**Mutation**

In [molecular biology](http://en.wikipedia.org/wiki/Molecular_biology) and [genetics](http://en.wikipedia.org/wiki/Genetics), **mutations** are changes in a [genomic sequence](http://en.wikipedia.org/wiki/Genome): the [DNA](http://en.wikipedia.org/wiki/DNA) sequence of a cell's [genome](http://en.wikipedia.org/wiki/Genome) or the DNA or [RNA](http://en.wikipedia.org/wiki/RNA) sequence of a virus. These random sequences can be defined as sudden and spontaneous changes in the cell. Mutations are caused by [radiation](http://en.wikipedia.org/wiki/Radioactive_decay), [viruses](http://en.wikipedia.org/wiki/Virus), [transposons](http://en.wikipedia.org/wiki/Transposon) and [mutagenic chemicals](http://en.wikipedia.org/wiki/Mutagen), as well as [errors](http://en.wikipedia.org/wiki/DNA_error) that occur during [meiosis](http://en.wikipedia.org/wiki/Meiosis) or [DNA replication](http://en.wikipedia.org/wiki/DNA_replication).[[1]](http://en.wikipedia.org/wiki/Mutation#cite_note-Bertram-0)[[2]](http://en.wikipedia.org/wiki/Mutation#cite_note-transposition764-1)[[3]](http://en.wikipedia.org/wiki/Mutation#cite_note-Burrus-2) They can also be induced by the organism itself, by [cellular processes](http://en.wikipedia.org/wiki/Cellular_processes) such as [hypermutation](http://en.wikipedia.org/wiki/Somatic_hypermutation).

Mutation can result in several different types of change in sequences; these can either have no effect, alter the [product of a gene](http://en.wikipedia.org/wiki/Gene_product), or prevent the gene from functioning properly or completely. One study on genetic variations between different species of [*Drosophila*](http://en.wikipedia.org/wiki/Drosophila) suggests that if a mutation changes a [protein](http://en.wikipedia.org/wiki/Protein) produced by a gene, the result is likely to be harmful, with an estimated 70 percent of amino acid [polymorphisms](http://en.wikipedia.org/wiki/Polymorphism_%28biology%29) having damaging effects, and the remainder being either neutral or weakly beneficial.[[4]](http://en.wikipedia.org/wiki/Mutation#cite_note-Sawyer2007-3) Due to the damaging effects that mutations can have on genes, organisms have mechanisms such as [DNA repair](http://en.wikipedia.org/wiki/DNA_repair) to prevent mutations

**Causes**

[*Mutagenesis*](http://en.wikipedia.org/wiki/Mutagenesis)

Two classes of mutations are spontaneous mutations (molecular decay) and induced mutations caused by [mutagens](http://en.wikipedia.org/wiki/Mutagen).

**Spontaneous mutation**

*Spontaneous mutations* on the molecular level can be caused by:[[21]](http://en.wikipedia.org/wiki/Mutation%22%20%5Cl%20%22cite_note-20)

* [Tautomerism](http://en.wikipedia.org/wiki/Tautomerism) – A base is changed by the repositioning of a hydrogen atom, altering the hydrogen bonding pattern of that base resulting in incorrect base pairing during replication.
* [Depurination](http://en.wikipedia.org/wiki/Depurination) – Loss of a purine base (A or G) to form an apurinic site (AP site).
* [Deamination](http://en.wikipedia.org/wiki/Deamination) – Hydrolysis changes a normal base to an atypical base containing a keto group in place of the original amine group. Examples include C → U and A → HX (hypoxanthine), which can be corrected by DNA repair mechanisms; and 5MeC (5-methylcytosine) → T, which is less likely to be detected as a mutation because thymine is a normal DNA base.
* [Slipped strand mispairing](http://en.wikipedia.org/wiki/Slipped_strand_mispairing) – Denaturation of the new strand from the template during replication, followed by renaturation in a different spot ("slipping"). This can lead to insertions or deletions.





A [covalent](http://en.wikipedia.org/wiki/Covalent) [adduct](http://en.wikipedia.org/wiki/Adduct) between [benzo[*a*]pyrene](http://en.wikipedia.org/wiki/Benzo%28a%29pyrene), the major [mutagen](http://en.wikipedia.org/wiki/Mutagen) in [tobacco smoke](http://en.wikipedia.org/wiki/Tobacco_smoking), and DNA[[22]](http://en.wikipedia.org/wiki/Mutation#cite_note-21)

**Induced mutation**

**Induced mutations on the molecular level can be caused by:**

* Chemicals
	+ [Hydroxylamine](http://en.wikipedia.org/wiki/Hydroxylamine) NH2OH
	+ [Base analogs](http://en.wikipedia.org/wiki/Base_analog) (e.g. [BrdU](http://en.wikipedia.org/wiki/BrdU))
	+ Alkylating agents (e.g. [*N*-ethyl-*N*-nitrosourea](http://en.wikipedia.org/wiki/ENU)) These agents can mutate both replicating and non-replicating DNA. In contrast, a base analog can only mutate the DNA when the analog is incorporated in replicating the DNA. Each of these classes of chemical mutagens has certain effects that then lead to transitions, transversions, or deletions.
	+ Agents that form [DNA adducts](http://en.wikipedia.org/wiki/DNA_adduct) (e.g. [ochratoxin A](http://en.wikipedia.org/wiki/Ochratoxin_A) metabolites)[[23]](http://en.wikipedia.org/wiki/Mutation#cite_note-22)
	+ DNA [intercalating](http://en.wikipedia.org/wiki/Intercalation_%28chemistry%29) agents (e.g. [ethidium bromide](http://en.wikipedia.org/wiki/Ethidium_bromide))
	+ [DNA crosslinkers](http://en.wikipedia.org/wiki/Crosslinking_of_DNA)
	+ [Oxidative damage](http://en.wikipedia.org/wiki/Oxidative_stress)
	+ Nitrous acid converts amine groups on A and C to diazo groups, altering their hydrogen bonding patterns which leads to incorrect base pairing during replication.
* Radiation
	+ [Ultraviolet](http://en.wikipedia.org/wiki/Ultraviolet) radiation (nonionizing radiation). Two nucleotide bases in DNA – cytosine and thymine – are most vulnerable to radiation that can change their properties. UV light can induce adjacent [pyrimidine](http://en.wikipedia.org/wiki/Pyrimidine) bases in a DNA strand to become covalently joined as a [pyrimidine dimer](http://en.wikipedia.org/wiki/Pyrimidine_dimer). UV radiation, particularly longer-wave UVA, can also cause [oxidative damage to DNA](http://en.wikipedia.org/wiki/DNA_oxidation).[[24]](http://en.wikipedia.org/wiki/Mutation#cite_note-Kozmin-23) [Mutation rates](http://en.wikipedia.org/wiki/Mutation_rate) also vary across species. Evolutionary biologists[[*citation needed*](http://en.wikipedia.org/wiki/Wikipedia%3ACitation_needed)] have theorized that higher mutation rates are beneficial in some situations, because they allow organisms to evolve and therefore adapt more quickly to their environments. For example, repeated exposure of bacteria to antibiotics, and selection of resistant mutants, can result in the selection of bacteria that have a much higher mutation rate than the original population ([mutator strains](http://en.wikipedia.org/wiki/Mutator_genotype%22%20%5Co%20%22Mutator%20genotype)).