**5. Heredity in classical genetics – mendelism**

We will be discussing Mendel's experiment. What was his aim? What methods did he use? How did he evaluate it? And, most importantly, what can be concluded from his experiments? We can find the motivation for Mendel's experiment in the introduction of his article from 1866. His motivation was to find out what causes the diversity in colors of ornamental plants when utilizing hybridization (artificial pollination). Notice that he does not mention anything about inheritance. However, it can be implied that he was indeed interested in inheritance. The methodology is important, particularly these points. He chose an experimental organism that had to fulfill certain conditions, such as high fertility, self-pollination, and having simple traits. These traits are alternative traits, meaning traits that have either one variant or the other. He ultimately chose pea plants. He conducted two years of creating pure lines with these plants, obtaining two parent lines, each with one variant of the trait.

He then intentionally crossed the parent lines. He transferred pollen grains from one set of parents to the stigma of the other set of parents using a brush. He observed what he obtained in the subsequent generations of offspring. He always recorded the numbers of individuals with specific traits in each generation. He mathematically evaluated the data using probability theory. From the obtained data, he inferred how inheritance occurs.

Mendel studied at the University of Vienna, where he encountered new scientific knowledge and methods. Among other things, he realized the fundamental reproductive principles of higher organisms. He based his work on the basic principle of reproduction, which requires the fusion of male gametes, or pollen grains, with female gametes, or eggs. Both types of gametes are equally important. He assumed that in order for parents and offspring to resemble each other, parents must pass something to their offspring through the gametes. What is present in the gametes must have half the amount of hereditary material. The fusion of gametes results in a zygote, an offspring, which must inevitably have the same amount of this hereditary material as the parents. Nowadays, we don't find this surprising because we understand that higher organisms are usually diploid. In order for diploid parents to produce diploid offspring, there must be a reduction of the hereditary material by half in the gametes. From this assumption, Mendel likely derived the basic idea, hypothesis, that what is inherited must be a discrete element, a unit. Each individual has two of these units, and there must be only one unit in the gametes. Towards the end of his work, he called these hereditary units "die Elementen".

Mendel chose 7 pairs of contrasting traits in peas, each with only two variants. One example is seed shape - round or wrinkled. Another example is seed color - yellow or green. Mendel noticed during the crosses that one variant dominated over the other in the case of hybrids. The terms dominance and recessiveness come from Mendel.

We will describe 2 types of crossings. The first one is monohybrid crossing. In the parental generation, phenotypically different parents in a particular trait were deliberately crossed. We will choose only the pea color. So we have parents with only yellow or only green peas. Mendel created female plants from one variant (e.g. yellow color) (by removing immature stamens) and only had female flowers. From the other parents (green color), he then transferred pollen grains to the stigma of the castrated plants using a brush. This way, he had control over what is being transferred where. After fertilization, he found in the F1 generation that all offspring had only one type of trait, which was the dominant one, with only yellow peas - we speak of phenotypic uniformity. When he allowed this F1 generation to reproduce freely among themselves, he found that both plants with yellow and green seed color appeared in the population of offspring in the F2 generation. There was no dilution of colors, only those two basic colors were present. But when he counted them, he found that the ratio of yellow to green peas was 3:1. And he obtained this ratio in the same experiment for all seven traits. This is not a coincidence.

How did Mendel explain this? He used his hypothesis of the discreteness of the hereditary material and identified elements for the dominant trait with a capital letter "A" and for the recessive trait with a lowercase letter "a". If parents pass on these elements through gametes to their offspring, then both parents and offspring must have these elements in pairs and only one in gametes. And because he selected pure lines for parents, they must carry both the same elements - today we call them dominant and recessive homozygotes. Dominant homozygous parents with yellow peas only produce gametes with the dominant element - today called an allele. The second parent only produces gametes with the recessive allele. When the gametes combine, hybrid individuals with both the dominant allele and the recessive allele "Aa" necessarily arise - today we call them heterozygous genotypes. Mendel called them hybrids. This genotypic uniformity causes the emergence of phenotypic uniformity. Only one variant, the dominant one, is expressed. The recessive trait, green color, does not appear. The expression of the recessive allele is suppressed. But it is present in individuals. When F1 individuals, heterozygotes, reproduce among themselves, gametes are formed again. But this time it is necessary to take into account that those two alleles are different and that gametes will be formed with both the dominant allele A and the recessive allele. Mendel called this segregation. In each gamete of hybrid individuals, there is either the first or the second variant. These gametes are formed in large quantities and therefore in a ratio of 1:1. And this is the key to explaining the ratios he found in the F2 generation. Male and female gametes are now formed in a 50%: 50% ratio with the dominant allele to the recessive allele. The fusion of gametes during fertilization is determined by the probability of the fusion of these gametes multiplied by the probability of the occurrence of these gametes in the genofond of the parents. This creates again dominant homozygotes in the F2 generation in a ratio of ¼ (because ½ of female gametes have allele A and ½ of male gametes have the recessive allele, which is ½ * ½ = ¼). And this applies to every combination of parental gametes. The results are best shown by Punnett's combination square. And that is why dominant allele can also be combined with the recessive one, resulting in two variants of heterozygotes Aa. BUT two recessive alleles can also combine, again with a probability of ¼. And that is the reason why the recessive trait, recessive homozygotes, reappear in the F2 generation. And when we add up these probabilities, the ratio of 3:1 is obtained. So nothing is random. That is important. Inheritance has its rules and these rules come from the mathematical probability of combining parental gametes to create a specific genotype of offspring.

Although Mendel never mentioned the term "inheritance" in his work, from his experiments and how he interpreted them, it follows that Mendel was the first to understand how inheritance works, what and how is inherited. That inheritance is about the transfer of these elements through gametes to offspring. In other words, genetic information is not diluted, mixed, on the contrary, it is discrete and constant.

And when we project it back into the initial scheme of reproduction and add sets of chromosomes, whose existence and function in inheritance Mendel did not know at that time, we see that it fits together, both the elements, alleles, and the behavior of chromosomes during gamete formation.

These are the basic three Mendelian principles that can be derived from monohybrid crosses: Genetic characteristics are controlled by unit factors, which exist in pairs (genotypes) in individual organisms.

The second principle is dominance and recessiveness. It refers to the expression of the phenotype in heterozygous individuals, where only one of the traits is manifested in the phenotype - the dominant one. The recessive allele remains in those individuals, but it is not expressed, although it can be passed on to the next generation.

The main principle is the principle of segregation, which tells us that during the formation of gametes, the paired unit factors separate, so that each gamete receives one or the other element with equal probability.

In the dihybrid experiment, Mendel observed the variability of two different traits simultaneously in the same experimental design as in monohybrid crosses.

Let's use an example of two traits: seed color and seed shape. The dominant color is yellow, the recessive color is green; the dominant shape is round, and the recessive shape is wrinkled. It didn't matter if the parental plants carried both traits as dominant or if one parent carried both traits as recessive. Or if the parents carried different combinations of dominant and recessive variants for both traits (one dominant and the other recessive). They were still pure lines, i.e., homozygotes. In the F1 generation, Mendel again observed phenotypic uniformity. All individuals carried both dominant traits - yellow color and round seeds. And when the F1 individuals were crossed with each other, a specific ratio of 9:3:3:1 was obtained again in the F2 generation. This happened every time he chose two different traits out of the seven.

How did Mendel explain this? He again used symbols of capital and small letters to represent dominant and recessive alleles, and determined which alleles for both traits could appear in the gametes. And because both types of parents were pure lines, i.e., homozygotes, each parent produced only one type of gamete. And when they combined, heterozygous individuals were always produced in the F1 generation. In the F1, we have dihybrids, double heterozygotes, and these were crossed with each other.

The result is best described using this combination table. Heterozygous parents of the F1 generation YyRr can produce 4 types of gametes that combine one allele from each partial genotype, the Y gene for color and the R gene for seed shape. The alleles of the two genes combine freely, resulting in a ratio of 1:1:1:1. Each type of gamete is formed with a probability of ¼. When these male and female gametes are combined during fertilization, new combinations of genotypes of the F2 generation offspring are formed. And when we determine their phenotype based on their genotypes, we must obtain the ratio 9 3 3 1. These two different traits are genetically independent, and this is precisely manifested in the free combinability of alleles of different genes during gamete formation. This conclusion is called the principle of independent assortment.

Mendel, as a true scientist, tested his hypothesis through test crosses, in which he crossed heterozygotes with recessive homozygotes from the parental generation. Because recessive homozygotes form only one type of gamete and heterozygotes form 4 types of gametes in a ratio of 1:1:1:1, all 4 types of phenotypic combinations appear in the test offspring in a ratio of 1:1:1:1.

The rule of independent assortment is a conclusion from Mendel's dihybrid cross experiments. During gamete formation, different pairs of unit factors segregate independently of each other (alleles of one allelic pair are independent of the segregation of alleles of the second allelic pair).

From Mendel's experiments and his conclusions, the most important thing is evident. This is why Mendel is considered the father of genetics, as he first understood how inheritance works. Mendel understood that traits are not inherited. Traits do not inherit. What is inherited is what is in the gametes; there are no traits there. What is inherited are precisely those discrete genetic elements, which we now call genes, and which are found in one variant in each gamete.

Thank you for your attention.