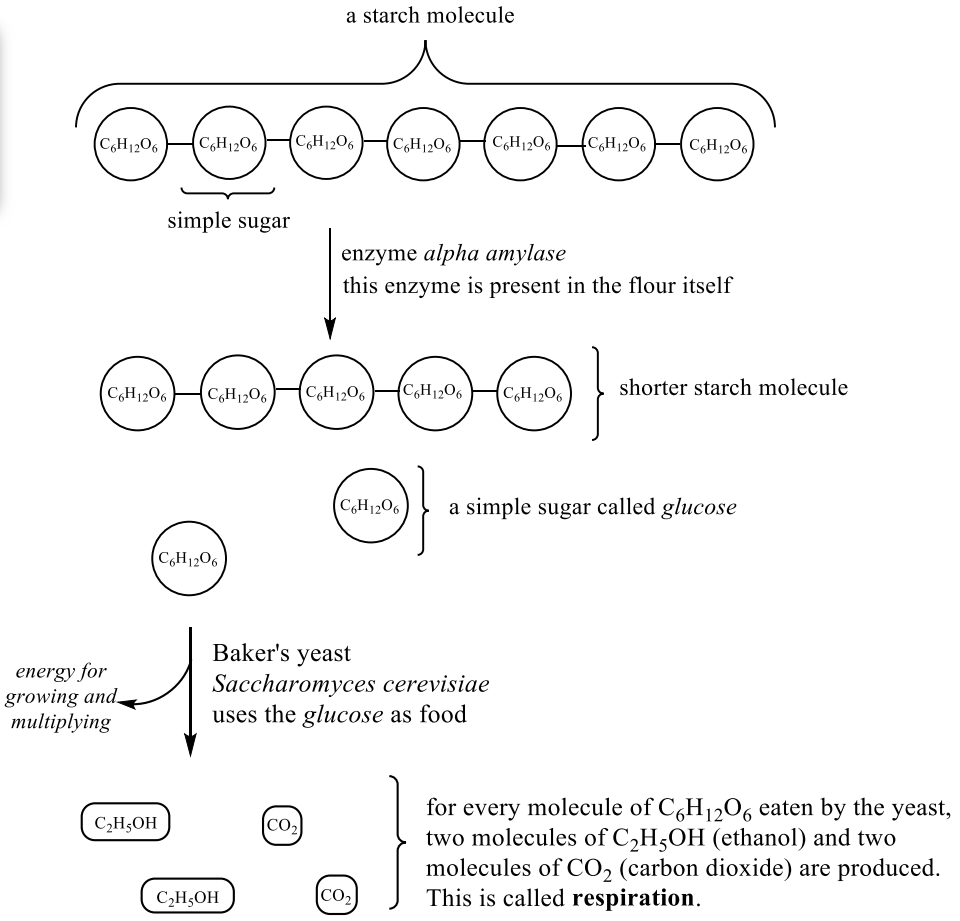
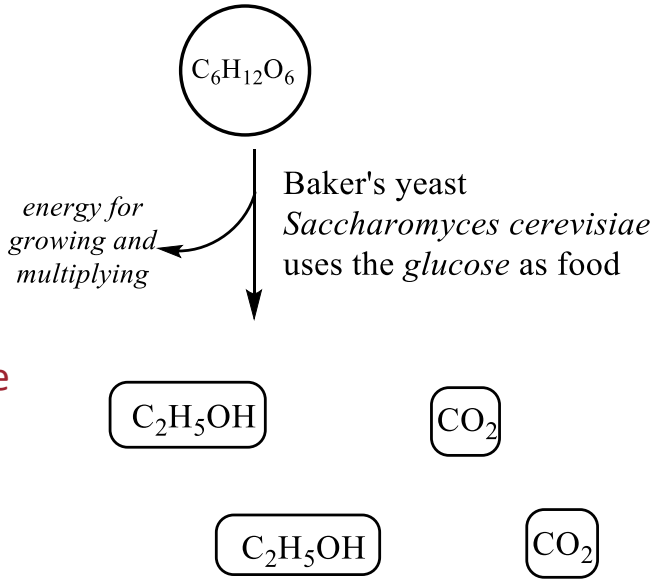
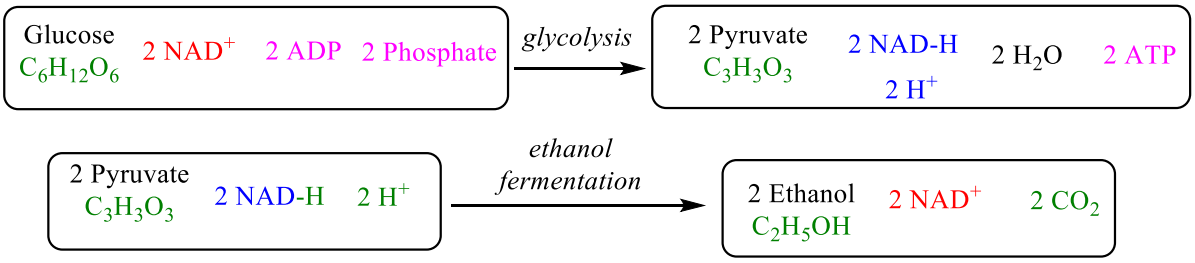
Unit 1

YEAST, ENZYMES, AND COFACTORS



Ethanol and carbon dioxide are merely by products of yeast *respiration*. For yeast, the ultimate goal of consuming *glucose* is to generate energy to power its cellular machinery and eventually grow and multiply.





The steps of glycolysis

		Substrate(s) consumed	Product(s) produced	Enzyme catalyst
These steps = 1X per glucose	1	Glucose + ATP	Glucose-6-phosphate + ADP	Hexokinase
	2	Glucose-6-phosphate	Fructose-6-phosph	Phosphoglucoisomer*ase*
	3	Fructose-6-phosphate		osphofructokin*ase*
	4	Fructose-1,6-bisphosph	glyceraldehyde-3-phosphate	dol*ase*
	5	Dihydroxyacetone phosphate	glyceraldehyde-3-phosphate	Triose phosphate isomer*ase*
These steps = 2X	6	Glyceraldehyde-3-phosphate + Phosphate + NAD^+	1,3-bisphosphoglycerate + NAD-H	Glyceraldehyde-3-phosphate dehydrogen*ase*
	7	1,3-bisphosphoglycerate + ADP	3-phosphoglycerate + **ATP**	Phosphoglycerate kin*ase*
	8	3-phosphoglycerate	2-phosphoglycerate	Phosphoglycerate mut*ase*
	9	2-phosphoglycerate	phosphoenolpyruvate + H_2O	enol*ase*
	10	Phosphoenolpyruvate+ ADP	**Pyruvate** + **ATP**	Pyruvate kin*ase*

A catalyst makes the chemistry *easier*. It is NOT a substrate , nor a product

How does the process of consuming glucose produce energy?

Glucose $C_6H_{12}O_6$ + 2 NAD^+ + 2 ADP + 2 Phosphate —*glycolysis*→ 2 Pyruvate $C_3H_3O_3$ + 2 NAD-H + 2 H^+ + 2 H_2O + 2 ATP

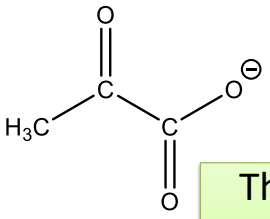
2 Pyruvate $C_3H_3O_3$ + 2 NAD-H + 2 H^+ —*ethanol fermentation*→ 2 Ethanol C_2H_5OH + 2 NAD^+ + 2 CO_2

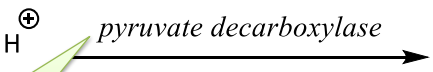
- At the conclusion of glycolysis, there is a net production of the energy molecule ATP, but a net *consumption* of the molecule NAD^+.
- One molecule of NAD^+ was converted to NAD—H.
- Every organism that breaks down glucose via glycolysis – that includes humans and *S. cerevisiae* (baker's/brewer's yeast) – must have a way to regenerate the NAD^+ from the NAD—H or *metabolism* – the chemical reactions that create life – will cease.

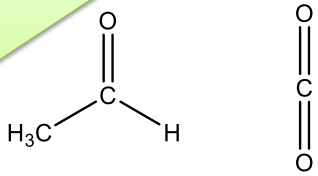
2 Pyruvate $C_3H_3O_3$ + 2 NAD-H + 2 H^+ —*ethanol fermentation*→ 2 Ethanol C_2H_5OH + 2 NAD^+ + 2 CO_2

What bonds have been broken/formed in this chemical reaction?

Pyruvate



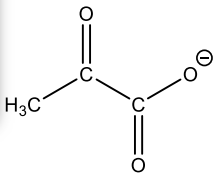




This is an enzyme

An *enzyme is a kind of protein*. When an **enzyme** catalyzes the chemical reaction it accelerates the rate (or speed) of the reaction without being a reactant or a product. The enzyme (or catalyst) is unchanged by the reaction; it only helps the reaction go faster.

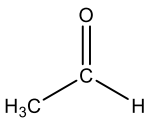
Pyruvate

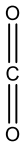


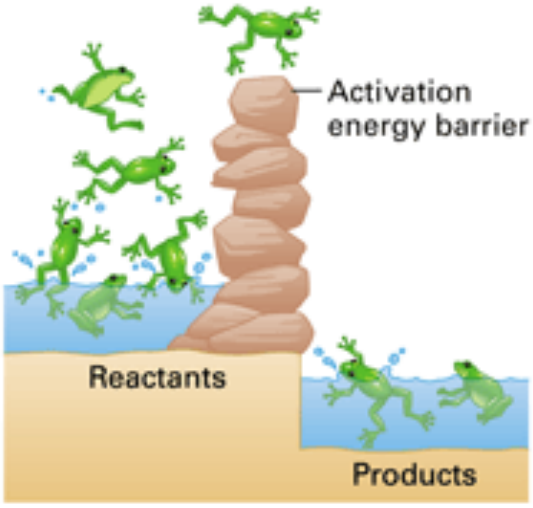
This is an enzyme

$H^{\oplus}$ —*pyruvate decarboxylase*→ (requires the cofactor Thiamin)

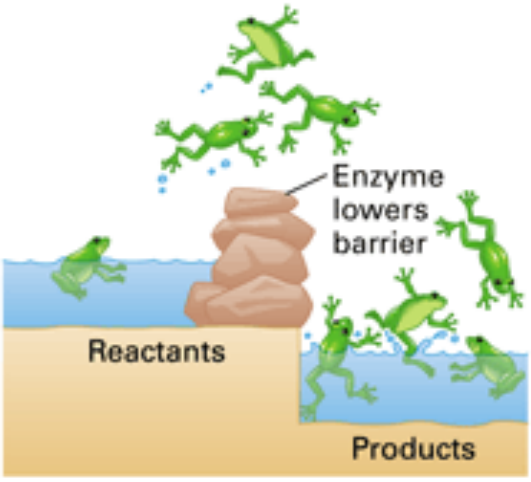
Acetaldehyde







Without enzyme



With enzyme

2 Pyruvate $C_3H_3O_3$ + 2 NAD-H + 2 H^+ —*ethanol fermentation*→ 2 Ethanol C_2H_5OH + 2 NAD^+ + 2 CO_2

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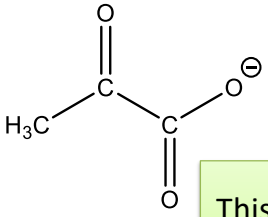
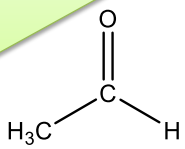
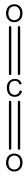
Pyruvate



$H^{\oplus}$ —*pyruvate decarboxylase*→ (requires the cofactor Thiamin)





This is an enzyme

A cofactor is an “enzyme helper”

- Sometimes, enzymes need a little help to catalyze difficult chemical reactions.
- **Cofactors** can be organic (that is, containing carbon atoms) or inorganic (that is, containing no carbon atoms) molecules that are required by an enzyme to catalyze its reaction.
- Compared to the enzyme itself, which is a large macromolecular protein, cofactors are relatively small.

Common *organic* Cofactors

(organic means…made of carbon)

Cofactors are “small(er)” molecules that are necessary for some enzymatic reactions.

Cofactors for enzyme catalyzed reactions that are also Vitamins.		
Cofactor	*Vitamin name*	*Condition caused by deficiency*
FAD – flavin adenine dinucleotide, FMN – flavin mononucleotide	Riboflavin	Slow growth
Thiamin	Vitamin B1	Beriberi
Coenzyme A	Vitamin B3	Deficiency is very rare
Biotin	Biotin	Dermatitis
Pyridoxal phosphate	Vitamin B6	Various symptoms
Tetrahydofolate	Folate/Folic Acid	Anemias
Adenosylcobalmin	Vitamin B12	Pernicious anemia
L-Ascorbic Acid	Vitamin C	scurvy

Wait a minute! Weren’t we talking about yeast? Why do people eat Vitamins?

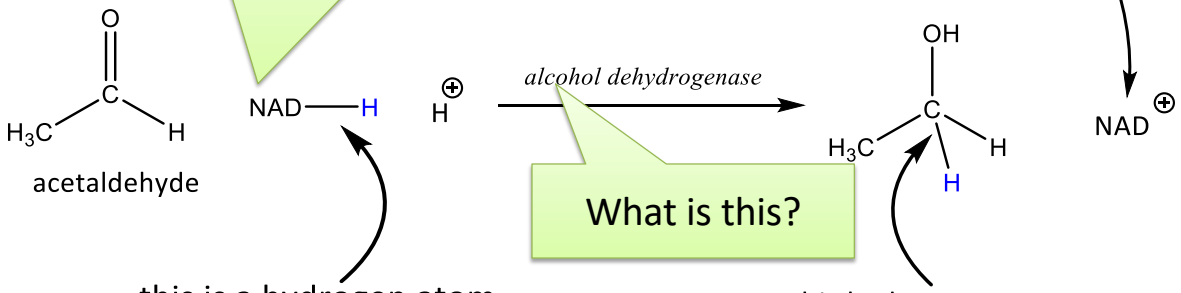
PERCENTAGE OF U.S. RECOMMENDED DAILY ALLOWANCES (U.S. RDA)

	CEREAL	WITH SKIM MILK
PROTEIN	4	15
VITAMIN A	25	30
VITAMIN C	* *	2
THIAMIN	25	30
RIBOFLAVIN	25	35
NIACIN	25	25
CALCIUM	* *	15
IRON	100	100
VITAMIN D	10	25
VITAMIN B_6	25	25
FOLIC ACID	25	25
VITAMIN B_{12}	25	35
PHORUS	15	25
NESIUM	15	20
	25	30
PER	8	10

2 Pyruvate $C_3H_3O_3$ + 2 NAD-H + 2 H^+ —*ethanol fermentation*→ 2 Ethanol C_2H_5OH + 2 NAD^+ + 2 CO_2

NAD is not an elemental symbol is the large molecule nicotinamide adenine dinucleotide

There is an anion to balance this charge, but I am leaving it out for simplicity



What is this?

this is a hydrogen atom covalently bonded via 2 electrons to the larger NAD molecule

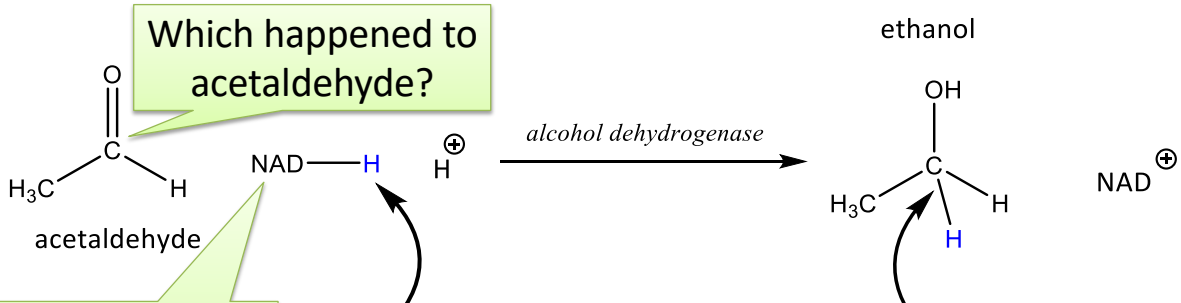
this hydrogen was transfered from the NAD-H with 2 electrons to made a new bond with the carbon

Oxidation and reduction (redox)

Loss of bonds to hydrogen; gain bonds to oxygen

Gain bonds to hydrogen atoms; loss of bonds to O

Which happened to acetaldehyde?



What about NAD?

this is a hydrogen atom covalently bonded via 2 electrons to the larger NAD molecule

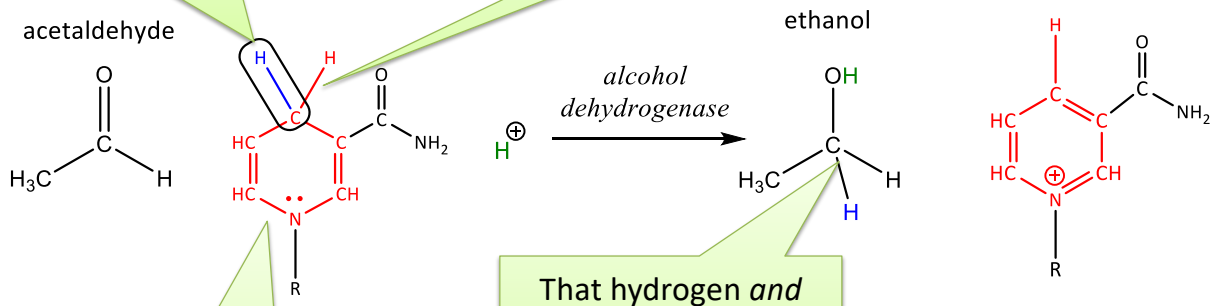
this hydrogen was transfered from the NAD-H with 2 electrons to made a new bond with the carbon

Redox reactions

Oxidation and reduction…can't have one without the other.

NADH has an "extra" bond to hydrogen. This covalent bond to hydrogen is made with 2 electrons.

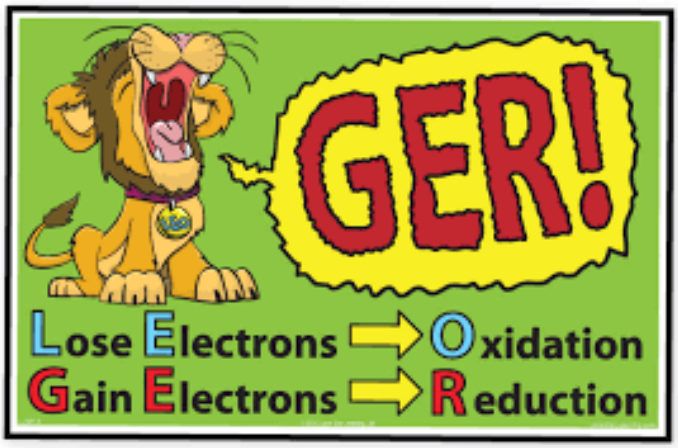
How does "oxidation" describe what happened to NADH?



That hydrogen *and* the two electrons end up here

This is more of what NAD(H) looks like

Redox Reaction



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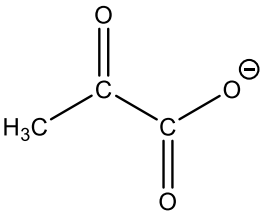
2 Pyruvate $C_3H_3O_3$ + 2 NAD-H + 2 H^+ —*ethanol fermentation*→ 2 Ethanol C_2H_5OH + 2 NAD^+ + 2 CO_2

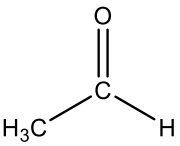
Which enzymatic reaction produces the gas for bread rising?

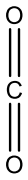
Pyruvate



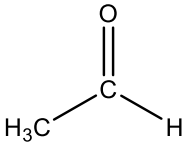
H⊕ —*pyruvate decarboxylase*→ requires the cofactor Thiamin

Acetaldehyde



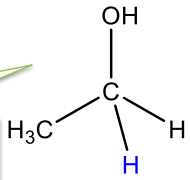


ethanol



acetaldehyde

NAD—H + H⊕ —*alcohol dehydrogenase*→



NAD⊕

The alcohol of beer and wine.