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Why offspring from the same parents are different in appearance.

The appearance of the organism is the phenotype which is the physical expression of the genotype. The genotype itself is the combination of alleles of a gene so the phenotype is determined by the genotype. In order for the genotype to be physically expressed, the gene must first be transcribed and translated into an amino acid sequence which later becomes a protein. Transcription occurs in the nucleus and begins with DNA helicase which breaks the hydrogen bonds between complementary base pairs in DNA, thus separating the double helix into two strands. The template strand now has exposed nucleotide bases so free nucleotide bases complementary base pair to the exposed bases. RNA polymerase binds to a promoter on the template strand and forms phosphodiester bonds between the free nucleotide bases, joining them together into a strand of pre-mRNA. The pre-mRNA then needs to be spliced using an enzyme as the mRNA contains introns which are non-coding genes and need to be removed before translation. The mRNA then enters the cytoplasm via the nuclear pores. In viruses' transcription occurs in a similar way but is used for RNA replication, the process is catalysed by viral RNA replicase. The mRNA is then translated into a sequence of amino acids by ribosomes and tRNA, the amino sequence forms the primary structure of a protein like the enzyme amylase. Good eg.

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As the phenotype is determined by the genotype, changes in genotype can influence the phenotype as different proteins can be produced through mutation of the DNA base sequence. Mutations can occur during semi-conservative replication and can include base addition, deletion or substitution which can alter the mRNA transcribed which then changes the protein translated and therefore the phenotype. However, some mutations can be silent and will have no effect on the amino acid sequence as the genetic code is degenerate meaning more than one triplet can code for the same amino acid, so a mutated triplet may still code for the original amino acid so there will be no effect on the protein. For mutations which are not silent, a change in base sequence will cause a change in primary structure. This then causes a change in primary and tertiary structure as the ionic, disulphide and hydrogen bonds change position. If the tertiary structure changes this can lead to a non-functional protein, for example if an enzyme's specific 3D shape changes, its active site will no longer be complementary to the substrate so the enzyme will be denatured. If the gene coding for the protein haemoglobin mutates, an abnormal haemoglobin molecule will be produced leading to sickle-cell disease as the Hb in red blood cells can't carry enough oxygen to supply the cells. This is very serious as the body cells don't have enough oxygen to aerobically respire leading to hypoxia.

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The transcription of genes can also be affected by epigenetics which is the study of changes in organisms due to changes in gene expression caused by environmental factors like diet, stress and toxins, rather than changes in base sequence of DNA. Double stranded DNA is associated with proteins called histones, the DNA has a negative charge due to the negative phosphate ions and histones have a positive charge. Adding methyl groups to the epigenome of DNA causes the DNA to have a more negative charge so there's a stronger attraction between the DNA and histones, therefore the DNA is more tightly packed so it's harder for transcription factors to bind. Without the transcription factors, RNA polymerase can't bind so the gene is not transcribed or expressed. Adding acetyl groups to histones causes the histones to have a less positive charge, thus there's a weaker association between the DNA and histones and the DNA is more loosely coiled. Therefore, the transcription factors can bind to the DNA so the gene is transcribed and expressed.

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Offspring can then differ in appearance from their parents due to environmental factors causing methylation or acetylation of DNA so different genes are expressed in the offspring so they have different phenotypes.

The differences in genotype of offspring to their parents is genetic variation which is caused by crossing over and independent segregation in meiosis. Crossing over occurs in the pachytene stage of prophase one during synapsis. Once the homologous pairs are aligned, sections of non-sister chromatids wrap around each other at points called chiasmata. The non-sister chromatids exchange DNA forming recombinants with different combinations of maternal and paternal alleles. Thus the offspring formed from the gametes will have a different genotype to its parents. Furthermore, independent segregation occurs in which the bivalents randomly arrange themselves at the equator of the cell during metaphase 1. During anaphase different chromosomes are pulled to each pole of the cell, forming different combinations of maternal and paternal alleles. Therefore, the offspring will have a different genotype to its parents and so will differ in phenotypes and appearance.

The difference in features between offspring and parents is caused by genetic and environmental variation which leads to evolution over many generations. Evolution is a product of natural selection in which an organism has a random mutation which produces a new allele for a gene which gives a selective advantage. This advantageous allele then enables the organism to survive longer and have greater reproductive success in which the allele is passed on to its offspring. Over many generations the frequency of the allele increases in the population. Variation causes selection in a population of a species, for example disruptive selection in which the extremes of the phenotype are selected and occurs when an environmental factor takes two or more distinct forms. Disruptive selection is important in bringing about evolutionary change. Natural selection leads to offspring having different phenotypes to their parents due to certain phenotypes being favoured.