Biotechnology
What is biotechnology?

Biotechnology is a field of applied biology that involves the use of living organisms and bio-processes in engineering, technology, medicine and other fields requiring bio-products.

Its major uses are in the production or preservation of food.

Using scientific methods with organisms to produce new products or new forms of organisms.
Traditional biotechnology

For many centuries the process of fermentation has used micro-organisms (yeasts and bacteria) to make beer, yogurt, cheese bread making, and pickling.

The basis of the fermentation process is the conversion of glucose (sugar) to alcohol or to lactic acid by enzymes in the micro-organisms.
What is the uses of fermentation?

- It can be used for preservation, converting a perishable food into one that has a longer shelf-life.
- It can be used to change the nutritional value of food products, e.g. converting milk to cheese.
- It can create or improve sensory characteristics of foods (flavour, aroma and texture).
FERMENTED BEVERAGE
Types of fermented beverage

Alcoholic beverages are divided into three general classes: **BEERS**, **WINES**, and **SPIRITS**.
BEER
Beer making

• **Ingredients**
  • Malted barley,
  • Hops,
  • Yeast and
  • Water.
Beer making

- **Barley** -- a grain and the base ingredient of beer.

- **Hops**--the ripe, dried blossoms of a perennial vine, in the mulberry family.
  - Hops add a **bitter flavor, pleasant aroma** to beer and **help to preserve it**.
Beer making

- **Yeast** -- an important ingredient of the beer.
  - This is a single celled fungus that plays the central role in converting sugars into carbon dioxide and alcohol during fermentation.
  - Two main varieties of yeast.
    - *Saccharomyces cerevisiae*.
    - *Saccharomyces carlsbergensis*.

- **Water** -- beer is at least ninety percent water, special consideration is given to how the water tastes before it goes into the brew kettle.
Beer making

• Malting
• Mashing
• Fermentation
• Sedimentation
• Aging
Beer making

1. Malting

– barley are allowed to soak in water for about 2 – 3 days.
– Once the barley grains reach 40-45% moisture the barely is allowed to germinate.
– Germination of the grain allows for plant enzymes to convert starch into more simple sugars like amylases.
– Once the epicotyl forms, the grains are dried.
Beer making

2. Mashing

- Dried barley has to be cracked open so that water can get inside and activate the enzymes.
- It is mixed with water (65°C).
- They convert the amylase from the barley into simple sugars maltose. This process is known as mashing. (starch to maltose and glucose)
- After the solids are strained out the dark, sweet liquid is called "wort"
- The wort must be boiled for 30-90 minutes depending on the recipe.
Beer making

3. Hops are added at different times during the boiling phase.

- Hops contributing to the **bitterness of the beer** are added **early in the boil** so the resins have time to dissolve into the wort.
- Hops that are added for their **aromatic flavoring** are added **within the last few minutes of the boil**. Otherwise the quickly dissolved oils get steamed out of the wort.
Beer making

3. Fermentation

- The *wort* is cooled, so the yeasts to be added next don't die.
- The yeast is allowed to ferment the wort for up to 5-14 days, depending on the type of beer.
- During this phase, the *alcohol* is made and the *carbonation* is allowed to escape through the fermentation lock.

4. Sedimentation

- After this, the dead yeast, proteins and hop resins are allowed to settle out, helped by ‘clarification agents’.
Beer making

5. Aging.
The bottles are then set aside in a cool, dark place and left untouched until ready to drink.
  • "Green beer" can be drunk at one week after bottling.
  • Most homebrewers leave their beer sit three or four weeks before the first bottle is opened.
• **Ale yeast**-favor higher temperatures between 17 -22°C, usually **top fermenting** with a **greater O$_2$** requirement. This is usually *Saccharomyces cerevisiae*.

• **Lager yeasts**-favor lower temperatures 1.6-10°C, usually **bottom fermenting**, with a **lesser O$_2$** requirement. This is usually *Saccharomyces uvarum* (formerly known as *Saccharomyces carlsbergensis*).
Beer making

• Yeast is added to the wort. The commonly used species of yeast are *Saccharomyces cerevisiae* and *S. carlsbergensis*. Enzymes in the yeast convert maltose to glucose. In the early stages of fermentation, yeast respires aerobically, oxidized the glucose to carbon dioxide and water and dividing rapidly. As the oxygen supply diminishes, anaerobic respiration takes over and the glucose is oxidized only as far as alcohol and carbon dioxide.
Beer making

– Respiration--the yeast converts simple sugars to carbon dioxide and water. The yeast obtains it's energy for fermentation and sedimentation during this phase.

– Fermentation--the conversion of sugar to alcohol and carbon dioxide. It is the longest of the three phases.

– Sedimentation--the yeast cells settle to the bottom of the fermentation vessel because most of the sugars have been converted and utilized for respiration, and the begin to prepare for dormancy. Sedimentation last for 2-3 days. At the time the beer appears clear, the yeast's density is less than 1 million cells per milliliter.
Process of Beer Production

1. Germinate, dry Barley
   - Amylases formed in seedling
2. Malt
   - Starch
   - Amylases
   - Maltose
3. Grind, incubate in water
4. Wort
5. Hops
6. Fermentation
   - Maltose
   - Glucose
   - Ethanol + CO₂
7. Beer
Beer making.flv
How is Beer Made  The Brewing Process.flv
Question

1. Beers are broken into two basic types, of which sub-types are created.
2. What does yeast eat?
3. Which grain most often used to make beer?
4. How the colour in the beer is derived from?
5. What are the two important by-products of fermentation?
Summary

• Barley is soaked in water for 2-3 days.
• Allowed to germinate.
• Germinated grain is crushed and dried.
• Water is added to the dried grain and heated.
• Grain separated from liquid (wort).
• Yeast and hops added.
• Anaerobic respiration - Glucose – CO\(_2\) and alcohol. Top – fermenting is ales, Bottom fermenting is lagers
• It is pasteurized.
Fermented Foods

• Wine
  – “Wine is Fine”
  – Produced from the fermentation of fruit juice, usually from grapes

  • For white wines, white grapes are usually used, and the skins are removed from the must (“pressing”) before fermentation
  • For red wines, red or black grapes are used, and the skin is allowed to remain during fermentation
  • For rosé wines, red grapes are used and the juice is allowed to remain in contact with the skins just long enough for a rose or pink color to develop
Processing Lines

• There are five basic components or steps to making wine:
  
  • Harvesting
  • Crushing and Pressing
  • Fermentation
  • Clarification (sedimentation)
  • Aging and Bottling
The Harvest

• Harvesting or picking is certainly the first step in the actual wine making process.

• In order to make fine wine, grapes must be harvested at the precise time, preferably when physiologically ripe.

• Harvesting can be done mechanically or by hand.

• Once the grapes arrive at the winery, reputable winemakers will sort the grape bunches, culling out rotten or under ripe fruit before crushing.
Crushing and Pressing

• Crushing the whole clusters of fresh ripe grapes is traditionally the next step in the wine making process.

• Today, mechanical crushers perform the time-honored tradition of stomping the grapes into what is commonly referred to as must.

• Mechanical pressing has also improved the quality and longevity of wine, while reducing the winemaker's need for preservatives.

• Up until crushing and pressing the steps for making white wine and red wine are essentially the same.
• The extracted juice is treated with sulphur dioxide to kill bacteria and naturally occurring yeasts.
• The **sugar content and pH** are adjusted before adding a starter culture of yeast, usually a variety of *Saccharomyces cerevisia*.
• Natural yeasts on the skins of the grapes may be used, but in commercial production cultured yeast is often used to give more predictable results. The amount of sugar in the liquid during fermentation is measured with a **saccharometer** (a calibrated hydrometer).
Fermentation

• Fermentation is indeed the magic at play in the making of wine.

• Many winemakers prefer to intervene at this stage by inoculating the natural must.

• Fermentation can require anywhere from ten days to a month or more.

• Sweet wine is produced when the fermentation process stops before all of the sugar has been converted into alcohol.
Clarification

• Once fermentation is completed, the clarification process begins.

• Filtering and fining may also be done at this stage.

• Often, winemakers will add egg whites, clay, or other compounds to wine that will help precipitate dead yeast cells and other solids out of a wine.

• These substances adhere to the unwanted solids and force them to the bottom of the tank. The clarified wine is then racked into another vessel, where it is ready for bottling or further aging.
Aging and Bottling

• The final stage of the wine making process involves the aging and bottling of wine.

• After clarification, the winemaker has the choice of bottling a wine immediately.

• Further aging can be done in bottle, stainless steel or ceramic tanks, large wooden ovals, or small barrels, commonly called barriques. The choices and techniques employed in this final stage of the process are nearly endless, as are the end results. However, the common result in all cases is wine. Enjoy!
Why is acid balance (pH) important in wine making?

• Fruit, including grapes, contain different types of acids. Too much acid renders a wine undrinkable. On the other hand, if wine does not have enough acidity, the result is a flat or insipid tasting wine. That's why it's important to check the acid levels and adjust if necessary.
Why is sulphite added in wine?

Sulphite is a natural bacteria inhibitor. A small amount of sulphite in your wine will not only discourage bacteria that could ruin it, but it also helps prevent oxidation.
Why is clean equipment important in wine-making?

• Unwanted **bacteria** will compete with the wine-making yeast and have the potential to ruin the wine
How sweet wine is produced?

• Sweet wine is produced when the fermentation process stops before all of the sugar has been converted into alcohol.
Why does wine ‘go off’ if left exposed to the air?

• Yes, especially red wine. The wine gets oxidized. That is why some serious wine connoisseurs either finish a bottle of wine or they have a re corking system that replaces any air with nitrogen.
Question

1. In the winemaking process, what is the name for the crushed grapes and juice?
2. What gives red wines their dark colour?
3. Name the alcoholic drinks produced without distillation.
Fermented Foods

• YOGURT yuuummmmyyyyy

• Milk from cows, sheep or goats may be used to prepare yoghurt.

• Yogurt usually use mixture of 2 cultures:

Streptococcus thermophilus and Lactobacillus bulgaricus

• Fermented at 28-32 °C
YOGURT

• On a commercial scale the fat and protein content of the milk is adjusted

• The milk is homogenized.

• The milk is then pasteurized.

• Breaks up fat droplets and prevents them from separating.

• Destroys pathogenic bacteria and other micro-organisms
YOGURT

• Then it is fermented by adding a ‘starter culture’ of bacteria, usually a mixture of *Streptococcus thermophilus* and *Lactobacillus burgaricus*.

• These bacteria act on the milk sugar, *lactose* and convert it to *lactic acid* which, in turn coagulates the milk protein, *casein* to produce the thick creamy consistency of yoghurt.
Yogurt

• The fermentation works best at a temperature of 46°C and, when complete, the yoghurt is cooled to 5°C to stop the bacterial processes.
• The lactic acid gives the yoghurt its slightly sour taste.
• Throughout the process, the materials and containers must be kept in a sterile condition, i.e. free from any micro-organisms that might compete with the *Streptococcus* and *Lactobacillus* and produce unwanted substances.
  – Acid produced from the fermentation causes the protein in the milk (casein) to coagulate into a semisolid curd
  – If you want strawberries or peaches, you must add them after the yogurt is made
Health Benefits of Yogurt

* Yogurt helps in boosting one's immune system.
* Yogurt helps in fighting Candida yeast infections.
* Yogurt is rich in calcium and thus, keeps the bones strong and reduces the risk of osteoporosis.
* Yogurt is well known for its anti-inflammatory properties.
* Yogurt heals skin disorders faster.
* Yogurt aids in keeping eating disorders in check.
The Art of Cheese-making:

Milk is **homogenized** and **pasteurized** and cooled to around $30^0\text{C}$ and add the starter culture.
• **Acidification**: *Starter culture* is added to milk to change lactose (milk sugar) into lactic acid. This process changes the acidity level of the milk and begins the process of turning milk from a liquid into a solid called curdling.

• **Coagulation**: *Rennet* is added to further encourage the milk to solidify.

• **Curds and Whey**: Curds are cut using a knife or a tool that resembles a rake. Cutting the curds further encourages them to expel liquid, or whey.
Cheese-making:

• Rennet, which was traditionally obtained from the stomach of unweaned calves. It reacts with the casein protein in the milk to convert it into curd, the main element of cheese.
Cheese-making:

• After Cutting ………

• **Cooking** - After the cutting step the curd is cooked. This is done to expel moisture.

• **Draining** - Once a fairly solid mass of curd is obtained, it is pressed to expel further whey. This either done in block forming towers (dry salt production) or collected in moulds and pressed further (brine salt production). Salt is added before this process in dry salt production while brine salt production sees the cheese being immersed in a brine solution after being in moulds.

• **Ripening** - The cheese is left to ripen in a temperature controlled environment. This ripening period allows the various enzymes, acids and bacteria to spread throughout the cheese, developing each cheese's distinctive taste.
How it's Made  Cheese.flv
Summary

• Cheese
  – Milk is treated with lactic acid bacteria and an enzyme called rennin that partially hydrolyses the protein and causes it to coagulate into “curds.” The liquid portion of the milk at this time is called “whey.”
  – The whey is separated from the curds, and the curds are aged (“ripened”)
  – Different microbes in the early and late stages of processing give rise to cheeses with different characteristics
Question

• In which food would you find lactic acid bacteria? Mention some of their useful applications.

• What organism is used to make yogurt?

• Name the first organic acid produced by microbial fermentation.

• *Lactobacillus* usually grows in ________ and produce ________
Bread Making

• In bread-making, cereal grain is crushed to form flour, thus exposing the stored starch. Water is added (making a dough) to activate the natural enzymes, e.g. amylases, in the flour, which then hydrolyse the starch via maltose into glucose.
Bread Making

- Yeast, *Saccharomyces cerevisiae*, is added which uses the glucose as a respiratory substrate, producing carbon dioxide. This carbon dioxide forms small bubbles which become trapped in the dough; upon baking in an oven these expand giving the bread a light texture. A protein called gluten gives the dough a sticky, plastic texture which holds the bubbles of gas.
Bread Making

- Dough is often kneaded – a process which traps air within it. This not only helps to lighten the bread directly but also provides a source of oxygen so that the yeast can respire aerobically, producing a greater quantity of carbon dioxide. Some anaerobic respiration nevertheless takes place and the alcohol produced is evaporated during baking.
Gasohol production

- Ethyl alcohol or ethanol,
- Molasses - the thick brown uncrystallized syrup obtained from sugar during refining
- Bagasse – once the sugar is extracted from the sugar cane, the fibrous waste is called bagasse.
- Used as a source of cellulose for some paper products and can be dried and burnt as power source for distillery.
BIOGAS ENERGY
WHAT IS BIOGAS?

• Biogas is a methane rich flammable gas that results from the decomposition of organic waste material.
• Biogas Energy is the use of biogas to produce heat or power.
**ANIMAL MANURE DIGESTER**

- The Anaerobic Digestion of animal waste creates *methane*.
- A container known as a *digester* is filled with appropriate waste (domestic rubbish, sewage or agricultural waste can be used) to which is added a mixture of many bacterial species, e.g. *Methanobacterium* spp.

- The anaerobic fermentation of these wastes yields *methane*, which is collected ready for use for cooking, lighting or heating.
• The remaining solids can be used for:
  – Fertilizer
  – Animal bedding (sterilized of all pathogens)
BIOGAS MAY BE USED TO PRODUCE HEAT AND POWER

• The cleaned methane can be piped to an engine or turbine and generator to produce electricity or sent through the pipeline as a usable gas.
Wastewater –
Its Journey to Treatment and Return to the Environment
Where does it all go!

Where does the water from the washer go?

When you flush the toilet where does the contents go?

By gravity flow, the waste is on its way to your local wastewater treatment plant!
Sewage Plant

• Sewage contains all the waste from the baths, sinks, and lavatories of homes and factories.

• A sewage plant makes the water safe to be passed back into the waterworks.

These are the jobs it carries out.
3 stages of treatment.

Primary.
This is only a **physical separation** to remove solid matter.
Effluent is allowed to settle for a few hours.

Secondary.
The organic and nutrient load is decreased by **microbial activity** or **biological treatment**
Up to 95% so that the effluent is of a quality to be able to go into rivers.

Tertiary.
This is a complete treatment, but it is very expensive and not used much.
When the treatment is done…

- Sludge – very nutrient rich
  - applied directly to land as fertilizer
Advantage of the anaerobic bio-digester

• The bulk of the sludge is greatly reduced.

• The high temperatures of anaerobic fermentation destroy potential pathogens so that the residue can be safely used as a soil conditioner or compost and the remaining liquid can be used or sold as a liquid fertilizer.

• The odours are greatly lessened (particularly valuable in intensive cow or pig farms).

• Dumping of sludge is reduced and the potential for water pollution with farmyard slurry is avoided.

• The methane (‘biogas’) is a valuable, relatively non-polluting source of energy.
Question

- Name the compound found in biogas.
- Name the compound found in gasohol.
- What kinds of microorganisms are employed in the treatment of sewage? Give their activities.
- What are the different uses of biogas?
- Explain the working of a biogas plant.
Summary

• Biotechnology is the application of living organisms, systems or processes in industry

• Many biotechnological processes use micro-organisms (fungi and bacteria) to bring about the reactions

• Most biotechnological processes are classed as ‘fermentations’.

• Fermentation may be aerobic or anaerobic.
Summary

• Yoghurt and cheese are made from fermented milk using bacteria.
• Beer and wine are produced from fermented sugars using yeast.
• **Hops** is a plant, the flowers of which give the bitter flavour and aroma to beer.
• Antibiotics are produced from bacteria and fungi.
• Sterile condition are essential in biotechnology to avoid contamination by unwanted microbes.
• **Bacteria** and protozoa play an essential role in the purification of sewage.
• Fermentation
  – Fermentation in food processing typically is the conversion of carbohydrates (sugar) to alcohols and carbon dioxide or lactic acids using yeasts, bacteria, or a combination thereof, under anaerobic conditions used for making certain foods.

• Beer:
  – Alcoholic beverage made from barely grain that has been fermented by the yeast

• Wine:
  – The grape juice is fermented with the help of Saccharomyces cerevisiae
• Biogas:
  – Biogas typically refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. It is a mixture of methane and carbon dioxide, produced by anaerobic digestion of organic waste matter, used as a fuel.

• Methane:
  – It is a fuel which is produced by anaerobic fermentation from the wastes yields.

• Gashol:
  – Gasohol a gasoline substitute consisting of 90% gasoline and 10% grain alcohol by fermenting agricultural crops or crop wastes.

• Sewage:
  – Waste matter carried away in sewers or drains.