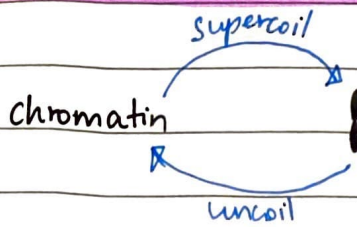
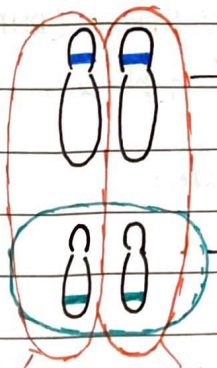
INHERITANCE





Diploid (2n)

Contains 2 complete sets of chromosomes.

Homologous chromosomes

- same length/shape
- same position of centromere
- carry same genes in same loci (positions)

1 set of chromosomes | 1 set of chromosomes

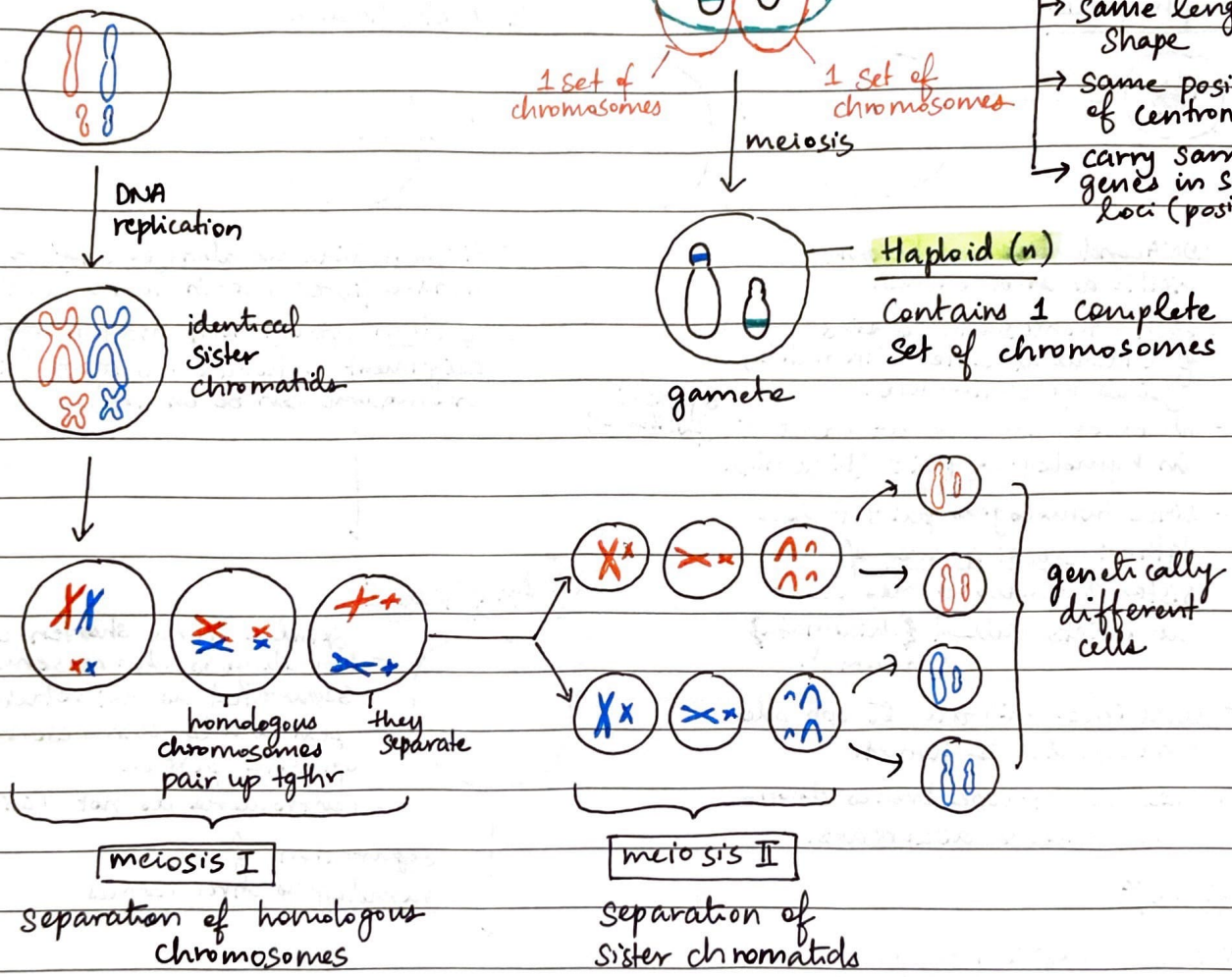
meiosis

Haploid (n)

Contains 1 complete set of chromosomes

gamete

MEIOSIS



Mitosis	Vs.	Meiosis
- produces genetically identical cells, having same no. of chromosomes as original cell/parent cell.		- produces genetically different cells, having half the no. of chromosomes as parent cell.

Purpose: produces gametes for sexual reproduction.

Reduction Division

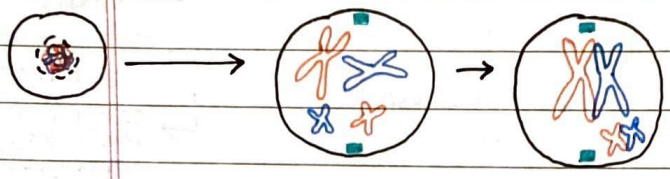
- halves the no. of chromosomes in nucleus.
- changes a diploid cell (2n) → haploid cell (n)

Interphase → G_1 phase
→ S phase (DNA replication)
→ G_2 phase

After Interphase :

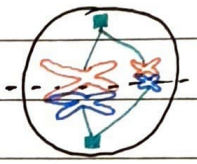
MEIOSIS I

① Prophase I



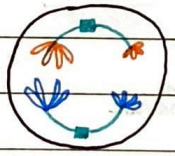
- DNA condenses and becomes visible as chromosomes.
- each chromosome consists of 2 identical sister chromatids, joined by centromere.
- chromosomes are arranged in homologous pairs (bivalents). (synapsis = pairing up)
- since homologous pairs v close tgthr : crossing-over of non-sister chromatids may occur at points called chiasmata (chiasma).
- centrioles migrate to opp poles and spindle is formed.
- nuclear envelope breaks down and nucleolus disappears.

② Metaphase I



- Bivalents line up along equator of spindle.
- Spindle fibres attach to the centromeres.
- random assortment may occur : random alignment of homologous pairs (either chromosome can be on top).

③ Anaphase I



- spindle fibres shorten and homologous chromosomes are separated as microtubules pull whole chromosomes to opposite poles.
- Centromeres do not divide.

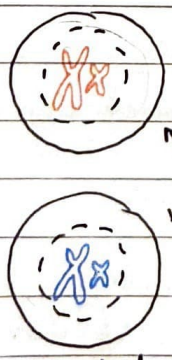
separation of homologous chromosomes

④ Telophase I

- chromosomes arrive at opp. poles.
- Spindle fibres break down.
- nuclear envelope reforms and nucleoli reappear.

* Some plants go straight into meiosis II without reformation of nucleus in telophase I.

cytokinesis



2 haploid cells (contain ½ the no. of centromeres)

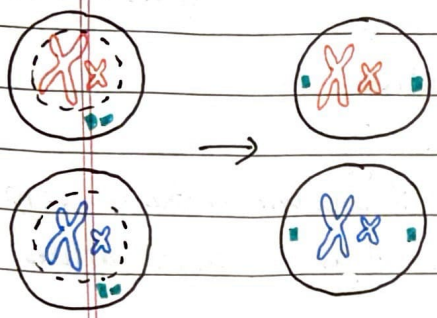
cytokinesis*

- division of cytoplasm occurs.
- cell organelles get distributed btwn the 2 developing cells.
- Animal cells : cell surface membrane pinches inward, creating cleavage furrow in middle of cell, which contracts & divides cytoplasm in half.
- Plant cells : vesicles from Golgi apparatus gather along equator of spindle. Vesicles merge & form new cell surface membrane

* contd.
- layers of cellulose are laid down to form primary & secondary walls of cell.

MEIOSIS II

① Prophase II

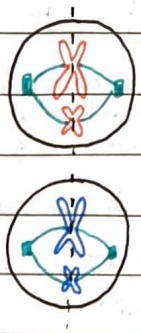


- nuclear envelope breaks down and nucleolus disappears.
- a spindle forms at right angles to the old one.

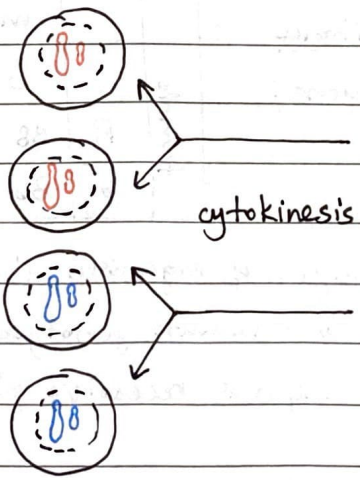
cytokinesis

cytoplasm divides.

② Metaphase II

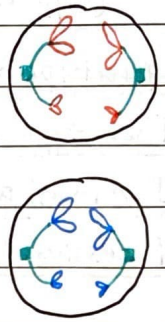


- Sister chromatids line up in single file along the equator of spindle.
- Spindle fibres attach to centromeres



4 haploid ~~chromosomes~~ cells

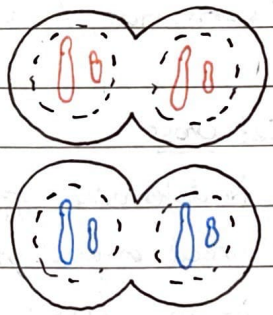
③ Anaphase II



separation of sister chromatids

- centromeres divide
- individual chromatids are pulled to opp. poles by microtubules. spindle fibres shorten

④ Telophase II



- nuclear envelope reforms and nucleoli reappear.
- spindle fibres break down.

To identify stages :

→ homologous pairs of chromosomes ⇒ meiosis I

individual sister chromatids ⇒ meiosis II

→ **Genes**: length of DNA that codes for a single polypeptide / protein

→ **Allele**: 2 or more diff forms of the same gene. (diff base sequences, but same locus)
↳ **locus**: position of a gene on chromosome.

→ **Genotype**: alleles of a gene present in an organism / individual.

→ **Phenotype**: observable characteristics/features of an organism.

→ **Dominant allele**: allele that is always expressed if present in the genotype.

→ **Recessive allele**: allele that is only expressed when dominant alleles are absent.

→ **Codominant**: 2 different alleles affect phenotype / can be expressed in phenotype at the same time.

→ **Homozygous**: same alleles in the genotype.

→ **Heterozygous**: diff alleles in the genotype.

→ **Monohybrid Inheritance**

Inheritance of 1 gene.

		male	
		B	b
female	B	BB	Bb
	b	Bb	bb

F_1 = homozygous dom x homozygous rec

3:1 blue:red

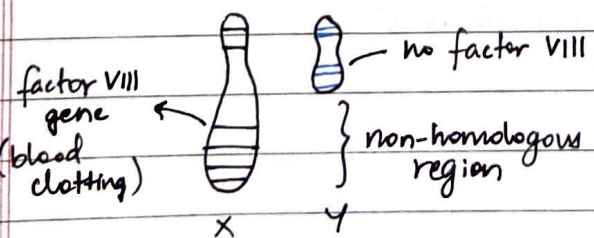
F_2 = ~~x~~ offspring when $2F_1$ individuals crossed.

Test cross

- to determine genotype of organism that expresses dominant phenotype.
- breed organism w/ unknown genotype with homozygous recessive organism.
- if any offspring express recessive phenotype → genotype was heterozygous.

→ **Sex chromosomes and sex-linkage**

- first 22 pairs of chromosomes in human = autosomes
  23rd pair = sex chromosomes (male: XY ; female: XX) ← 2 sex chromosomes
  ↳ not homologous
  ↳ homologous



~~Sex-linkage~~ **Sex-linked inheritance**
↳ inheriting genes located on the sex chromosomes.

eg. factor VIII gene has 2 alleles: H & h, located on X chromosome.
↙ normal blood clotting ↘ haemophilia

genotypes are written this way: X^HX^H (normal) X^hX^h (haemophilia) X^HX^h (carrier) — females

X^HY (normal) X^hY (haemophilia) — males

→ **Autosomal vs. Sex-linked Inheritance**

autosomal inheritance: inheritance of genes located on autosomes.

→ if gene located on sex-chromosome: male carries 1 allele } affects them differently
female carries 2 alleles }

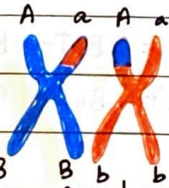
→ if gene located on autosome: male & female carry 2 alleles. affects them equally.

Meiosis — Sources of Genetic Variation

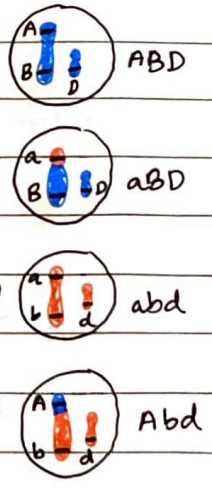
① **Crossing over**

chiasma: point where the chromatids overlap/ entangle

(bivalents during Prophase I)
entangling puts stress on DNA molecules
∴ breaking & rejoining of chromatid sections.
If blue has alleles: A, B, D
red has alleles: a, b, d

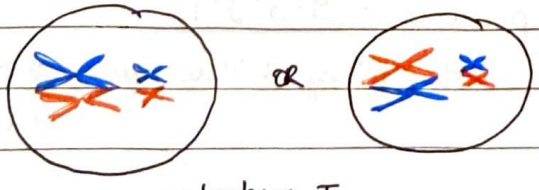


new combinations of alleles formed



* process by which non-sister chromatids exchange alleles.
↓ usually occurs away from centromere.

② **Random / independent assortment**



metaphase I

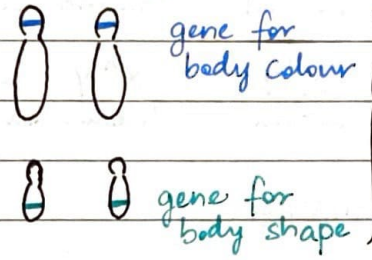
orientation of one homologous pair is independent (unaffected) by orientation of another.

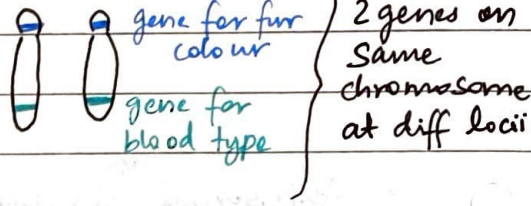
* production of different allele combinations in daughter cells due to random alignment of homologous pairs along equator of spindle during metaphase I.

Dihybrid Inheritance

Inheritance of 2 genes.

unlinked genes (vs.) linked genes





Inheritance of Unlinked Genes

i) Homozygous dominant × Homozygous recessive

BBTT × bbtt

B = blue
b = red
T = triangle
t = square

	BT	BT	BT	BT
bt	BbTt	BbTt	BbTt	BbTt
bt	BbTt	BbTt	BbTt	BbTt
bt	BbTt	BbTt	BbTt	BbTt
bt	BbTt	BbTt	BbTt	BbTt

phenotype = 100% blue triangles

genotype = 100% BbTt (heterozygous)

ii) Heterozygous × Heterozygous

BbTt × BbTt

	BT	Bt	bT	bt
BT	BBTT	BBTt	BbTT	BbTt
Bt	BBTt	BBtt	BbTt	Bbtt
bT	BbTT	BbTt	bbTT	bbTt
bt	BbTt	Bbtt	bbTt	bbtt

phenotype : 9:3:3:1

blue triangle : blue square : red triangle : red square

iii) Test cross

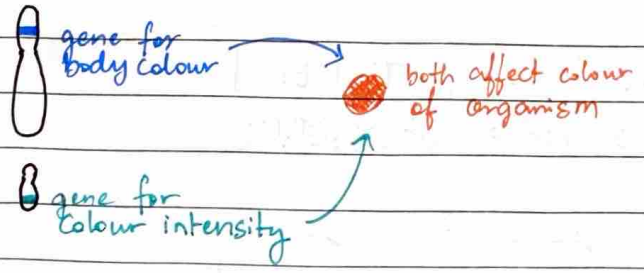
Phenotype : blue triangle B?T? × bbtt
Genotype : ?

→ if all ~~org~~ offspring blue triangle : genotype = ~~BBBB~~ BBTT
→ if 50% blue triangle, 50% blue square : genotype = BBTt

→ Epistasis

2 genes at different loci interact with each other to affect 1 phenotype.

eg.



Inheritance of Linked Genes – Autosomal Linkage

genes are on autosomes
genes are on same chromosome

eg. gene 1 : plant height → T (tall), t (short)

gene 2 : flower colour → R (red), r (white)

NOTE: unlinked : TTRR

Genotype is written as : (TR)(TR)

alleles on same chromosome written tgthr in brackets.

i) Homozygous dominant × homozygous recessive
100% tall, red (TR)(tr)

independent assortment gives equal chance of getting gametes.

NOTE: for linked genes, independent assortment has no effect.
But cross-over may or may not occur and has an effect.

ii) Heterozygous × Homozygous recessive

1) phenotype : tall, red
genotype : (TR)(tr)
gametes : (TR) (tr) (Tr) (tR)

more likely — less likely: only arises in case of cross-over.

2) phenotype : Short, white
genotype : (tr)(tr)
gametes : (tr)

	TR	tr	Tr	tR
tr	(TR)(tr)	(tr)(tr)	(Tr)(tr)	(tR)(tr)

parental type (look like either parent) — higher chances

recombinant type (mixed features) — lower chances

→ if ratios not 1:1:1:1, but you get more parental type offspring than recombinant type, the genes are likely to be linked.
↳ for heterozygous × homozygous recessive

→ if ratios not 9:3:3:1, then genes likely to be linked.
↳ for heterozygous × heterozygous

Genes, Proteins, Phenotype

① TYR gene → Tyrosinase → Skin, hair, iris colour

→ located on an autosome (chromosome 11).

→ codes for tyrosinase enzyme.

tyrosine (amino acid) $\xrightarrow{\text{tyrosinase}}$ DOPA $\xrightarrow{\text{tyrosinase}}$ Dopaquinone ⟶ melanin pigment

→ mutation in TYR ⇒ change in primary structure ⇒ change in tertiary

dopaquinone ⇐ DOPA ⇐ non-functional tyrosinase enzyme ↵

↳ melanin ⇒ pale hair, skin, pinkish iris ⇒ Albinism

normal TYR gene — Dominant (A)

mutated TYR gene — Recessive (a)

AA or Aa ⇒ normal
aa ⇒ albino

② F8 gene → Factor VIII protein → Normal blood clotting

→ located on X-chromosome ⇒ sex-linked

normal F8 gene — H allele (X^H)

mutated F8 gene — h allele (X^h)

♂		♀		
X^HY	X^hY	X^HX^H	X^HX^h	X^hX^h
✓	haemophilia	✓	✓	haemophilia
			carrier	

③ HTT gene → Huntingtin protein → affects brain development

→ located on an autosome (chromosome 4)

recessive (h) ← normal HTT gene (21 CAG repeats) ⟶ no problems

dominant (H) ← HTT gene (36-39 repeats) ⟶ may develop Huntington's disease

dominant (H) ← HTT gene (> 40 repeats) ⟶ v high chance of developing Huntington's disease!!

- symptoms develop with age : mood swings, loss of muscle coordination, loss of cognition.

HH or Hh	⇒	Huntington's disease
hh	⇒	normal

④ HBB gene → β-globin → affects shape of RBC & O_2 transport

↓

(part of haemoglobin)

~~Located~~ → located on an autosome (chromosome 11)

normal HBB gene — Hb^A allele

mutated HBB gene (glu → val) — Hb^S allele → sickle cell anaemia
- less O_2 transport
- blockage in capillaries

they are codominant

Hb^A Hb^A	Hb^S Hb^S	Hb^A Hb^S
normal	Sickle-cell anaemia	Codominance ↓ mild sickle-cell anaemia

(5) Le gene → enzyme needed to produce active gibberellins → tall plants

enzyme in the gibberellin synthesis pathway

- Stimulates XET enzyme.
- breaks bonds btwn hemicellulose.
- cellulose microfibrils move further apart.

↓ cell elongation

Le gene → enzyme → active gibberellin → cell elongation → tall plant

le gene (mutation) → codes for non-functional enzyme ⇒ cell elongation ~~elongation~~ ⇐ plant remains as a dwarf

Dominant allele – Le
recessive (mutated) allele – le

Le Le	le le	Le le
tall	dwarf	tall

Control of Gene Expression

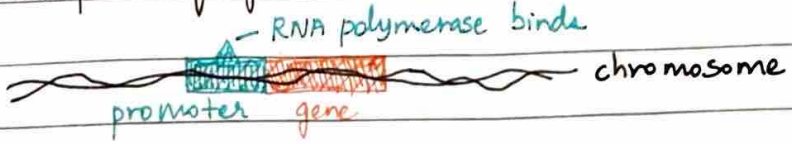
gene —transcription→ mRNA —translation→ polypeptide

→ all body cells (except gametes) are genetically identical — same genes
→ ∴ not all genes in cells are expressed : genes can be turned on / off.
→ gene expression can also be increased / decreased.

→ **Structural genes**
codes for a protein that has a function within a cell.

Regulatory genes
codes for a protein that affects the expression of other genes.

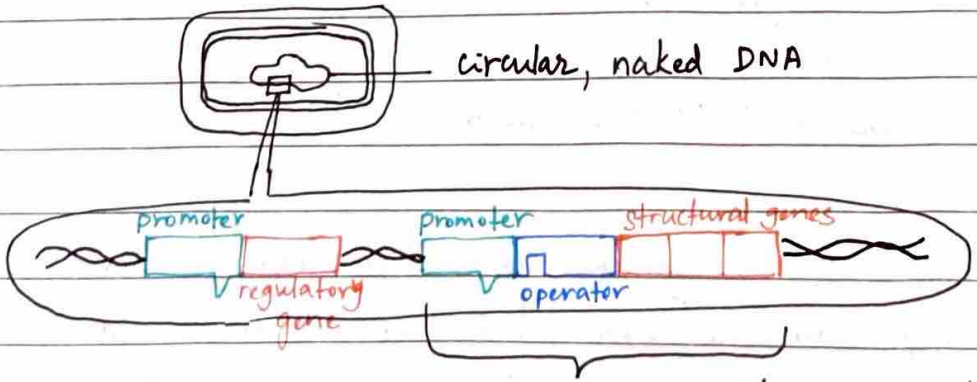
→ **Promoters**
- a length of DNA that is the binding site of RNA polymerase
- so that transcription of genes can occur.



→ **Inducible enzyme**
an enzyme that is synthesised when its substrate is present.

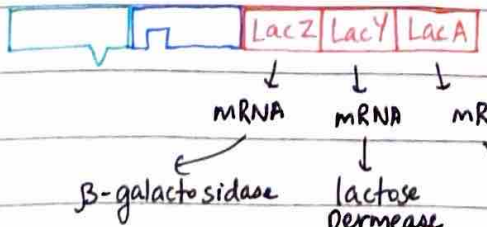
Repressible enzyme
an enzyme that is normally produced, but its synthesis can be blocked by an effector / molecule.

Control of Gene Expression in Prokaryotes



operon: a group of genes controlled by one promoter.

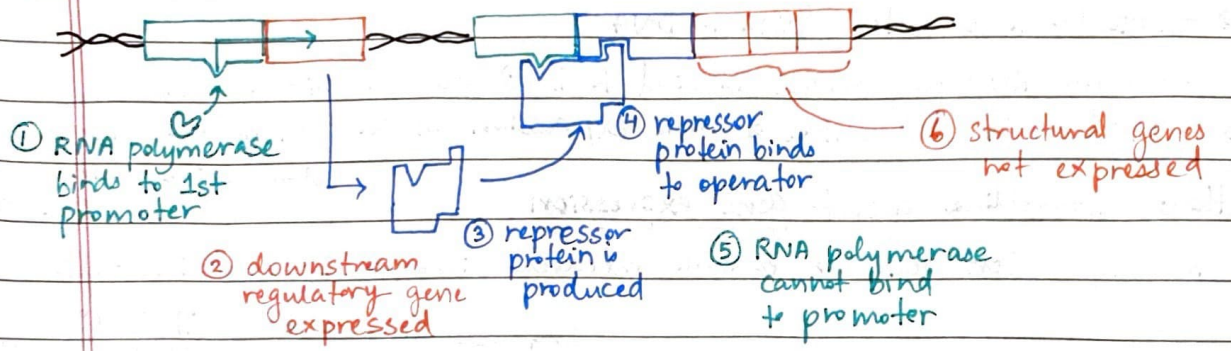
Lac operon



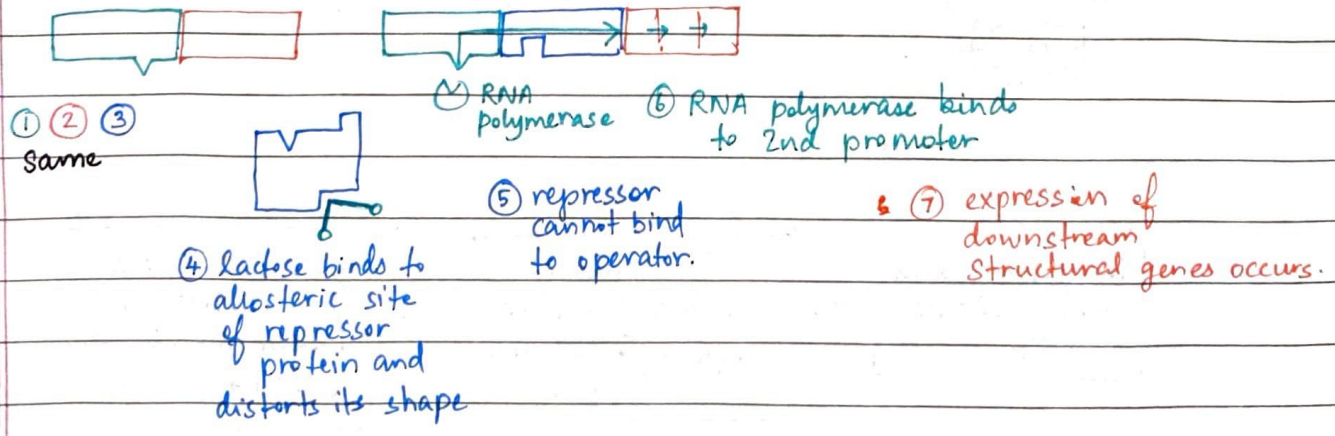
→ B-galactosidase: hydrolyses lactose.
→ lactose permease: makes the bacterium permeable to lactose

not surrounded by lactose	Surrounded by lactose
- the structural genes are not expressed because the proteins are not needed. → conserves ATP & amino acids.	- lacZ, lacY, lacA expressed.

no lactose :

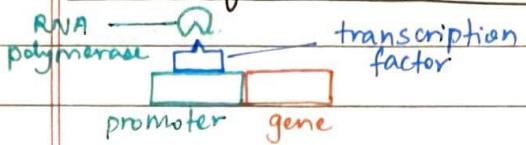


lactose :



∴ lactose permease, β-galactidose } inducible enzymes (by substrate lactose)

Control of Gene Expression in Eukaryotes

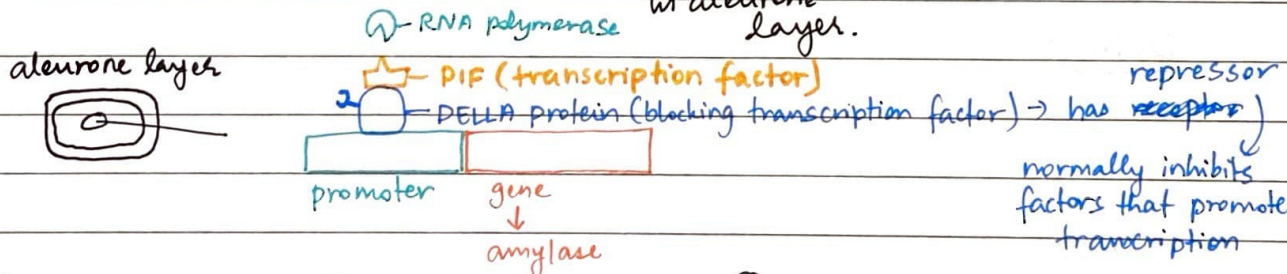


Transcription factor

* - protein
* - attaches to promoter / bind to DNA
  - allows RNA polymerase to bind to it → acts as binding site.
* - involved in the control of gene expression in eukaryotes by increasing/decreasing rate of transcription.

How gibberellins affect gene expression

* → H_2O enters seed → embryo releases gibberellins → gibberellins diffuse to aleurone layer → amylase is synthesised in aleurone layer.



1. H_2O enters seed and activates embryo
2. embryo released gibberellins that diffuse to aleurone layer
3. gibberellins bind to receptor on DELLA protein and activates an enzyme
4. this enzyme destroys DELLA proteins (breaks down the DELLA protein repressors)
5. PIF then binds to promoter
6. RNA polymerase binds to PIF
7. expression of downstream gene for amylase
8. aleurone layer synthesises amylase