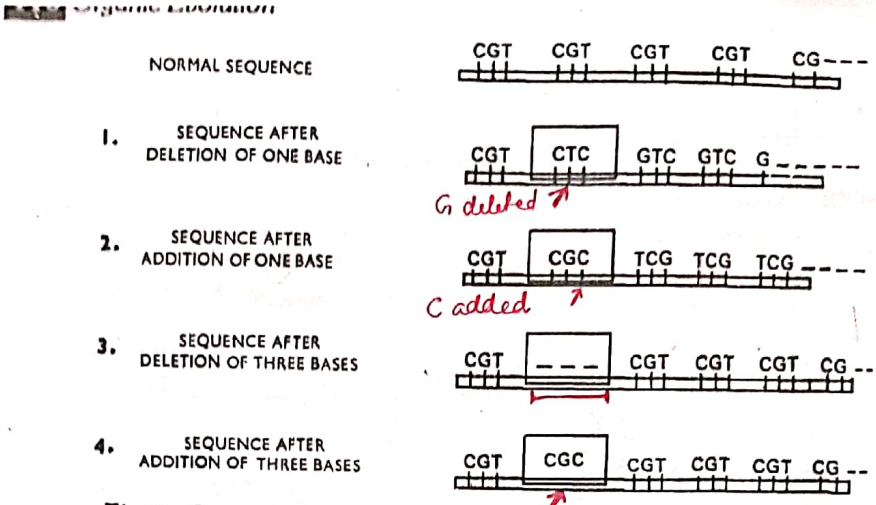


Fig. 11. Frame-shift mutation and changes in the reading of genetic code.

Role of Mutation

(1) **Agriculture**: Several mutant varieties have been developed in wheat, rice, barley, pulses, vegetables, fruits, cereals etc.
eg:- wheat (Sharbati Sonara), Rice (Jagannath, Prabhavati)
Cotton (MCU 7, MCU 10), Sugarcane (Co 8152, Co 8153)
Pea (Hans), Moong (TAT 7), Tobacco (Jayasri)

(2) **Variations**: Mutations cause variation and that leads to adaptibility of organisms to environment

(3) **Evolution**: Mutations along with variation considered as a raw material for evolution of new species.

(4) **Health**: Various physical and chemical Mutagens exposes the workers to hazards

(5) **Industrial Microbiology**: New mutant varieties are developed for better fermentation and good Yield of Antibiotics.

is inserted in place of Purine, it is transversion. In the next cycle of DNA replication, a DNA molecule is formed which contain complete Transversion. This is non reversible.

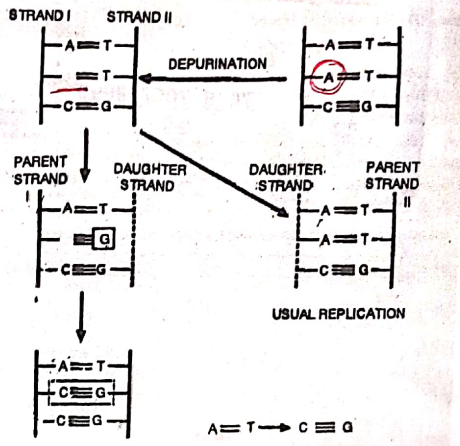


Fig. 10. Substitution of A = T by C ≡ G as a result of transversion

II Frame-Shift Mutation

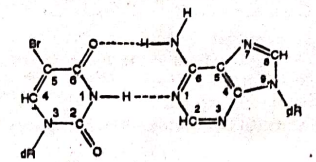
The mutation caused by the addition or deletion of nitrogenous bases in the DNA or mRNA

① Deletion Mutation :- due to loss or deletion of one or more nucleotide.

② Insertion Mutation : due to addition of one or more extra nucleotide in a DNA molecules.

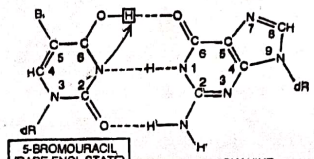
★ This changes all the codons of DNA from the site of deletion or insertion onwards, so shifting the whole coding frame and are called Gibberish or frameshift.

PAIRING OF 5-BROMOURACIL WITH ADENINE



5-BROMOURACIL (NORMAL KETO STATE) ADENINE

PAIRING OF 5-BROMOURACIL WITH GUANNE:

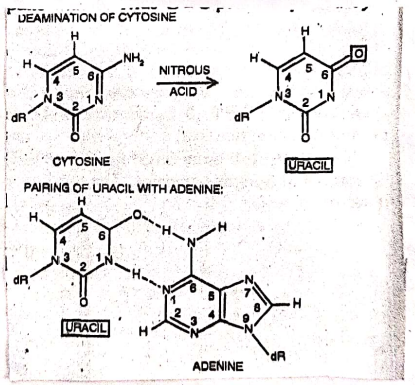


5-BROMOURACIL (RARE ENOL STATE) GUANINE

Fig. 7. Base pairing of 5-BU with adenine and guanine in keto and enol form respectively

(ii) Aminopurine :- Artificial base Analog of Adenine.

(d) Deamination : Nitrous acid, Hydroxylamine are chemicals which cause deamination of Nitrogenous bases by replacing NH_2 by -OH group



⇒ Hinder the process of Normal DNA Replication

- Other agents
  - diethyl sulphate
  - Ethyl Methane Sulphonate
  - Methyl methane Sulphonate

(2) Transversions

- Chemical Alkylating agents like Ethyl methane sulphonate and methyl Methane Sulphonate cause depurination (removal of Purine).
- Removal of Purine from the strands leaves gap.
- At the time of replication if Pyrimidine

(b) **Tonisation** Transitions may be introduced by Tonisation of base at the time of DNA replication.

Tonisation involve loss of H from No. 1 Nitrogen of nitrogenous base.

eg:- Tonised thymine pair with Normal Guanine
Tonised Guanine pair with Normal Thymine

(c) **Base Analogs** chemical compounds have molecular structure similar to nitrogenous bases called base Analogs.

eg:
Natural BA
- 5-methyl cytosine (occure in wheat & grasses)
- 5-hydroxymethyl cytosine (E coli)
- 5-hydroxymethyl uracil (Viruses)
- 6-Methyl Purine (Bacteria)

Artificial BA
- 5 bromo uracil
- 5 Iodo uracil
- 2 bromo cytosine

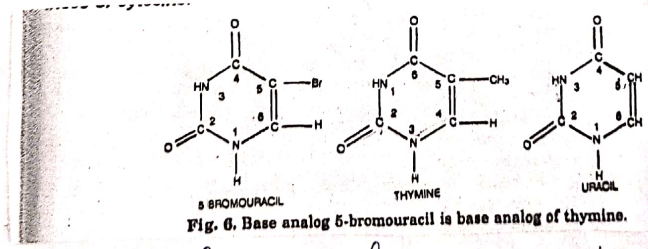


Fig. 6. Base analog 5-bromouracil is base analog of thymine.

(a) **5 Bromouracil** : analog of Thymine
Structure is very much like Thymine

The enol form is short lived and soon changes to keto form. When such mispairing occure and DNA undergoes further replication G pairs with C while keto-BU pairs with A.

① Transitions

Purine ⟷ Purine
Pyrimidine ⟷ Pyrimidine

The transitional substitutions can be introduced by any of the following ways during DNA replication and described as copy error mutations

(a) Tautomerisation

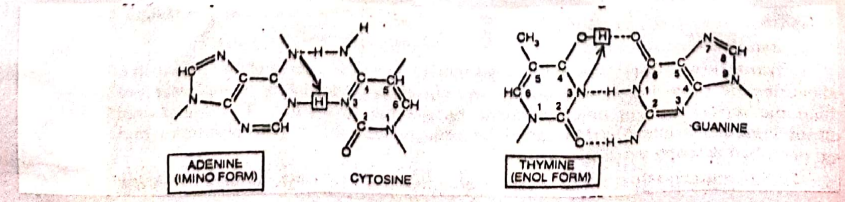
Tautomers are the alternate forms of bases and are produced by rearrangement of electrons and Protons in the molecules.

Due to tautomerism the $-NH_2$ group of cytosine and Adenine is converted to (−NH) imino gp. C=O gp of thymine and guanine is converted to enol (C-OH) group.

In its rare or tautomeric state, a nitrogenous bases cannot pair to its normal partners.

- Tautomeric Purine, adenine pairs with normal cytosine
- " guanine pairs with thymine
- " Thymine pairs with normal Guanine
- " Cytosine with Adenine.

Such bases are also known as forbiddey base pairs / unusual base pairs.



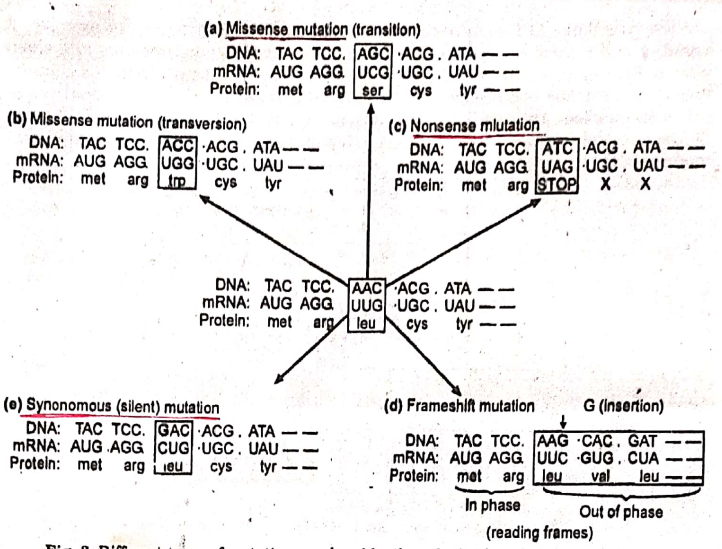


Fig. 3. Different types of mutations produced by the substitution of nitrogenous bases.

★ Types of Substitution Mutation

(1) Transition

Mutation that involve replacement of one purine by another Purine and one pyrimidine by another.

(2) Transversion

that involve replacement of Purine by Pyrimidine and Pyrimidine by Purine.

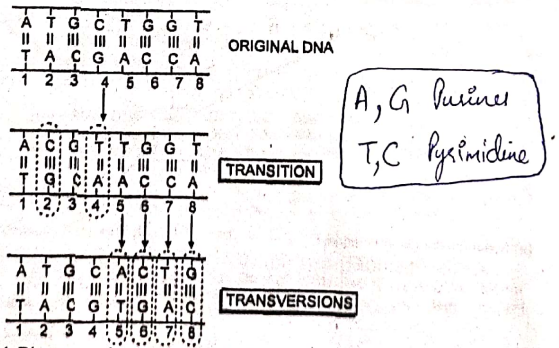
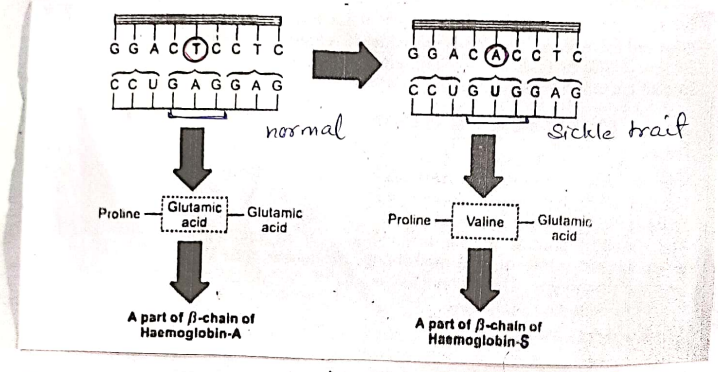


Fig. 4. Diagram to show two types of substitution mutations.

(1) Missense Mutation

These arise due to substitution of one or more amino acid for another one in a protein. This results in altered gene product producing minor to drastic or lethal phenotypic effect

Example: sickle cell Anaemia



- Substitution of T by A base in the sixth codon in DNA
- GAG replaced by GUG causing sickle cell trait.

(2) Nonsense Mutation The substitution of a nitrogenous base in a functional codon changes it to stop / termination codon.

(3) Synonomous / Same Sense Mutation substitution in which a codon is replaced by another such codon, that also codes for the same amino acid. Also called silent Mutation

Gene Mutation

- Change in the number or arrangement of nucleotides in DNA occure at molecular level. are called Gene Mutation.
- Smallest part of a gene that can mutate is Muton
- The smallest change in the arrangement or in number of nucleotides in a poly-nucleotide chain of DNA may change the genetic code and consequently the Protein and the Phenotype.

Gene Mutation

- I Substitution Mutation
  - (1) Transition
  - (2) Transversion
- II Frame-Shift Mutation
  - (1) Deletion Mutation
  - (2) Insertion Mutation

I. Substitution Mutation

A nitrogenous base of a triplet codon of DNA is replaced by another nitrogenous base, Changing the codon.

Lewis & John have identified following types—

D. Types of Mutations based on Mutagenic Effect (Dominant and Recessive Mutations)

1. Dominant Mutations : These mutations introduce dominant changes *i.e.*, a normal gene becomes recessive and mutant gene becomes dominant. The dominant mutations express themselves immediately in the cells in which these are present, whether homozygous or heterozygous. These are easy to be identified. But dominant mutations are very rare.

2. Recessive Mutations : These mutations produce recessive effect *i.e.*, a mutant gene is recessive to normal and is able to express itself only when the mutant gene is present in both the homologous chromosomes. The mutant character is not expressed immediately, but takes several generations to become homozygous.

E. Types of Mutations according to their Significance (Beneficial, Lethal, Deterimental and Biochemical Mutations)

1. Beneficial Mutations : When present these are useful to the organisms.

2. Lethal Mutations : These mutations produce a visible effect when heterozygous but are lethal in homozygous condition. In such cases, normal or wild type character is recessive. Sickle cell anaemia trait in human beings is an example of lethal mutations.

3. Deterimental Mutations : These are recessive mutations that affect viability only in homozygous condition. The heterozygous individuals are normal.

4. Biochemical Mutations : Biochemical mutations affect metabolic reactions causing changes in the intermediate metabolites or the end products. In living systems, the various steps in the metabolic pathways are controlled by enzymes. Usually, there is one enzyme for each step. Enzymes are proteins and proteins are synthesised by genes. Normally, there is one gene for the synthesis of one enzyme. When a gene undergoes mutation, it may fail to produce the specific enzyme or produces a modified enzyme. In the absence of specific enzyme, the particular substrate, on which it acts, is not converted into the products. This causes accumulation of specific substance in the body. This leads to serious complications expressed in the form of disease. These are called **biochemical disorders** and such mutations are **biochemical mutations.**

For example, in human beings, **phenylketonuria** and **alkaptonuria** are two metabolic disorders caused by mutation in genes controlling metabolic pathway of phenylalanine.

F. Types of Mutations based on their Size

1. Micromutations or Invisible Mutations : Mutations which do not produce significant change or visible phenotypic effect are called **micromutations.** They are insignificant.

2. Macromutations or Visible Mutations : These mutations cause prominent phenotypic effects.

G. Types of Mutations based on the Method of Introduction (Spontaneous and Induced Mutations)

1. Spontaneous Mutations : Naturally occurring mutations are known as **spontaneous mutations.** These appear in the progeny of parents which were not treated or induced with any known mutation-producing substances. These are known as spontaneous because the exact cause of their appearance is not known. After the discovery of mutagenic effect of X-rays, other similar radiations and certain chemical substances, it was presumed that spontaneous mutations may be caused by cosmic rays and other high radiations of the atmosphere.

2. Induced Mutations : Mutations caused by mutagenic agents are known as **induced mutations.** It has been shown that mutation rate can be raised well above the spontaneous rate by various mutagenic substances. Number of mutations is in direct proportion with the dose of radiation but is independent of intensity. For example, a dose of 5,000 rontgens (unit of radiation) will cause the same number of mutations whether received over a period of 20 minutes or 20 months. Chromosome breaks are presumed to be proportional to dose also.

H. Mutations according to Direction

Normal Gene ⇄ Mutated Gene (forward / backward)

1. Forward Mutations : When mutation produces a changed phenotype, it is called **forward mutation.**

2. Reverse or Backward Mutations : The mutated genes when mutate back to normal they exhibit reverse mutations.

⇒ Mutation is any hereditary change in genetic make up of an individual or It is sudden, stable, discontinuous and inheritable variation which appear in organism due to permanent change in their genotype.

classification of Mutations

CLASSIFICATION OF MUTATIONS

Mutational changes are classified according to the nature of tissue, the nature of genetic material, the stage in the life cycle when mutation occurs and the mutagenic effect of mutation.

(A) **A. Types of Mutations according to the Nature of Tissue (Somatic and Germinal Mutations)**

1. Somatic Mutations : These occur in the somatic cells of organisms. These produce local phenotypic change in structure and functions of the organ where mutations have occurred. Only the descendents of mutant cell express that change. Hence, these mutations are insignificant, being localized to few cells only.

Somatic mutations are **nonheritable** and are lost with the death of organism. However, if somatic mutations occur during early developmental stage or during embryonic stage, these might show phenotypic effect and may even be transferred to germ cells.

In plants, mutant progeny can be obtained by vegetative reproduction like budding, grafting, layering or cutting, etc. Some examples of mutant varieties in plants are :

(a) Emperor seedless grapes.

(b) Golden delicious apples.

(c) Horticultural varieties of garden plants.

2. Germinal Mutations : These mutations occur in germplasm, germ cells or gametes. These are heritable, are expressed in the next generation and are established in the populations. Germinal mutations are established in the gene pool of the populations.

(B) **B. Types of Mutations according to the Nature of Genetic Material (Gene Mutations and Chromosomal Mutations)**

1. Gene Mutations or Point Mutations : These are sudden changes in the structure or function of genes or both.

2. Chromosomal Mutations : These are changes in the structure of chromosomes and involve either change in the number of genes or in the arrangement of genes in a chromosome.

(C) **C. Types of Mutations based on the Stage in Life Cycle (Gametic and Zygotic Mutations)**

1. Gametic Mutations : Such mutations are introduced in the gametes or at the time of gamete formation. These are heritable mutations.

2. Zygotic Mutations : These occur in the zygote and are heritable.