Energy Workshop – Week 2 for 7.013 @ ESG

Two main hindrances to using ethanol as an everyday, clean fuel are cost and resource efficiencies. The main source of ethanol currently is corn. The sugars in corn are broken does by assorted enzymes and reactions to produce the desired product. However, so much corn is needed that food prices are increased, which is an obvious drawback. Along the same path, so much corn is used that in terms of resources (land, actual corn, etc), ethanol production is inefficient.

However, the Q bacteria may hold the answer to efficient, cheaper ethanol production. It is one of the few bacteria that convert cellulose directly into ethanol. As the article from the Boston Magazine pointed out, this process usually takes two steps: breaking down cellulose into sugars then the sugars into ethanol.

1) How can enzymes be used to facilitate direct conversion from cellulose to ethanol? What mechanisms could Q's enzymes use to promote the conversion?

2) What is cellulose? Where is it located in a plant's cell? Why is it a good starting point for ethanol formation?

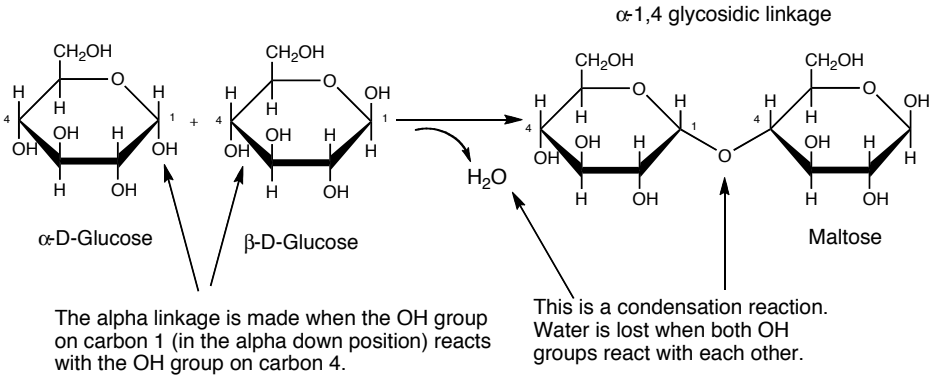
3) What are the 2 main linkages glucose molecules have with each other and other sugars? Could Q possibly be able to break down more than just cellulose? Explain.

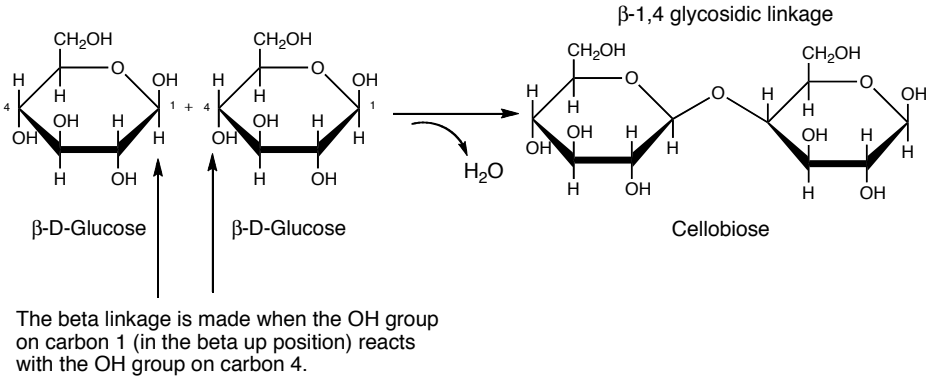
4) The article points out that Q releases dozens of enzymes into water. Thus, Q can dissolve/eat many forms of cellulose or other types of biological material. Could Q be able to produce more other useful alcohol-based fuels? What applications would these have?

5) A key part of the research on Q is being able to optimize its ethanol production. Bacterial harvesting is a popular method for such a purpose. If one Q produces more ethanol than another Q, it can be isolated so it can produce more optimal Q bacteria for ethanol production. What traits of Q can be altered to optimize ethanol production? What techniques may be used to separate Q bacteria from each other?

Solutions to Energy Workshop – Week 2 for 7.013 @ ESG

1) **How can enzymes be used to facilitate direct conversion from cellulose to ethanol? What mechanisms could Q's enzymes use to promote the conversion?**
   Answer:
   Enzymes are used as catalysts to promote the conversion. Catalysts lower the activation energy of a given reaction, enabling it to proceed at a much faster rate. Enzymes can use one of 3 mechanisms for the conversions: 1) They can orient the substrates needed for reaction in such a way that reaction can proceed with ease; 2) They can strain the substrate bonds by stretching them, causing an unstable state, allowing the substrate to react with compounds different than originally intended and 3) They can add different chemical groups to substrates, making the substrates more reactive towards different species.
2) **What is cellulose? Where is it located in a plant's cell? Why is it a good starting point for ethanol formation?**
   Answer:
   Cellulose is an unbranched polymer of glucose with β-1,4-glycosidic linkages that are very stable. It is located in plant cell walls, giving the cells great strength. The bond formed is quite strong. It is a good starting point for ethanol formation because if the linkage is broken, glucose molecules are formed. Ethanol is formed from sugars biologically and glucose is a wonderful starting sugar for this purpose. Glycolysis helps with this transformation, as you will see at a later time.
3) **What are the 2 main linkages glucose molecules have with each other and other sugars? Could Q possibly be able to break down more than just cellulose? Explain.**
   Answer:
   Glucose molecules for two main linkages: alpha linkages and beta linkages. The two examples below provide fine examples of these linkages, both 1,4-glycosidic linkages between two glucose molecules:





Glucose molecules can form these linkages with a wide variety of different sugars at different bonding points. Basically, the alpha linkage will result in the hydrogen atoms

connected to the carbons in the reaction being in the cis plane, directly across from each other, while in the beta position, these hydrogens are trans, or diagonally opposite from each other. Q has the ability to break these linkages in cellulose and should be able to do the same with any glucose-sugar interaction if the enzymes are suited for the breakdown.

4) **The article points out that Q releases dozens of enzymes into water. Thus, Q can dissolve/eat many forms of cellulose or other types of biological material. Could Q be able to produce more other useful alcohol-based fuels? What applications would these have?**
Answer:
Q may possible be able to produce other fuels/alcohols, like methanol, propanol, etc. Methanol has a use in direct methanol fuel cells, which use liquid methanol as the fuel source, much like ethanol is used as the fuel source for cars as above. However, the DMFCs are much more suited for smaller applications in the handheld regime.

5) A key part of the research on Q is being able to optimize its ethanol production. **Bacterial harvesting is a popular method for such a purpose. If one Q produces more ethanol than another Q, it can be isolated so it can produce more optimal Q bacteria for ethanol production. What traits of Q can be altered to optimize ethanol production? What techniques may be used to separate Q bacteria from each other?**
Answer:
The main trait of Q in this case is ethanol production and having the enzymes to do so. Based on ethanol production/enzyme count, one can separate the greater producing Q bacteria out of a group and use it to reproduce more ethanol-friendly Q. This separation can go on and on until a maximum is hit. Techniques that may be used for separation are streak plating, where the bacteria will move on a plate "dosed" with a compound that will facilitate its movement. Another technique used is if you know what compounds can interact with a certain bacteria only, you can "dissolve" the bacteria in this compound and then separate it out using a centrifuge.