1. **What is fermentation? (2 marks)**

Fermentation is a metabolic process in which an organism [converts a carbohydrate](https://www.thoughtco.com/chemistry-of-carbohydrates-603878), such as starch or a [sugar](https://www.thoughtco.com/chemical-formula-of-sugar-604003), into an [alcohol](https://www.thoughtco.com/alcohol-versus-ethanol-3976082) or an acid. For example, yeast performs fermentation to obtain energy by converting sugar into alcohol. Bacteria perform fermentation, converting carbohydrates into lactic acid. The study of fermentation is called **zymology**. **How Does Fermentation Work?**

Microbes use carbohydrates (sugars, such as glucose) for energy to fuel their survival. To make use of that energy, organic chemicals like [adenosine triphosphate](https://www.britannica.com/science/adenosine-triphosphate) (ATP) deliver it when needed to every part of a cell.

Microbes - and our own body cells - use [respiration](https://en.wikipedia.org/wiki/Cellular_respiration) to generate ATP. The most efficient way for them to do that is through a process known as [aerobic respiration](https://en.wikipedia.org/wiki/Cellular_respiration#Aerobic_respiration), which requires oxygen.

Aerobic respiration starts with [glycolysis](https://en.wikipedia.org/wiki/Glycolysis), where glucose is converted into [pyruvic acid](https://en.wikipedia.org/wiki/Pyruvic_acid). Then, when there's enough oxygen around, aerobic respiration takes place.

Fermentation is similar to the kind of respiration that takes place when there isn't enough oxygen present, namely [anaerobic respiration](https://en.wikipedia.org/wiki/Anaerobic_respiration). However unlike respiration, which uses pyruvic acid, fermentation leads to the production of different organic molecules like lactic acid, which also leads to ATP.

Individual cells and microbes have the ability to switch between these different modes of energy production based on the environmental conditions.

1. **Three main types of fermentation (3 marks) Identification of the one used in their food product – 1 mark**

### Ethanol Fermentation

Yeast and certain bacteria perform ethanol fermentation where pyruvate (from glucose metabolism) is broken into ethanol and [carbon dioxide](https://www.thoughtco.com/carbon-dioxide-poisonous-607545). The net chemical equation for the production of ethanol from glucose is:

C6H12O6 (glucose) → 2 C2H5OH (ethanol) + 2 CO2 (carbon dioxide)

Ethanol fermentation has used the production of beer, wine, and bread. It's worth noting that fermentation in the presence of high levels of pectin results in the production of small amounts of methanol, which is toxic when consumed.

### Lactic Acid Fermentation

The pyruvate molecules from glucose metabolism (glycolysis) may be fermented into lactic acid. Lactic acid fermentation is used to convert lactose into lactic acid in yogurt production. It also occurs in animal muscles when the tissue requires energy at a faster rate than oxygen can be supplied. The next equation for lactic acid production from glucose is:

C6H12O6 (glucose) → 2 CH3CHOHCOOH (lactic acid)

The production of lactic acid from lactose and water may be summarized as:

C12H22O11 (lactose) + H2O (water) → 4 CH3CHOHCOOH (lactic acid)

### Hydrogen and Methane Gas Production

The process of fermentation may yield hydrogen gas and methane gas.

Methanogenic archaea undergo a disproportionation reaction in which one electron is transferred from a carbonyl of a carboxylic acid group to a methyl group of acetic acid to yield methane and carbon dioxide gas.

Many types of fermentation yield hydrogen gas. The product may be used by the organism to regenerate NAD+ from NADH. Hydrogen gas may be used as a substrate by sulfate reducers and methanogens. Humans experience hydrogen gas production from intestinal bacteria, [producing flatus](https://www.thoughtco.com/chemical-composition-of-farts-608409).

**Fermentation: Three Main Different Types**

There are [three basic forms](http://modernhippiehw.com/2014/02/08/fermentation-101-basics-fermenting-food/) of fermentation:

1. [Lactic acid](https://simple.wikipedia.org/wiki/Lactic_acid) fermentation; when [yeasts](https://en.wikipedia.org/wiki/Yeast) and bacteria convert starches or sugars into lactic acid in [foods](https://eatcultured.com/blogs/news/fermented-foods-science) like [sauerkraut](https://en.wikipedia.org/wiki/Lactic_acid_fermentation), kimchi, pickles, yoghurt and sourdough bread.
2. [Ethyl alcohol](https://en.wikipedia.org/wiki/Ethanol_fermentation) fermentation; where the [pyruvate molecules](https://en.wikipedia.org/wiki/Pyruvic_acid) in starches or sugars are broken down by yeasts into alcohol and carbon dioxide molecules to produce [wine](https://en.wikipedia.org/wiki/Fermentation_in_winemaking) and beer.
3. [Acetic acid](https://www.sciencedirect.com/topics/neuroscience/acetic-acid) fermentation of starches or sugars from grains or fruit into sour tasting vinegar and condiments. This is the difference, for example, between [apple cider vinegar and apple cider](https://www.livestrong.com/article/497150-what-is-the-difference-between-cider-vinegar-apple-cider-vinegar/).

Each of these kinds of fermentation is down to the work of [microbes](http://learn.genetics.utah.edu/content/microbiome/intro/) specialized at converting certain substances into others.

#### ****What are the three main stages in general food fermentation****

#### ****Different Stages of Food Fermentation****

[Primary fermentation](https://www.homebrewtalk.com/wiki/index.php/Primary_Fermentation) is when microbes rapidly set to work on initial raw ingredients such as fruit, vegetables or dairy.

Initially the microbes present or in the surrounding liquid (such as [brine](http://www.fermentools.com/blog/stages-of-fermentation/) for fermented vegetables) prevent [putrefying bacteria](https://en.wikipedia.org/wiki/Putrefying_bacteria) from colonizing the food instead.

During this short phase, yeasts or other microbes convert carbohydrates (sugars) into other substances such as alcohols and acids. (1 mark process, 1 mark reactants and products named)

[Secondary fermentation](http://winemakersacademy.com/secondary-fermentation/), a term often referred to in winemaking and brewing circles, refers to a longer stage of fermentation that takes place over several days or weeks.

Secondary fermentation occurs when many yeasts and microbes start to die off and their available food source (the carbohydrates) becomes more scarce.

At this stage, the pH of the ferment may be significantly different from when it started out, which also affects the chemical reactions taking place between the microbes and their environment. (1 mark process, 1 mark reactants and products named)

The length and stages of fermentation will vary depending on what's being made. Beer and wine, for example, pass through several different stages of fermentation that behave and look markedly different from each other. (1 mark process, 1 mark reactants and products named)

#### ****Description of food product (3 marks)****

* Brief description - 1 mark
* Detailed description – 2 marks
* Detailed description using chemical terminology - 3 marks

1. Explain how your food product is made, outlining how fermentation is brought about, used and controlled during the process. (6 marks)

* How the product is made is outlined in simple steps/general way (1)
* As above but explains processes (2)
* As above but explain processes in detail (3)
* States the effects of the fermentation process (1)
* Describes how fermentation is brought about and used in the process (2)
* Explain in detail, using scientific terminology, how fermentation is brought about, used and controlled during the making of the product (3)

1. **Explain how the fermentation process is halted. (3 marks)**

* States how process is halted (1)
* States how process of fermentation is halted to ensure the product made is as should be (2)
* Discusses in detail at what point the process is halted and why, including why that ensures the product is not spoiled or has the correct properties (3)

1. **Explain how the food product is stored so that it is kept in the best condition for consumption. (3 marks)**

* States how product is stored (1)
* Explain how the product needs to be stored to keep it in the optimal condition(2)
* Discusses in detail the storage of the product in terms of chemical reactions that enable it to be kept in optimal condition (3)

#### ****Getting Fermentation Started****

While many microbes are naturally present in the air we breathe, fermentation often requires a specific "starter" set of cultures.

Making fermented vegetables, on the other hand, is a more gradual process composed of several phases that don't require as much direct intervention to manage.

Many of the commercially available fermented foods today are produced using select microbes whose role in producing healthy fermented foods has been scientifically evaluated.

These microbes can be introduced into food in a number of different ways. Many [cultured dairy](http://nourishedkitchen.com/cultured-dairy-foods/)products, for example, start with dairy [grains](https://www.culturesforhealth.com/learn/milk-kefir/how-to-find-milk-kefir-grains/) or specific strains of milk-loving cultures, which are commercially cultivated.

The flavor and textures of products such as yoghurt and cheese can be manipulated by selecting specific starter cultures. The environment in which they're produced can then further refine these qualities.

Similarly many wines and craft beers owe their particular characteristics to the wild or commercially cultivated yeasts used to produce them. These can be added during the [brewing process](https://eatcultured.com/blogs/news/fermented-foods-science).

The subsequent production and [aging process](https://en.wikipedia.org/wiki/Aging_of_wine) for these products should ideally be controlled to prevent spoilage through external microbial contamination.

[Kombucha](https://en.wikipedia.org/wiki/Kombucha) requires a [SCOBY](https://en.wikipedia.org/wiki/SCOBY), or collection of microorganisms that turn tea into a sparkling fermented drink. Similarly fermented sodas are crafted using a "[bug](https://lustrecollective.com/blog/2016/7/25/turmeric-ferment-recipe)," or collection of starter cultures.

Once fermentation begins, controlling the rate of fermentation and end product is all down to the balance of water and sugars, temperature and time.

This bringing this science and craft of fermentation into new categories of products to make them healthier, more nutritious and tastier is what we specialize in at [eatCultured](https://eatcultured.com/blogs/our-awesome-blog/eatcultured.com" \t "_blank). Like a perfume maker, we select and team-up with natural microbes to revolutionize everyday products like coffee. We believe microbes are the future of sustainable healthy food.

#### ****Fermentation: Protecting Your Food****

Exposing your fermenting food to air can not only prevent proper fermentation from taking place but also increase the risk of spoilage and food poisoning.

There are a number of ways to prevent this.

Solution

Aside from being a part of many recipes, submerging fermenting food in brine (a [salt](https://www.culturesforhealth.com/learn/natural-fermentation/how-much-salt-brine/) solution) prevents it from coming into contact with the air. This method works for solid pieces of food like chopped vegetables.

The exact [pH](https://en.wikipedia.org/wiki/PH) of the fermentation, which governs how much [oxygen will be present](http://modernhippiehw.com/2014/02/08/fermentation-101-basics-fermenting-food/), can also be controlled through the addition of vinegar.

Storage

Many home fermenters use containers such as a [mason jar with a lid](http://ferment.works/blog/2015/4/21/fermenting-vegetables-in-a-mason-jar-2-basic-techniques) or storage containers where food can be sealed and stored for long periods without air contamination.

Typically this equipment will have a valve or release to vent carbon dioxide released during fermentation unless the end product (wine or kombucha, for example) benefits from carbonation.

Alternatively sealed containers can be opened on a regular basis to manually let trapped carbon dioxide out. This process requires more careful monitoring to prevent food spoilage.

#### ****Managing Fermentation****

Microbes typically like to work in a warm, [room temperature](https://eatcultured.com/blogs/news/fermented-foods-science) environment. The exact temperature range will vary based on the types of microbes involved and product that's being fermented.

Changing the temperature can have a big impact on fermentation. Moving a fermenting product to a cooler temperature, for example by placing it in the fridge, will slow down the rate of fermentation or stop it altogether. Heating a ferment too much may kill the microbes doing the fermentation.

Commercial fermentation requires specialist equipment such as [fermentation tanks](https://beerandbrewing.com/dictionary/YCCmYUmOuv/fermentation-vessels/) for brewing beer, for example. Using special equipment enables fermentation to be controlled and standardized at scale.

Aside from these basics, the rest of the fun is all down to the recipe!

## Selecting Yeast in Beer Brewing and Wine Making

Humankind has benefited from fermentation products, but from the yeast's point of view, alcohol and carbon dioxide are just waste products. As yeast continues to grow and metabolize sugar, the accumulation of alcohol becomes toxic and eventually kills the cells (Gray 1941). Most yeast strains can tolerate an alcohol concentration of 10–15% before being killed. This is why the percentage of alcohol in wines and beers is typically in this concentration range. However, like humans, different strains of yeast can tolerate different amounts of alcohol. Therefore, brewers and wine makers can select different strains of yeast to produce different alcohol contents in their fermented beverages, which range from 5 percent to 21 percent of alcohol by volume. For beverages with higher concentrations of alcohol (like liquors), the fermented products must be distilled.