

## reacciones de enzimas

TABLE 15.5 Types of chemical reactions in metabolism

Type of reaction	Description
Oxidation-reduction	Electron transfer
Ligation requiring ATP cleavage	Formation of covalent bonds (i.e., carbon-carbon bonds)
Isomerization	Rearrangement of atoms to form isomers
Group transfer	Transfer of a functional group from one molecule to another
Hydrolytic	Cleavage of bonds by the addition of water
Carbon bond cleavage by means other than hydrolysis or oxidation	Two substrates yielding one product or vice versa. When H <sub>2</sub> O or CO <sub>2</sub> are a product, a double bond is formed.

## tipos de regulacion enzimatica

- 1) control allosterico
- 2) isoenzimas
- 3) modificacion covalente reversible
- 4) activacion proteolitica
- 5) cantidad de enzima presente

## Vitaminas B

TABLE 15.3 The B vitamins

Vitamin	Coenzyme	Typical reaction type	Consequences of deficiency
Thiamine (B <sub>1</sub> )	Thiamine pyrophosphate	Aldehyde transfer	Beriberi (weight loss, heart problems, neurological dysfunction)
Riboflavin (B <sub>2</sub> )	Flavin adenine dinucleotide (FAD)	Oxidation-reduction	Cheilosis and angular stomatitis (lesions of the mouth), dermatitis
Pyridoxine (B <sub>6</sub> )	Pyridoxal phosphate	Group transfer to or from amino acids	Depression, confusion, convulsions
Nicotinic acid (niacin) (B <sub>3</sub> )	Nicotinamide adenine dinucleotide (NAD <sup>+</sup> )	Oxidation-reduction	Pellagra (dermatitis, depression, diarrhea)
Pantothenic acid (B <sub>5</sub> )	Coenzyme A	Acyl-group transfer	Hypertension
Biotin (B <sub>7</sub> )	Biotin-lysine adducts (biocytin)	ATP-dependent carboxylation and carboxyl-group transfer	Rash about the eyebrows, muscle pain, fatigue (rare)
Folic acid (B <sub>9</sub> )	Tetrahydrofolate	Transfer of one-carbon components; thymine synthesis	Anemia, neural-tube defects in development
B <sub>12</sub>	5'-Deoxyadenosyl cobalamin	Transfer of methyl groups; intramolecular rearrangements	Anemia, pernicious anemia, methylmalonic acidosis

## Vitaminas

TABLE 15.4 Noncoenzyme vitamins

Vitamin	Function	Deficiency
A	Roles in vision, growth, reproduction	Night blindness, cornea damage, damage to respiratory and gastrointestinal tract
C (ascorbic acid)	Antioxidant	Scurvy (swollen and bleeding gums, subdermal hemorrhaging)
D	Regulation of calcium and phosphate metabolism	Rickets (children): skeletal deformities, impaired growth Osteomalacia (adults): soft, bending bones
E	Antioxidant	Lesions in muscles and nerves (rare)
K	Blood coagulation	Subdermal hemorrhaging

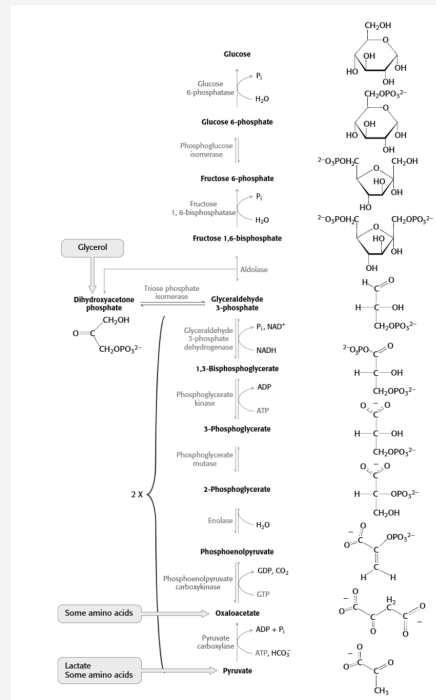
## transportadores de electrones

TABLE 15.2 Some activated carriers in metabolism

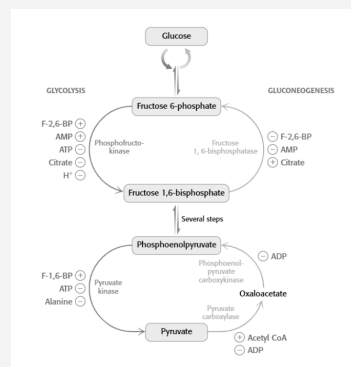
Carrier molecule in activated form	Group carried	Vitamin precursor
ATP	Phosphoryl	
NADH and NADPH	Electrons	Nicotinate (niacin) (vitamin B <sub>3</sub> )
FADH <sub>2</sub>	Electrons	Riboflavin (vitamin B <sub>2</sub> )
FMN	Electrons	Riboflavin (vitamin B <sub>2</sub> )
Coenzyme A	Acyl	Pantothenate (vitamin B <sub>5</sub> )
Liposamide	Acyl	
Thiamine pyrophosphate	Aldehyde	Thiamine (vitamin B <sub>1</sub> )
Biotin	CO <sub>2</sub>	Biotin (vitamin B <sub>7</sub> )
Tetrahydrofolate	One-carbon units	Folate (vitamin B <sub>9</sub> )
S-Adenosylmethionine	Methyl	
Uridine diphosphate glucose	Glucose	
Cytidine diphosphate diacylglycerol	Phosphatidate	
Nucleoside triphosphates	Nucleotides	

Note: Many of the activated carriers are coenzymes that are derived from water-soluble vitamins.

## Glicolisis



## regulacion de glucosa



## Gluconeogenesis

TABLE 16.8 Reactions of gluconeogenesis

Step	Reaction
1	Pyruvate + CO <sub>2</sub> + ATP + H <sub>2</sub> O → oxaloacetate + ADP + P <sub>i</sub> + 2H <sup>+</sup>
2	Oxaloacetate + GTP → phosphoenolpyruvate + GDP + CO <sub>2</sub>
3	Phosphoenolpyruvate + H <sub>2</sub> O → 2-phosphoglycerate
4	2-phosphoglycerate → 3-phosphoglycerate
5	3-phosphoglycerate + ATP → 1,3-bisphosphoglycerate + ADP
6	1,3-bisphosphoglycerate + 2-NADH + H <sup>+</sup> → glyceraldehyde 3-phosphate + NAD <sup>+</sup> + P <sub>i</sub>
7	Glyceraldehyde 3-phosphate → dihydroxyacetone phosphate
8	Glyceraldehyde 3-phosphate → dihydroxyacetone phosphate → fructose 1,6-bisphosphate
9	Fructose 1,6-bisphosphate + H <sub>2</sub> O → fructose 6-phosphate + P <sub>i</sub>
10	Fructose 6-phosphate → glucose 6-phosphate
11	Glucose 6-phosphate + H <sub>2</sub> O → glucose + P <sub>i</sub>

### oxidacion y reduccion

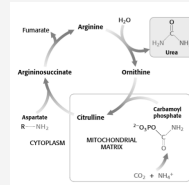
**TABLE 18.1 Standard reduction potentials of some reactions**

Oxidant	Reductant	n	E <sub>0</sub> '(V)
Succinate + O <sub>2</sub>	n-Ketoglutarate	2	-0.67
Ketone	Ketohydroxyacid	2	-0.60
Ferrous (oxidized)	Ferrous (reduced)	1	-0.43
Zn <sup>2+</sup>	H <sub>2</sub>	2	-0.42
NAD <sup>+</sup>	NADH + H <sup>+</sup>	2	-0.32
NADP <sup>+</sup>	NADPH + H <sup>+</sup>	2	-0.32
Lipoate (oxidized)	Lipoate (reduced)	2	-0.29
Gluoxalase (oxidized)	Gluoxalase (reduced)	2	-0.23
FAD	FADH <sub>2</sub>	2	-0.22
Aspirin (oxidized)	Ethanol	2	-0.20
Pyruvate	Lactate	2	-0.19
Zn <sup>2+</sup>	H <sub>2</sub>	2	-0.09
Fumarate	Succinate	2	+0.03
Cytochrome c (+3)	Cytochrome c (+2)	1	+0.02
Dihydroxyacetone	Acetate	2	+0.08
Ubiquinone (oxidized)	Ubiquinol (reduced)	2	+0.10
Cytochrome c (+2)	Cytochrome c (+3)	1	+0.22
Fe(OH) <sub>3</sub>	Fe(OH) <sub>2</sub>	1	+0.22
1/2 O <sub>2</sub> + 2 H <sup>+</sup>	H <sub>2</sub> O	2	+0.82

Note: E<sub>0</sub>' is the standard oxidizing-reducing potential (pH 7, 25°C) and is the number of electrons transferred. E<sub>0</sub>' refers to the partial reaction written as Oxidant + e<sup>-</sup> = reductant.

\*Standard oxidation-reduction potential at pH = 0.

### ciclo de urea



### enfermedades de almacenamiento de glucosa

**TABLE 21.2 Glycogen-storage diseases**

Type	Defective enzyme	Organ affected	Glycogen in the affected organ	Clinical features
I	Glucose 6-phosphatase or transport system	Liver and kidney	Increased amount; normal structure.	Major consequence of the liver: failure to thrive; acute hypoglycemia, ketosis, hepatomegaly, hyperlipemia.
II	α-1,4-Glycosylase (lysosomal)	All organs	Major increase in amount; normal structure.	Cardiomyopathy failure; causes death, usually before age 2.
III	α-1,4-Glycosylase (debranching enzyme)	Muscle and liver	Increased amount; short outer branches.	Like type I, but milder course.
IV	Branching enzyme (α-1,6-α-1,4)	Liver and spleen	Normal amount; very long outer branches.	Progressive cirrhosis of the liver; liver failure causes death, usually before age 2.
V	Phosphorylase	Muscle	Moderately increased amount; normal structure.	Limited ability to perform strenuous exercise because of potential muscle cramps; often the patient is normal and well developed.
VI	Phosphorylase	Liver	Increased amount.	Like type I, but milder.
VII	Phosphofructotransferase	Muscle	Increased amount; normal structure.	Like type V.
VIII	Phosphorylase kinase	Liver	Increased amount; normal structure.	Mild liver enlargement; mild hypoglycemia.

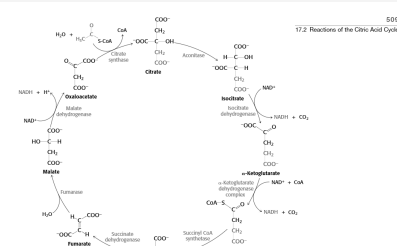
Note: Types I through VII are inherited as autosomal recessives. Type VIII is an X-linked.

### pentosas fosfato

**TABLE 20.3 Pentose phosphate pathway**

Reaction	Enzyme
<b>Oxidative phase</b>	
Glucose 6-phosphate + NADP <sup>+</sup> → 6-phosphogluconate + NADPH + H <sup>+</sup>	Glucose 6-phosphate dehydrogenase
6-Phosphogluconate + H <sub>2</sub> O → 6-phosphogluconate + H <sup>+</sup>	Lactonase
6-Phosphogluconate + NADP <sup>+</sup> → ribulose 5-phosphate + CO <sub>2</sub> + NADPH + H <sup>+</sup>	6-Phosphogluconate dehydrogenase
<b>Nonoxidative Phase</b>	
Ribulose 5-phosphate → ribose 5-phosphate	Phosphotransferase
Ribulose 5-phosphate → xylulose 5-phosphate	Phosphotransferase
Xylulose 5-phosphate + ribose 5-phosphate → sedoheptulose 7-phosphate + glyceraldehyde 3-phosphate	Transketolase
Sedoheptulose 7-phosphate + glyceraldehyde 3-phosphate → fructose 6-phosphate + erythrose 4-phosphate	Transaldolase
Xylulose 5-phosphate + erythrose 4-phosphate → fructose 6-phosphate + glyceraldehyde 3-phosphate	Transketolase

### ciclo de acido citrico



**FIGURE 17.15 The citric acid cycle.** Notice that since succinate is a symmetric molecule, the identity of the carbon from the acetyl unit is lost.

**TABLE 17.2 Citric acid cycle**

Step	Reaction	Enzyme	Prosthetic group	Type*	ΔG <sup>0</sup> (kJ mol <sup>-1</sup> )	ΔG <sup>0</sup> (kcal mol <sup>-1</sup> )
1	Acetyl-CoA + succinyl-CoA + H <sub>2</sub> O → citrate + CoA + H <sup>+</sup>	Citrate synthase		a	-31.4	-7.5
2a	Citrate → isocitrate + H <sub>2</sub> O	Acid anhydrase	Fe-S	b	+8.8	+2.9
2b	α-Ketoglutarate + H <sub>2</sub> O → isocitrate	Acid anhydrase	Fe-S	c	-2.1	-0.5
3	Isocitrate + NAD <sup>+</sup> → α-ketoglutarate + NADH + H <sup>+</sup>	Isocitrate dehydrogenase		d + e	-8.4	-2.0
4	α-Ketoglutarate + NAD <sup>+</sup> + CoA → succinyl-CoA + CO <sub>2</sub> + NADH + H <sup>+</sup>	α-Ketoglutarate dehydrogenase	Lipoate, Fe-S, TPP	f + g	-30.1	-7.2
5	Succinyl-CoA + P <sub>i</sub> + ADP → succinate + ATP + CoA	Succinyl-CoA synthetase		f	-3.3	-0.8
6	Succinate + FAD (enzyme-bound) → fumarate + FADH <sub>2</sub> (enzyme-bound)	Succinate dehydrogenase		g	0	0
7	Fumarate + H <sub>2</sub> O → malate	Fumarate hydratase		h	-3.8	-0.9
8	Malate + NAD <sup>+</sup> → oxaloacetate + NADH + H <sup>+</sup>	Malate dehydrogenase		e	+29.7	+7.1

\*Reaction type: (a) condensation; (b) dehydratase; (c) hydratase; (d) decarboxylase; (e) oxidase; (f) substrate-level phosphorylation.

### pasos en sintesis de Amino Acidos

- 1) debe haber nitrogeno reactivo NH<sub>3</sub> → NH<sub>4</sub>
- 2) esqueletos carbonados (de glicolisis, ciclo de krebs, & pentosas fosfato)

### Principales formas de fijacion de nitrogeno

- 1) rhizobium 60%
- 2) Fritz Haber 15%
- 3) Rayos UV 25%

### rhizobium

hacen fijacion de nitrogeno (N<sub>2</sub> → NH<sub>3</sub>).  
son anaerobicos y simbioticos con plantas

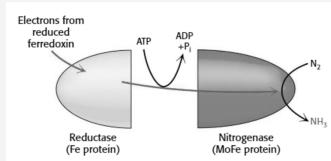
### componentes etc

**TABLE 18.2 Components of the mitochondrial electron-transport chain**

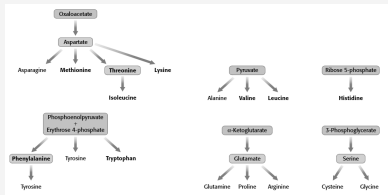
Enzyme complex	Mass (kDa)	Subunits	Prosthetic group	Matrix side	Membrane core	Cytoplasmic side
NADH-Q oxidoreductase	>900	46	FMN	NADH	Q	
Succinate-Q reductase	140	4	FAD	Fe-S	Succinate	Q
Q-cytochrome c oxidoreductase	250	11	Heme b <sub>L</sub> Heme b <sub>H</sub> Heme c <sub>1</sub> Fe-S		Q	Cytochrome c
Cytochrome c oxidase	160	13	Heme a Heme a <sub>3</sub> Cu <sub>2</sub> and Cu <sub>1</sub>			Cytochrome c

Information from J. W. Drenth and L. Ernster, *Ann. Rev. Biochem.* 46:215-237; Y. Hagi, *Ann. Rev. Biochem.* 54:1015-1045; and J. E. Walker, *Q. Rev. Biophys.* 22:251, 1991.

### complejo fijador de nitrógeno



### familias biosintéticas de aminoácidos



### 20 aminoácidos

#### ESENCIALES

- histidina
- isoleucina
- leucina
- lisina
- metionina
- fenilalanina
- treonina
- triptofano
- valina

#### NO ESENCIALES

- alanina
- arginina
- asparagina
- aspartato
- cisteina
- glutamato
- glutamina
- glicina
- prolina
- serina
- tirosina

### enfermedades de metabolismo de aminoácidos

Disease	Enzyme deficiency	Symptoms
Citralinuria	Aspartoaminotransferase	Lethargy, seizures, reduced mental status
Tyrosinemia	Various enzymes of tyrosine degradation	Weakness, liver damage, mental retardation
Albinism	Tyrosinase	Absence of pigmentation
Hemifacial atrophy	Catalase and peroxidase	Asymmetry, muscle weakness, mental retardation, skin blemish
Hypothyroidism	α-Ketoglutarate oxidase, thyroxine dioxygenase	Swollen, mental retardation, lack of muscle tone, ataxia

### enzimas en síntesis de novo

Step	Enzyme
1	Glycinamide ribonucleotide (GAR) synthetase
2	GAR transformylase
3	Formyltransferase II
4	Aminoimidazole ribonucleotide synthetase
5	Carbamoyltransferase II
6	5-Aminoimidazole-4-carboxamide ribonucleotide synthetase
7	Adenylosuccinylase
8	Aminoimidazole carboxamide ribonucleotide transformylase
9	Inosine monophosphate cyclohydrolase

### biosíntesis de purimidinas

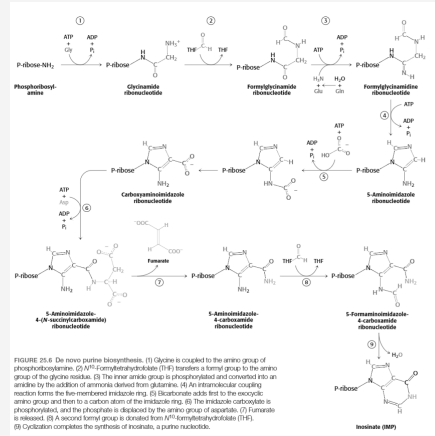


FIGURE 25.4 De novo purine biosynthesis. (1) Glycine is coupled to the amino group of phosphoribosylamine. (2)  $\text{N}^5\text{,N}^7$ -methylene-THF provides a formyl group to the amino group of the glycine residue. (3) The amino group is phosphorylated and converted into an amide by the addition of a carbon atom from glutamine. (4) An intramolecular condensation reaction forms the five-membered imidazole ring. (5) Electrophilic attack by the exocyclic amino group and then to a carbon atom of the imidazole ring. (6) The imidazole carboxamide is phosphorylated, and the phosphate is displaced by the amino group of aspartate. (7) Formate is released. (8) A second formyl group is donated from  $\text{N}^5$ -formylaminoimidazole (FICAR). (9) Cyclization completes the synthesis of inosinate, a purine nucleotide.

### síntesis de ácidos grasos

Step	Reaction	Enzyme
1	Acetyl CoA + $\text{HCO}_3^- + \text{ATP} \rightleftharpoons$ acetyl CoA + $\text{ADP} + \text{P}_i + \text{H}^+$	Acetyl CoA carboxylase
2	Acetyl CoA + ACP $\rightleftharpoons$ acetyl ACP + CoA	Acetyl transacylase
4	Malonyl CoA + ACP $\rightleftharpoons$ malonyl ACP + CoA	Malonyl transacylase
5	Acetyl ACP + malonyl ACP $\rightleftharpoons$ acetoacetyl ACP + $\text{CO}_2$	Malonyl synthase
7	Acetoacetyl ACP + NADPH + $\text{H}^+ \rightleftharpoons$ 3-hydroxybutyryl ACP + $\text{NADP}^+$	$\beta$ -Ketoacyl synthase
8	$\alpha$ -3-Hydroxybutyryl ACP $\rightleftharpoons$ crotonyl ACP + $\text{H}_2\text{O}$	$\beta$ -Ketoacyl dehydratase
9	Crotonyl ACP + NADPH + $\text{H}^+ \rightleftharpoons$ butyryl ACP + $\text{NADP}^+$	Enoyl reductase

### oxidación ácidos grasos

Step	Reaction	Enzyme
1	Fatty acid + CoA + ATP $\rightleftharpoons$ acyl CoA + AMP + $\text{P}_i$	Acyl CoA synthetase (also called fatty acid thioesterase and fatty acyl CoA ligase)
2	Carnitine + acyl CoA $\rightleftharpoons$ acyl carnitine + CoA	Carnitine acyltransferase (also called carnitine palmitoyl transferase)
3	Acyl CoA + FAD $\rightleftharpoons$ acyl CoA + FADH <sub>2</sub>	Acyl CoA dehydrogenase (several isozymes having different chain length specificities)
4	Acyl CoA + $\text{H}_2\text{O} \rightleftharpoons$ 3-hydroxyacyl CoA	Enoyl CoA hydratase (also called crotonase or 3-hydroxyacyl CoA hydratase)
5	3-hydroxyacyl CoA + NAD <sup>+</sup> $\rightleftharpoons$ 3-ketoacyl CoA + NADH + $\text{H}^+$	$\beta$ -Ketoacyl CoA dehydrogenase
6	3-ketoacyl CoA + CoA $\rightleftharpoons$ acetyl CoA + acyl CoA (shortened by $\text{C}_2$ )	$\beta$ -Ketothiolase (also called thiolase)

\*An AMP-forming ligase.

### lipoproteínas del plasma

Plasma lipoprotein	Density ( $\text{g ml}^{-1}$ )	Diameter (nm)	Apolipoprotein	Physiological role	Composition (%)					
					TG	CE	PL	C	P	
Chylomicrons	<0.95	75-1200	B-48, C, E	Dietary fat transport	86	3	1	8	2	
Very low density lipoproteins	0.95-1.000	30-80	B-100, C, E	Endogenous fat transport	52	14	7	18	8	
Intermediate-density lipoproteins	1.006-1.019	15-35	B-100, E	LDL precursor	38	30	8	23	11	
Low-density lipoproteins	1.019-1.063	18-25	B-100	Cholesterol transport	10	58	8	22	21	
High-density lipoproteins	1.063-1.21	7.5-20	A	Reverse cholesterol transport	5	10	14	3.7	19	29

Abbreviations: TG, triacylglycerol; CE, cholesteryl ester; C, free cholesterol; PL, phospholipid; P, protein.

### regulación de apetito

TABLE 27.2 Gastrointestinal peptides that regulate food intake

Appetite-suppressing signals
Cholecystikinin
Cholecystikinin-like peptide 1
Cholecystikinin-like peptide 2
Anorexin
Somatomedin
Bombesin
Enterostatin
Apolipoprotein A-IV
Gastric inhibitory peptide

Appetite-enhancing peptides
Ghrelin

Information from M. H. Sipson, ed., *Behavioral, Physiological, Molecular Aspects of Hunger, Satiety, and Food Intake* (New York, 1991), p. 67, 68, 221.



