Introduction to Genetics

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Introduction

What is Genetics?

- Genetics is the science of heredity and variation in living organisms

- The science of genetics deals with the principles that explain the similarities between parents and their progeny and the differences among individuals of a single species

Chromosomes carry the hereditary information (genes)

Arrangement of nucleotides in DNA

DNA → RNA → Proteins

What is heredity?

- **Heredity**, also called inheritance or biological inheritance, is the passing on of traits from parents to their offspring; either through asexual or sexual reproduction.

- Thus, the offspring cells or organisms acquire the genetic information of their parents

- The distinct functional units known as **genes** are transmitted from parents to progeny, and it is genes that govern the development of traits/characters of an individual

- Through heredity, variations between individuals can **accumulate** and cause species to evolve by natural selection

- **Natural selection**: is the differential survival and reproduction of individuals due to differences in phenotype. It is a key mechanism of evolution, the change in the heritable traits characteristic of a population over generations

What is Character or trait?

- **Character or trait** denotes a morphological, anatomical, physiological, biochemical or behavioral features of an organism

  - Human characters: eye color, hair color, skin color, presence of hairs on ears, etc.

  - Plant characters: plant height, number of tillering, number of seed per plant, pod length, seed weight, lodging, seed color, oil/protein content, Zn/Fe content, stress resistance or susceptible etc.

❖The differences among individual of a single species for a character constitute the variation for that character. Since the development of characters are governed by **genes**, the presence of variation in different character of an organism indicates variation in genes governing them

So, **Genetics** is defined as the science that deals with the structure, organization, transmission and function of genes and origin of variation in them

What is genetics as we know it today?

Genetics is **the scientific study of genes and heredity-**of how certain qualities or traits are passed from parents to offspring as a result of changes in DNA sequence.

- A gene is a segment of DNA that contains instructions for building one or more molecules that help the body work.

A plant geneticist is a scientist involved with the study of genetics in botany. Typical work is done with genes in order to isolate and then develop certain plant traits

- Definition. Agricultural genetics is **the applied study of the effects of genetic variation and selection used to propagate valuable heritable trait combinations** in crop plants and farm animals.

- Plant genetics differs from animal genetics in a number of ways: somatic mutations can contribute to the germ line more easily as flowers develop at the end of branches composed of somatic cells; polyploidy is more common; and plants additionally **contain chloroplastic DNA**.

- Summary. Like all living organisms, plants **use deoxyribonucleic acid (DNA) as their genetic material**. The DNA in plant cells is found in the nucleus, the mitochondria and the chloroplasts.

- Some benefits of genetic engineering in agriculture are **increased crop yields, reduced costs for food or drug production**, reduced need for pesticides, enhanced nutrient composition and food quality, resistance to pests and disease, greater food security, and medical benefits to the world's growing population.

- Adverse environmental conditions, such as drought, flooding, extreme heat and so on, affect crop yields more than pests and diseases. ... Crops developed by genetic engineering can not only be used to **enhance yields and nutritional quality** but also for increased tolerance to various biotic and abiotic stresses.

How do plants genetics work?

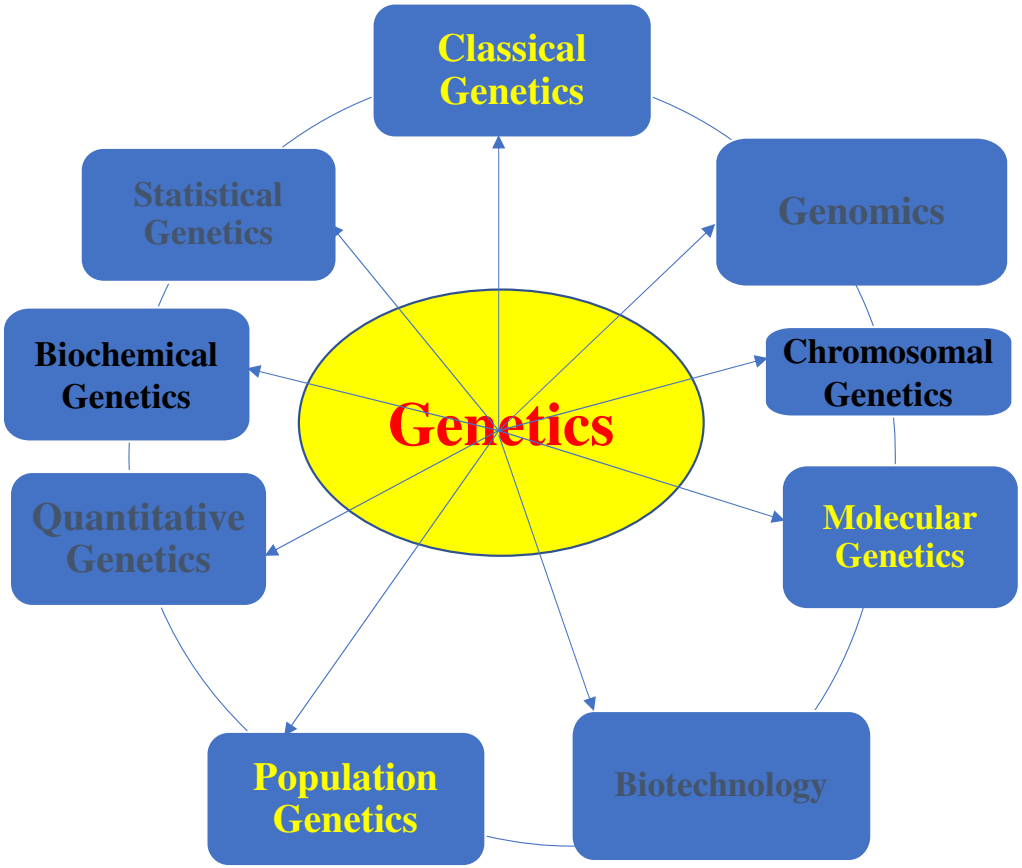
- Much of Mendel's work with plants still forms the basis for modern plant genetics. Plants, like all known organisms, **use DNA to pass on their traits**. Plants are unique in that they are able to produce energy-dense carbohydrates via photosynthesis, a process which is achieved by use of chloroplasts.

- **Is plant DNA different from human?:** In fact, the actual structure of the DNA molecule and how it codes for proteins is the same from bacteria to yeast to plants and animals. The DNA molecule in plants, humans, and all living things are all the same shape - like a twisted ladder, or a double helix.

Do plants feel pain?

- Unlike us and other animals, plants do not have **nociceptors**, the specific types of receptors that are programmed to respond to pain. They also, of course, don't have brains, so they lack the machinery necessary to turn those stimuli into an actual experiences. This is why **plants are incapable of feeling pain.**

Branches of Genetics



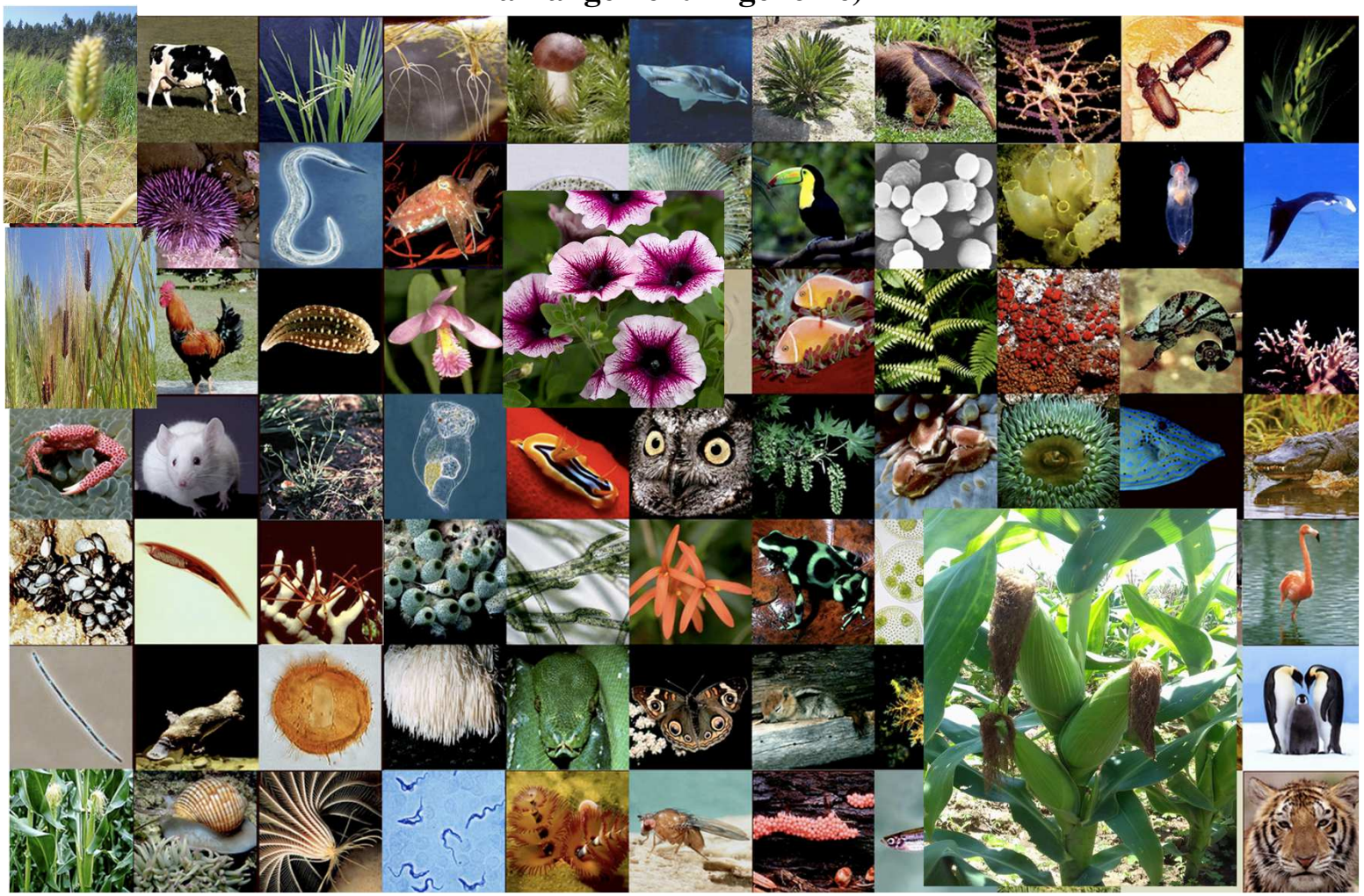
The concepts of Genetics

- Heredity affects many of our physical features as well as our susceptibility to many diseases and disorders

- Genetics contributes to advances in agriculture, pharmaceuticals, and medicine and is fundamental to modern biology

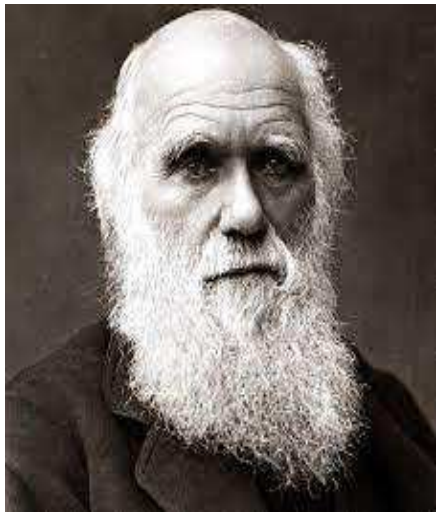
- Genetic variation is the foundation of the diversity of all life

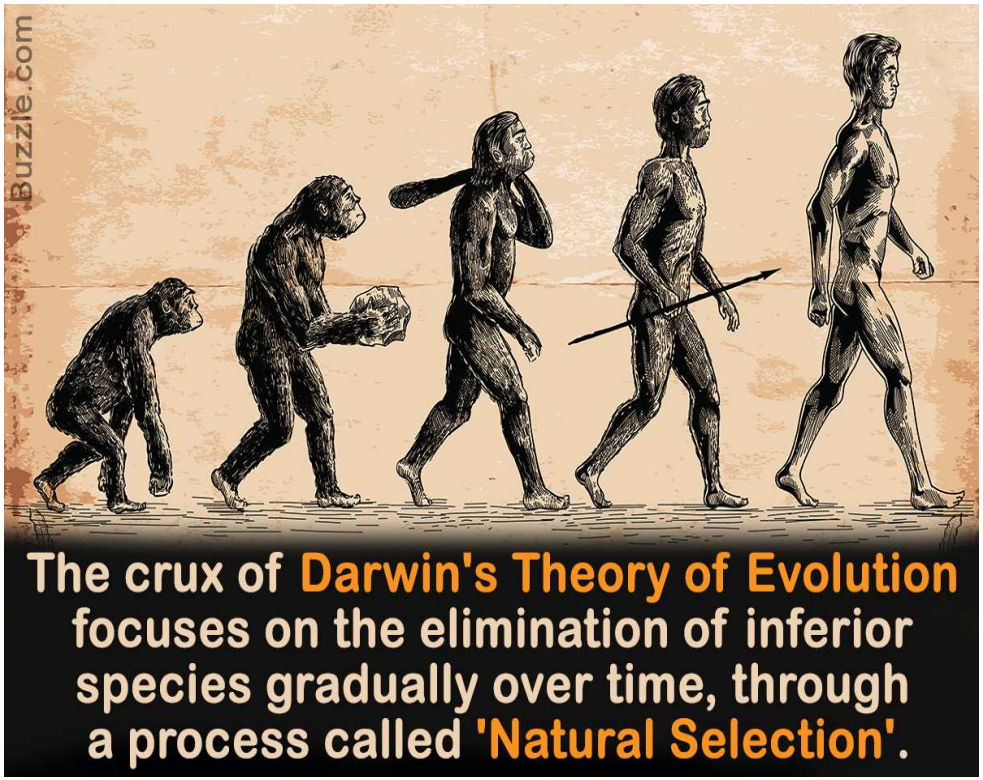
The diversity in life is due to the differences in gene compositions (genomes size and base arrangement in genome)



Natural selection

- The origins of genetics lie **in the development of theories of evolution**. It was in 1858 that the origin of species and how species variability was developed after the research work of **Charles Darwin and Wallace**. They described how new species arose via evolution and how natural selection occurred to evolve new forms.





Darwin’s theory of evolution

- Charles Darwin's theory of evolution had three main components:

1. variation occurred randomly among members of a species;
2. an individual's traits could be inherited by its progeny; and
3. the struggle for existence would allow only those with favorable traits to survive.

Terms in Darwin's theory of evolution

competition, adaption, variation, overproduction, and speciation

- **competition**. demand by organisms for limited environmental resources, such as nutrients, living space, or light.

- **adaption**. inherited characteristics that increase chance of survival.

- **Variation.** is the differences between individuals within a species. This can be caused by inherited or environmental factors. Variation can be **continuous or discontinuous**.

- **Overproduction.** each generation has more offspring than can be supported by the environment. Because of this, competition takes place for limited resources. "overproduction of offspring" and "struggle for existence"

- **Speciation** is how a new kind of plant or animal species is created. Speciation occurs when a group within a species separates from other members of its species and develops its own unique characteristics.

- **When was genetics first discovered?- 1866** - Gregor Mendel discovers the basic principles of genetics. In 1866, an unknown Augustinian monk was the first person to shed light on the way in which characteristics are passed down the generations. Today, he is widely considered to be the father of genetics.

- **Who named gene? botanist Wilhelm Johannsen**: **Danish botanist Wilhelm Johannsen** coined the word gene to describe the Mendelian units of heredity.

- **How many genes do humans have**?: An international research effort called the Human Genome Project, which worked to determine the sequence of the human genome and identify the genes that it contains, estimated that humans have **between 20,000 and 25,000 genes**. Every person has two copies of each gene, one inherited from each parent.

- **How much human DNA is junk?**: Our genetic manual holds the instructions for the proteins that make up and power our bodies. But less than 2 percent of our DNA actually codes for them. The rest — **98.5 percent of** DNA sequences — is so-called "junk DNA" that scientists long thought useless

- **How much of DNA is genes**?: Only about **1 percent** of DNA is made up of protein-coding genes; the other **99 percent is noncoding**.

- **How many combinations of human DNA are there?:**There are **8,324,608 possible combinations of 23 chromosome pairs**. As a result, two gametes virtually never have exactly the same combination of chromosomes. Each chromosome contains dozens to thousands of different genes.

- **Do we understand DNA?: We do not know what most** of our DNA does, nor how, or to what extent it governs traits. In other words, we do not fully understand how evolution works at the molecular level.

History of Genetics

Early theories of transmission

- Hippocrates 400 B.C. (Greek Physician)-**known as the father of medicine**. first explanation for the **idea of hereditary traits-** Suggested "seeds" were produced by different parts of the body and passed on to offspring at conception; "seeds" caused certain traits of the offspring to resemble their parents

- Pythagoras, 500 BC "moist vapor descends and condenses into semen which develops into individual in uterus (womb); assumed the female made a matching vapor and the two fused

- Aristotle, 300 BC emphasized the importance of blood in heredity. He thought that the blood supplied generative material for building all parts of the adult body, and he reasoned that blood was the basis for passing on this generative power to the next generation

- Until 1600's, many believed life could arise from nonliving materials (**spontaneous generation**)

Mendel and post-Mendel era

- 1865 Gregor Mendel's paper, Experiments on Plant Hybridization (statistical patterns of inheritance)
- 1869 Friedrich Miescher discovers a weak acid in the nuclei of white blood cells that today we call DNA
- 1880-1890Walther Flemming, Eduard Strasburger, and Edouard van Beneden clarify chromosome distribution during cell division/mitosis
- 1889 Hugo de Vries postulates that "inheritance of specific traits in organisms comes in particles", naming such particles "(pan) genes"
- 1903 Walter Sutton hypothesizes that chromosomes, which segregate in a Mendelian fashion, are hereditary units (rediscovery of Mendel work)
- 1931 Crossing over is identified as the cause of recombination

Blending inheritance

- The genetic material, the medium of inheritance, was **liquid, possibly blood**. The genetic material from the two parents was presumed to blend in the progeny so that the characters of progeny were intermediate between those of the two parents.

- Parental traits are "Mixed" in the offspring

- But, fail to explain the effect of dominant and recessive genes

The DNA era

- **1944**, Oswald Theodore Avery, Colin McLeod and Maclyn McCarty isolate DNA as the genetic material (at that time called transforming principle); DNA is first connected to the inheritance of traits

- 1948: Barbara McClintock discovers transposons in maize. We call it mobile genetic elements, or "jumping genes,"

- 1950, Erwin Chargaff showed that the four nucleotides are not present in nucleic acids in stable proportions, but that some general rules appear to hold. The principle that **in any sample of DNA the amount of adenine equals the amount of thymine and the amount of guanine equals the amount of cytosine**. It is a consequence of base pairing.

- 1952- Rosalind Franklin The first sharp X-ray diffraction photographs of DNA are obtained

- 1953-James D. Watson and Francis Crick- DNA structure was described to be a double helix

- 1956-Joe Hin Tjio and Albert Levan established the correct chromosome number in humans to be 46

- 1956 - DNA is made artificially
- 1966 - DNA is found to be present not only in chromosomes but also in the **mitochondria**

- 1969 - The first single gene is isolated
- 1970 - The first artificial gene is made

- 1970- Restriction enzymes were discovered in studies of a bacterium, Haemophilus influenzae, enabling scientists to cut and paste DNA

The genomics era

- 1972- Walter Fiers and his team were first to determine the sequence of a gene Bacteriophage MS2 coat protein
- 1973 - Genetic engineering begins with the ability to insert genetic material
- 1978 - Bacteria are engineered to produce insulin
- 1981 - A gene is transferred from one animal species to another.
- 1983 - The first artificial chromosome
- 1983: Kary Banks Mullis invents the polymerase chain reaction enabling the easy amplification of DNA
- 1987: Yoshizumi Ishino accidentally discovers and describes part of a DNA sequence which later will be called CRISPR

- 1988 - The Human Genome Organization aims to map the complete sequence of DNA
- 2000 - The first draft of the human genome announced

- 2001 First draft sequences of the human genome are released simultaneously by the Human Genome Project and Celera Genomics.

- 2003- (14 April) Successful completion of Human Genome Project with 99% of the genome sequenced to a 99.99% accuracy

- 2007- Gene-editing:- CRISPR/cas9 (pronounced as '**crisper**')

- 2010: Transcription activator-like effector nucleases (or TALENs) are first used to cut specific sequences of DNA

- 2016: A genome is sequenced in outer space for the first time
- **Genomics** is the study of the structure, function, and evolutionary comparison of whole genomes
- Bioinformatics is the computer-based discipline that deals with the analysis of such large sets of biological information, especially as it applies to genomic information.

Applied genetics

1. Medicine

- Genetic techniques are used in medicine to diagnose and treat inherited human disorders.

2. Agriculture and animal husbandry

- Agriculture and animal husbandry apply genetic techniques to improve plants and animals. Breeding analysis and transgenic modification using recombinant DNA techniques are routinely used.

- Animal breeders use artificial insemination to propagate the genes of prize bulls.
- Plant geneticists/breeders use special techniques to produce new species, such as hybrid grains (i.e., produced by crossing wheat and rye), and plants resistant to destruction by insect and fungal pests.

3. Industry

- Various industries employ geneticists; the brewing industry, for example, may use geneticists to improve the strains of yeast that produce alcohol.

About human genome

- **Humans share about 90% of genetic material with mice** and 98% with chimpanzees
- We get 23 chromosomes from our mother and 23 from our father
- Some diseases are inherited through genes
- Around 5-8% of your DNA isn't human – it's viral DNA
- We share 96% of our DNA with primates such as gorillas and orangutans
- Around 99.9% of the DNA in all humans is identical
- Humans have approximately 10 trillion cells
- There are thought to be about **3 billion base pairs** in the human genome
- Human beings have 20,000 to 25,000 genes but they account for only about 3% of our DNA. Scientists are not sure about the function of the remaining 97%, although they think it may have something to do with controlling the genes
- We all know about the double helix structure, but scientists have recently discovered another form of DNA in living human cells. It's called **i-motif** and has been described as **"a four-stranded knot of DNA".**

Exciting time in Genetics

- **Genetic engineering** is the process of using **recombinant DNA (rDNA) technology** to alter the genetic makeup of an organism

- Genetic engineering involves the direct manipulation of one or more genes. Most often, a gene from another species is added to an organism's genome to give it a desired phenotype

The output of genetic engineering in Agriculture

- Some benefits of genetic engineering in agriculture are increased crop yields, reduced costs for food or drug production, reduced need for pesticides, enhanced nutrient composition and food quality, resistance to pests and disease, greater food security, and medical benefits to the world's growing population. Genetic engineering crops(GM crops) are engineered for insect resistance or herbicide tolerance.
  - **Bt** (Bacillus thuringiensis): **Bt cotton, Bt corn** and other crops with herbicide and insect resistance
  - edible vaccines
  - Cloning of whole organisms
  - DNA fingerprinting in forensics and disease diagnostics

GM crops

- **soybeans, corn (field and sweet), canola, cotton, alfalfa, sugar beets, summer squash, papaya, apples and potatoes**

Genetically Modified Organism(GMO)

- A GMO is a plant or animal that has been genetically modified through the addition of a small amount of genetic material from other organisms through molecular techniques.

Currently, GMOs have been given genetic traits to provide protection from pests, tolerance to pesticides, or improve quality.

- Examples of GMO field crops include Bt-potatoes, Bt-corn, Bt-sweet corn, Roundup Ready soybeans, and Roundup Ready Corn.

Bt cotton

Bt cotton is a **genetically modified pest-resistant plant cotton variety**, which produces an insecticide to combat bollworm

- Bt cotton is a variety of cotton genetically modified to contain a gene (cry1Ac) of Bacillus thuringiensis (Bt), which is **foreign to its genome** and is a naturally occurring soil bacterium used to control Lepidopteran insects because of a toxin it produces.

- ***Bt corn*** is a variant of maize that has been genetically altered to express one or more proteins from the bacterium Bacillus thuringiensis

- Bt corn can **help producers keep crop loss at a minimum and retain higher profit margins**. It also saves producers the time and money associated with scouting for pests and spraying pesticides on infected crops.