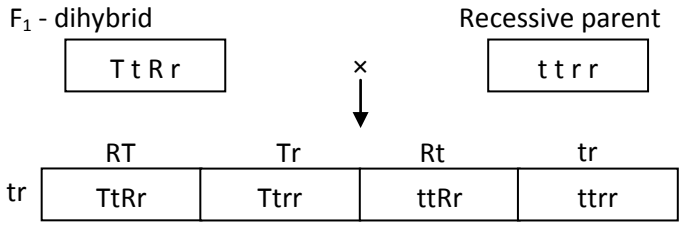
(b) **Dihybrid test cross :-** the progeny is obtained from dihybrid test cross are four types and each of them is 25%



The ratio of Dihybrid test cross =1:1:1:1

Conclusion:- In test cross phenotypes and genotype ration are same.

Reciprocal cross:-

When two parents are used in two experiment in such way that in one experiment A is used as the female parent and "B" is used as the male parent in the other experiment "A" will be used as the male parent and "B" as the females parent such type of set two experiments is called reciprocal cross

Character which are controlled by karyogene are not affected by reciprocal cross in case of cytoplasmic inheritance result change by reciprocal cross.

(a) TT X tt
(female) (male)

All tall

(b) TT X tt
(male) (female)

All Tall

CHROMOSOMAL THEORY OF INHERITANCE

This theory was proposed by Walter Sutton and Theodor Boveri (1902) Following are the main point of this theory-

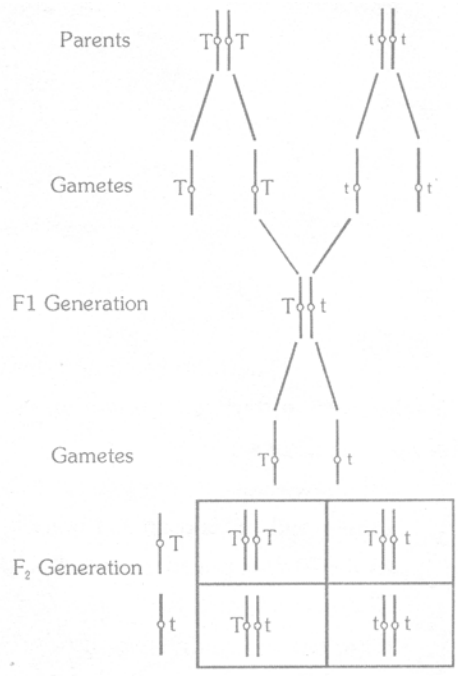
1. Gametes serve as the bridge between two successive generations.
2. Mlae and female gametes play an equal orle in contributing hereditary components of future. Generation
3. Only the nucleus of sperm combines with ovum Thus the hereditary information is contained in the nucleus
4. Chomatin in the nucleus is associated with the cell division in the form of chromosomes.
5. Any type of dilation or addition in the chromosome can cause structural and functional changes in living beings.
6. A sort of Parallelism is observed between mendelian factors and chromosomes.
7. A number of genes or mendelian factors are found in each chromosome.
8. Determination of sex in most of the animals and plant is affected by specific chromosomes these chromosomes are called sex chromosomes.

Parallelism Between Gene and chromosome.

1. chromosomes are also transferred from one generation to the next as in the case of genes (mendelian factor)
2. Teh number of chromosomes is fixed in each living species. these are found as homologous pairs in diploid cells one chromosome from father and the other contributed by the mother constitute a homologous pair
3. Befored cell division each chromosome as a whole and the alleles of genes get replicated and are separated during mitotic division.
4. Meiosis takes place during gamete formation .Homologous chromosomes form synapses during prophase-I stage which in later course get separated and transferred to daughter cell Each gamete a or a haploid cell has only one allele of each gene present in the chromosome.

5. A characteristic diploid number is again established by the union of the two haploid gametes.

6. Both chromosomes and the alleles(mendelian factor)behave in accordance to Mendel law of segregation
In the homologous chromosomes of pure tall plant allele (T) is found for tallness in each chromosome Likewise in a pure dwarf plant (tt) allele (t) is present in each chromosome These homologous chromosomes get separated during meiotic division Hence each gamete possesses only on chromosome of an each pair Accordingly all the gametes of tall plants possess a chromosome with an allele of tallness(T) while the gametes of dwarf plant possess a chromosome with an allele for deafness (t) Their cross to produce F_1 generation will yield tall hybrid plant with homologous chromosomal pair containing Tt allelic pair in this generation two kinds of gamete will be formed during gamesomeness 50%with the allele (T) for tallness and 50%with the allele for deafness (t) Random combination of these gametes will produce offsprings in F_2 generaion in the ratio of 25% pure tall (TT) 50% hybrid tall (Tt) and 25% dwarf(tt)



CYTOPLASMIC INHERITANCE (CORRENS)

Inheritance of characters which are controlled by cytogene or cytoplasm is called cytoplasmic inheritance
Genes which are present in cytoplasm called cytogene or plasmagene or extra nuclear gene
Total cytogene present in cytoplasm is called plasmon Agene which is located in the nucleus is called karyogene

- Inheritance of cytogene in higher plants only through the female because female gamete has karyoplasms simultaneously it has cytogene because of more cytoplasm.

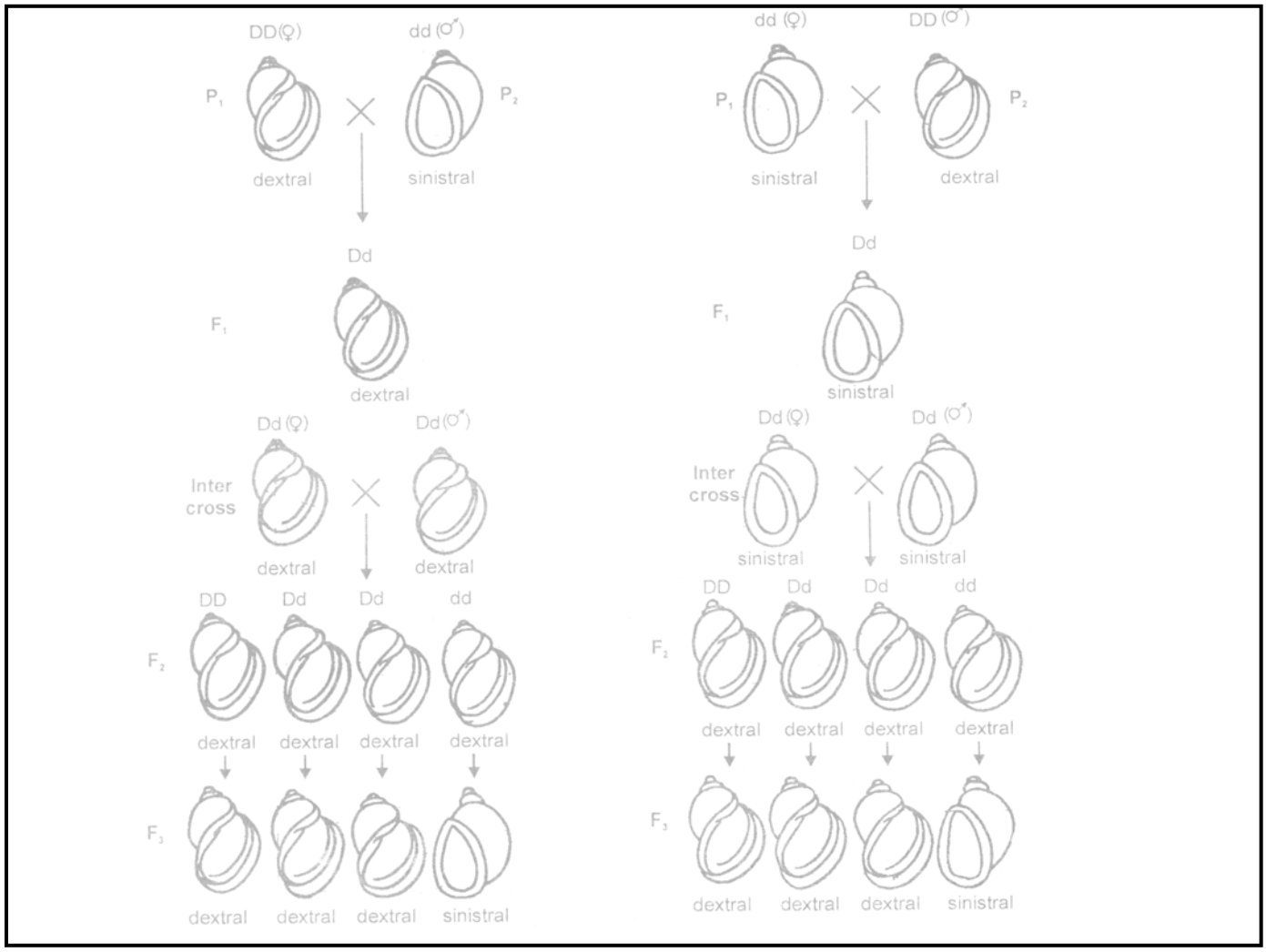
- The male gamete of higher plant is called male nucleus it has very minute (equivalent to nil) cytoplasm so male gamete only inherited karyogene.

- Thus inheritance of cytogene only through female (also called maternal inheritance)

- If there is reciprocal cross in this condition then results may be effected.

Cytoplasmic inheritance of three types:

1. Maternal effect depending indirectly on nuclear genes and involving no known cytoplasmic hereditary unit called as predetermination in this maternal effect is determine before fertilization.
2. Cytoplasmic inheritance involving dispensable land infective hereditary particle in cytoplasm which may or may not depend on nuclear genes called as Dauermodification
3. Cytoplasmic inheritance involving essential organelles like chloroplast and mitochondria called as organellar Genetics
Example of predetermination
Shell coiling in snail(limmara peregra)
In shell coiling of snail can be dextral (coiling to the right)or sinistral (coiling to the left) this direction of coiling is genetically controlled the dextral coiling depending upon dominant allele D and sinistral coiling depending upon recessive allele so the dextral is DD ,Dd and sinistral is dd.



Above reciprocal cross indicates that phenotype of offspring is decided by genotype of female parent not the phenotype of female parent If female parent conation only one dominant gene D then phenotype of all offspring's is dextral

Example: Dd (♀) sinistral × dd (♂) dextral → F_1 – All dextral

Dd (♂) sinistral × dd (♀) dextral → F_1 – All sinistral

Example of Dauermodification-

(a) sigma particle in drosophila theses particles are virus like particles which are present in drosophila and related to co_2 sensitivity inheritance of sigma particle takes place through the egg cytoplasm.

(b) Kappa particle in paramecium Kappa particle are found in certain "killer strains" of paramecium and are responsible of substance paramecia which is toxic to strain not possessing kappa (sensitive strain)
The minimum number of kappa particle is 400 to secrete paramecin Kappa particle are symbiotic bacteria named "**caedobacter taeniospiralis"**

Example of organellar genetic :(True examples of cytoplasmic inheritance)

(a) **plastid inheritance in mirabilis jalapa**-cytoplasmic inheritance first discovered by correns in Mirabilis jalapa

- In mirabilis jalapa plastid inheritance ie. Branch colour is example of cytoplasmic inheritance.

Branch colour

(a) Pale ♀ × Green ♂ → F_1 - Pale

(b) Green ♀ × Pale ♂ → F_1 - Green

(c) Variegated ♀ × Pale or Green or variegated ♂ → F_1 – Pale, Green and variegated

(b) male sterility in maize plant- gene of make sterility present in mitochondria if a normal male plant crossed with a female plant which has genes of male sterility then all the generation of male become sterile because a particular gene was present with female which inherited by female and male plant of the progeny are sterile.

(c) Albinism in plant: gene of albinism found in chloroplast gene of albinism in maize is lethal.

(d) inheritance of bacterial plasmid in bacteria plasmid inheritance is due to conjugation.

(e) petite form in yeast = (mitochondrial)gene petite is mutant form of yeast this mutant form is slow growing in culture medium.

(f) Lojap inheritance in maize lojap is characterize by contrasting strip of green and white colour of leaves.

(g) poky Neurospora (mitochondrial gene)poky is mutant form of neurospora it is slow growing on culture medium.

Exceptions of conclusions of Mendel.

1. Exception of dominance: there are two exception of law of dominance.

(A) incomplete dominance.(B) Co dominance.

(a) INCOMPLETE DOMIONANCE: according to Mendel law of dominance dominant character must be present in F_1 generation but in some organisms F_1 generation is different from the both parents.

Both factors such as dominant and recessive ae present in incomplete dominance but dominant factor are unable to express their character completely resulting different type of generation is formed which is different from the both parents.

- Incomplete dominance was first discovered by correns in mirabilis jalapa this plant is called as **'4 O clock plant** or **gule bans'**

(a) Three different types of plant are found in mirabilis on the basis of flower colour such as red white and pink when plants with red flowers is crossed with white flower plant with pink flower abstained in f_1 generation the reason of this is that the genes of red colour incompletely dominant over the genes of white colour.

When f_1 generation of pink flower is self pollinated then phenotypic ratio of F_2 generation is red pink White =1:2:1 in place of normal monohybrid cross=3:1

The ratio of phenotype and genotype of $f_2$generation in incomplete dominance is always same.

Red × White

RR rr

F1 generation Rr(Pink) →

↓ Self pollination

F_2 – Generation

	R	r
R	RR	Rr
r	Rr	rr

RR = Red - 1
Rr = Pink - 2
Rr = White - 1

(b) Antirrhinum majus :- incomplete dominance is also seen in this plant is also known as snapdragon or dog flower incomplete dominance is present for their feather colour when a black colour fowl is crossed with a white colour fowl the colour fowl the colour of f_1 generation is blue.

(c) Andalusia fowls:-Incomplete dominance is present for their feather colour when a black colour fowl is crossed with a white colour fowl the colour of f_1 generation is blue.

(B) **CO-DOMINANCE** :- in this phenomenon both the gene expressed for a particular character in f_1 hybrid progeny.
There is no blending of characters whereas both the characters expressed equally.
Examples :- Co-dominance is seen in animal for coat colour.
When a black parent is crossed with white parent a roan colour F_1progeny is produced.
When we obtain F_2generation from the F_1 generation the ratio o black; black white (roan) white of animals is 1:2:1
Note:- F_2 generation is obtained in animal by sib mating cross.

BLACK × WHITE

R_1R_1 R_2R_2

F_1 generation R_1R_2 (Roan)

Sib-mating cross

	R_1	R_2
R_1	R_1R_1	R_1R_2
R_2	R_1R_2	R_2R_2

It is obvious by above analysis that the ratio of phenotype as well as genotype is 1:2:1 in co dominance .

Sp Note:- In incomplete dominance characters are blended phenotypic ally while in co dominance both the genes of la pair exhibit both the characters side by side and effect of both the character is independent from each other
Other examples of co dominance:

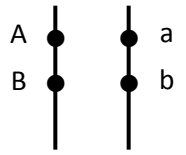
(ii) AB blood group in heritance(I^AI^B)

(iii) carrier of sickle cell anaemia (Hb^AHb^s)

2. Conclusion of segregation :-There is no exception of law of segregation The segregation is essential during the meiotic division in all sexually reproducing organisms.
(Nondisjunction may be exception of this law)

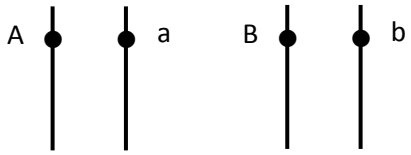
3. Exception of conclusion of independent assortment
The law fo independent assortment is most criticized linkage is the exception of this
Linkage – collective inheritance of character is called linkage .Linkage first time seen by bate son and punnett in lathyrus odoratus and gave coupling and repulsion phenomenon but they did not explain the phenomenon of linkage .sex linkage was first discovered by Morgan in drosophila &coined the term linkage. He proposed the theory of linkage.
Linkage and independent assortment can be represented in dihybrid plant

In case of linkage in dihybrid AaBb



It produces two types of gamete
AB : ab

In case of independent assortment in dihybrid AaBb



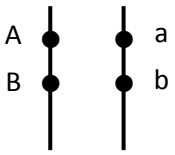
It produces four types of gamete
AB : ab : aB : Ab

Theory of linkage

1. Linked genes are linearly located on same chromosome they get separated if exchange (crossing over) Takes place between them
2. strength of linkage α1/distance between the genes it means if the distance between two genes is increased then strength of linkage is reduced and it proves that greater is the distance between genes the greater is the probability of their crossing over.
   Crossing over obviously disturbs or degenerates linkage linked genes can be separated by crossing over Factors effecting over (c.O):-
   (1) Distance ↑=c.o↑
   (2) temperature ↑=c.o. ↑
   (3) X-ray↑=c.o. ↑
   (4) Age↑c.o ↓
   (5) Sex-,male c.o↓(crossing over totally absent in male drosophila)

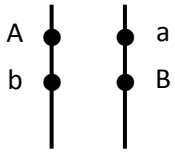
Arrangement of linked genes on chromosome.

The arrangement of linked genes in any dihybrid plant is two types.



(a)Cis –Arrangement :- When two dominant genes located on none chromosome and both recessive genes located on another chromosome such type of arrangement is termed as cis arrangement Cis arrangement is an original arrangement.

- wo types of gamete can be produced in cis arrangement –(AB) and(ab)



(b)Trans arrangement :- When a chromosome bears on dominant and one excessive gene and another chromosome also possess one dominant and one recessive gene such type of arrangement is called trans arrangement trans arrangement is not an original form It is due to crossing over Two types of gamete also formed in trans arrangement but it is different from Cis arrangement (Ab)and(aB)

Types of linkage :-there are two types of linkage-

1. **COMPLETE LINKAGE:-** linkage in which genes always show parental combination It never forms new combination.
   Crossing over is absent in it such genes are located very close on the chromosomes such type of linkage very rare in nature e.g male drosophila female silk moth.

2. **INCOMPLETE LINKAGE:-** When new combination also appear along with parental combination in off springs this type of linkage is called incomplete linkage the new combinations form due to crossing over the percent
   Linkage group:- All the genes which are located on one pair of homologous chromosome form one linkage group genes which are located on homologous chromosomes are allelic so we consider one linkage group

- Linkage group = haploid no of homologous chromosomes.
-

	2n	N	Pair	Linkage group
Pea	14	7	7	7
Maize	20	10	10	10
drosophila	8	4	4	4
Barley	14	7	7	7
Mouse	42	21	21	21

Application of linkage:-

Distance can be identified by the incomplete it unit is centi morgan.

$$\text{Strength of linkage} \propto\propto \frac{1}{dis\tan ceb/wlinkedgene} \propto \frac{1}{cros\sin gover}$$

Genetic map/linkage map /chromosome map:- In genetic map different genes are linearly arranged according to % of crossing over (∝Distance) between them.

With the help of genetic map we can find out the position of a particular gene on chromosome genetic map is helpful in the study of genome.

Sex linkage

When the genes of vegetative /somatic character are present on sex chromosome is termed as sex linked gene and such phenomenon is known as sex linkage two types of sex linkage.

1. **X linkage.**

Genes of somatic characters are found on x chromosome the in heritance of x linked character may be through the males and females.

e.g Haemophilia colour blindness

2. **Y-linkage-** The genes of somatic characters are located on Y-chromosome the inheritance of such type of character only through the males, such type of character is called Holandric character these character only found in male.

e.g. (1) Gene which forms TDF

(2) Hypertrichosis (excessive hair on ear pinna)

Gene which is located on differential region of Y chromosome is known as Holandric gene

Example of X Sex linkage:-

(i) Eye colour in drosophila:- Eye colour in drosophila is controlled by a x linked gene

If a red eyed colour gene is represented as+ and white eyed colour represented w then on basis of this different type of genotypes are found in drosophila.

Gene for red eye dominant (+) and white colour of eye is recessive (w)

Homozygous red eyed female	=	X^+X^+	Pea
Homozygous red eyed female	=	X^+X^W	Maize
Homozygous white eyed female	=	X^WX^W	drosophila
Hemizygous red eyed male	=	X^+Y	Barley
Hemizygous white eyed male	=	X^wY	Mouse

It is clear by above different types of genotype that female either homozygous or heterozygous for eye colour.But for the male eye colour it is always Hemizygous.

(ii) Haemophilia:-

Haemophilia is also called “bleeder’s disease” and first discovered by john otto (1803)the gene of Haemophilia is recessive and x-linked lethal gene

On the basis of x-linked following types of genotype are found,
X^hX = carrier female
X^hX^h=Affected female
X^hY=affected male
But X^hX^h type of female dies during embryo stage because in homozygous condition this becomes lethal and cause death.
Haemophilia -A→due to lack of factor –VIII (Anithaemophilic globulin AHG)
Haemophilia B or Christmas disease due to lack of factor IX (plasma thromboplastin component)
Haemophilia-c→due to lack of factor XI (plasma thromboplastin antecedent)
(iii) Colour Blindness :- The in inheritance of colour blindness is alike as Haemophilia but it is not lethal disease of it is found is male and female (discovered by Horner)
Three types of colour blindness are-
(a)protanopia :-it is for red colour.
(b)Deuteeranopia:-it is green colour
(c)Tritancopia:- For blue colour blindness colour blindness is cheked by ishihara chart.

Other examples of X sex linkage.
(iv)Diabetes insipidus (recessive)
(v)duchenne muscular dystrophy(recessive)
(vI)fragile x syndrome (recessive)
(vii)pesudoricketes (dominant)
(viii)Defective enamel of teeth (dominant)

Type o inheritance of sex linked character.

1. **Criss cross inheritance (morgan)**:- in criss cross inheritance male or female parent transfer x linked character to grandson or grand daughter through the offspring of opposite sex

   (a) Diagenic:- inheritance in which characters are inherited from father to the daughter and form daughter to grandson.
   Father →daughter →grand son.

   (b) diandric:- inheritance in which characters are inherited from mother to the son and from son to grand
   Daughter.Mother→son→Grand-daughter.

2. **Non criss croos inheritance :** in this inheritance male or female parent transfer sex linked character to grand son or grand daughter through the offspring of same sex

   (a) Hologenic:-Mother→daughter→grand daughter)female to female)
   (b) Holandric:-father →son→grand son (male to male)
   (B) sex limited character:- these charters are present in one sex and absent in another sex but thegenes are present in both the sexes and their expression is depend on sex hormone.
   Example:-Secondary sexual characters→these genes located on the autosomes and these genes are present in both male and female but effect of these are depend upon presence or absence of sex hormones.
   For example –genes of beard moustache express their effect only in the presence of male hormone – testosterone
   (c) Sex influenced characters:- genes of these characters are also present on autosomes but they are influenced differently in male and female. IN heterozygous condition their effect different in both the sexes.Example;- Baldness:- gene of baldness is dominant(B)

Genotype	Male	Female
BB	Baldness	Baldness present
Bb	Baldness absent	Baldness absent
Bb	Baldness present	Baldness absent

Gene Bb shows partiality in male and female baldness in found in male due to effect of this gene but baldness is absent in female with this genotype

Multiple allele

More than 2 alternative forms of same gene called as multiple allele.
Multiple allele is formed due to mutation.
Multiple allele is located on same locus of homologous chromosome.
A diploid individual contains two alleles and gamete contains on allele for a character
Ex. Blood group -3allele
Coat colour in rabbit -4 allele
If n is the number of allele of a gene then number of different possible genotype= $\frac{n(n+1)}{2}$

Example of multiple allele.

1. **ABO blood group→**ABO blood group are determined by allele I^A alleleI^B allele I^o
I^A=dominant
I^B=dominant
I^o=redessive
Possible phenotypes A,B,AB,O

Blood group	Genotype	Antigen or agglutiongen	Antibody or agglutinin
A	$I^A I^A$,$I^A I^o$	A	b
B	$I^B I^B$, $I^B I^o$	B	a
AB	I^A	A&B	none
O	$I^o I^o$	none	a&b

Possible genotype number = $\frac{3(3+1)}{2} = 6$ genotype.

2. **Coat colour in rabbit** → four alleles for coat colour in rabbit
Wild type =Full coloured =agouti=C^+
Himalayan (white with black tip on extremities (like nose tail and feet)=c^h
Chinchilla (mixed coloured and white hairs)=c^{ch}
Albino =colourless =c^a
These alleles show a gradient in dominance $C^+ > c^{ch} > c^h > c^a$
Possible genotypes –
Coloured =C^+C^+,C^+c^{ch}, C^+c^h, C^+c^a
Chinchilla=$c^{ch}c^{ch}$, $c^{ch}c^hc^{ch}c^a$
Himalayan=c^hc^h, c^hc^a
Albino=c^ac^a
Possible = $\frac{4(4+1)}{2} = 10$ genotypes