Breaking down molecules for energy

Model 3: All living things consume molecules in the form of food in order to produce energy and build molecules that make up the organism. In this activity, we will consider the *metabolism* of sugar by yeast – *Sacchromyces cerevisae.* It is this very process that produces the gas which puffs up bread dough ("the rise") during in the process of making bread, and the *ethanol* that is the alcohol of beer brewing.

Wheat flour is composed of ~70-80% starch and 7-15% protein.

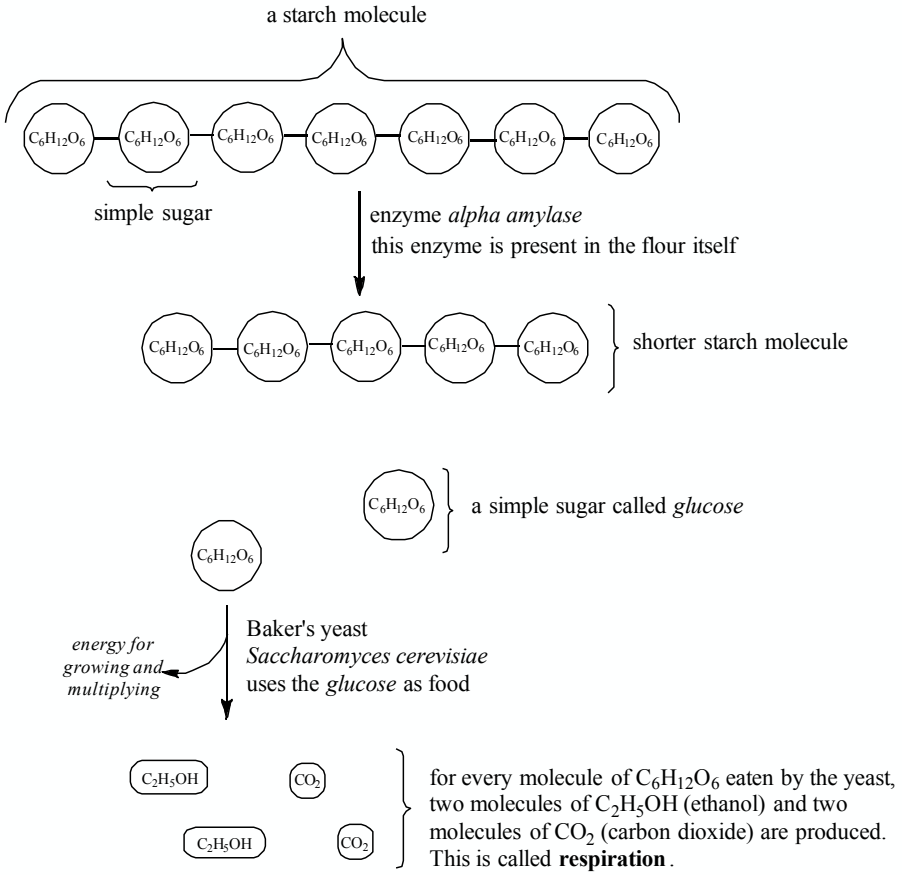


Figure 14.5. The overall breakdown of starch into sugar, then ethanol and CO_2 by yeast.

Let's look more closely at the breakdown of sugar by yeast. 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. How does the process of consuming glucose produce energy? The energy

produced in stored in the form of *high-energy bonds* specifically, the bonds of ATP – *adenosine triphosphate.* The energy released from breaking the phosphodiester bonds can be used to drive difficult chemical reactions – in this way, the cell generates and uses energy to grow and multiply.

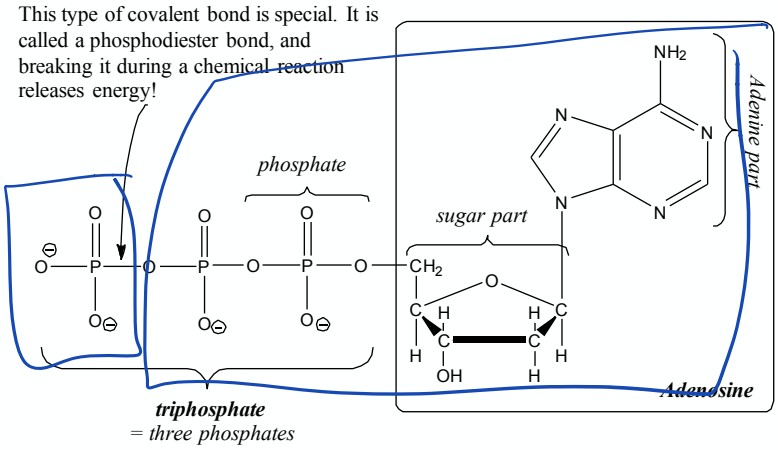


Figure 14.6. The structure of Adenosine Triphosphate, ATP.

When yeast consume glucose, ATP is produced. Consider Figure 14.7 and Table 14.2 below. The process of breaking down sugar to make ATP is called *glycolysis* – "glyco-" for *sweet* and "lysis" for *split* or *break.* At the end of glycolysis there are 2 molecules of ATP produced along with 2 molecules of pyruvate (pronounced PIE-RU-VATE), 2 NAD[6]-H, and 2 H^+. In yeast, the process of ethanol fermentation is designed to recycle the NAD^+ (we will learn more about NAD^+ and its role in Activity X), but the added side benefit for us is that the yeast produce ethanol (for making beer) and CO_2 (for baking bread) in the process.

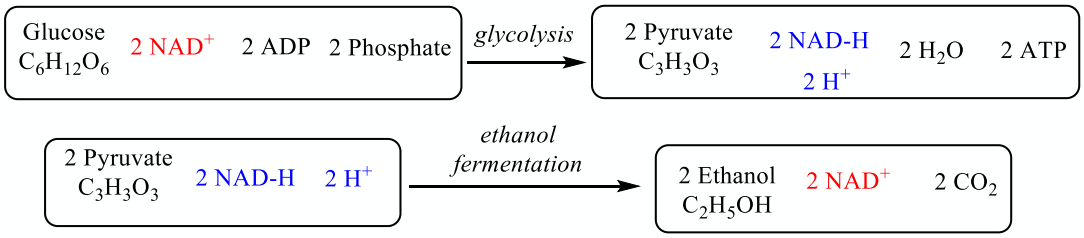


Figure 14.7. The overall equations for glycolysis and ethanol fermentation. In red, the NAD^+ molecule is *nicotinamide adenine dinucleotide*, while the blue NAD-H is *nicotinamide adenine dinucleotide* with an additional bond to another hydrogen atom.

[6] NAD is not a combination of any elemental symbols. It stands for Nicotinamide Adenine Dinucleotide. See Activity 15 for more on NAD.

Table 14.2. The balance of molecules consumed and produced from yeast "eating" sugar. Areas that are grayed out indicate those molecules are both consumed and produced from the process – and therefore cancel out.

	Consumed	**Produced**
Glycolysis	Glucose ($C_6H_{12}O_6$)	2 Pyruvate ($C_3H_3O_3$)
	2 NAD^+	2NAD—H and 2 H^+
	2 ADP + 2 Phosphates	2 ATP and 2 H_2O
Ethanol Fermentation	2 Pyruvate ($C_3H_3O_3$)	2 Ethanol (C_2H_5OH) and 2 CO_2
	2 H^+ and 2 NAD—H	2 NAD^+

Questions:

9. According to Figure 14.5, what does the enzyme alpha amylase do?

Breaks down starch into smaller pieces

10. Complete Table 14.3.

Table 14.3. Quantity of atoms before and after yeast act on sugar

	Quantity (#) of the atom	
	Glucose (before the yeast)	Ethanol + carbon dioxide (after the yeast)
Carbon	6	6
Hydrogen	12	12
Oxygen	6	6

Compare the # of atoms of Carbon before the sugar is eaten by the yeast and after. Do the same for hydrogen and oxygen.

a) What do you notice?

Same # of each

b) So if the atoms themselves didn't change, what did change? Please explain.

The bonds between the atoms

11. "Proofing yeast" requires mixing yeast with sugar and warm water until a "head of foam" forms. What is causing this foam (a foam is a mass of gas bubbles in a matrix of liquid film)? And why does it "prove" the yeast are ok to use?

Yeast eating sugar and producing CO_2. This shows that the yeast is alive

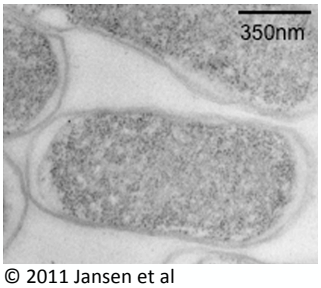
12. When yeast consume sugar, they make the energy molecule ATP in the process of glycolysis. ATP is formed from the molecule ADP through the addition of a phosphate molecule. ADP is *adenosine diphosphate.* On Figure 14.6, draw two boxes around the ADP and phosphate pieces that combined to form ATP.

13. While ethanol fermentation is useful to humans in brewing beer and baking bread, why do the yeast perform ethanol fermentation?

To regenerate NAD^+ so that glycolysis can continue.

Putting it all together:

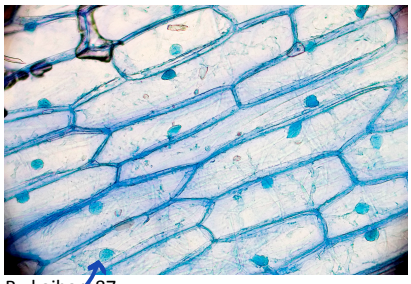
14. Here are some images of cells. Determine if they are prokaryotic or eukaryotic and explain your reasoning:



© 2011 Jansen et al

Salmonella
(Salmonella species cause food poisoning)

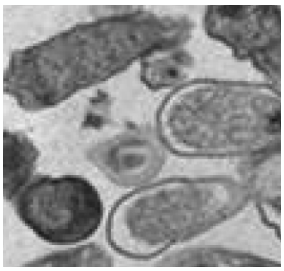
prokaryotic: small
no organelles



By kaibara87

onion cell

nucleus
∴ eukaryotic



© 2013 Ahn et al

Listeria monocytogenes (causes listeriosis, a food borne illness)

prokaryotic
(small & no organelles)

15. Based on your understanding of *eukaryotic* and *prokaryotic*, predict which class the following living things belong to:
    a) Broccoli eukaryotic
    b) A chicken eukaryotic
    c) Lactobacillus – the active ingredient in yogurt prokaryotic

16. Although we are not supposed to mix yeast with boiling water, we are supposed to cook eggs and poultry up to 160-165˚F. Considering, that eggs and poultry are carriers of *salmonella,* what is the purpose of this instruction?

Kills the salmonella by this temperature