Microbial Genetics

- Virtually all the microbial traits are controlled or influenced by heredity traits of microbes include their shape and structural features, their metabolism, their ability to move or behave in various ways, and their ability to interact with other organisms-perhaps causing disease. Individual organisms transmit these characteristics to their offspring through genes, the units of the hereditary material that contain the information that determines these characteristics.
- An understanding of genetics is key to grasping a number of concepts in microbiology. For example, many antibiotics act by inhibiting steps in protein synthesis.
- Knowing how biological information flows from genes to proteins can help us understand how some antibiotic work, thereby enabling us to develop new weapons against disease.
- Researchers are trying to solve the difficult medical problem of microbes' developing antibiotic resistance.
- A microorganism can become resistant to antibiotics in any of several ways, all of which depend on genetic information. Resistant microbes somehow obtained a gene or set of genes that will prevent the action of the antibiotic.
- Emerging diseases provide another example of the importance of understanding genetics. New diseases are the result of genetic changes in some existing organisms.
- Currently, biologists are using genetics to discover relatedness among organisms and how life evolved on Earth. It was by looking at genes that Carl Woese discovered that there are two types of prokaryotes, bacteria and archaea.

Mutations

What Are Mutations?

- Changes in the nucleotide sequence of DNA
- May occur in somatic cells (aren't passed to offspring)
- May occur in gametes (eggs & sperm) and be passed to offspring

- Mutation is a sudden permanent heritable changes in genetic material. The term of mutation is coined in 1901 by Devries to explain variation observed in crosses involving in the evening prime rose.
- The term mutation refers both the change in genetic material and to the process by which the change occurs. An organism exhibiting a novel phenotype as a result of mutation called mutant.
- Mutation is the ultimate source of all genetic variation; it provides the raw material for evolution.
- Without mutation, all genes would exist in only one form. Alleles would not exist, and thus, genetic analysis would not be possible. Most important, organisms would not be able to evolve and adapt to environmental changes.

Mutate or Mutant

- A change in a cell which changes a trait.
- Usually a change in a gene sequence:

…AACTAGGGACATTTACG…

…AACTAGGGCAATTTACG…

Can also be a gene loss.

Mutations

- **Causes**:
  - Radiation e.g. UV
  - Chemical e.g. Cigarette Smoke
  - Spontaneous
- **Types**:
  - In body cells, can lead to cancer.
  - In sex cells, can lead to new traits in offspring.

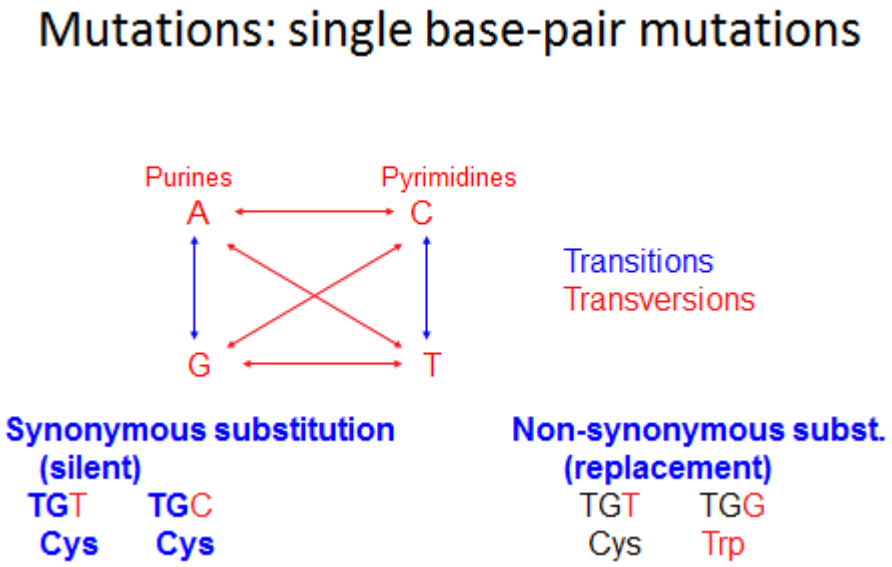
Are Mutations Helpful or Harmful?

- Mutations happen regularly
- Almost all mutations are neutral
- Chemicals & UV radiation cause mutations
- Many mutations are repaired by enzymes

Are Mutations Helpful or Harmful?

- Some type of skin cancers and leukemia result from somatic mutations
- Some mutations may improve an organism's survival (beneficial)

Types of Mutations



Other 'silent' mutations

- single-base mutations, deletions, or insertions within introns
- mutations within other non-coding regions such as repetitive DNA and pseudogenes

Chromosome Mutations

- May Involve:
  - **Changing the structure** of a chromosome
  - The **loss or gain** of part of a chromosome

Gene Mutations

- Change in the **nucleotide sequence** of a gene
- May only involve a single nucleotide
- May be due to **copying errors**, **chemicals**, **viruses**, etc.

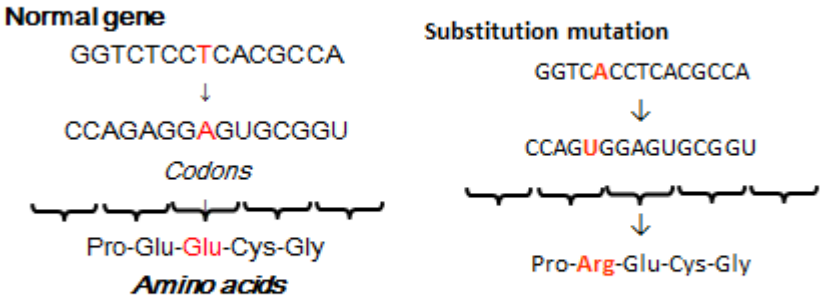
Types of Gene Mutations

- Include:
  - Point Mutations
  - Substitutions
  - Insertions
  - Deletions
  - Frameshift

Point Mutation

- Change of a **single** nucleotide
- Includes the deletion, insertion, or substitution of **ONE** nucleotide in a gene
- **Sickle Cell disease** is the result of one nucleotide substitution
- Occurs in the **hemoglobin gene**

Mutations: Substitutions



- Substitutions will only affect a single codon
- Their effects may not be serious unless they affect an amino acid that is essential for the structure and function of the finished protein molecule (e.g. sickle cell anaemia)

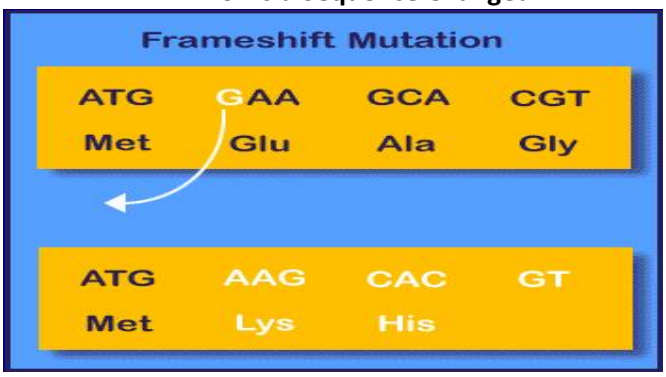
Frameshift Mutation

- **Inserting or deleting** one or more nucleotides
- Changes the "**reading frame**" like changing a sentence
- **Proteins** built **incorrectly**

Frameshift Mutation

- Original:
  - The fat cat ate the wee rat.
- Frame Shift ("a" added):
  - **The fat caa tet hew eer at.**

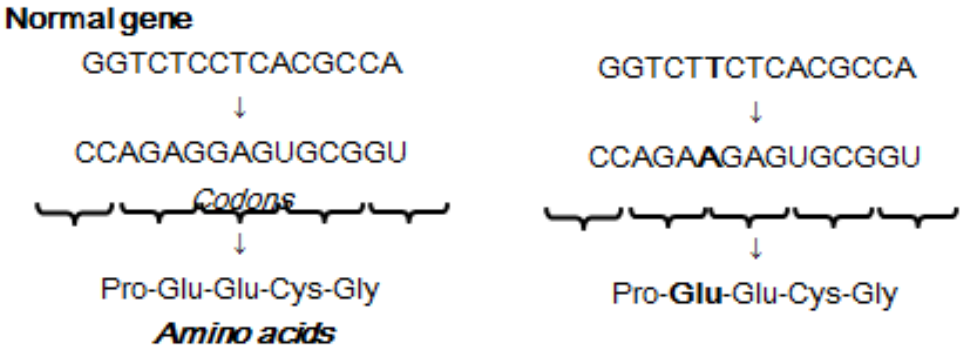
Amino Acid Sequence Changed



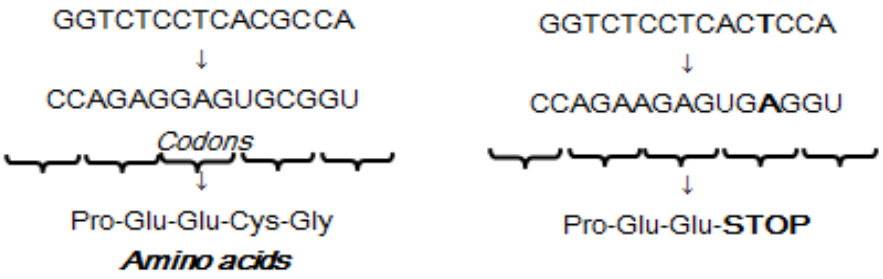
The genetic code is degenerate

- A mutation to have no effect on the phenotype
- Changes in the third base of a codon often have no effect

No change

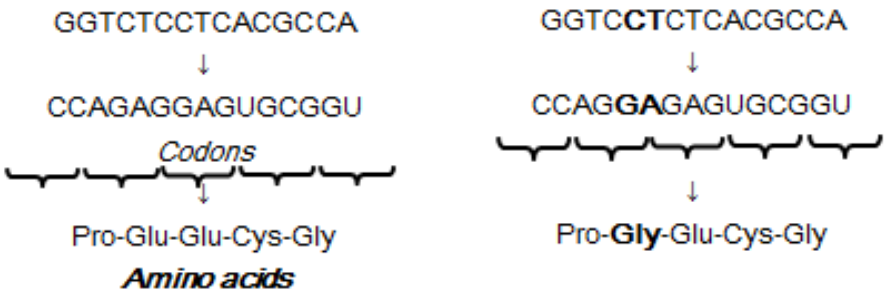


Disaster



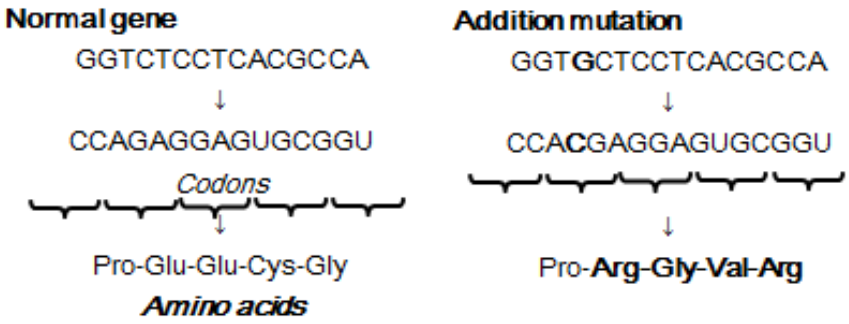
Mutations: Inversion

Inversion mutations, also, only affect a small part of the gene



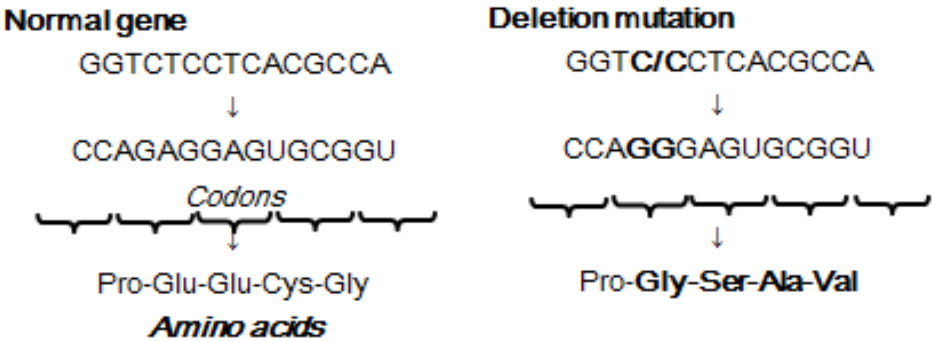
Mutations: Additions

frame shift mutation



Mutations: Deletions

A frame shift mutation



Mutations of haemoglobin

- Haemoglobin is a tetramer = 2 α and 2 β-chains
- The genes for these polypeptides are found on different chromosomes
- The β-chain gene is found on chromosome 11
- The α-chain gene is found on chromosome 16
- The nucleotide sequences have been worked out
- Several inherited diseases occur on the β-chain, which contains 146 amino acids

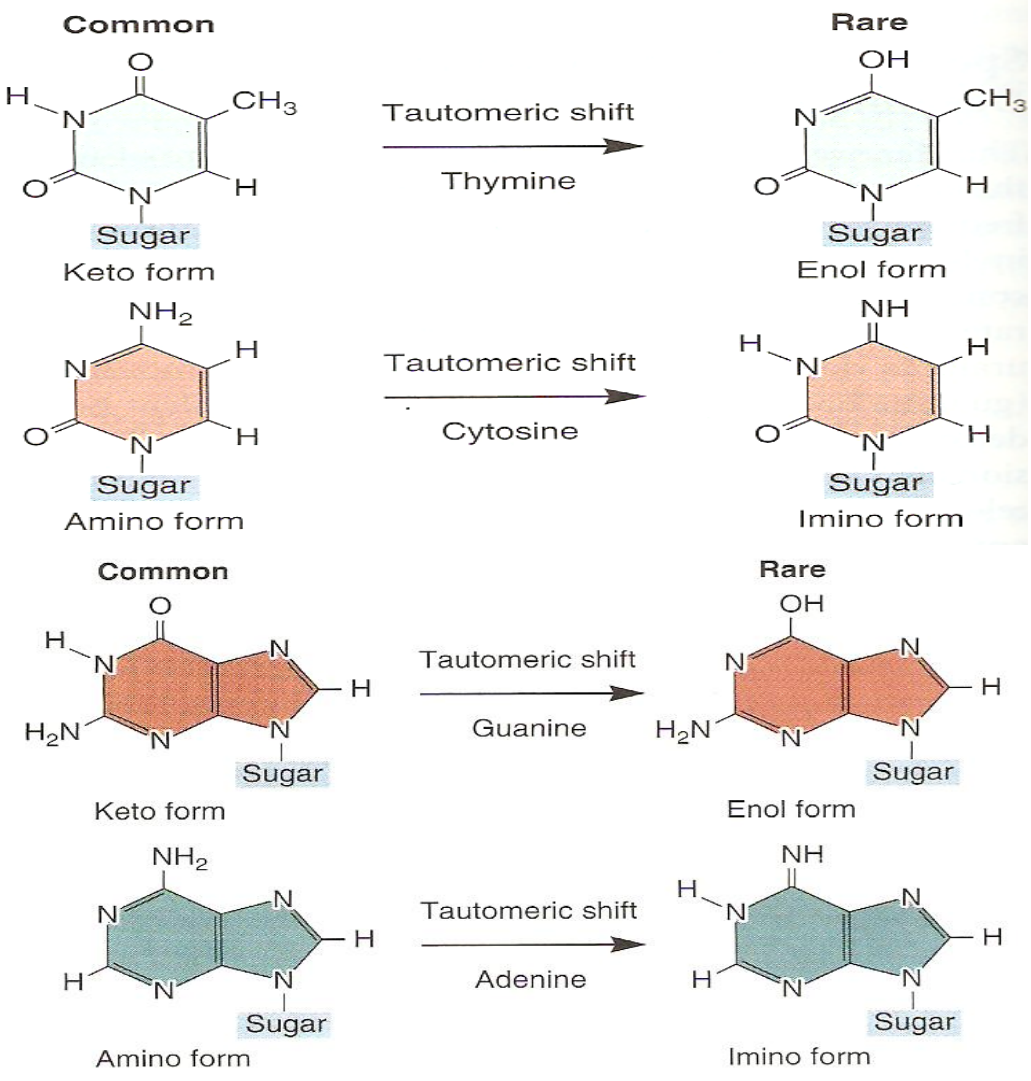
➢ **Spontaneous mutations** are those that occur without a known cause. They may be truly spontaneous, resulting from an inherent low level of metabolic errors, that is, mistakes during DNA replication, or they may actually be caused by mutagenic agents present in the environment.

Tautormeric shifts or tautomerization of nitrogen bases

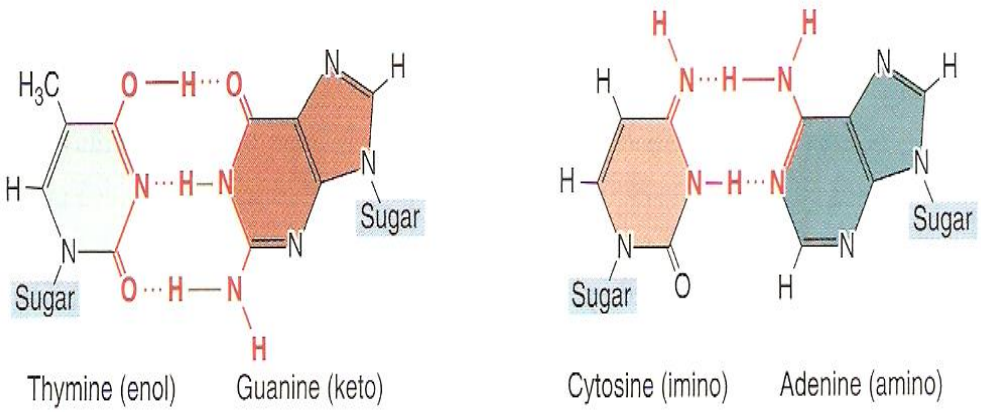
In 1953 Watson and Crick recognized that DNA exist in tautomeric forms, nitrogen bases in alternate form called Isomere each differing by only a single proton shift in the molecule because such a shift changes the banding structure of a molecule.

The common, stable form of thymine and guanine is the keto form, while the common form of adenine and cytosine is the amino form. At a low rate, T and G can interconvert to an enol form, while A and C can change to an imino form.

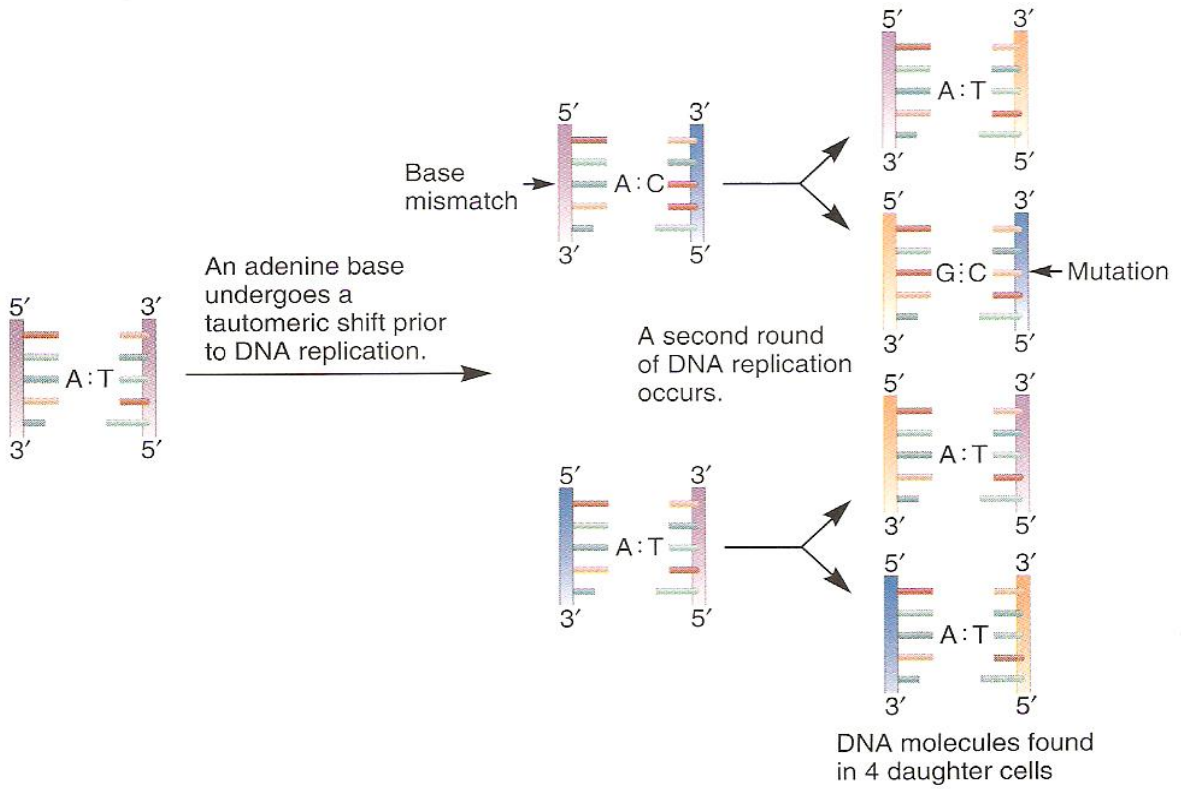
Though the relative amounts of the enol and imino forms of these bases are relatively small, they can cause mutation because these rare forms of the bases do not conform to the AT/GC rule of base pairing. Instead if one of the bases is in the enol or imino form, hydrogen bonding will promote AC and GT base pairs.



(a) Tautomeric shifts that occur in the 4 bases found in DNA



(b) Mis–base pairing due to tautomeric shifts



(c) Tautomeric shifts and DNA replication can cause mutation

For a tautomeric shift to cause a mutation, it must occur immediately prior to DNA replication. This phenomenon is shown in figure. An adenine base in the template strand has undergone a tautomeric shift just prior to the replication of complementary daughter strand. During replication, the daughter strand will incorporate a cytosine opposite this adenine, creating a base mismatch. This mismatch could be repaired via a mismatch repair system or via the proofreading function of DNA polymerase. However, if these repair mechanisms fail, the next round of DNA replication will create a double helix with a GC base pair, while the correct base pair should be AT. One of four daughter cells will inherit this GC mutation.