate kinase.
* The enol pyruvate, however, rearranges rapidly and non-enzymatically to yield the keto form of pyruvate (i.e. ketopyruvate). The keto form predominates at pH 7.0.
* The enzyme catalyzes the transfer of a phosphoryl group from phosphoenolpyruvate to ADP, thus forming ATP.

 **Enzyme involve in glycolysis**

 in the extra-mitochondrial fraction of the cell in the cytosol. One common characteristic in all the enzymes involved in glycolysis is that nearly all of them require Mg2+. The following are the enzymes that catalyze different steps throughout the process of glycolysis:

1. Hexokinase
2. Phosphoglucoisomerase
3. Phosphofructokinase
4. Aldolase
5. Phosphotriose isomerase
6. Glyceraldehyde 3-phosphate dehydrogenase
7. Phosphoglycerate kinase
8. Phosphoglycerate mutase
9. Enolase
10. Pyruvate kinase

**Q3: Discuss digestion and absorption of Carbohydrates.**

**Ans.** All the food you eat goes through your [digestive system](https://www.healthline.com/health/fun-facts-about-the-digestive-system) so it can be broken down and used by the body. Carbohydrates take a journey starting with the intake at the mouth and ending with elimination from your colon. There’s a lot that happens between the point of entry and exit.

#  **Digestion and Absorption of Carbohydrates**

## **From the Mouth to the Stomach**

The mechanical and chemical digestion of [carbohydrates](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/carbohydrates/) begins in the mouth. Chewing, also known as mastication, crumbles the carbohydrate foods into smaller and smaller pieces. The salivary glands in the oral cavity secrete saliva that coats the food particles. Saliva contains the enzyme, [salivary amylase](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/salivary-amylase/). This enzyme breaks the bonds between the monomeric sugar units of disaccharides, oligosaccharides, and starches. The salivary amylase breaks down [amylose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/amylose/) and [amylopectin](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/amylopectin/) into smaller chains of [glucose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/glucose/), called dextrins and [maltose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/maltose/). The increased concentration of maltose in the mouth that results from the mechanical and chemical breakdown of starches in whole grains is what enhances their sweetness. Only about five percent of starches are broken down in the mouth. (This is a good thing as more glucose in the mouth would lead to more tooth decay.) When carbohydrates reach the stomach no further chemical breakdown occurs because the amylase enzyme does not function in the acidic conditions of the stomach. But mechanical breakdown is ongoing—the strong peristaltic contractions of the stomach mix the carbohydrates into the more uniform mixture of [chyme](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/chyme/).

## **From the Stomach to the Small Intestine**

The chyme is gradually expelled into the upper part of the small intestine. Upon entry of the chyme into the small intestine, the pancreas releases [pancreatic juice](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/pancreatic-juice/) through a duct. This pancreatic juice contains the enzyme, pancreatic amylase, which starts again the breakdown of dextrins into shorter and shorter carbohydrate chains. Additionally, [enzymes](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/enzymes/) are secreted by the intestinal cells that line the villi. These enzymes, known collectively as disaccharidase, are sucrase, maltase, and lactase. Sucrase breaks [sucrose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/sucrose/) into glucose and [fructose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/fructose/) molecules. Maltase breaks the bond between the two glucose units of maltose, and lactase breaks the bond between [galactose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/galactose/) and glucose. Once carbohydrates are chemically broken down into single sugar units they are then transported into the inside of intestinal cells.

When people do not have enough of the enzyme lactase, [lactose](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/lactose/) is not sufficiently broken down resulting in a condition called [lactose intolerance](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/lactose-intolerance/). The undigested lactose moves to the large intestine where bacteria are able to digest it. The bacterial digestion of lactose produces gases leading to symptoms of diarrhea, bloating, and abdominal cramps. Lactose intolerance usually occurs in adults and is associated with race. The National Digestive Diseases Information Clearing House states that African Americans, Hispanic Americans, American Indians, and Asian Americans have much higher incidences of lactose intolerance while those of northern European descent have the least.[[1]](http://pressbooks-dev.oer.hawaii.edu/humannutrition/chapter/digestion-and-absorption-of-carbohydrates/#footnote-608-1) Most people with lactose intolerance can tolerate some amount of dairy products in their diet. The severity of the symptoms depends on how much lactose is consumed and the degree of lactase deficiency.

## **Absorption: Going to the Blood Stream**

The cells in the small intestine have membranes that contain many transport proteins in order to get the monosaccharides and other nutrients into the blood where they can be distributed to the rest of the body. The first organ to receive glucose, fructose, and galactose is the liver. The liver takes them up and converts galactose to glucose, breaks fructose into even smaller carbon-containing units, and either stores glucose as [glycogen](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/glycogen/) or exports it back to the blood. How much glucose the liver exports to the blood is under hormonal control and you will soon discover that even the glucose itself regulates its concentrations in the blood.

## **Maintaining Blood Glucose Levels: The Pancreas and Liver**

Glucose levels in the blood are tightly controlled, as having either too much or too little glucose in the blood can have health consequences. Glucose regulates its levels in the blood via a process called negative feedback. An everyday example of negative feedback is in your oven because it contains a thermostat. When you set the temperature to cook a delicious homemade noodle casserole at 375°F the thermostat senses the temperature and sends an electrical signal to turn the elements on and heat up the oven. When the temperature reaches 375°F the thermostat senses the temperature and sends a signal to turn the element off. Similarly, your body senses blood glucose levels and maintains the glucose “temperature” in the target range. The glucose thermostat is located within the cells of the pancreas. After eating a meal containing carbohydrates glucose levels rise in the blood.

[Insulin](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/insulin/)-secreting cells in the pancreas sense the increase in blood glucose and release the hormone, insulin,

## **Leftover Carbohydrates: The Large Intestine**

Almost all of the carbohydrates, except for [dietary fiber](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/dietary-fiber/) and resistant starches, are efficiently digested and absorbed into the body. Some of the remaining indigestible carbohydrates are broken down by enzymes released by bacteria in the large intestine. The products of bacterial digestion of these slow-releasing carbohydrates are short-chain fatty acids and some gases. The short-chain fatty acids are either used by the bacteria to make energy and grow, are eliminated in the feces, or are absorbed into cells of the colon, with a small amount being transported to the liver. Colonic cells use the short-chain fatty acids to support some of their functions. The liver can also metabolize the short-chain fatty acids into cellular energy. The yield of energy from dietary [fiber](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/fiber/) is about 2 kilocalories per gram for humans, but is highly dependent upon the fiber type, with soluble fibers and resistant starches yielding more energy than insoluble fibers. Since dietary fiber is digested much less in the gastrointestinal tract than other carbohydrate types (simple sugars, many starches) the rise in blood glucose after eating them is less, and slower. These physiological attributes of high-fiber foods (i.e. whole grains) are linked to a decrease in [weight](http://pressbooks-dev.oer.hawaii.edu/humannutrition/glossary/weight/) gain and reduced risk of chronic diseases, such as Type 2 diabetes and cardiovascular disease.

**Q4: Explain step by step the Tricarboxylic acid cycle.**

**Ans.** The Krebs cycle, also known as the citric acid cycle or TCA cycle is a series of reactions that take place in the mitochondria resulting in oxidation of acetyl CoA to release carbon dioxide and hydrogen atoms that later lead to the formation of water.

* This cycle is termed the citric acid cycle as the first metabolic intermediate formed in the cycle is citric acid.
* This cycle is also termed tricarboxylic acid (TCA) because it was then not certain whether citric acid or some other tricarboxylic acid (g., isocitric acid) was the first product of the cycle. However, now it has been known that the first product is indeed citric acid and thus the use of this name has since been discouraged.
* This cycle only occurs under aerobic conditions as energy-rich molecules like NAD+ and FAD can only be retrieved from their reduced form once they transfer electrons to molecular oxygen.
* The citric acid cycle is the final common pathway for the oxidation of all biomolecules; proteins, fatty acids, carbohydrates. Molecules from other cycles and pathways enter this cycle through Acetyl CoA.
* The citric acid cycle is a cyclic sequence of reactions formed of 8 enzyme-mediated reactions.
* This cycle is also particularly important as it provides electrons/ high-energy molecules to the electron transport chain for the production of ATPs and water.
* Pyruvate formed at the end of [**glycolysis**](https://microbenotes.com/glycolysis/) is first oxidized into Acetyl CoA which then enters the citric acid cycle.

###  **Step 1: Condensation of acetyl CoA with oxaloacetate**

* The first step of the citric acid cycle is the joining of the four-carbon compound oxaloacetate (OAA) and a two-carbon compound acetyl CoA.
* The oxaloacetate reacts with the acetyl group of the acetyl CoA and water, resulting in the formation of a six-carbon compound citric acid, CoA.
* The reaction is catalyzed by the enzyme citrate synthase that condenses the methyl group of acetyl CoA and the carbonyl group of oxaloacetate resulting in citryl-CoA which is later cleaved to free coenzyme A and to form citrate.

###  **Step 2: Isomerization of citrate into isocitrate**

* Now, for further metabolism, citrate is converted into isocitrate through the formation of intermediate cis-aconitase.
* This reaction is a reversible reaction catalyzed by the enzyme (aconitase).
* This reaction takes place by a two-step process where the first step involves dehydration of citrate to cis-aconitase, followed by the second step involving rehydration of cis-aconitase into isocitrate.

###  **Step 3: Oxidative decarboxylations of isocitrate**

* The third step of the citric acid cycle is the first of the four oxidation-reduction reactions in this cycle.
* Isocitrate is oxidatively decarboxylated to form a five-carbon compound, α-ketoglutarate catalyzed by the enzyme isocitrate dehydrogenase.
* This reaction, like the second reaction, is a two-step reaction.
* In the first step, isocitrate is dehydrogenated to oxalosuccinate while the second step involves the decarboxylation of oxalosuccinate to α-ketoglutarate.
* Both the reactions are irreversible and catalyzed by the same enzyme.
* The first step, however, results in the formation of NADH while the second step involves the release of CO2.

###  **Step 4: Oxidative decarboxylation of α-ketoglutarate**

* This step is another one of the oxidation-reduction reactions where α-ketoglutarate is oxidatively decarboxylated to form a four-carbon compound, succinyl-CoA, and CO2.
* The reaction irreversible and catalyzed by the enzyme complex α-ketoglutarate dehydrogenase found in the mitochondrial space.
* This reaction is similar to the oxidative decarboxylation of pyruvate involving the reduction of NAD+ into NADH.

###  **Step 5: Conversion of succinyl-CoA into succinate**

* In the next step, succinyl-CoA undergoes an energy-conserving reaction in which succinyl-CoA is cleaved to form succinate.
* This reaction is accompanied by phosphorylation of guanosine diphosphate (GDP) to guanosine triphosphate (GTP).
* The GTP thus formed then readily transfers its terminal phosphate group to ADP forming an ATP molecule.
* The reaction is catalyzed by the enzyme, succinyl-CoA synthase

###  **Step 6: Dehydration of succinate to fumarate**

* Here, the succinate formed from succinyl-CoA is dehydrogenated to fumarate catalyzed by the enzyme complex succinate dehydrogenase found in the intramitochondrial space.
* This is the only dehydrogenation step in the citric acid cycle in which NAD+ doesn’t participate.
* Instead, another high-energy electron carrier, flavin adenine dinucleotide (FAD) acts as the hydrogen acceptor resulting in the formation of FADH2.
* The FADH2 then enters the electron transport chain via the complex II transferring the electrons to ubiquinone, finally forming 2ATPs.

### **Step 7: Hydration of fumarate to malate**

* The fumarate is reversibly hydrated to form L-malate in the presence of the enzyme fumarate hydratase.
* As it is a reversible reaction, the formation of L-malate involves hydration, whereas the formation of fumarate involves dehydration.

### **Step 8: Dehydrogenation of L-malate to oxaloacetate**

* The last step of the citric acid cycle is also an oxidation-reduction reaction where L-malate is dehydrogenated to oxaloacetate in the presence of L-malate dehydrogenase, which is present in the mitochondrial matrix.
* This is a reversible reaction involving oxidation of L-malate and reduction of NAD+ into NADH.
* Oxaloacetate thus formed, allows the repetition of the cycle and NADH formed participates in the oxidative phosphorylation.
* This reaction completes the cycle

Q5: Differentiate between fat and oil also explain “solid fat is beneficial for health or oil”.

**Ans. Fat.** Some compounds that are soluble in organic solvents and mostly insoluble in water are called fats.

They are solid at room temperature. There are two types of fats that are solid at room temperature. They are saturated fats and trans fats.

**Saturated fat is also known as solid fat.** Saturated fat in fish and poultry is less when compared to animal fat or red meat. This fat can increase your cholesterol levels. Tropical oils such as cocoa butter, coconut oil, palm oil also have saturated fats. It is mostly found in non-dairy products and snacks in large quantity. Cakes, butter, cookies are some examples of food containing maximum saturated fats.

A fat is changed to increase its shelf life. The process to make this change happen is called hydrogenation. This fat is harder at room temperature. The importance of trans fat is that it makes flakier pie crusts and crispier crankers. It is found in cookies, chips, processed food etc. Avoid eating or consume fewer foods containing trans fats as it increase your cholesterol levels.

**Oil :** Fats that are liquid at room temperature are called oils.

Unsaturated fats belong to this category. Consuming food containing unsaturated fat helps improve cholesterol levels. There are two types of unsaturated fats. Monounsaturated fats and polyunsaturated fats.

Monounsaturated fat is found in nuts, vegetable oils and avocado. Consuming food that is rich in monounsaturated fats helps in controlling cholesterol levels by keeping high good HDL cholesterol and lowering bad LDL cholesterol.

Polyunsaturated [fat is found in oils](https://byjus.com/chemistry/tests-of-oils-and-fats/) such as sunflower, corn and soybean. Seafood majorly consists of these fats. Replacing saturated fat with polyunsaturated fat in food consumption may help in lowering LDL cholesterol. There are two types of polyunsaturated fats. They are Omega 3, Omega 6.

##  **Difference between Fats and Oils Table**

To make you understand how **Oils and fats**are different from each other, here are some major **differences between oils and fats:**

|  |
| --- |
| **Difference between Fats and Oils** |
| **Fats** | **Oils** |
| Solid at room temperature | Liquid at room temperature |
| Saturated and trans are its types | Unsaturated fats like monounsaturated and polyunsaturated are its types |
| Mostly derived from animal | Mostly derived from plants |
| Increases cholesterol levels | Improves cholesterol levels |
| Mainly comes from animal food but also through vegetable oil by process called hydrogenation | Mainly comes from plants or fish |
| Example: Butter, beef fat | Example:Vegetable oil, fish oil |
| Contains 9 cal/gm | Contains 9 cal/gm |

 Solid fats are fats that are solid at room temperature, like beef fat, butter, and shortening. Solid fats mainly come from animal foods and can also be made from vegetable oils through a process called hydrogenation. Some common solid fats are

* butter
* milk fat
* beef fat (tallow, suet)
* chicken fat
* cream
* pork fat (lard)
* stick margarine
* shortening
* hydrogenated and partially hydrogenated oils\*
* coconut oil\*
* palm and palm kernel oils\*

The starred items are called "oils" because they come from plant sources. Even though they are called "oils," they are considered to be solid fats because they are high in saturated or trans fatty acids.

 **The end**

 **All question are complete**

 **Thank you.**