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FACULTY OF ENGINEERING & TECHNOLOGY
DEPARTMENT OF BIOTECHNOLOGY

LINKAGE

“Tendency of genes to remain together in their original combination during inheritance is called **linkage**”

- The phenomenon of linkage was firstly reported by *Bateson and Punnet* in 1906.
- *T H Morgan* put forth the theory of linkage and concluded that coupling and repulsion were two phases of single phenomenon, linkage.

Chromosomal theory of inheritance

- *Sutton and Boveri* proposed the chromosomal theory of inheritance.
- According to chromosome theory of inheritance, *it is well established that many genes are located in each chromosome in a linear fashion.*
- And all genes located in same chromosome would move to same pole during cell division.
- As a consequence, such genes will fail to show independent segregation and would tend to be inherited together.

Types of Linkage

- Linkage is generally classified on the basis of three criteria

(i) Crossing over

(ii) Genes involved and

(iii) Chromosomes involved

Types of Linkage: **Based of Crossing over**

- **Based on crossing over:** Linkage may be classified into
(a) complete and (b) incomplete / partial linkage
- (a) Complete linkage:** It is known in case of males of *Drosophila* and females of silkworms, where there is complete absence of recombinant types due to absence of crossing over.
- (b) Incomplete / partial linkage:** If some frequency of crossing over also occurs between the linked genes, it is known as incomplete / partial linkage. Incomplete linkage has been observed in maize, pea, *Drosophila* female and several other organisms.

Types of Linkage: **Based on genes involved**

Based on genes involved : Depending on whether all dominant or some dominant and some recessive alleles are linked together, linkage can be categorized into (a) Coupling phase and (b) Repulsion phase

(a) Coupling phase: Dominant alleles present on the same chromosome and recessive alleles present on same chromosome shows coupling phase

TR	tr	
----	----	Coupling phase
TR	tr	

(b) Repulsion phase: Dominant alleles of some genes are linked with recessive alleles of other genes on same chromosome shows repulsion phase

Tr	tR	
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Tr	tR	

Types of Linkage: **Based on chromosomes involved**

- **Based on chromosomes involved:** Based on the location of genes on the chromosomes, linkage is categorized into

(a) Autosomal linkage: It refers to linkage of those genes which are located in autosomes (other than sex chromosomes).

(b) Allosomal linkage // sex linkage: It refers to linkage of genes which are located in sex chromosomes i.e. either 'X' or 'Y' (generally 'X')

Characteristics of Linkage

- i. Linkage involves two or more genes which are located in same chromosome in a linear fashion.
- ii. Linkage reduces variability.
- iii. Linkage may involve either dominant or recessive alleles (coupling phase) or some dominant and some recessive alleles (repulsion phase).
- iv. Linkage usually involves those genes which are located close to each other.
- v. The strength of linkage depends on the distance between the linked genes. Lesser the distance, higher the strength and vice versa.
- vi. Linkage can be determined from test cross progeny data.

Linkage groups

- Linkage group refers to a group of genes which are present in one chromosome. In other words, all those genes which are located in one
- Chromosome constitute one linkage group. The number of linkage groups is limited in each individual. The maximum number of linkage groups is equal to the haploid chromosome number of an organism.
- Eg- For example there are ten linkage groups in corn ($2n = 20$), seven in garden pea ($2n = 14$), seven in barley ($2n = 14$), four in *Drosophila melanogaster* ($2n = 8$) and 23 in man ($2n = 46$).

Detection of linkage

- Test cross is the most common method of detecting the linkage. In this method, the F₁ heterozygous at two loci (AB/ab) is crossed to a double recessive parent (ab/ab) and the phenotypic ratio of test cross progeny is examined.
- If the phenotypic ratio of test cross progeny shows 1:1:1:1 ratio of parental and recombinant genotypes, it indicates absence of linkage.
- If the frequency of parental types and recombinant types deviate significantly from the normal dihybrid test cross ratio of 1:1:1:1, it reveals presence of linkage between two genes under study.

Significance of Linkage in Plant Breeding

- i. Linkage limit the variability among the individuals.
- ii. Linkage between two or more loci controlling different desirable characters is advantageous for a plant breeder. A linkage between genes controlling two different desirable characters will help in simultaneous improvement of both the characters.
- iii. Linkage is undesirable when desirable and undesirable genes are linked together.

Difference between crossing over and linkage

Crossing over	Linkage
1. It leads to separation of linked genes	1. It keeps the genes together
2. It involves exchange of segments between non-sister chromatids of homologous chromosomes	2. It involves individual chromosomes
3. The frequency of crossing over can never exceed 50 %	3. The number of linkage groups can never be more than haploid chromosome number
4. It increases variability by forming new gene combinations	4. It reduces variability

Thank you !