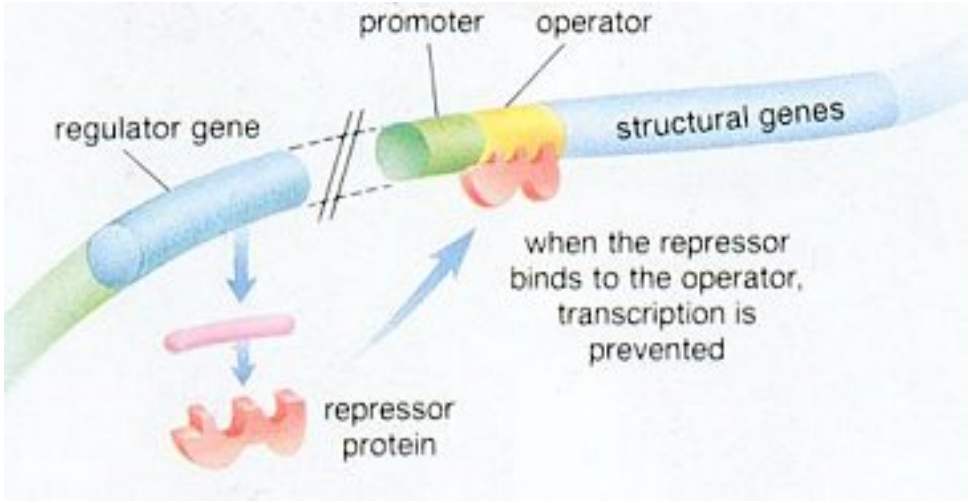
12.4 Gene Regulation and Mutation

Gene regulation is used to control which genes are transcribed

(so you only make the proteins you need at that time)

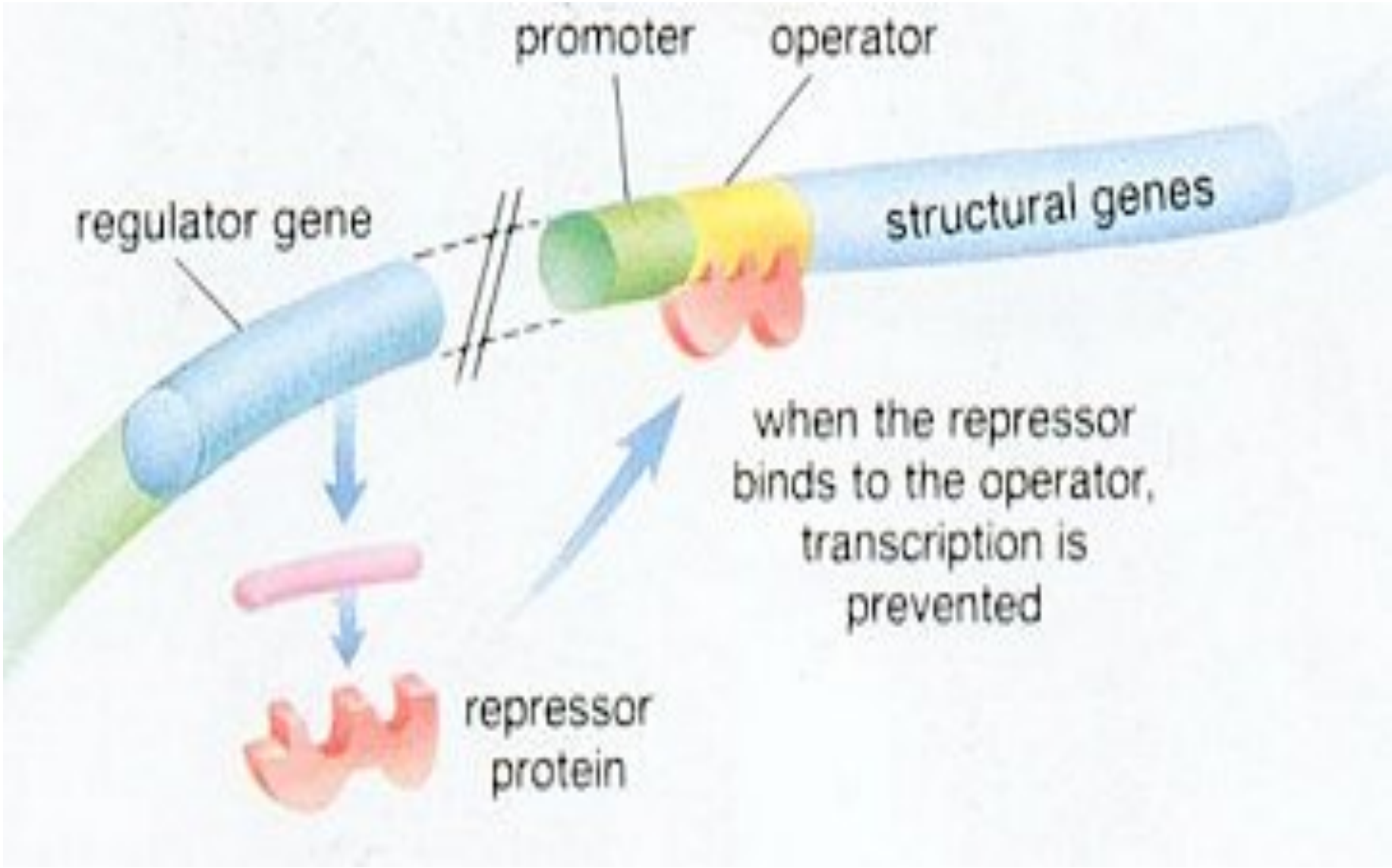
Prokaryotic Gene Regulation

Operon- a section of DNA that contains information related to a specific metabolic pathway.



An operon contains:

- **Operator** – on/off switch
- **Promoter** –RNA polymerase binds
- **Regulatory gene** – makes repressor
- **Genes**- coding for proteins

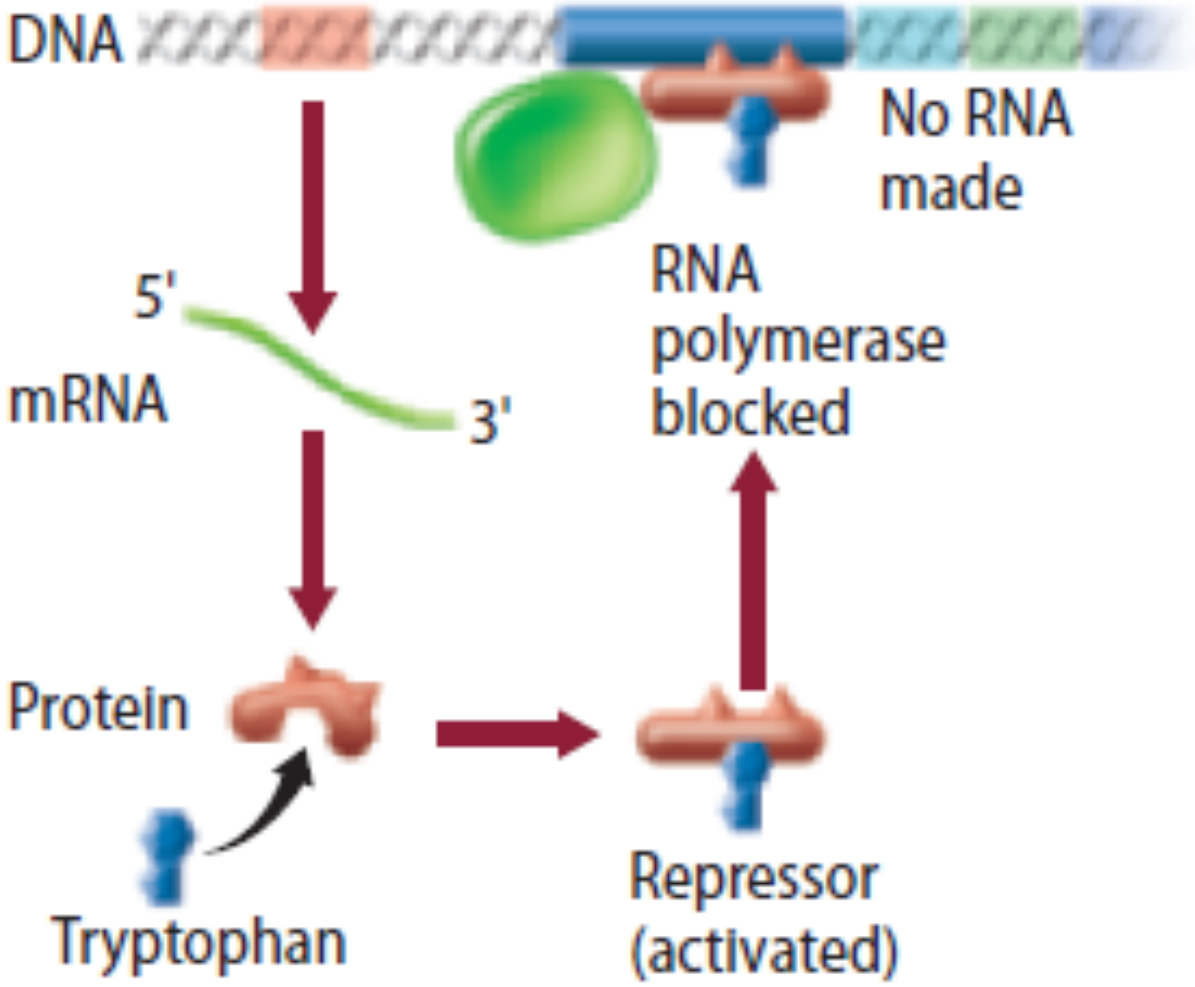

promoter
operator
regulator gene
structural genes
when the repressor binds to the operator, transcription is prevented
repressor protein

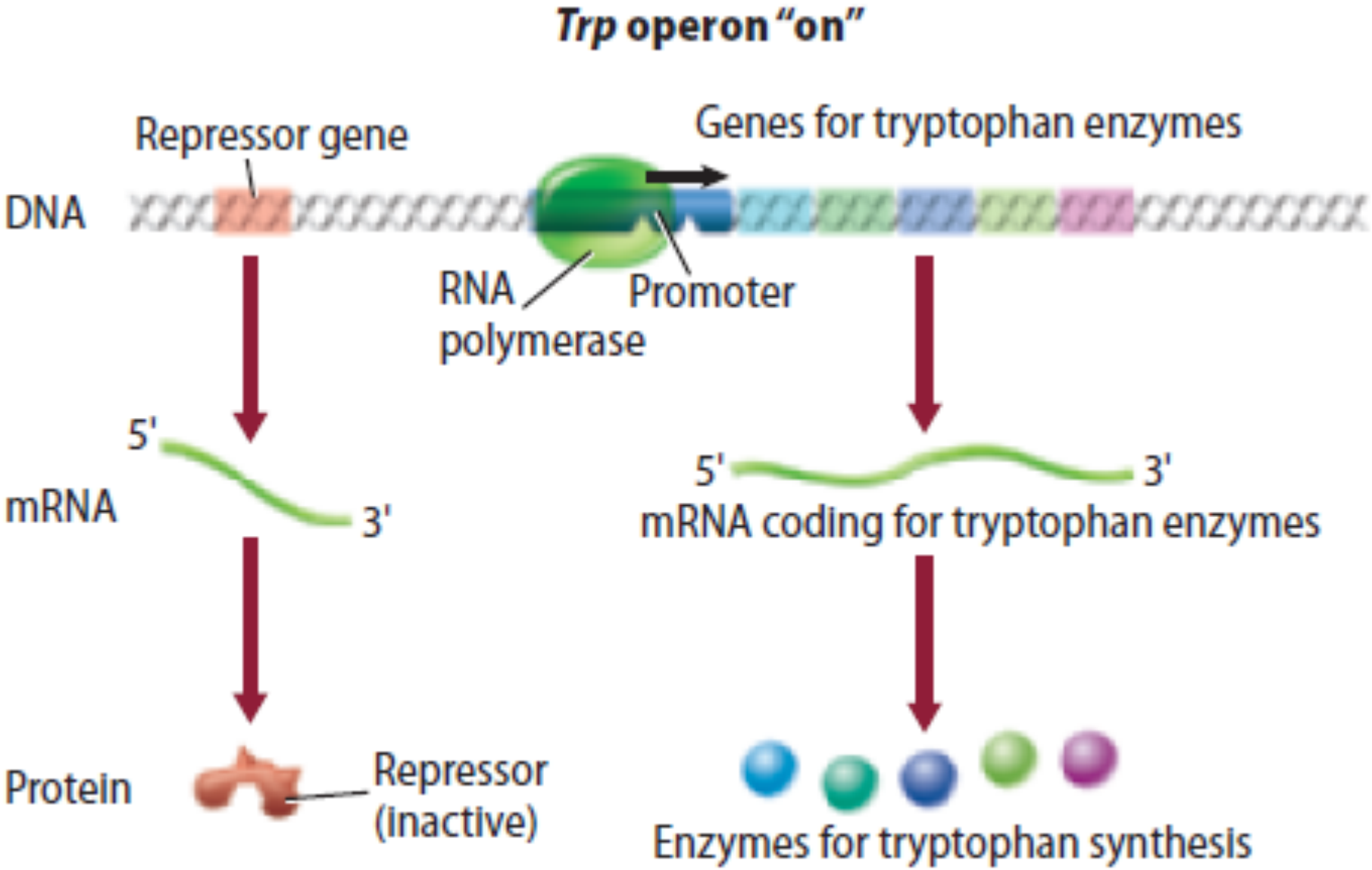
***trp* operon**

- Tryptophan synthesis occurs in five steps controlled by the ***trp* operon**.

- The *trp* operon is a **repressible operon**, because it is usually repressed or turned off.

Trp operon "off"



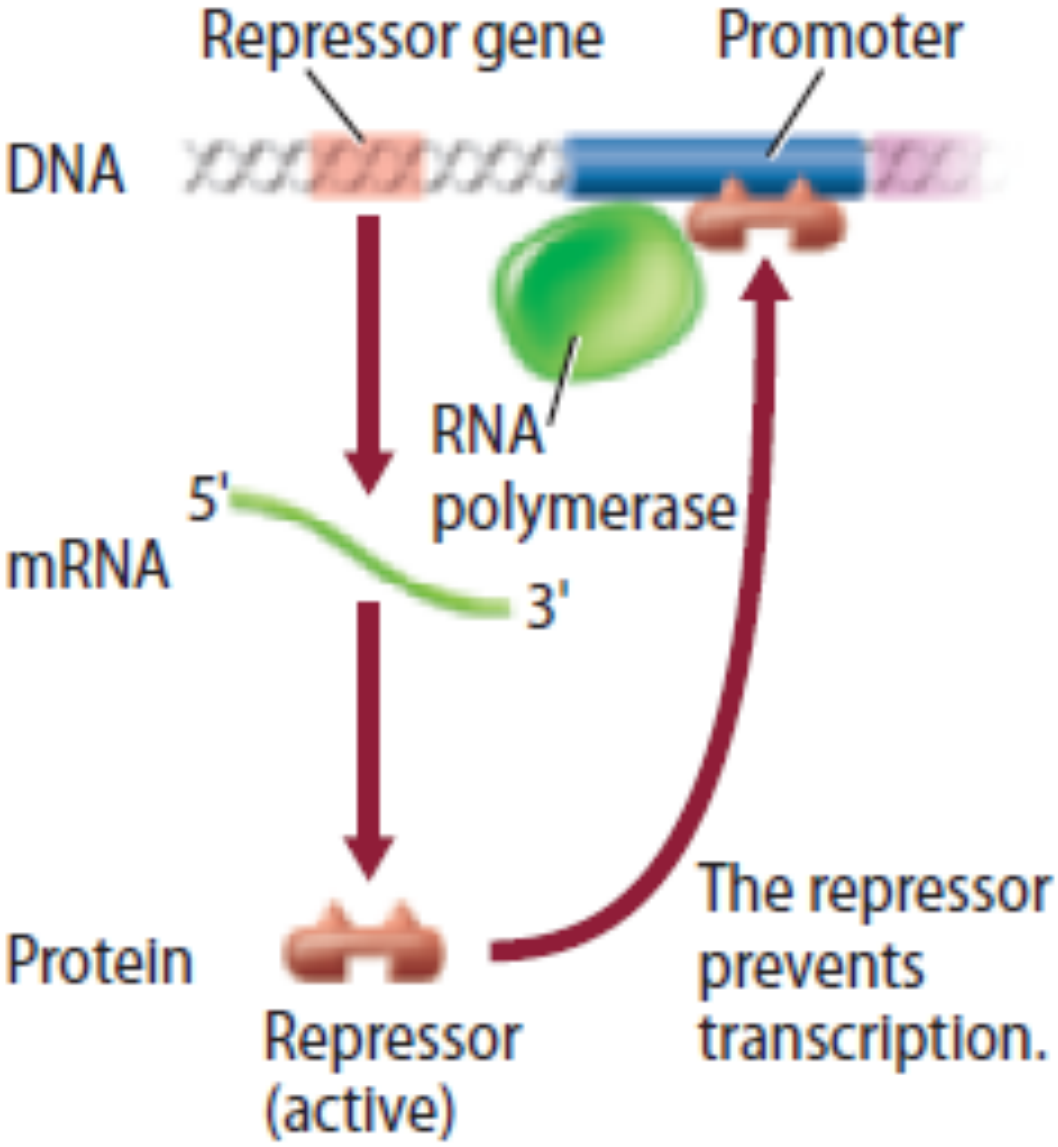

Trp operon "on"
Repressor gene
Genes for tryptophan enzymes
DNA
RNA polymerase
Promoter
5'
3'
mRNA
5'
3'
mRNA coding for tryptophan enzymes
Protein
Repressor (Inactive)
Enzymes for tryptophan synthesis

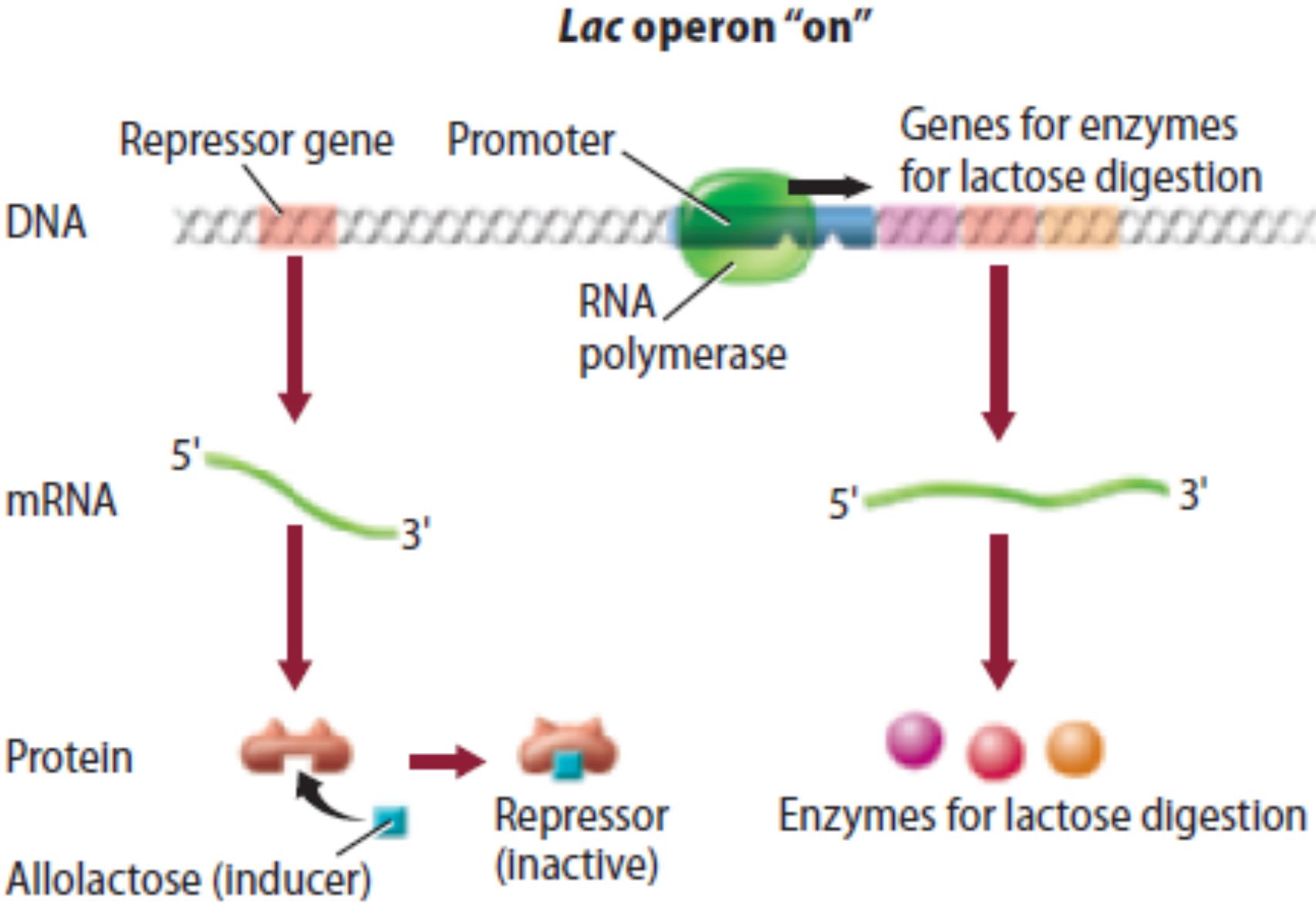
lac operon

- *E. coli* can synthesize an enzyme to use lactose for an energy source.

- The ***lac* operon** is an **inducible operon** because when lactose is present an "inducer" deactivates the repressor, turning transcription on.

Lac operon "off"




Lac operon "on"
Repressor gene
Promoter
Genes for enzymes for lactose digestion
DNA
RNA polymerase
5'
mRNA
3'
5'
3'
Protein
Repressor (inactive)
Enzymes for lactose digestion
Allolactose (inducer)

Eukaryotic Gene Regulation

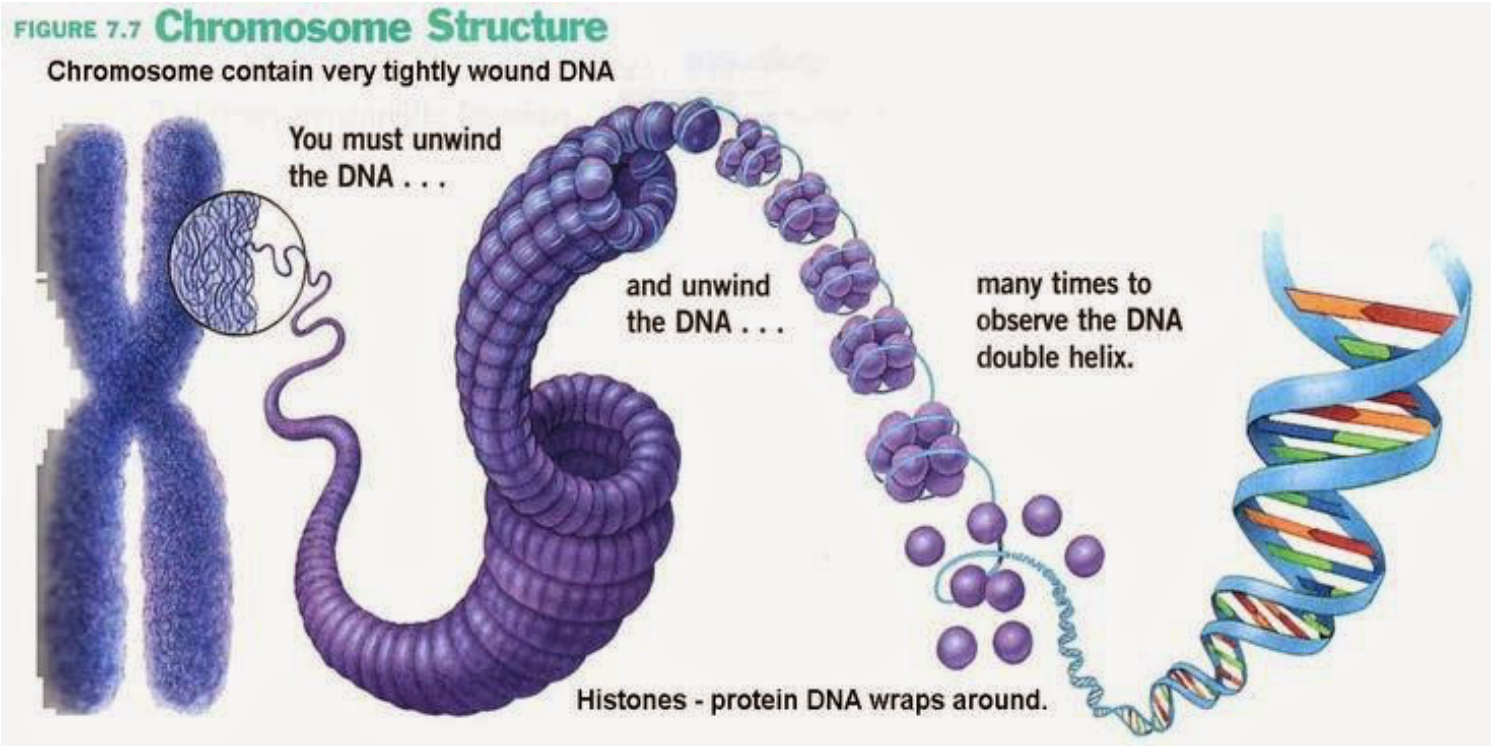
Much more complicated!

Transcription factors ensure a gene is used at the right time in the right amount.

2 types of transcription factors:

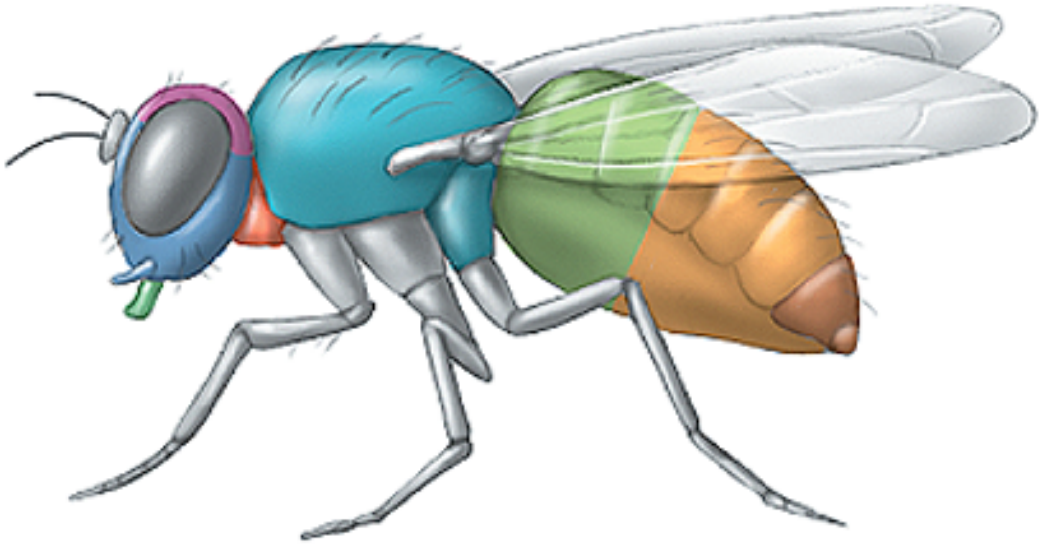
1. Guide binding of RNA polymerase to a promoter
2. Proteins that help control the rate of transcription

Shape of DNA and location of genes on the strand also helps control transcription



Gene regulation is crucial during development and cell differentiation.

Adult *Drosophila*



Drosophila embryo

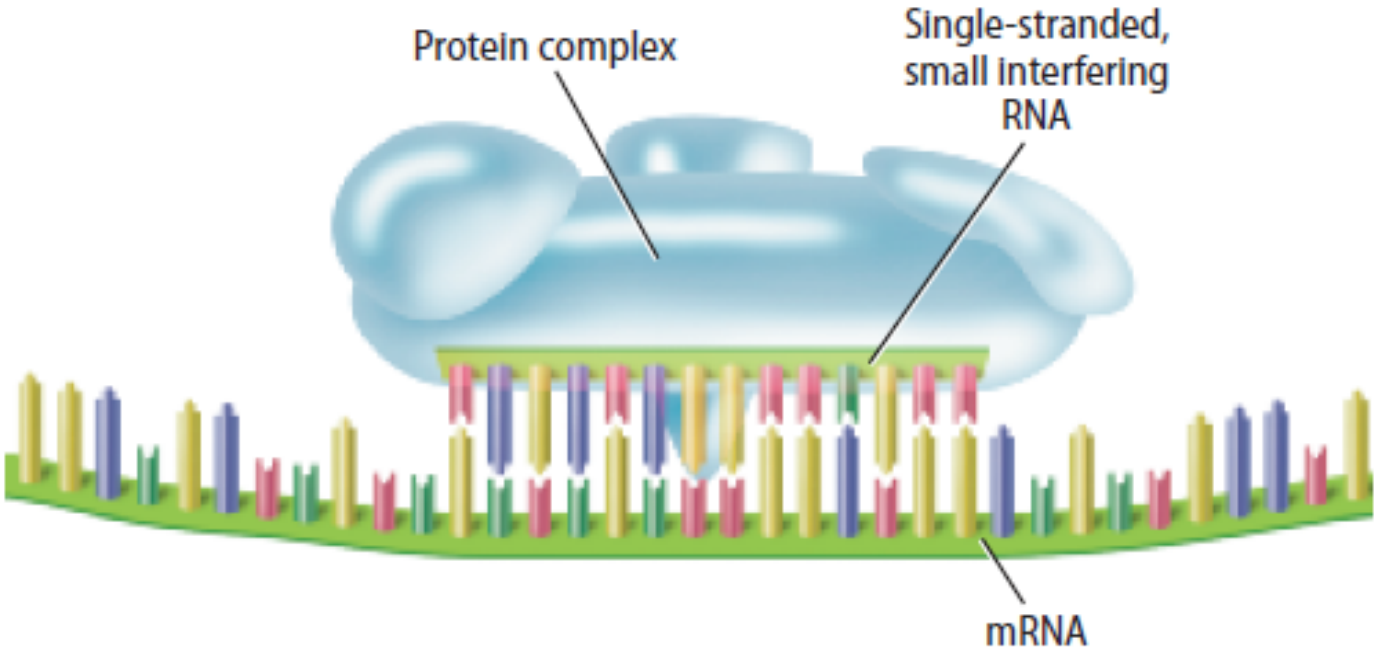
Drosophila Hox genes

homeobox (Hox) genes control cell differentiation

Hox genes are transcribed at specific times in specific places, to control what body part will develop at a given location.

RNA interference (RNAi)

Single-stranded small interfering RNA and protein complexes bind to mRNA and stop translation.

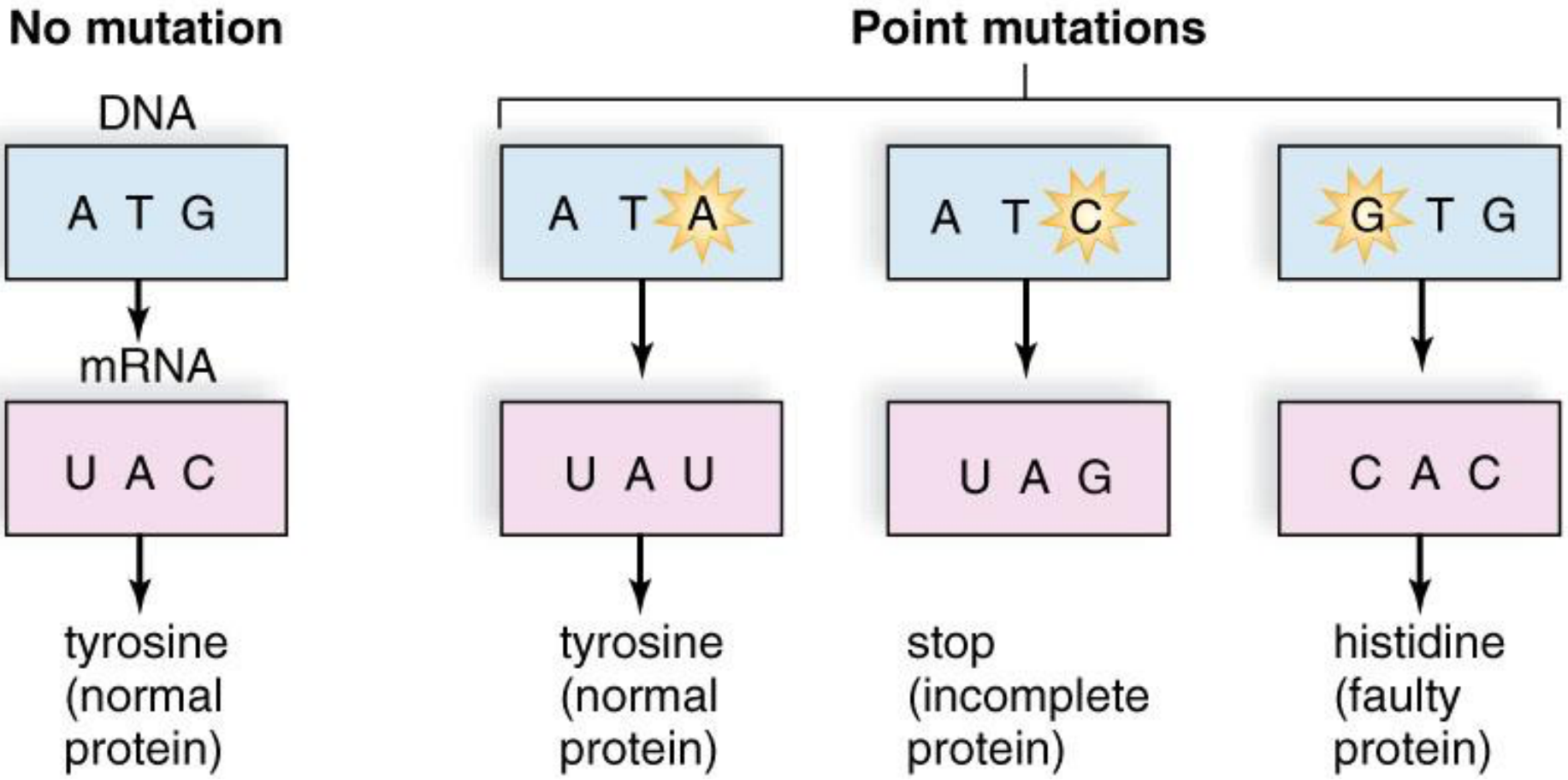


Sometimes a cell makes a mistake when replicating. Some mistakes can be caught and fixed by the cell, but some aren't.

Mutation A permanent change that occurs in a cell's DNA

Types of mutations

Point mutation: involve chemical change to just one base pair



Silent: DNA codes for the same amino acid

	No mutation	Silent
DNA level	TTC	TTT
mRNA level	AAG	AAA
protein level	**Lys**	**Lys**

Missense substitutions: DNA codes for the wrong amino acid

THE BIG FAT CAT ATE THE WET RAT

THE BIZ FAT CAT ATE THE WET RAT

Nonsense mutation:
Codon for amino acid becomes a **stop** codon

THE BIG FAT CAT ATE THE WET RAT

THE BIG RAT

Frameshift Mutations

Insertion or Deletion of a nucleotide in the DNA sequence

These are extremely harmful because they impact every amino acid after the mutation.

THE **BIG** FAT **CAT** ATE **THE** WET **RAT**

THB **IG**F AT**C AT**A TE**T HE**W ET**R AT**

THE **BIG** ZFA T**CA T**AT E**TH E**WE T**RA**

Normal	Substitution	Insertion	Deletion	Inversion
				
BEAST	FEAST	BREAST	BEST	BEATS
		⬆	⬇	
			A	

Expanding mutation (repeats)

Generation 1

THE BIG FAT **CAT** ATE THE WET RAT

Generation 2

THE BIG FAT **CAT** CAT CAT ATE THE WET RAT

Generation 3

THE BIG FAT **CAT** CAT CAT CAT CAT CAT ATE THE WET RAT

Expanding mutation was only discovered in 1991

Fragile X syndrome-

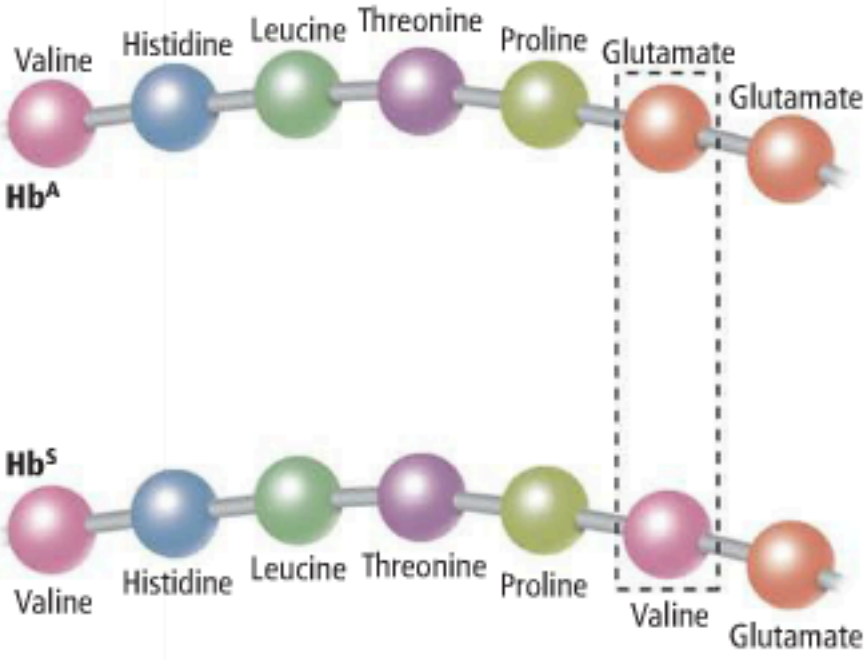
Near the end of a normal X chromosome there is a series of about 30 CGG codons. In fragile X it repeats hundreds of times.

Large pieces of chromosomes can also be deleted or moved, which can also impact the expression of genes.

Protein folding and stability

Even small changes in the DNA code can cause genetic disorders.

The change in one amino acid can change the sequence of the protein enough to affect both the folding and stability of the protein.



Normal shape of red blood cell

Sickle shape of red blood cell

However, most mutations have little to no effect on the organism.

Scientists estimate that you inherit 60-100 mutations from your parents and that you have about 400 mutations throughout your body.

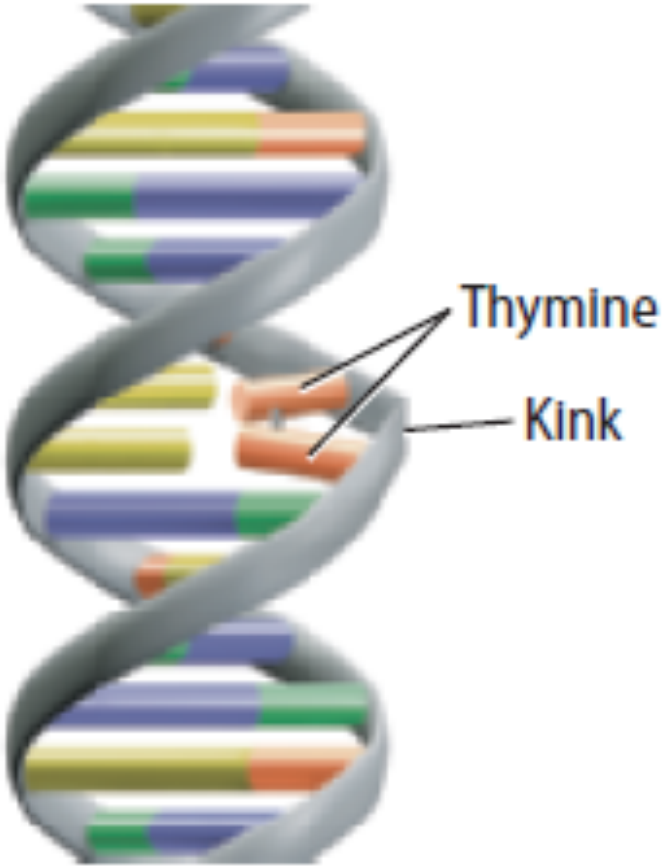
Causes of mutation

Mutations can occur spontaneously – DNA polymerase can attach the wrong nucleotide, but this is rare and usually corrected.

Mutagens chemicals and radiation that can cause mutations.

- Mutagens can cause mispairing of base pairs, or substitute for base pairs making replication impossible.

radiation can eject electrons from atoms within the DNA molecule, leaving behind unstable free radicals.



Body-cell v. sex-cell mutation

- **Body cell mutations** are only passed to that cell's daughter cells, they are not passed on to offspring. (ex: skin cell)

- **Sex cell mutations**

(egg or sperm)

are passed on to the offspring and will be present in every cell of the offspring.