Biology Grade 12 unit one

Unit one

Applications of Biology

- Applications of Biology in our day-to-day Life is numerous.
- Biology is a science in charge of studying all living beings.
- It helps to understand every living organism from the smallest bacteria to the biggest blue whales.
- Biological science is very useful science to determine where some diseases and pests come from such as infections, animal pathologies and damages to plants.
- Biology covers the study of functions of living organisms, the evolution of species, the factors that produce diseases as well as the discovery of new drugs.
- This discipline allows human beings to explore topics such as genetic engineering, research applications with mother cells, and the global warming.
- It also helps to understand nature and how humans, animals and plants interact in life.
- Biology gives the vision of;
  - ➢ how living things evolve,
  - ➢ understanding the rate of extinction,
  - ➢ how species depend on and affects the habitats where it lives,
  - ➢ improving the effectiveness of conservation.
- A practical application of biology with which most people are familiar with is hand washing, domestication, and traditional fermentation.
- Regular soap washing removes acquired microbes from the skin and help control the spread of infectious diseases,
- other applications of biology are in next topics.

1.1. Application in Conservation of natural resources

- **Conservation** is the careful maintenance and wise use of natural resources to prevent them from disappearing.
- **Natural resources** are physical supplies that exist in nature (or actual and potential resources supplied by nature).
- These include **soil**, **water**, **air**, **plants**, **animals**, and **energy**.
- **Conservation biology** is a mission-oriented science that focuses on how to protect and restore biodiversity.
- Ethiopia has **many** natural resources, such as: **gold**, **platinum**, **potash, limestone**, **natural gas, coal**, etc.
  - **timber**s, **crop plants** and **coffee** plantations.
  - many different **species of animals** and **plants**, which make up **rich ecosystems** and
  - many different **breeds of domestic animals**.
- Natural resources can be classified as
  1. **renewable** or
  2. **non- renewable**.

1. Renewable resources are capable of being produced indefinitely, not used up.
  - they are mainly living things and their products.
  - When managed carefully, they can be **used**, **reused**, and **replaced**.
  - the main sources of renewable resources are the sun, winds, water, the earth's heat (geothermal) and the biomass (living things)
  - Examples of renewable resources are **crop plants**, **trees**, **cattle,** and **chickens**.

2. Non-renewable resources are not living things, and when they are used, they **cannot be replaced** or **easily made**.

- Examples of non-renewable resources include **metals** such as **gold** and **iron** and **fossil fuels** such as **gas**, **coal,** and **gas oil**.
- Even **renewable** resources **can be lost** if we do not manage them carefully.

- Because trees able to produce new trees, forests can last for about thousands of years.
- But, if all the trees are cut down and used for timber at once, the forest will not be able to renew itself and all the species within it will be lost.
- Similarly, if an animal is hunted until there are no more of that species left or its habitat is destroyed it can no longer feed or breed.
- As a result, other **natural resources** will be **lost forever** when the species become **extinct.**
- Species may be **lost** in a **particular area,** or they may be **lost everywhere** in the **world** when they are extinct.
- Therefore, biology plays a vital role in creating awareness on the **natural resources conservation**, **development**, and **genetic resources conservation**.
- Biologists take positions in conserving species and saving them from extinction through **preservation** of animals and plants in terms of **zoos, wildlife reserves**, establishing **national parks**, **sanctuaries**, **seedbanks,** or **gene banks,** and by **stopping the destruction** of their natural habitats.
- **Conservation** is the **protection** and **preservation** of our natural environment so that
  - **non-renewable** resources are used **sparingly**, and
  - **renewable resources** are **managed properly** so that they can **last for a long period of time** in the future.

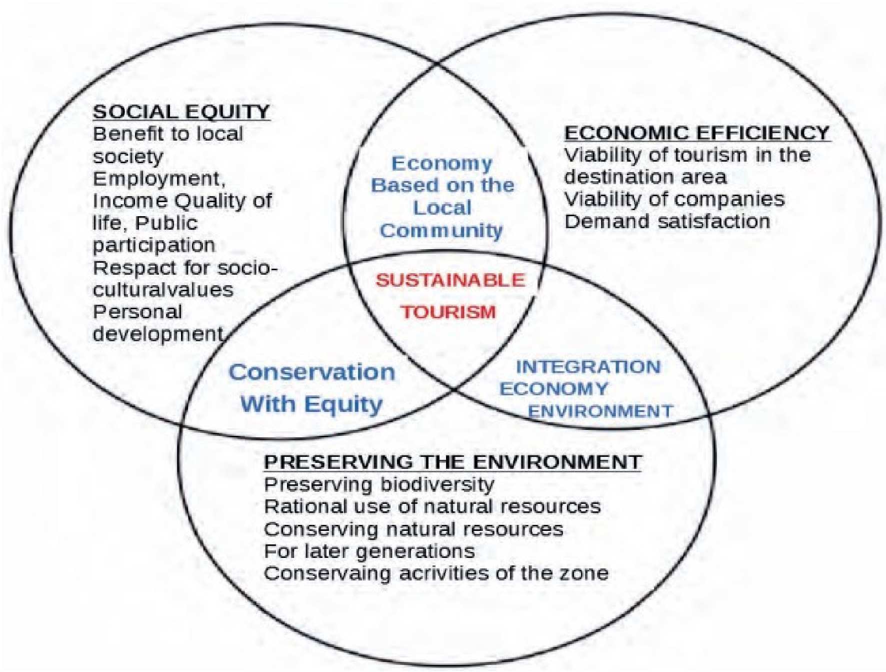
1.2. Food and nutrition security

- **Food security**, as defined by the United Nations' Committee on World Food Security, is a state in which **all the people** have **physical**, **social**, and **economic** access to **sufficient**, **safe**, and **nutritious food** that meets their **food preferences** and **dietary** needs for an **active and healthy** life at all times.
- However, food insecurity is often **rooted in poverty** and has **long-term impacts** on the potential of families, communities, and countries to develop and prosper.
- Prolonged undernourishment **stunts growth**, **slows cognitive development** and increases susceptibility to illness.
- **Nutrition security** is a situation whereby individuals have access to
  - sufficient, safe, and nutritious food,
  - safe water and adequate sanitation, and also
  - the ability to access health services, and
  - the knowledge of sound household and community practices in a childcare, food storage and preparation and hygiene.
- Therefore, food security is ensured only if:
  - ✓ **enough food** is available for all in a county and
  - ✓ when all individuals have the capacity to buy **food of acceptable quality**, and
  - ✓ when there is **no barrier** to access food.
- Biology plays a key role in **producing high-nutrient staple crops** and **developing new products** that can **combat malnutrition,** and thereby **improving food utilization.**

- Biotechnologists design the **manufacturing processes** and **machinery** used to produce food and drink.
- This allows products to have consistent **flavor**, **color**, and **texture** to be produced in large quantities.

1.3. Creating conscious citizens and ensuring sustainable development

- A **conscious citizen** is
  - one who places value on being fully human while connecting with a higher purpose.
  - one who values human life and the relationship with all living things, and
  - one who takes the responsibility for transforming skills into action through ethical decision making, to ultimately improve life and living on the planet.
- Biology has a vital role in creating **conscious citizen**
  - ✓ by expanding awareness of the **social**, **global**, and **environmental** conditions,
  - ✓ by empowering people to assume **personal responsibility**,
  - ✓ **by engaging in**,
  - ✓ **by being committed to** and **initiating positive impact**.
- Nowadays, the interplay of biology and technology or **biotechnology** has become vital in facilitating the sustainable development and diminution of degradation of nature.
- conscious citizen will use the biotechnology application to improve life on earth.
- **conscious citizen biologist** develop **innovative** and **cost-effective** bio-based technologies which;
  - ✓ consume fewer resources,
  - ✓ incorporate recycling,
  - ✓ reuse components, and reduce production of wastes, and
  - ✓ use strategies/methods for sustaining greener earth and improving production.



A model for sustainable development

- According to the world conservation union (IUCN, 2006) the three dimensions of sustainability (economic, social and environmental) are represented as pillars, embedded circles or in popular above Venn diagrams of three overlapping circles.

- The conscious global citizens (biologists) in Ethiopia involved in sustainable development through
  - protecting, managing, and monitoring the existing resources of our land including: analyzing soil, water, and air for chemical pollution.
  - Finding ways to clean up pollution.
  - Identifying, recording, and monitoring the plants and animals that share the land we use.

1.4 Applications in biotechnology

- **Biotechnology is** the applications of technologies that involves the **use of living organisms** or **products from living organisms**(enzymes) for the development of products that **benefit** human.
- **Genetically modified organisms** (**GMOs**) have received genetic materials via recombinant DNA technology (**genetic engineering**).
- If an **organism** has received genetic material from different species, it is called **transgenic organism**.
- A **gene** from one species that is introduced to another species is called **transgene**.
- Crops can be genetically modified to **increase yields** and to **obtain novel products**.
- Biotechnology can be used in the prevention and mitigation of contamination from **industrial**, **agricultural**, and **municipal wastes**.
- biotechnology also can be used in **diagnosis** and **treatment of diseases**.

i. Applications of biology in food processing and production

- This method involves the **increasing** of food productivity **using microorganisms**.
- A technology that shows some promises in **increasing world food productivity**.
  E.g., **Single Cell Proteins** (SCP) can be produced from wide range of microorganisms.
  - Best examples are **mushroom**, **spirulina**, **yeast, green algae.**
  - **SCP technology** is a promising area in **alleviating food security** in ever-growing population.

❖ **Mycoprotein** means 'protein from fungus' produced using the fungus ***Fusarium venenatum.***

- Mycoprotein, a **pale yellow solid** with a **faint taste of mushrooms,** is a **high protein**, **low-fat meat substitute** used by **vegetarians.**

❖ **spirulina** is **dark pellets** or **powder** filled in the bottles, found in **Health** food stores.

- It is made from culture of a spiral-shaped cyanobacteria called spirulina.
- **Spirulina** is harvested from the surfaces of the **lakes** and **ponds** where it grows in great mats.
- In some parts of **Africa, Asia**, and **Mexico,** spirulina has become a **viable alternative** to green plants as **primary nutrient sources**.
- It can be eaten in a **natural form** or can be **added to** other **foods** or **beverages.**

❖ **Vitamins** are also produced using biotechnology.

- **Vitamin C** was the first vitamin to be produced during **fermentation** process by using bacteria.
- **Vitamin B12**(cyanocobalamin) and **vitamin B2**(riboflavin) were obtained from **animal liver** extract.
- But now days, the production of **vitamin B12** involved **propionic bacteria.**
- In nature **vitamin B2** is found in **cereals, vegetables,** and **yeast** but the **yields** of vitamin B2 can be **enhanced** 100 to 300-fold by **using microbes.**

A. Dairy products

- **Wide variety of dairy products** is made by different kinds of microorganisms.
- **Cultured buttermilk**- is made by adding *Streptococcus cremoris* to pasteurized skim milk and

allowing fermentation to occur until desired consistency, flavour, and acidity are riched., and popular in the developed countries,

- *Streptococcus lactis,*
- *Streptococcus diacetylactis,*
- *Leuconostoc citrovorum,*
- *Leuconostoc cremoris.*
- *Leuconostoc dextranicum*

– make **buttermilk** with different flavours because of variations in fermentation products.

- **Sour cream** is made by adding one of these organisms to the cream.
- **Yogurt** is made by adding *Streptococcus thermophilus* and *Lactobacillus bulgaricus* to milk.
- these organisms release other products (lactic acid) and so yogurt has different flavour and texture.
- **Fermented milk** have been made for centuries in various countries in the globe, especially Africa, Asia, and eastern Europe.
- the products vary in **acidity** and **alcohol** content.
- **Acidophilus milk** is made by adding *Lactobacillus acidophilus* to **sterile** milk.
- sterilization prevent uncontrolled fermentation by organisms that already be present in non- sterilized milk.
- **Bulgarian milk** is made by adding *Lactobacillus bulgaricus*; it is similar to **buttermilk** except that it is **more acidic** and lacks the flavor imparted by the *Leuconostocs.*

B. Fermented meats

- Microbes such as *Lactobacillus plantarum* and *Pediococcus cerevisiae* add flavour by fermenting meats such as **salami, summer sausage** and **Lebanon bologna**.
- **The heterolactic acid fermentation** help preserve the **meat** and gives it a **tangy** flavour.
- Fungi such as *Penicillium* and *Aspergillus* growing naturally on the surface of country hams, help to produce their distinctive flavour.

C. production of beer, wine, and spirits

- **Beer** and **wine** are made by fermenting **sugary juices**.
- **Spirits** such as **whiskey**, **gin**, and **rams** are made by fermenting juices and distilling the fermented products.
- Distillation separates the **alcohols** and other **volatiles substances** from **solid** and **non-volatile** substances.
- Strains of **saccharomyces** are fermenters of all alcoholic beverages.

Beer making process

- **To make beer**, cereal grains (usually barely) are malted (partially germinated) to increase the concentration of starch digesting enzymes that provide sugar for the fermentation.
- Malted grain is **crushed** and mixed with **hot water** about 65^0C producing **mash**.
- After a few hours, a liquid extract called **wort** is separated from mix.
- Hops (flowers come from hop plants) are added to wort for flavoring and the mixture is boiled to stop enzyme action and precipitate protein.
- A strain of saccharomyces is added, and fermentation produce ethyl alcohol, CO2, and other substances including amyl, isoamyl alcohol, and acetic and butyric acids, which add to the flavor of beer.
- After fermentation the yeast is removed and the beer is **filtered**, **pasteurized**, and **bottled**.

<u>Wine making process</u>

- **Most wine** are made from juices extracted from grapes, although it can be made from nuts and dandelion blossoms.
- Juice is treated with sulfur dioxides to kill any wild yeasts that may already be present.
- Sugar and strain of saccharomyces is added and fermentation proceeds.
- Ethyl alcohol is the main products of fermentation and other products are similar to those in beer that add flavor to wine.
- In both **beer** and **wine,** the particular characteristic of **the juice** and the **yeast strains** determine the **flavor** of **final product.**
- When fermentation is completed, liquids in the wine siphoned to separate it from yeast sediments and if necessary, cleared with agents such as charcoal to remove suspended particles.
- Finally, it is bottled and aged in a cool place.

<u>Spirits making process</u>

- **Spirits** are made from fermentation of a variety of foods including
  - malted barley (scotch whiskey),
  - rye (rye whiskey, gin),
  - corn(bourbon),
  - wine or fruit juices(brandy),
  - potatoes(vodka), and
  - molasses(rum).
- After fermentation, distillation separates the alcohols and other volatiles substances that impart flavor from the solid and non-volatile substances.
- Because of distillation the alcohol content of spirits ranges from **40% to 50%** much high than the typical **12%** for wine and **6%** for beer.

<u>D. Bread making</u>

- Microorganisms accomplish three processes in bread making
  1. leavening the flavor-based dough
  2. imparting the flavor and odor, and
  3. conditioning the dough to make it workable.

❖ **Leavening** is achieved primarily through the release of gas to produce **porous** and **spongy** product.

- Without leavening, the bread dough remains **dense, flat** and **hard**.
- Although various microbes and the leavening agents (**baking soda**) can be used, **the most commons** are various strains **of baker's yeast saccharomyces** cerevisiae.
- Other gas forming microbes such as **coliform** bacteria, certain **clostridium** spp, **heterofermentative lactic acid** bacteria and **wild yeast**.
- Yeast metabolism requires a source of **fermentable sugar** such as **maltose** or **glucose**.
- Because the yeast **respires aerobically** in bread dough, the chief products of maltose fermentation are **CO_2** and **H_2O** rather than alcohol (the main product in beer and wine).
- Other contributions to **bread texture** come from **kneading**, which incorporates **air** into dough, and form microbial enzymes, which breaks down flour protein(**gluten**) and give the dough **elasticity**.

❖ **Imparting flavors**

- Bread fermentations generate other **volatile organic acids** and **alcohols** that impart **delicate**

flavors and **aromas.**

- **Yeast** and **bacteria** can also impart **unique flavors**, depending upon the **culture mixture** and **baking techniques** used.
- The **pungent** flavor of **rye bread** for example, comes in part from the **starter culture** of lactic acids bacteria such as - ***Lactobacillus plantarum***,
  - ***Lactobacillus brevis***,
  - ***Lactobacillus. bulgaricus***,
  - ***Leuconostoc mesenteroides***, and
  - ***Streptococcus thermophilus.***
- **Sourdough bread** gets its unique tangy from ***Lactobacillus sanfrancisc***.

ii. Applications of biology in Genetic engineering

- Genetic engineering is the process of transferring a **DNA** from one organism into another that result in a genetic modification.
- Genetic engineering is being used in the production of **pharmaceuticals, gene therapy**, and development of **transgenic plants** and **animals**.

A. Animal breading and transgenic animals and plants and disease, and pest management

- **Selective animal breeding** addresses the genetic values of livestock.
- Selecting for breeding animals with **superior traits** in **growth rate**, **egg**, **meat**, **milk, wool production** or with the other **desirable traits**- has **revolutionized** the livestock and plant production throughout the entire world.
- Animals can be also **genetically modified** (**transgenic** animals) for **valuable traits**.
- There are many potential applications of transgenic methodology in developing **new** and **improved** and **strains** of livestock.
- **Practical application** of transgenic methodology in livestock production include
  - Enhancing the **prolificacy(yield)** and **reproductive performance**,
  - Increasing **feeding utilization** and **growth rate**.
  - Improving **milk production** and **composition**
  - Modification of **hair** or **fiber**
  - Increasing **disease resistance** in animals.
- The development of the transgenic farm animals will allow more flexibility in the direct genetic manipulation of livestock.
- **Gene transfer** is relatively **rapid way of** altering the genome of domestic livestock.

B. tissue culture (Micropropagation)

- Plants can be **propagated quickly** and in **large quantity** by tissue culture technique.
- **Tissue culture** is method of biological research in which **fragments of tissues** from an **animal** or **plant** are transferred to an **artificial environment** in which they can continue **to survive** and **function**.
- The **cultured tissue** may consist of a **single cell**, a **population of cells,** a **whole** or **parts** of an **organ.**
- Plants produced in large amount using this technique include **palm trees**, **orchids**, **bananas**, and **carrots**.
- Using this technology large quantity of food with **desired quality** can be produced in reasonably little area.
- Therefore, **tissue culture** is seen as important biotechnology for developing countries for the

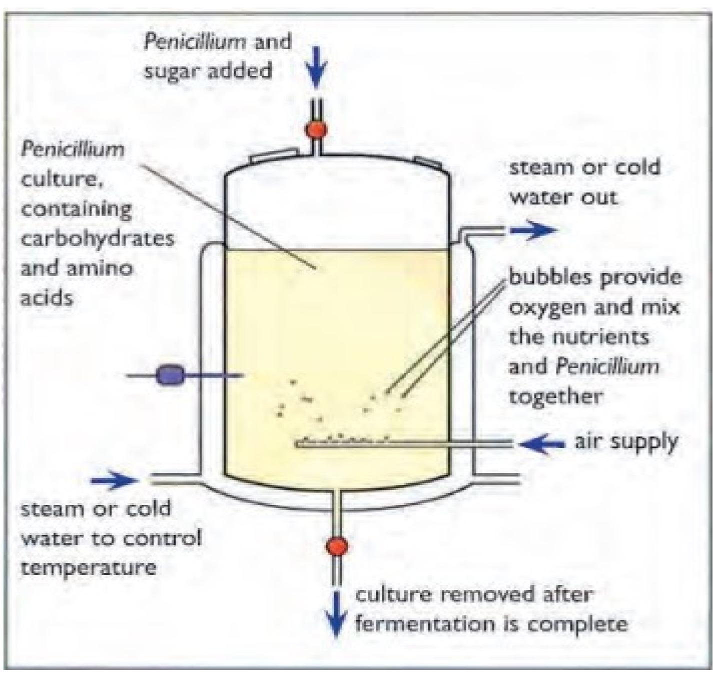
production of
- o Disease free
- o High quality planting materials and
- o The rapid production of many uniform plants

iii. Application of biotechnology in Health and well beings

- **Human drugs** such as **insulin** for diabetics, **growth hormones** for individuals with pituitary dwarfism and tissue **plasminogen activator** for heart attack victims as well as
- **Animal drugs** like the **growth hormones**, **bovine** and **porcine somatotrophin**, are being produced by fermentation of **transgenic bacteria** that has received **appropriate gene** from **human** and **cow** or **pig**.

A. the manufacturing of antibiotics

- When the microorganisms are used to produce antibiotic, it is not their fermentation product that are wanted but, complex organic called antibiotics.
- Most of the **antibiotics** that we use come from **bacteria** or **fungi** live in soil.
- The function antibiotics in this situation is not clear.
- One theory suggest that the chemical help to suppress the competition for limited food resources, but the evidence doesn't support this theory.
- One of the most prolific sources of antibiotics is **Actinomycetes**, these are filamentous bacteria that resembles microscopic mold fungi.
- The actinomycetes ***streptomyces*** produces the antibiotic **streptomycin**.
- The best-known antibiotic is **penicillin**, w/c produced mold fungus **penicillium** and was discovered by Sir Alexander Fleming in 1928.
- Penicillin is still important antibiotic but it is produced from mutant forms of different species of penicillium studied by Fleming.
- The different mutant forms of fungi produced different types of penicillin.
- The penicillin type is chemically altered in laboratory to make them more effective and to 'tailor' them for use with different diseases.



Fermenter used for producing penicillin

- ‘**Ampicillin**’, ‘**methicillin**’ and ‘**oxacillin**’ are examples.
- Antibiotics attack bacteria in a variety of ways.
    - **disrupting** the production of the **cell wall** and so **prevent** the bacteria from reproducing, or
    - **Causing** them **burst** open
    - **interfering** with **protein synthesis** and thus arrest bacterial growth.
      - those that stop bacteria from reproducing are said to be **bacteriostatic**.
      - those that kills are called **bactericidal.**
- Animal cells do not have cell walls, and the cell structures contains different protein, antibiotics do not damage human cells but may produce side-effects like allergic reactions.

Production of Vaccines

- Some vaccines are also adaptable to mass production through fermentation.
- **Vaccines** for ***Bordetella pertussis***, ***Salmonella typhi***, ***Vibrio cholerae***, and ***Mycobacterium tuberculosis*** are produced in large batch cultures.
- ***Corynebacterium diphtheria*** and ***Clostridium tetani*** are propagated for the synthesis of their toxins, from w/c toxoids for the DT vaccines are produced.

B. Biosensors

- **Biosensors** - is an analytical device for **detection** of an analyte that combines biological component with physicochemical detector component.
- **Biosensor production** is a rapidly developing area of biotechnology with arousing intense international scientific interest.
- In this field of **bioelectronics, living organisms** (or their **enzymes** or **organelles)** are linked with **electrodes**, and **biological reactions** are converted into **electrical currents** by these biosensors.
- **Biosensors** are being developed - to measure **specific component** in **beer**,
  - to **monitors pollutants**, and
  - to **detect flavor compounds** in food.
  - to measure the conc. of substance from many d/t environments.
- Applications of biosensors also include
    - the detection of **glucose**, **acetic acids**, **glutamic acids**, **ethanol**, and **biochemical oxygen demand (BOD).**
    - **to** measure **cephalosporin**, **nicotinic acids**, and **several B vitamins**.
- Recently biosensors have been developed using **immunochemical** based detection system.
- These new biosensors will **detect pathogen**, **herbicides**, **toxins**, **proteins,** and **DNA.**
- Many of these biosensors are based on the **use of a streptavidin-biotin** recognition system.
- One of the most interesting recent developments using these approaches is using handheld **aflatoxin detection system** for use in **monitoring** food quality.
- This automated unit(device), based on new column-based immunoaffinity fluorometric procedure, can be used for 100 measurements before being recharged.
- The unit(device) can detect from 0.1 to 50ppb of aflatoxin in a 1ml of sample in less than 2min.
- Rapid advances are being made in all areas of biosensor technology; including major improvements in the **stability** and **durability** of these units(devices), which are being made **more portable** and **sensitive**.

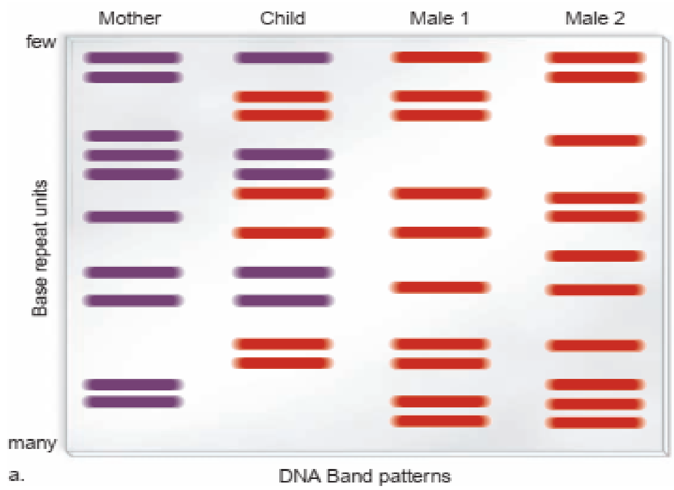
- Microorganisms and metabolites such as glucose can be measured, thus meeting critical needs in modern medicine.

C. Forensic science

- Forensic biologists inspect **crime scenes** to examine potential sources of evidence using **blood (WBC)**, **Semen (sperm cells)**, **skin tissue**, **saliva,** and **hair,** and then they analyze the specimens in a laboratory, focusing on **DNA analysis**.
- Additionally, **fingerprints** are also important tools to investigate **crime**.
- This because each individual has **unique** fingerprint that do not change throughout life.
- Genetic fingerprinting has nothing to do with actual fingerprints.
- **DNA fingerprint** is technique of comparing DNA of different people and used to determine the paternity case of a child.
- Based on their investigation, **forensic biologists** write up their findings in a **chemical report** and are called upon **to testify** in court.
- Finally, this data is used to investigate the related **transgression (Violation)** and then these facts are put forward in the court that is quite helpful to castigate(penalize) the criminal.
- These days '**bioinformatics'** is widely accepted in the field of forensic science, because with the help of computational tools, it has become quite easier and reliable to gather evidence regarding a particular crime scene.

(**Bioinformatic**s: is a sub-discipline of biology and computer science concerned with the **acquisition**, **storage**, **analysis,** and **dissemination** of **biological data**, most often DNA and amino acid sequences.)

-The most common approach to DNA profiling is to examine **short tandem repeats** (**STRs or** "satellite DNAs"), which are sequences of a few nucleotides that are repeated in noncoding regions of DNA.
- DNA extracted from cells of each sample is amplified using PCR. The **polymerase chain reaction** (**PCR**) rapidly produces millions of copies of a selected DNA sequence in a test tube.
- These fragments are then separated using **gel electrophoresis** (or a detector) to look for small variations in the length of the fragments.
- The chance of random two people having the same genetic fingerprint (unless they are identical twins) is **1** in **10 million**.
- This means that a genetic fingerprint can be used to provide strong evidence of **involvement in** or **innocence** of a crime.



- In the case of paternity testing, shown here, male 1 is father of child.

iv. Application of biotechnology in biomining

A. Microbiological mining

- **Biomining** is the process of using **microorganisms (microbes)** to **extract metals** of economic **interest from rock ores** or **mine waste**.
- **Biomining techniques** may also be used **to clean up** sites that have been **polluted with metals**.
- The new discipline known as **biohydrometallurgy,** the use of microbes to extract **metals** from **ores**.
- **Biohydrometallurgy** is **a technique** in the world of **metallurgy** that uses **biological agents (bacteria)** to **recover** certain **metals** from **ores** such as **copper**.
- **Copper** and other **metals** originally were thought to be **leached** from the **wastes of ore crushing** as result of an **inorganic chemical reaction.**
- It was then discovered that this leaching is due to the action of ***Thiobacillus ferrooxidans.***
- This chemolithotrophic acidophilic bacterium lives by oxidizing the **sulfur** that binds **copper**, **zinc**, **lead**, and **uranium** into their respective **sulfide minerals**, with a resultant release of **pure metals**.
- When acidic water is sprayed on such **ore**, *T. ferrooxidans* obtains energy as it uses oxygen from the atmosphere to oxidize the **sulfur atom** in **sulfide ores** to **sulfate.**
- The bacterium **does not use the copper;** it merely converts it to a water-soluble form that can be retrieved and used by humans.
- Other minerals also can be degraded by microbes.
- *T. ferrooxidans* releases **iron** from **iron sulfides** by the same process.
- Combination of ***T. ferrooxidans*** and a similar organism, ***T. thiooxidans***, degrades some **copper** and **iron** ores more rapidly than either one does alone.
- Another combination of organisms ***Leptospirrilum ferrooxidans*** and ***T. organoparus***, degrade **pyrite** (FeS_2) and **chalcopyrite** ($CuFeS_2$), although either organism can degrade the minerals alone.
- Other bacterium can be used to mine **uranium**, and bacteria may eventually be used to **remove arsenic**, **lead, zinc**, **cobalt,** and **gold.**
- Few mining companies are using microbes in their mining process.

v. Application of biotechnology in environment

A. Solid waste treatment: composting and landfill

- Most of solid waste ends up in landfill sites.
- **Landfill sites** is huge holes in the ground(depression) where refuse(garbage/food waste) is deposited to prevent it being a hazard.
- **Non-biodegradable** components (metals, plastics, rubble, etc,) remain there more or less for indefinite time.
- But **biodegradable** material (food, waste, textile, paper, etc) over a period of time, undergoes a decomposition process.
- The rate at which decomposition happens depends on the **nature of the waste** and the **conditions of the landfills** but can take several decades.
- **Aerobic process** gives ways to **anaerobic** ones and significant result is the generation of **methane**.
- **Modern landfill sites** incorporate system that removes methane to prevent it from being **fire** or **explosion hazard** and may put into good use as **fuel source**.
- Many householders separate organic waste items such as **vegetable peeling** and **grass cuttings** and use them to make **compost**.
- This practice significantly **reduces** the volume of waste material that must be disposed and also provide a useful gardening supplement.
- **Fungi** and **bacteria** particularly **actinomycetes**, breakdown the organic matter to produce CO_2, water and humus, a relatively stable organic product.
- **Compost** is not really a fertilizer, since its **nitrogen** content is **not high**, however it provides nutrient to a soil and helps to improve soil condition.
- **Composting** is carried out on a **large scale** by local authorities using the waste generated in municipal parks and gardens.

B. Waste treatment

- The aim of wastewater treatment is the removal of **undesirable substances(polluting organic matter)** and **hazardous microorganism** in order to make the water safe that enter a watercourse such as **river** or **stream**.
- Further **purification** procedure is required before it can be used as **drinking** water.
- **Waste water treatment** is fundamental to greatly reduce the incidence of **waterborne disease** such as **cholera**.
- Waste water may come from **domestic** or **commercial** sources; highly toxic **industrial** effluents may require **pretreatment** before entering a **water treatment system**.
- **Sewage** is a term used to describe liquid waste that contains faecal matter (urine and faeces of human and animal).
- The effectiveness of the treatment process is judged chiefly by the reduction of the wastewater's **biochemical oxygen demand** (BOD).
- BOD is a measure of the **amount of oxygen** needed by microorganisms to oxidize its organic content.
- A high BOD leads to the removal of oxygen from water, a certain **indicator of pollution**.
- Wastewater treatment usually occurs in stages,

  (1) **Primary treatment** (1^{st} stage) is purely physical and involves the removal of floating objects followed by **sedimentation**, a process that removes up to **one-third** of the BOD value.

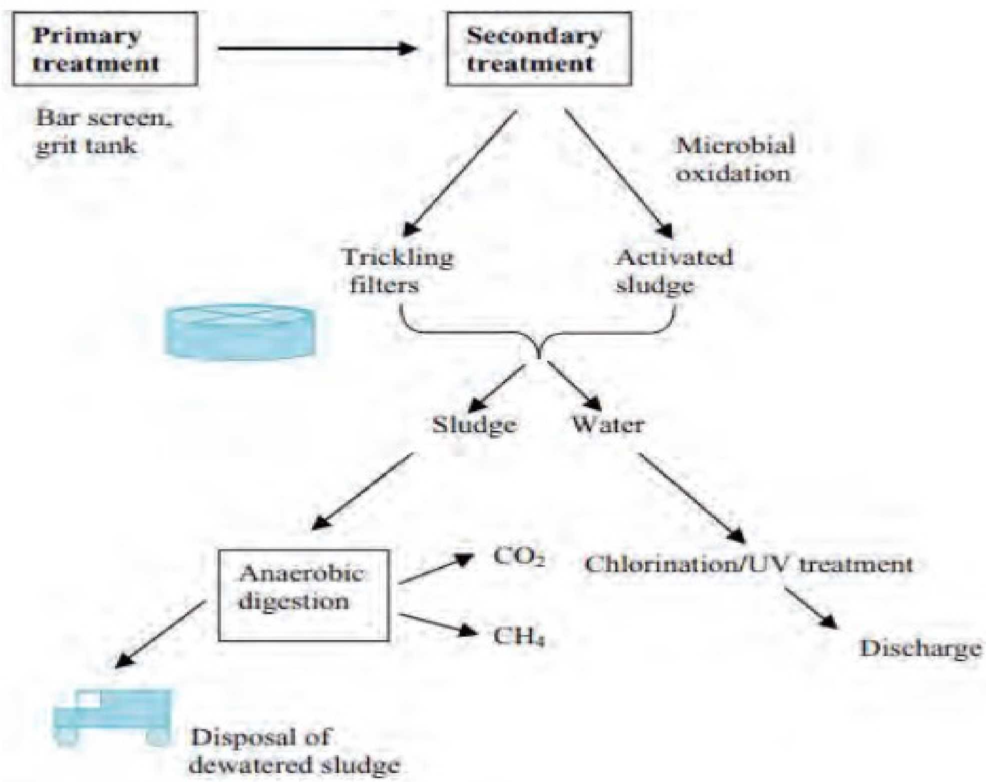
  (2) **Secondary treatment**(2^{nd} stage) involves microbial oxidation, leading to a substantial further reduction in BOD.

- **Secondary treatment** may take one of the two forms(methods), both of which are **aerobic**
  (i) **Trickling filter** method and
  (ii) **Activated sludge** method.

i. In the **trickling filter method**, the wastewater is passed slowly over **beds of stones(filter bed)** or pieces of **molded plastic** which develop a **biofilm** comprising **bacteria**, **protozoans**, **fungi** and **algae,** and the resulting treated water has its BOD reduced by some **80-85%.**

ii. In the **Activated sludge method-** facilities achieve a higher degree of BOD reduction.
- Here the wastewater is **aerated** in the tanks that have been **seeded** with mixed **microbial sludge**.
- The main component is the ***bacterium zoogloea***, which secretes **slime**, forming **aggregates** called **flocs** around which other microorganisms such as **protozoans** attach.
- Some of the **water's organic content** is not immediately oxidized but becomes incorporated into flocs.
- After a few hours of residence in the tank, the sludge is allowed to **settle out**, and the treated water passes out of the system.
- Before being discharged to a watercourse, it is treated with **chlorine** to remove any pathogenic microorganisms.

- The principal operating problem encountered with **activated sludge** is that of ***bulking.***
- This is caused by filamentous bacteria such as ***Sphaerotilus natans***; it results in the sludge not settling properly and consequently passing out with treated water.
- Both secondary treatment processes result in some **surplus sludge**, which undergoes **anaerobic digestion**, resulting in the production of **methane** and **CO2**.
- The methane can be used as a **fuel to** power the plant and any remaining sludge is **dewatered** and used as a **soil conditioner.**
- Care must be taken that the sludge does **not** contain **toxic heavy** metals.



The role of microorganisms in wastewater treatment

C. Bioremediation

- **Bioremediation** is the use of living organisms or their products for the **detoxification** and **degradation** of environmental pollutants.
- Today many pollutants are **degraded** with the help of **saprophytic microbes**; this process is also called **biodegradation**.
- Genetically engineered bacteria are used to **clean up** pollutants from the environments.
- The engineered bacteria metabolically breakdown **toxic** substance into **harmless** compounds.
- **Mercury resistant bacteria** process metallic mercury (which damages the nervous system) into **non-toxic** compounds.
- During bioremediation via microorganisms, **enzymes** produced by microorganisms **modify** a **toxic pollutant** by **altering** or **transforming** its structure. This event is called **biotransformation**.
- In many cases, biotransformation results in biodegradation, in which the **toxic pollutant** is **degraded**, were yielding **less complex**, **non-toxic** metabolites.
- Alternatively, **biotransformation** without biodegradation can occur. Eg. Toxic heavy metals can often be rendered **less toxic** by **oxidation** or **reduction** reactions carried out by microorganisms.

D. Biofuels

- **Biofuel**, any fuel that is obtained by fermentation of **biomass**, that is, **plant** or **algae** material or **animal** waste.
- The need to become **independent of fossil fuels** is driven by both **political** and **environmental** concerns has accelerated **interest** and **use of biofuels**- fuel(chiefly **ethanol**).
- **Corn** is currently the substrate of choices, and the **use of crop residues** could significantly boost biofuel yields.
- **Crop residues** are the **plant materials** usually left in the field after harvest, and it consists of **cellulose** and **hemi-cellulose**.
- These polysaccharides are polymers of five different **hexoses** and **pentose**: **glucose**, **xylose**, **mannose**, **galactose**, and **arabinose**.
- While **no** microorganisms **naturally** ferment all five sugars, a ***Saccharomyces cerevisiae*** has been engineered to ferment **xylose** and an ***E. coli*** strain that express ***Zymomonas mobilis*** gene able to ferment **all** these sugars.
- Another area of research focusing on **degrading** the cellulose and hemicellulose to release monomers is commonly done by **heating** plant materials and **treating it with acids**, which is both **expensive** and **corrosive**.
- Working to harvest cellulose and hemi-cellulose digesting enzymes from thermoacidopliles fungi to replace the **harsh thermochemical** approach with a biological treatment.

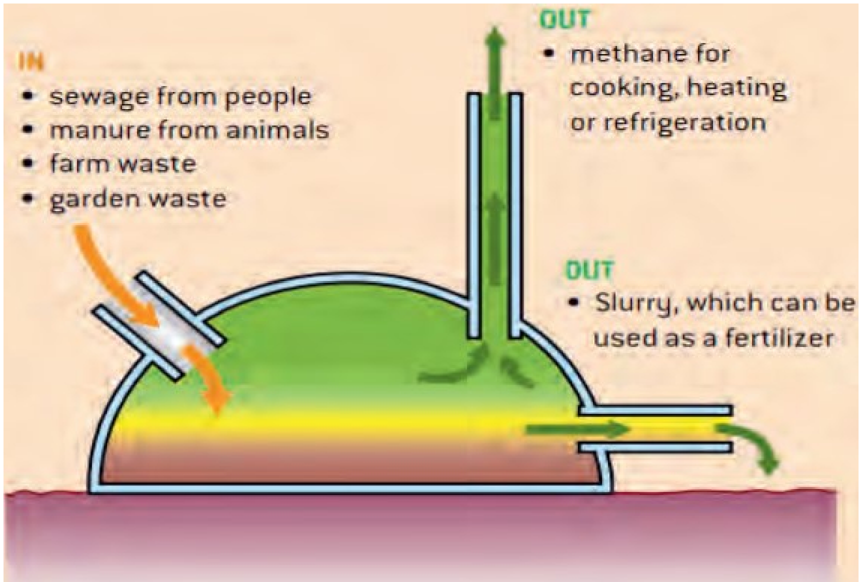
E. Biogas production

- **Biogas** is produced by **Bacteria** and **Archean** from **organic matter** in fermenters.
- **Biogas** is a combustible gas produced from the anaerobic breakdown of organic matter such as **manure**, **waste plant matter** from crops and **household organic waste** by the activities of the microorganisms.
- Depending on the construction of the **fermenter**, biogas is **mostly methane** with **some CO_2,** though **other gases** may be present.
- Three different communities of **anaerobic microbes** are required.

(1)The **first group** converts the **raw organic waste** into a mixture of **organic acids**, **alcohol**, **hydrogen**, and **CO_2**.
(2)The **second group**s use the **organic acids** and **alcohol** from the first stage to produce **acetate**, **CO_2** and **hydrogen**.
- These first two communities are **eubacteria**.
(3) The **last group** are **Archaea** called **methanogens**.
- The **methanogens** produce methane by one of the following two reactions

$CO_2 + 4H_2 \rightarrow \mathbf{CH_4} + 2H_2O$ (reduction of CO_2 to methane)

$CH_3COOH \rightarrow \mathbf{CH_4} + CO_2$ (splitting ethanoic acid to form methane and CO_2)



Designs of biogas generator

There are also **different sizes** and **designs** of biogas generator. The type chosen will depend on **local conditions**. For example,
- Many fermenters are **sunk into the ground**, which provides **very good insulation**.
- Others are **built above ground**, which may be easier and cheaper, but offers **less insulation**. If night-time temperatures fall too low, it could cause problems.
- The **waste** materials from **sugar factories**, **sewage farms** and **rubbish tips** all has the potential to act as a **starting point** for the production of biogas.
- Under **ideal conditions**, **10 kg of dry dung** can produce **3 m3** of biogas that
  - give you **three** hours' **cooking**,
  - **three** hours' **lighting** or
  - **24 hours** of **running a refrigerator**.
- Not only that, but you can use the waste from your generator as a **fertilizer**.

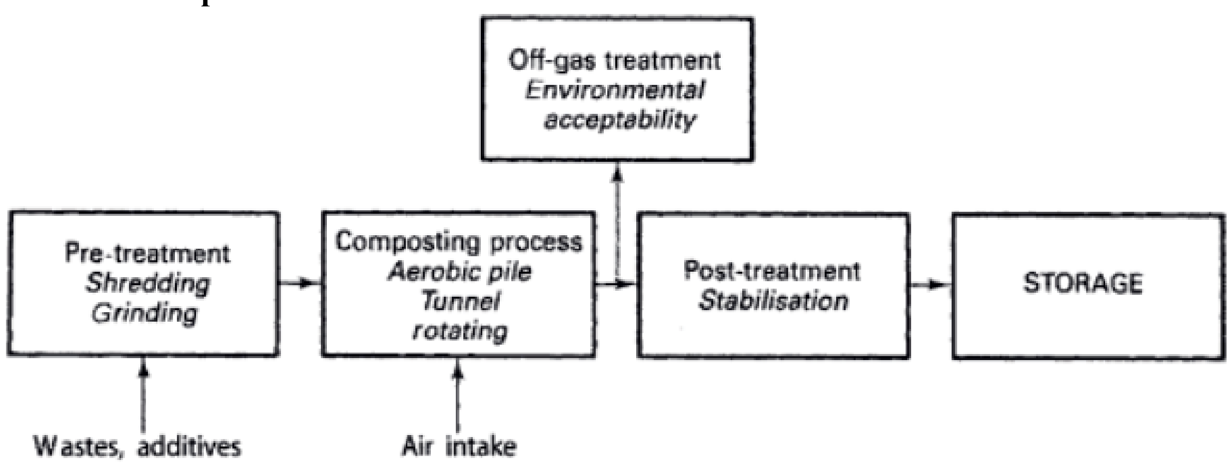
Advantages of biogas

1. Biogas is a fuel used to cook food, and light lamps.
2. Slurry left after biogas production forms a **soil conditioner**(manure).
3. Biogas is much **cheaper** than liquefied petroleum gas for home use.

F. Composting

- **Composting** is an **aerobic microbial** driven process that converts **solid organic wastes** into **stable**, **sanitary**, **humus**-like material, that has been reduced in bulk and safely returned to the environment.

- To be very effective, it should only **use** as substances **readily decomposable solid organic waste**.
- In **large scale operations** using largely **domestic solid organic wastes**, the final product is mostly used for **soil improvement**.
- But in more **specialized operations** using **specific organic raw substances** (**straw**, **animal manures**, etc), the final product become **the substrate** for the worldwide commercial **production** of the **mushroom *Agaricus bisporus***.
- **Composting** has recently become a serious **waste management technology**, and both theoretical and practical development of the technology is still in **its infancy**.
- The **primary aim** of a composting operation is - to obtain, in a limited time within limited compost, **final compost** with **desired product quality**.
- A composting plant must function under environmentally safe conditions.
- Composting is carried out in a **packed bed of solid organic particles** in which the **indigenous microbes** will grow and reproduce.
- Free access to **air** is an essential requirement.
- The **starting materials** are arranged **in static piles**(windrows), **aerated piles** or **covered tunnels**, or in **rotating bioreactors** (drums or cylinders).
- Some form of pre-treatment of the waste, such as **particle size reduction** by **shredding** or **grinding** may be required.
- The **basic biological reaction** of the composting process is the **oxidation** of the mixed organic substances with oxygen to produce **CO_2**, **H_2O** other **organic by-products**.
- After the composting process is completed, the final product most often needs to be **left for variable time periods** to **stabilize**.



Flow chart composting plants processes

vii. Application of biotechnology in industry

A. Enzymes

- Enzymes can be produced by **commercial fermentation** using readily available feed stocks such as **corn-steep liquor** or **molasses**.
- **Fungi**(eg. Aspergillus) or **bacteria**(eg. Bacillus) are two of the commonest organisms used to produce the **enzymes**.
- These organisms are selected because they are **non-pathogenic** and **do not produce antibiotics**.
- The fermentation process is similar to that described for penicillin.
- If the enzymes are **extracellular** then the **liquid feedstock** is **filtered** from the organism and the enzyme is extracted.

- If the enzymes are **intracellular**, the microorganisms have to be **filtered** from the feedstock.
- They are then **crushed** and the **enzymes extracted** with water or **other solvents**.

Some commercial uses of enzymes are listed below;

- **Proteases:** in washing powders for - dissolving stains from eg. Egg, milk and blood;
  - Removing hair from animal hides;
  - Cheese manufacture;
  - tenderizing meat.
- **Lipases; Flavors enhancer** in cheese; in washing powders for **removal of fatty stains**.
- **Pectinases**; **clarification** of fruit juices; **maximizing** juice extraction.
- **Amylases**; production of glucose from starch.

B. Biological washing powders

- Most of the commercial enzyme production involves **protein- digesting enzymes** (proteases) and **fat-digesting enzymes**(lipases) for use in the **food** and **textile** industries.
- When combined in washing powders they are effective in removing stains in clothes caused by **protein**, eg. Blood, egg, and gravy, and **fats**, eg. Greese.
- Protein and fat molecules tend to be **large** and **insoluble**.
- When they have been digested the products are **small**, **soluble molecules**, which can pass out of the cloth.
- **Biological washing powders** save energy because they can be used to wash clothes **at lower temperatures**, so there is no need to boil water. However, if they are put in the water at higher temperatures the enzyme become **denatured,** and they **lose their effectiveness**, except **subtilisin**, thermo stable enzyme used in washing powder.

Viii. Applications of biotechnology in agriculture

A. Biopesticides

- There has been a long-term interest in the use of **bacteria**, **fungi,** and **viruses** as bioinsecticides and biopesticides.
- These are defined as **biological agents,** such as bacteria, fungi, viruses, or their components, which can be used to kill a suspected insect.
- Bacteria: ***Bacillus thuringiensis*** and ***Bacillus popilliae*** are the two major bacteria of interest.
- ***Bacillus thuringiensis*** is used on a wide variety of **vegetable** and **field crops**, **fruits**, **shade trees**, and **ornamentals**.
- ***Bacillus popilliae*** is used primarily against **Japanese beetle larvae**.
- Both bacteria are considered harmless to humans.
- ***Pseudomonas fluorescens***, which contains the **toxin-producing gene** from ***Bacillus thuringiensis***, is used on maize to suppress **black cutworms.**

Viruses:

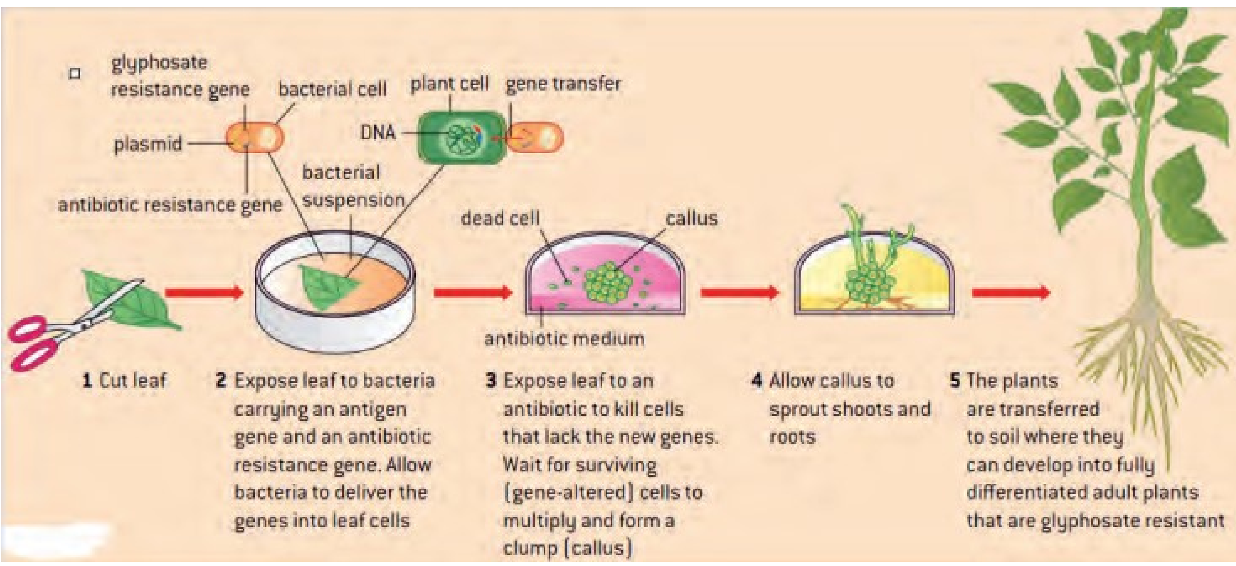
- Three major virus groups that do not appear to replicate in warm-blooded animals are used: Nuclear polyhedrosis virus (NPV), granulosis virus (GV) and cytoplasmic polyhedrosis virus (CPV).
- These **occluded viruses** are more protected in the environment.
- Over 500 different fungi are associated with insects.
- Infections and diseases occur primarily through the insect cuticle.

Four major genera have been used.

- ✓ ***Beauveria bassiana*** and ***Metarhizium anisopliae*** are used for control of Colorado potato beetle and the froghopper in sugar cane plantations, respectively.
- ✓ ***Verticullium lecanii*** and ***Entomophthora spp***., have been associated with control of aphids in greenhouse and field environments.

B. the use of Ti plasmid as vector

- Use of **tumor-inducing** (Ti) plasmid of *Agrobacterium tumefeciens* to introduce **glyphosate** resistance into soya bean crops.
- One way to introduce transgenes into plants is to use *Agrobacterium tumefeciens.* This is a species of bacteria that has a plasmid, called the **Ti plasmid**, that causes tumors in the plant it infects.
- The **glyphosate resistance gene** is inserted into the Ti plasmid along with an antibiotic resistance gene.
- The construct is then re-inserted into an ***Agrobacterium tumefeicens*** bacterium.
- Plant cells are then exposed to transgenic bacterium and cultured on the plate containing antibiotic.
- The only plant cells that grow are those that have taken up the plasmid. The others are killed by antibiotic.



The use of Ti plasmid as Vector

C. insect-resistance crops

-Another important agricultural development is that of genetically modified plants protected against attack by insect pests.

- **Maize** is protected against the **corn borer**, which eat leaves of plants and then burrows into the stalk, eating its way upward until the plant cannot support the ear.

-**Cotton** is protected against pests such as the **boll weevil**.

- In both plants, the yield is improved.
- Insect-resistance **tobacco** also exists, and is protected against the tobacco **bud worm**, but yet it has not been grown commercially.
- The most likely detrimental effects on the environment of growing an insect-resistance crop are:
  - ➢ The evolution of resistance by the insect pests.
  - ➢ A damaging erect on other species of insects

- The transfer of the added gene to other species of plant

- However, less pesticide is used, reducing the risk of spray carrying to and erecting non-target species of insects in the areas.
- remember also that only insects that eat the crop are erected.

D. pest-resistant crops

- Pest attack is one of the very common problems in number of different crops all around the globe, these may include fodder crops for the purpose of getting food.
- One example of such crops is BT-cotton.
- The genes of ***Bacillus thuringiensis*** (Bt), a very common, are inserted in cotton crop for development of certain protein in it.
- The protein is very **toxic** to number of **different insects**. With this aid the biotechnology, the development BT-cotton leads to a less pest attack ultimately leading to a significant more production.

E. Transgenic animals

- Although several recombinant proteins used in **medicine** are successfully produced in bacteria, some proteins require a eukaryotic animal host for proper processing.
- For this reason, the **desired genes** are **cloned** and expressed in animals such as **sheep**, **goats**, **chickens**, and **mice**.
- Animals that have been modified to express recombinant DNA are called **transgenic animals**.
- Several **human proteins** are expressed in the **milk** of **transgenic sheep** and **goats**.
- Some are expressed in the **eggs** of chickens.
- Mine have been used extensively for expressing and studying the effects of recombinant genes and mutations.

F. Transgenic plants

- Manipulating the DNA of plants (i.e. creating GMOs) has helped to create **desirable traits,** such as **disease resistance**, **herbicide** and **pesticide resistance**, **better nutritional value**, and **better shelf-life**.
- Plants are the important source of food for the human population.
- Farmers developed ways to select for plant varieties with desirable traits long before modern-day biotechnology practices were established.

NB.

-Transgenic crops are being created that **resistant disease**, are **tolerant of herbicides** and **drought** and have **improved nutritional quality**.
- **Plants** are also being used to produce **pharmaceuticals**, and **domesticated animals** are being genetically modified to produce **biologically active cpds**.
- Plants that have received recombinant DNA from other species are called **transgenic plants.**
- Because they are not natural, transgenic plants and other GMOs are **closely monitored** by government agencies to ensure that they **fit for human consumption** and **do not endanger** other plant and animal life.
- Because **foreign gene** can spread to other species in the environment, **extensive testing** is required to ensure **ecological stability**.

- Staples like **corn**, **potatoes**, and **tomatoes** were the first crop plants to be genetically engineered.

G. pest resistance

- The bacterium, ***Baccillus thuringiensis***, produces a **toxin** that kills **caterpillars** and other **insect larvae**.
- The toxin has been in use for some years as an **insecticide**.
- The gene for the toxin has been successfully introduced into some plant species using a bacterial vector.
- The plants produce the toxin and show **increased resistance** to attack by insect larvae.

H. Herbicide resistance

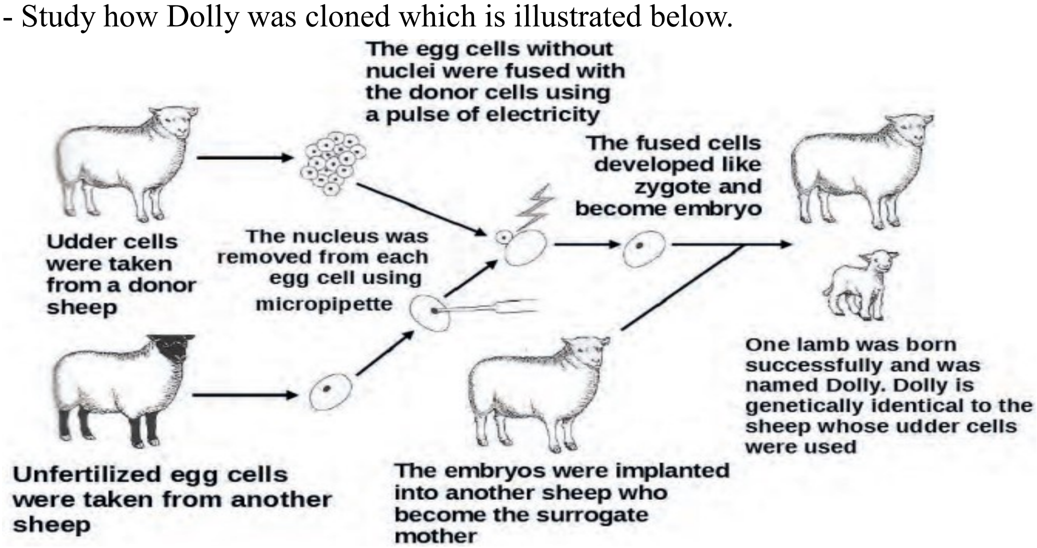
- Some of the **safest** and **most effective** herbicides are those, such as **glyphosate**, which **kill** any **green plant** but become harmless as soon as they reach the soil.
- These herbicides **cannot** be used **on crops** because they kill the **crop plants** as well as the **weeds**.
- A gene for an enzyme that breaks down glyphosate can be introduced into plant cell culture.
- This should lead to a reduced use of herbicides.

Cloning

- In method of producing identical copies of **genes**, **cells,** or **organisms**.
- The products of cloning are called a **clone.**
- **A clone** is a group of genetically identical organisms or cells produced either by asexual reproduction or artificially by cloning techniques.
- The main advantage of these techniques is that they can make **large numbers** of **plants** or **animals**, which are exact copies of the parent with **desirable traits**.
- Sometimes cloning is used to produce skin or other tissues needed to treat a patient.

I. Animal cloning

- Animals cannot be cloned in the same way from of their bodies.
- If animal embryo is divided up at early stage into several pieces, each piece can develop into a separate animal.
- However, it is hard to predict which embryos can develop into animals with desirable traits and should therefore be cloned.
- The first successful reproductive cloning of an adult with known character is **Dolly sheep**.
- Study how Dolly was cloned which is illustrated below.



- The researchers used a cloning technique called **somatic cell nuclear transfer.**

ix. Application of biotechnology in Biological warfare

- **Biological warfare** (BW) also known as **germ warfare** is the use of biological **toxins** or **infectious agent** such as **bacteria**, **viruses**, and **fungi** with the intent to kill or incapacitate humans, animals, or plants as an **act of war**.
- **Biological weapons** include any microorganism (such as bacteria, viruses, or fungi) or **toxin** (poisonous cpds produce by microorganisms) found in nature that can be used to **kill** or **injure** people.
- The **act of bioterrorism** can range from a **simple hoax** to the actual use of these biological weapons, also referred to as agents.
- Several nations have or are seeking to acquire biological warfare agents, and there are concerns that terrorist groups or individuals may acquire the technologies and expertise to use these destructive agents.
- Biological agent may be used for an **isolated assassination**, to cause incapacitation or death to thousands.
- If the environment is contaminated, a long-term threat to the population could be created.