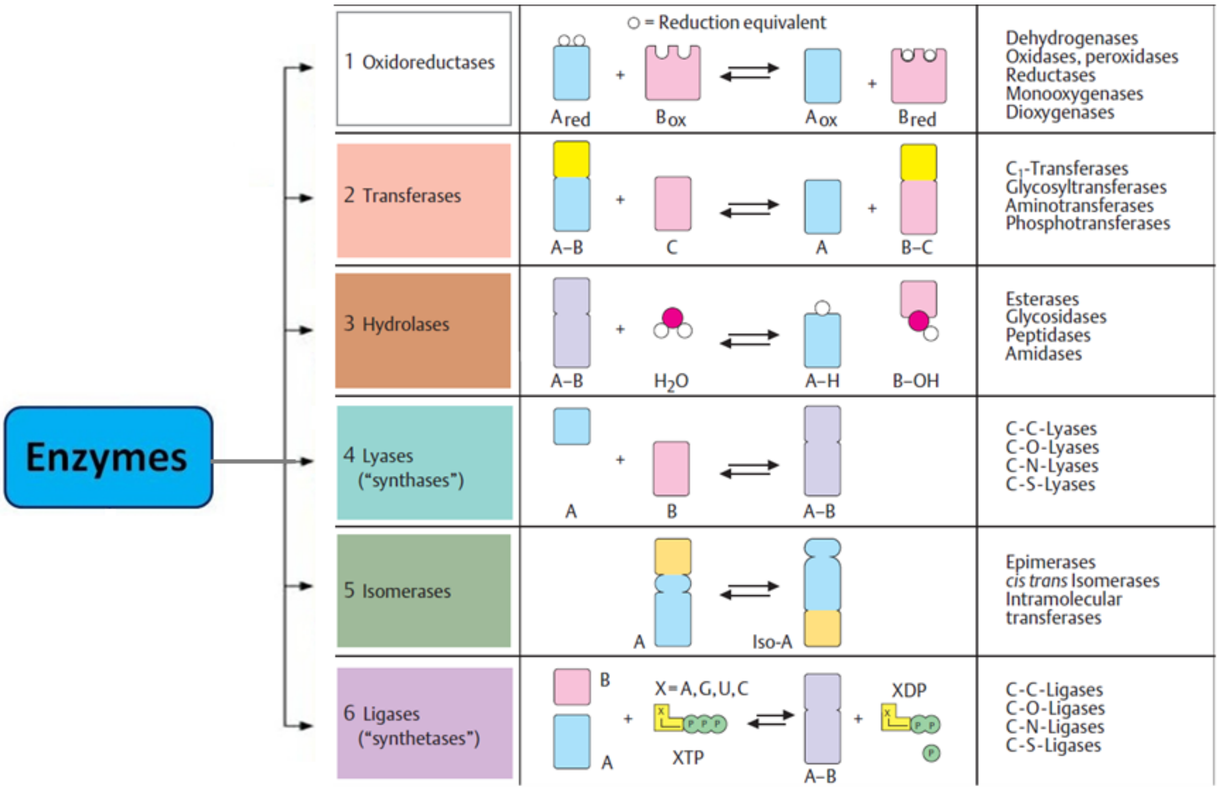
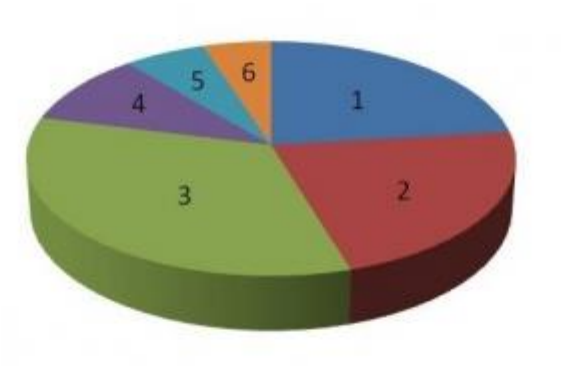
Enzymes: Types of enzyme

Even the simplest of organisms have hundreds of enzymes in every living cell, catalyzing reactions that are crucial for life. A classification systems exists that categorizes all the known enzymes based on the general class of reaction that they catalyse.

There are six groups, described below.



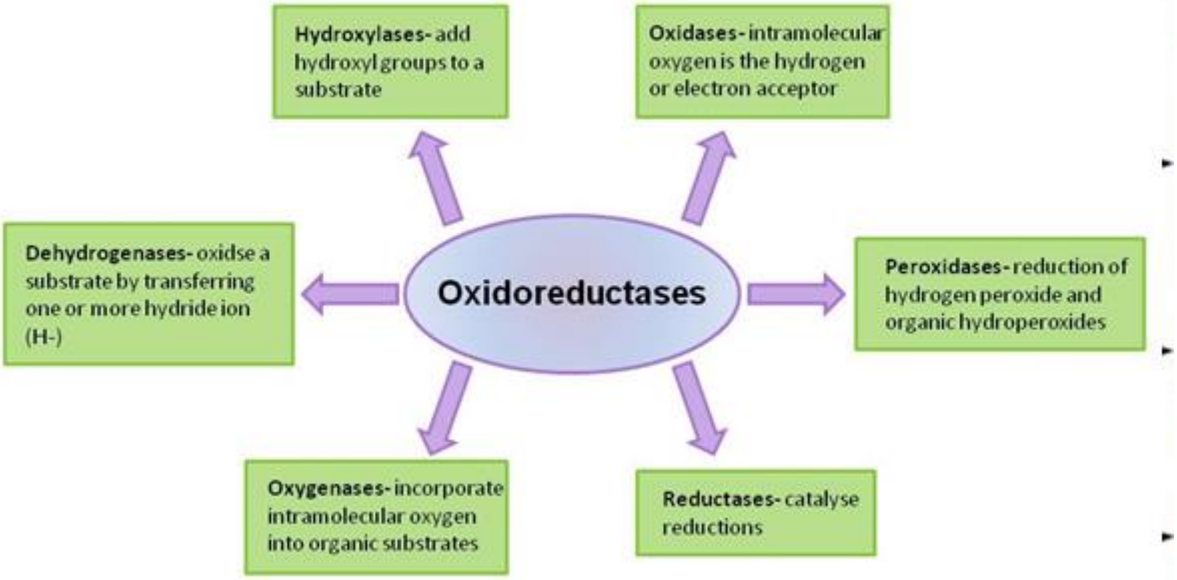


This pie chart shows the distribution of all the known enzymes.
1= oxidoreductases
2= transferases
3= hydrolases
4= lyases
5= isomerases
6= ligases
It is clear that the most populous group is the hydrolases, followed by oxidoreductases and transferases.
The proportion of enzymes in the other groups is significantly less.

Oxidoreductases

Oxidoreductases catalyse oxidation or reduction reactions, where electrons are transferred from one molecule (the reductant) to another molecule (the oxidant).
This can be shown as:
A- + B --> A + B-
Where **A**= the reductant and **B**= the oxidant and an electron has transferred from A to B.
This process often requires co-factors such as NAD(P)H.

The main sub-classes are:



They are very important enzymes, which are vital for many metabolic processes, particularly in aerobic and anaerobic respiration. For example, oxidoreductases can be found in glycolysis, the TCA cycle and oxidative phosphorylation.

Alcohol dehydrogenase is an important example.
This enzyme (EC 1.1.1.1) interconverts alcohols to either aldehydes or ketones.
In order for this to occur, NAD+ is reduced to NADH. This is similar to the majority of dehydrogenases that use NAD(P)+ or a flavin (such as FMN or FAD) as the electron acceptor.
This enzyme is crucial in breaking down alcohol, removing the toxicity which is so important for many animals. In many bacteria, yeast and plants, alcohol dehydrogenase catalyses the reaction preferentially in the opposite direction. This is an important part of the fermentation process, as it used to maintain a constant supply of NAD+ in these organisms which used up during glycolysis.

TRANSFERASES

Transferases are enzymes that catalyse the movement of a functional group from one molecule to another. These functional groups are very diverse can include phosphate, methyl and glycosyl groups.
The basic reaction can be shown as:

AX + B --> A + BX

Where **A=** the donor, **B**= the acceptor and **X**= the functional group.
There are many transferase enzymes. Here two sub-groups worth to be focused on.
Kinases
Kinases enzymes are involved in catalysing the transfer of phosphate groups in a process called phosphorylation. They can act on a range of different molecules, for example lipids, carbohydrates and nucleotides. This is often occurs to prime the molecule ready for different metabolic pathways. Protein kinases are extremely important, as they are used extensively in signal transduction and in controlling complex processes within the cell. They are very diverse, with more than 500 different kinases being identified in the human body alone!

Deaminases
Another group of transferases are the deaminases, which catalyse the transfer an amine group. One of their roles is in the breakdown of amino acids after excess protein consumption. This reaction involves removing the amino group from the amino acid and then converting this to ammonia. The rest of the amino acid is then either oxidised for energy or recycled.

HYDROLASES

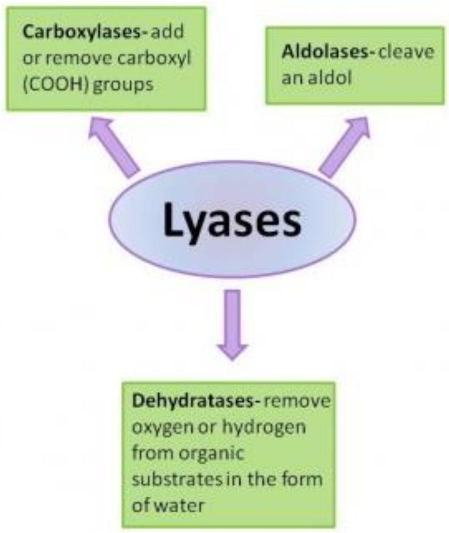
Hydrolase enzymes simply catalyse hydrolysis; the breaking of single bonds through the addition of water.
There is a huge variety of hydrolase enzymes. For example, the **digestive enzymes** that are classified based on their target:

- proteases/ peptidases cleave peptide bonds between amino acids in order to breakdown proteins
- lipases break down lipids into fatty acids and glycerol by cleaving ester bonds
- nucleases cleave phosphodiester bonds between nucleotide subunits in nucleic acids

They are termed exo or endo depending on where they cut. Endo enzymes cut in the middle of the chain, whereas exo enzymes cut at the end of the chain to release an individual monomer.

LYASES

Lyases catalyse lysis reactions that generate a double bond.
These are a type of elimination reaction but are not hydrolytic or oxidative.
The reverse reaction catalyses an addition reaction, where a substrate is added to a double bond.
These are often referred to as **synthase** enzymes.
An example of lyase would the **cyclase**:
ATP <--> cAMP + PPi
Generally one substrate is required in the forward direction, whereas two are needed for the backward reaction.

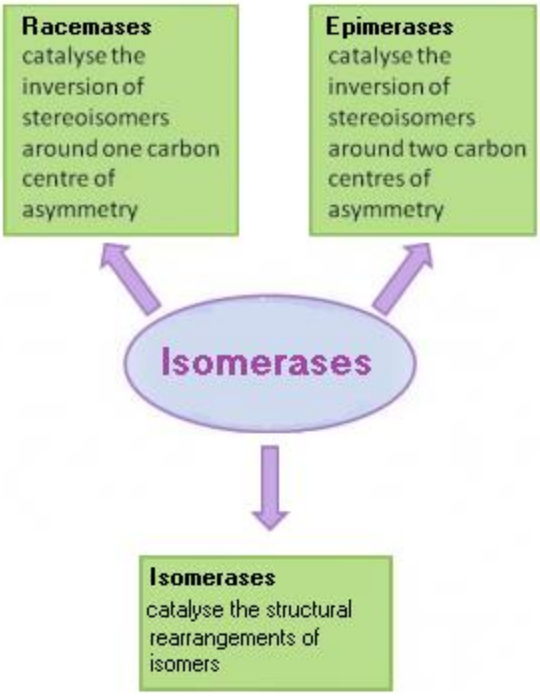


Ex. **Isocitrate lyase** is involved in the TCA cycle, where it converts isocitrate to succinate. This is done through cleaving the glycoxylate group from isocitrate. It is technically an aldolase, as an aldol group in the form of glycoxylate is cleaved.

ISOMERASES

Isomerases are enzymes that can catalyse structural changes within a molecule. There is only one substrate and one product with nothing gained or lost, so they represent only a change in shape. The diagram shows a simple example of this sort of reaction.
Isomers have the same molecular formula but differ in their structural formula. These differences can change the chemical properties of the molecule. There are multiple classes of isomerases, for example geometric, structural, enantiomers and stereoisomers.

Alanine racemase converts the amino acid alanine between its two optical isomers. It is used in both alanine and aspartate metabolism.
D-Alanine <--> L-Alanine
All amino acids can exist in these two forms, except from glycine. The L-isomers are far more common, though the D-isomer amino acids do have some very important roles in biology (i.e. in peptidoglycan structure).



Glucose-6-phosphate isomerase catalyses the conversion of glucose-6-phosphate to fructose-6-phosphate in the second step of glycolysis.
Both glucose and fructose are 6-carbon sugars, but with a different structural arrangement. This enzyme interconverts the sugar between its two forms.

LIGASES

Ligases are responsible for the catalysis of ligation: the joining of two substrates.
Usually chemical potential energy is required, so the reaction is coupled to the hydrolysis of a disphosphate bond in a nucleotide triphosphate such as ATP.

DNA ligase is a very important ligase enzyme: it catalyses the ligation between breaks in DNA by forming a phosphodiester bond.

There are different forms of the enzyme, and they catalyse different breaks. (In mammals, there are 4 different types.)
For example, double strand breaks are repaired by DNA ligase IV. Whereas DNA ligase I repairs single stranded breaks using the complementary strand as a template, like in DNA replication of the lagging strand. The reaction requires ATP, yet in some bacterial species, the co-factor NAD has been shown to be a requirement.

CLASSIFICAZIONE

Il codice associato a ogni enzima consiste delle lettere "EC" seguite da quattro numeri separati da punti. Tali numeri rappresentano una classificazione via via più fine dell'enzima.

Per esempio, l'enzima *tripeptide aminopeptidasi* ha il codice "EC 3.4.11.4", i cui componenti indicano:

- EC 3: enzimi della famiglia delle idrolasi, enzimi che usano una molecola di acqua per rompere altre molecole (il primo numero identifica la reazione catalizzata dall'enzima);
- EC 3.4: idrolasi che agiscono su un legame peptidico (il secondo numero identifica il tipo di substrato);
- EC 3.4.11: idrolasi che agiscono solo sull'amminoacido N-terminale di un peptide (il terzo numero specifica ulteriormente il tipo di substrato);
- EC 3.4.11.4: idrolasi che agiscono solo sull'amminoacido N-terminale di un tripeptide (il quarto è un numero d'ordine e segna l'ordine di scoperta degli enzimi);.

Analogamente per l' Esochinasi EC 2.7.1.1.

- 2 Transferasi
- 7 substrato è il gruppo fosfato
- 1 accettore gruppo alcolico
- 1 agisce solo sull'ossidrile in 6 di un esoso.

Per il molto simile enzima Glucochinasi si ha EC 2.7.1.2, tutto come sopra ma agisce su una molecola diversa, solo sul glucosio (l'ultimo numero 2)

In questa tabella c'è l'elenco delle sotto classi

Subclass	Name
EC 1	**Oxidoreductases**
EC 1.1	Acting on the CH-OH group of donors
EC 1.2	Acting on the aldehyde or oxo group of donors
EC 1.3	Acting on the CH-CH group of donors
EC 1.4	Acting on the CH-NH_2 group of donors
EC 1.5	Acting on the CH-NH group of donors
EC 1.6	Acting on NADH or NADPH
EC 1.7	Acting on other nitrogenous compounds as donors
EC 1.8	Acting on a sulfur group of donors
EC 1.9	Acting on a heme group of donors

EC 1.10 Acting on diphenols and related substances as donors

EC 1.11 Acting on a peroxide as acceptor

EC 1.12 Acting on hydrogen as donor

EC 1.13 Acting on single donors with incorporation of molecular oxygen (oxygenases)

EC 1.14 Acting on paired donors, with incorporation or reduction of molecular oxygen

EC 1.15 Acting on superoxide radicals as acceptor

EC 1.16 Oxidising metal ions

EC 1.17 Acting on CH or CH_2 groups

EC 1.18 Acting on iron-sulfur proteins as donors

EC 1.19 Acting on reduced flavodoxin as donor

EC 1.20 Acting on phosphorus or arsenic in donors

EC 1.21 Acting on the reaction X-H + Y-H = X-Y

EC 1.22 Acting on halogen in donors

EC 1.23 Reducing C-O-C group as acceptor

EC 1.97 Other oxidoreductases

EC 2 **Transferases**

EC 2.1 Transferring one-carbon groups

EC 2.2 Transferring aldehyde or ketonic groups

EC 2.3 Acyltransferases

EC 2.4 Glycosyltransferases

EC 2.5 Transferring alkyl or aryl groups, other than methyl groups

EC 2.6 Transferring nitrogenous groups

EC 2.7 Transferring phosphorus-containing groups

EC 2.8 Transferring sulfur-containing groups

EC 2.9 Transferring selenium-containing groups

EC 2.10 Transferring molybdenum- or tungsten-containing groups

EC 3 **Hydrolases**

EC 3.1 Acting on ester bonds

EC 3.2 Glycosylases

EC 3.3 Acting on ether bonds

EC 3.4 Acting on peptide bonds (peptidases)

EC 3.5 Acting on carbon-nitrogen bonds, other than peptide bonds

EC 3.6 Acting on acid anhydrides

EC 3.7 Acting on carbon-carbon bonds

EC 3.8 Acting on halide bonds

EC 3.9 Acting on phosphorus-nitrogen bonds

EC 3.10 Acting on sulfur-nitrogen bonds

EC 3.11 Acting on carbon-phosphorus bonds

EC 3.12 Acting on sulfur-sulfur bonds

EC 3.13 Acting on carbon-sulfur bonds

EC 4	**Lyases**
EC 4.1	Carbon-carbon lyases
EC 4.2	Carbon-oxygen lyases
EC 4.3	Carbon-nitrogen lyases
EC 4.4	Carbon-sulfur lyases
EC 4.5	Carbon-halide lyases
EC 4.6	Phosphorus-oxygen lyases
EC 4.7	Carbon-phosphorus lyases
EC 4.99	Other lyases
EC 5	**Isomerases**
EC 5.1	Racemases and epimerases
EC 5.2	*cis-trans*-Isomerases
EC 5.3	Intramolecular isomerases
EC 5.4	Intramolecular transferases (mutases)
EC 5.5	Intramolecular lyases
EC 5.99	Other isomerases
EC 6	**Ligases**
EC 6.1	Forming carbon—oxygen bonds
EC 6.2	Forming carbon—sulfur bonds
EC 6.3	Forming carbon—nitrogen bonds
EC 6.4	Forming carbon—carbon bonds
EC 6.5	Forming phosphoric ester bonds
EC 6.6	Forming nitrogen—metal bonds

Esempi di sotto-sotto classi

EC 1.1.1 With NAD or NADP as acceptor
EC 1.1.2 With a cytochrome as acceptor
EC 1.1.3 With oxygen as acceptor
EC 1.1.4 With a disulfide as acceptor
EC 1.1.5 With a quinone or similar compound as acceptor
EC 1.1.9 With a copper protein as acceptor
EC 1.1.98 With other, known, physiological acceptors
EC 1.1.99 With unknown physiological acceptors