

Bioengineering: An Interface with Biology and Medicine
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Lecture – 17
Genetics-II

Welcome to MOOC-NPTEL course on bioengineering, an interface with biology and medicine. Today, we will discuss some examples of Mendelian genetics. You will see how many human traits follow Mendelian patterns of inheritance but how these patterns are often more complex than just predicted by simple Mendelian genetics.

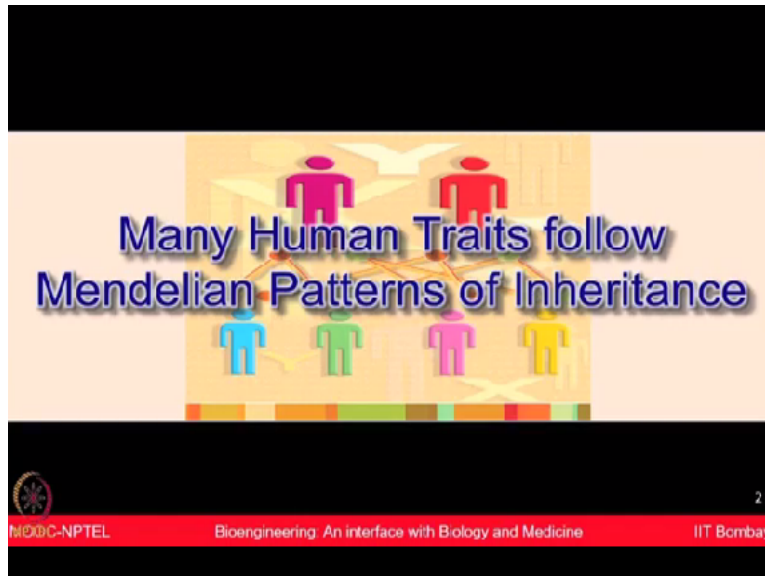
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So there are many examples of Mendelian genetics which we can study and I must say that, you know, the Mendelian rules, Mendelian laws were made based on the pea plants with very limited conditions. So we had 1 gene 2 alleles and we are, or we are talking about 2 genes and 4 alleles kind of properties.

But many times when we talk about human characteristics, things are much more complicated, much more complex. And at that time, the characteristics are governed from many genes, polygenic in nature. So it may not be always true that, you know, every inheritance pattern is going to follow Mendelian's law. It may not be always true.

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But there are many human traits which will still follow Mendelian rule and people have done the pedigree analysis.

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It means in the same family if you look at, you know, your grandfathers and the grandsons, their entire, you know, properties, are their certain characteristics which are appearing and disappearing and reappearing kind of stuff.

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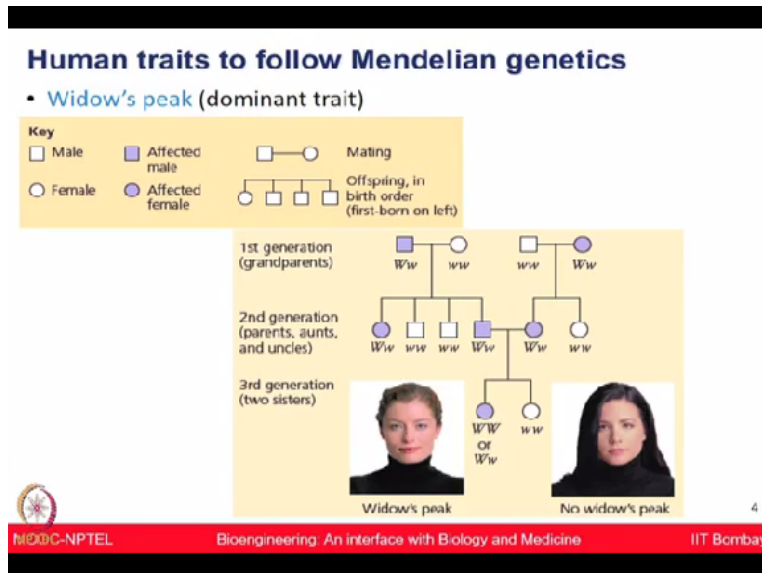
Pedigree analysis

Family history analysis for a particular trait and assembling information in family tree describing traits of parents and children across the generations - the family pedigree



So that is a pedigree analysis when you are looking at a family history for particular trait and then you are assembling that information and trying to derive some sort of family tree, a pedigree information from those traits. So many of the human traits for example, one is known as widow's peak which is something shown here.

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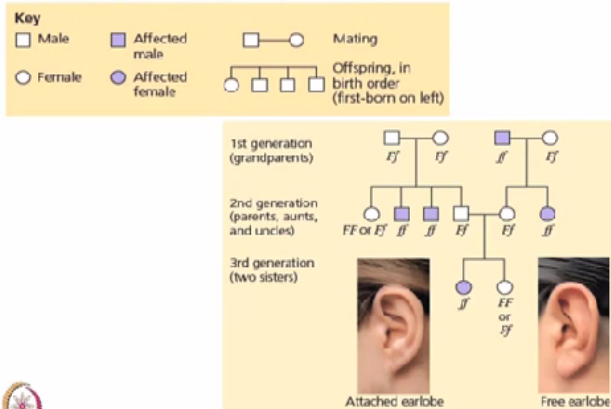


So this property is actually, you know, the sharp hair line is known as widow's peak which is observed in many families and these are dominant traits which are actually being followed in those women and they are always following the Mendelian ways of inheritance, Mendelian laws of inheritance.

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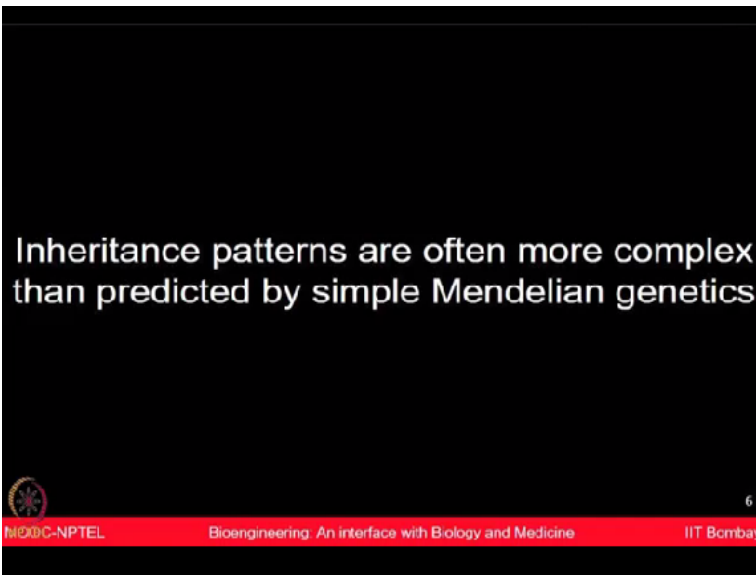
Human traits to follow Mendelian genetics

- Attached earlobe (recessive trait)



There are certain characteristics like if you look at the earlobe in this case here. So this attached earlobe or then the free earlobe, you will see some variations like this and then these are some of the recessive characteristics which are also found in some family and they also obey Mendelian laws of inheritance.

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So but as I mentioned the inheritance patterns are sometimes very complex. They are not as simple as just looking at a pea plant and 1 gene at a time. They are governed from many genes and many complex information. Those are polygenic in nature. So Mendel in some way was actually lucky because he was only looking at 1 thing at a time.

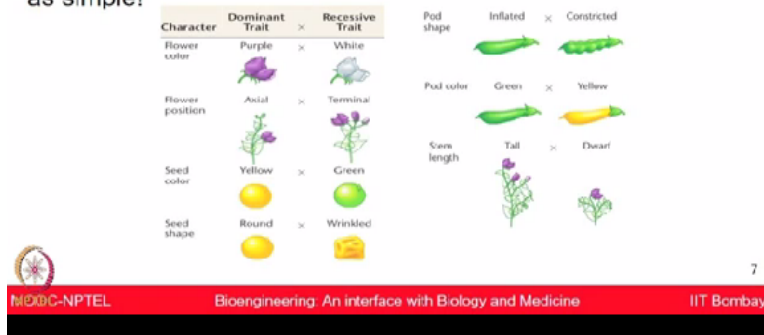
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Complex Inheritance Patterns

- In Mendelian genetics each character was determined by one gene, for which there are only two alleles (completely dominant or completely recessive)
- Relationship between genotype and phenotype are not always as simple!

Character	Dominant Trait	×	Recessive Trait
Flower color	Purple	×	White
Flower position	Axial	×	Terminal
Seed color	Yellow	×	Green
Seed shape	Round	×	Wrinkled

Pod shape	Inflated	×	Constricted
Pod color	Green	×	Yellow
Stem length	Tall	×	Dwarf



The diagram illustrates Mendel's pea plant traits. It shows two columns of traits. The left column lists: Flower color (Purple vs White), Flower position (Axial vs Terminal), Seed color (Yellow vs Green), and Seed shape (Round vs Wrinkled). The right column lists: Pod shape (Inflated vs Constricted), Pod color (Green vs Yellow), and Stem length (Tall vs Dwarf). Each trait is accompanied by a small illustration of the pea plant part. At the bottom of the slide, there is a logo for NIOOC-NPTEL, the text 'Bioengineering: An interface with Biology and Medicine', and 'IIT Bombay'.

And then he derived his conclusions based on those relationship between genotype and phenotype. Ideally is not as simple as just looking at their 1 genetic content.

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Degrees of Dominance

- Complete dominance occurs when phenotypes of the heterozygote and dominant homozygote are identical
- Incomplete dominance the phenotype of F_1 hybrids is somewhere between the phenotypes of the two parental varieties
- Co-dominance two dominant alleles affect the phenotype separately, distinguishable ways



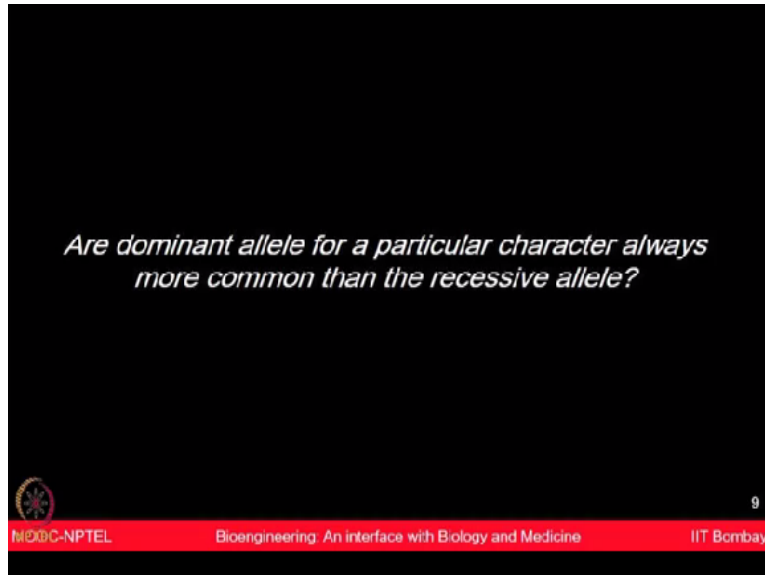
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So I will show you couple of examples where the dominant and recessive things may not be exactly following the same trends. So when we have, you know, the Mendelian kind of inheritance of complete dominance and recessive, that is known as complete dominant characteristics.

Sometime we have incomplete dominance, the phenotype of F_1 hybrids. They are somewhere in between the phenotypes of the 2 parental phenotypes. Or the co-dominance, it means there are 2

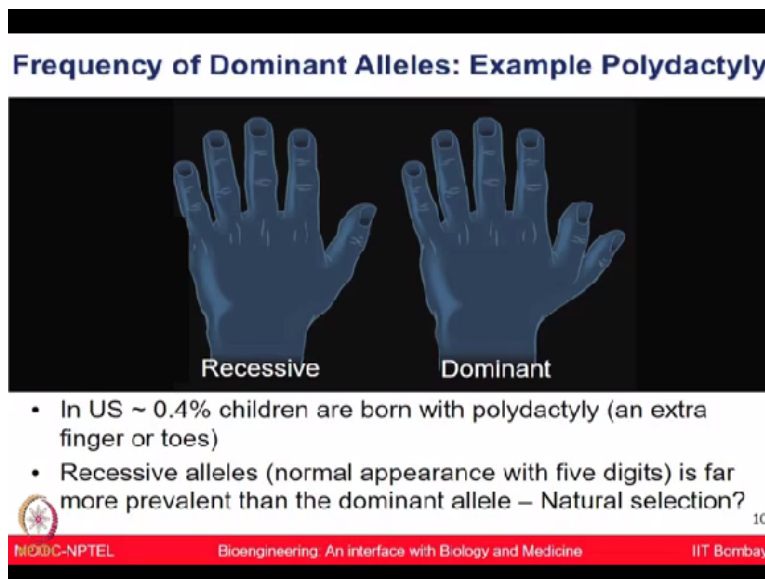
dominant alleles. They are resulting into a third property which is not exactly same like any parents. So those are co-dominant allele or co-dominant properties, are some of the dominant alleles.

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They are for a particular characteristics always more common than the recessive alleles.

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People have also looked at some of the frequency of dominant alleles. In this case look at the hand. So this is one of the dominant characteristic, especially lot of child born in US, they are having polydactyly, you know, multiple fingers, more than 5. So this extra finger or toes that is one of the characteristics which is example of polydactyly.

Recessive alleles in this case is the normal appearance with the 5 digits and is far more prevalent than the dominant allele. So is this because of natural selection. I think some of these, we will discuss in the context of evolution but just going to highlight that, you know, there are many variations in the human population available where one could start thinking about, you know, genetic principles.

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And some of these things one could think about at the single gene level and some of those are derived at the multiple gene level.

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PROBLEM SUMS BASED ON MENDELIAN GENETICS

We will now solve some problems based on the Mendelian genetics. Please try to solve them yourself first. Try to draw Punnett squares where applicable. It will be easier to solve questions in that way. Also remember 2 Mendelian laws, law of segregation and law of independent assortment and the concept of inheritance.

The law of segregation suggest that 2 alleles for heritable trait separate from each other during gamete formation and form different gametes. The law of independent assortment states that 2 or more genes assorted independently and each pair of alleles segregate independently during the gamete formation. Please revise the basic terminologies like what is dominant, recessive, genotype, phenotype, alleles and traits.

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Let us solve few problems now. You should try yourself but a TA will also guide you to show the solutions. So let us start it now.

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Concept check

1. When true breeding plants self-pollinate, all the offsprings are of _____ type(s)
- (A) Different
 - (B) Same**
 - (C) Two
 - (D) Difficult to predict



When true breeding plants self-pollinate, all the offsprings are of which type?
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Concept check

2. Which of the following represents a test cross
- (A) $AA \times aa$
 - (B) $Aa \times AA$
 - (C) $Aa \times Aa$
 - (D) $AA \times AA$



Which of the following represents a test cross?
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Concept check

3. Two alleles for leaf color are green (G) and orange (g). Green is dominant. Orange is the more common trait. What is the phenotype of a homozygous dominant individual?

- (A) Orange
- (B) Green**
- (C) A combination of A and B
- (D) Yellow

A common trait need not always be dominant and vice versa. For example, Widow's peak is dominant but NOT a common trait



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Two alleles for leaf colour are green G and orange g. Green is dominant. Orange is the more common trait. What is the phenotype of the homozygous dominant individual?

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Genetics problems

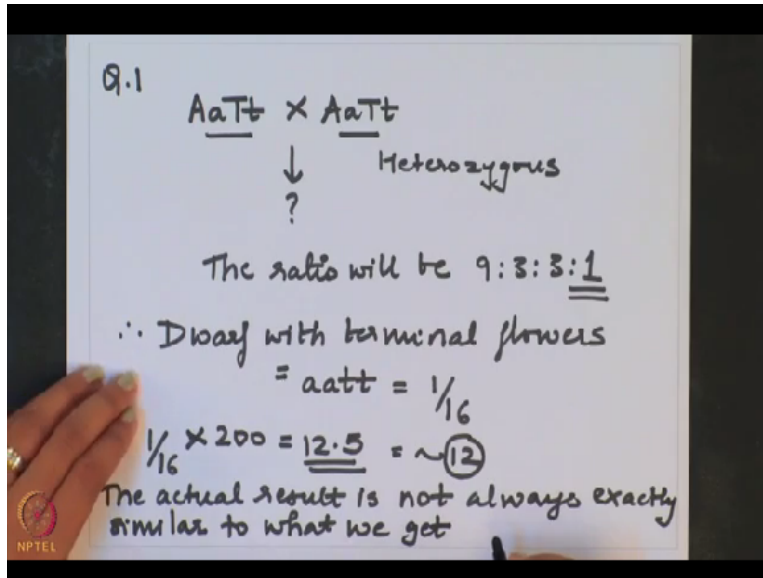
Q1. Self-pollination of two pea plants heterozygous for flower position and stem length (AaTt) yields many seeds, of which 200 are planted. How many offsprings would be predicted to be dwarf with terminal flowers?



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Self-pollination of 2 pea plants heterozygous for flower position and stem length AaTt yields many seeds, of which 200 are planted. How many offsprings would be predicted to be dwarf with terminal flowers?

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Say suggestively you should not make the Punnett square in case of heterozygous crosses. Simply use 9:3:3:1 ratio. So according to the law of independent assortment, 1 out of 16 of the offsprings are predicted to be aatt or recessive for both characters. The actual result is likely to differ slightly from this value.

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Genetics problems

Q.2 A pea plant heterozygous for axial flowers (Aa) is crossed with a plant homozygous for terminal flowers (aa). Draw a Punnett square for this cross to predict genotypic and phenotypic ratios.


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A pea plant heterozygous for axial flowers Aa is crossed with a plant homozygous for terminal flowers aa . Draw a Punnett square for this cross to predict genotypic and phenotypic ratios.

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Q.2) $Aa \times aa$

↓

?

	A	a	
a	Aa	aa	= $\underbrace{Aa}_{\frac{1}{2}}$ $\underbrace{aa}_{\frac{1}{2}}$
a	Aa	aa	

∴ Genotypic & phenotypic ratio is 1:1

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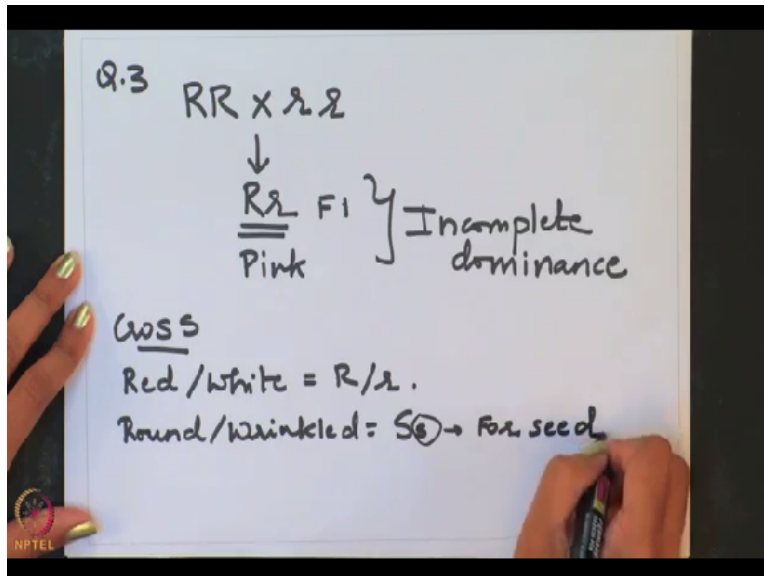
Genetics problems

Q.3 In some plants, a true-breeding, red-flowered strain gives all pink flowers when crossed with a white-flowered strain: RR (red) X rr (white) gives Rr (pink). If seed shape is inherited (round or wrinkled) as it is in peas, what will be the ratios of genotypes and phenotypes of the F1 generation resulting from the following cross: round-red (true-breeding) X wrinkled-white? What will be the ratios in the F2 generation?

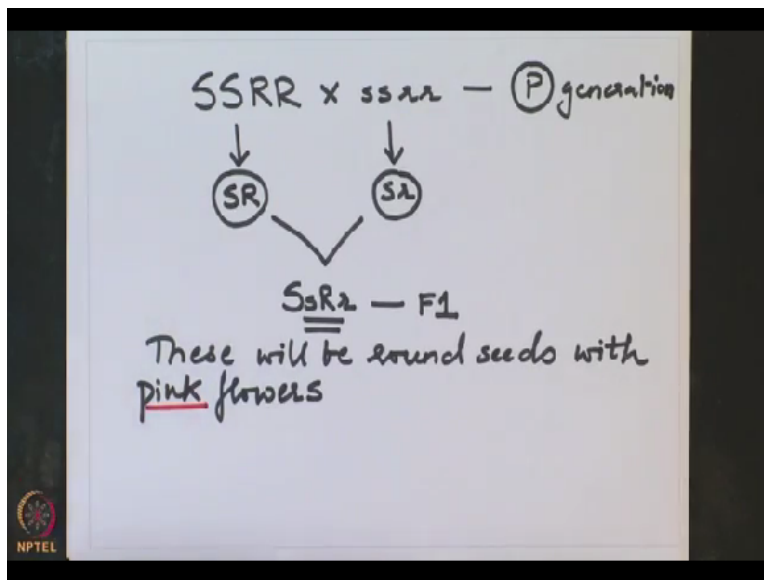
In this particular sum, one character belongs to a flower (flower colour) and the other belongs to a seed (seed shape).

In few plants, a true-breeding red-flowered strain gives all pink flowers when crossed with a white-flowered strain RR which is red crossed with rr which is white, gives Rr which is pink. If seed shape is inherited round or wrinkled as it is in peas, what will be the ratios of genotypes and phenotypes of the F1 generation resulting from the following cross which is round and red, true-breeding, crossed with wrinkled and white. What will be the ratios in the F2 generation?

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Now crossing F₁,
 $SRs_2 \times SRs_2$
 ↓
 F₂

	SR	S ₂	sR	ss
SR	SSRR	SSR ₂	SsRR	SsR ₂
S ₂	SSR ₂	SS ₂₂	SsR ₂	Ss ₂₂
sR	SsRR	SsR ₂	ssRR	ssR ₂
ss	SsR ₂	Ss ₂₂	ssR ₂	ss ₂₂

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The genotypes are:-

4 SsR₂ = 4:2:2:2:2:1:1:1:1=16

2 SsRR

2 SSR₂

2 ssR₂

2 Ss₂₂

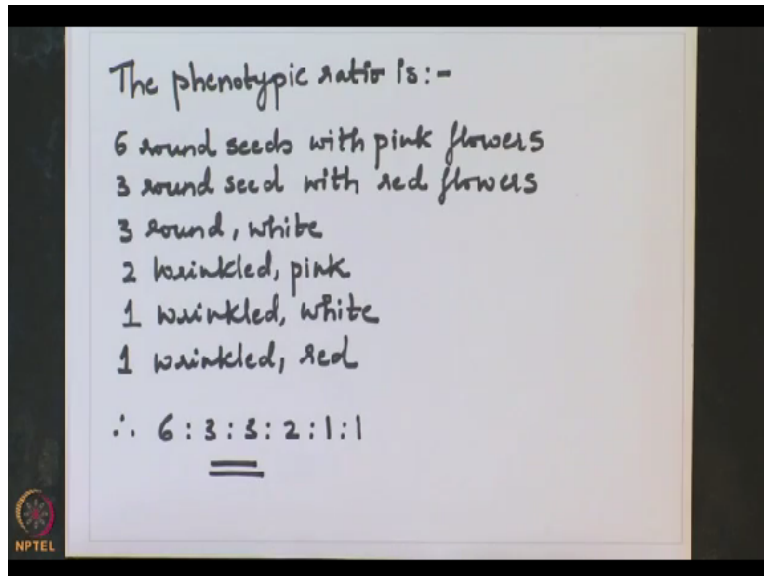
1 SSRR

1 ssRR

1 SS₂₂

1 ss₂₂

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Genetics problems

Q.4 A man has six fingers on each hand. His wife and their daughter are normal. Remember that extra digits is a dominant trait. What fraction of this couple's children would be expected to have extra digits?

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A man has 6 fingers on each hand. His wife and their daughters are normal. Remember that extra digits is a dominant trait. What fraction of this couple's children would be expected to have extra digits?

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Trait represented by 'D'
D for Digits.

Situation 1 ✗

Male × Female
DD ↓ dd

Child
✗ Dd → Daughter will have extra digits

Situation 2 ✓

Male × Female
Dd ↓ dd

✗ Dd × dd
Daughter

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Dd × dd

↓

	D	d	
d	Dd	dd	✗ Dd & dd 1/2 1/2 6 fingers Normal
d	Dd	dd	

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Genetics problems

Q.5A Inspired from Mendel's experiment, now you want to perform some genetics experiment in your farm. If you have a plant called *Vicia ervilia* (Bitter vetch) growing in your farm. This plant is usually short and bushy but the one growing in your farm is rather long. Now, assume that height in these plants is controlled by a single gene with short plants (S) being dominant to long ones. What is the genotype of your plant?

- (A) SS (B) Ss (C) ss (D) None of the above

Answer:

Since the plant is long and this is a recessive trait, its genotype is 'ss'

Q.5B Could one of the parents of your plant have had a short phenotype? If so, what would have been the genotype of that parent?

Yes, Ss

Answer: If the parents of this plant had a genotype Ss/SS, they could have still produced a progeny with 'ss' genotype



Inspired from Mendel's experiment, now you want to perform some genetics experiments in your farm. If you have a plant called *Vicia ervilia* or Bitter vetch growing in your farm. This plant is usually short and bushy but the one growing in your farm is rather long. Now, assume that height in these plants is controlled by a single gene with short plants S being dominant to the long ones. So what is the genotype of your plant?

Could one of the parents of your plant have had a short phenotype? And if so, what would have been the genotype of that parent?

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Genetics problems

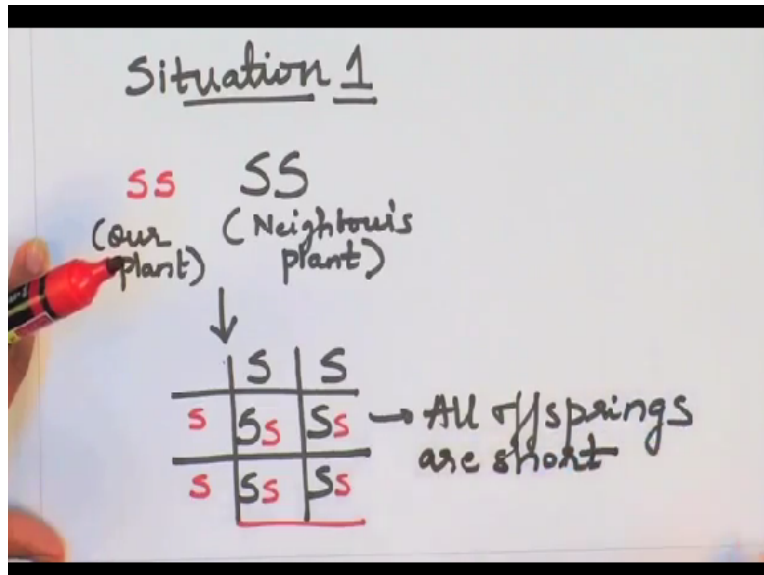
Q.6 From the premises of question Q.5, let's say your friend helped you to cross your plant with that of your neighbour's same *Vicia* plant which was short and bushy. You found that half of the resulting offsprings are short while others are long. What could be the genotype of your neighbour's plant?

- (A) SS (B) Ss (C) ss (D) None of the above

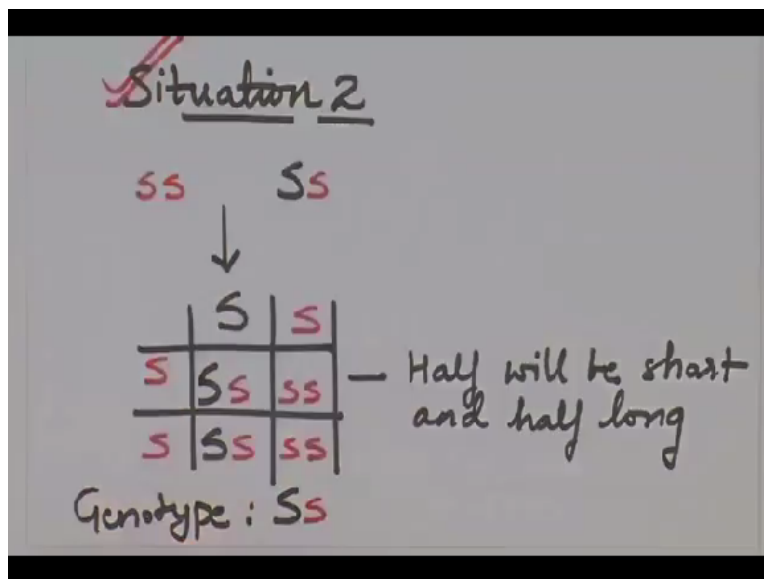
Let us say your friend help you to cross your plant with that of your neighbour's same *Vicia* plant

which are short and bushy. You found that half of the resulting offsprings are short while others are long. What could be the genotype of your neighbour's plant?

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So in conclusions, now you are familiar with some of the examples of Mendelian genetics.

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In the next lecture, we will discuss some deviations from Mendelian genetics where you will understand that not everything in the world follows Mendelian rules. Thank you and see you next week.

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References

- Campbell Biology - Reece, Urry, Cain, Wasserman, Minorsky, Jackson 10th Edition, Pearson
- A few sums have been modified from Campbell Biology - Reece, Urry, Cain, Wasserman, Minorsky, Jackson 10th Edition, Pearson
- *Acknowledgment*
 - Cover images – getty images

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