Pleiotropy, Penetrance and Expressivity

What is Gene?

The basic physical unit of heredity consisting of a DNA sequence at a specific location on a chromosome.

Allele

Specific form of a gene

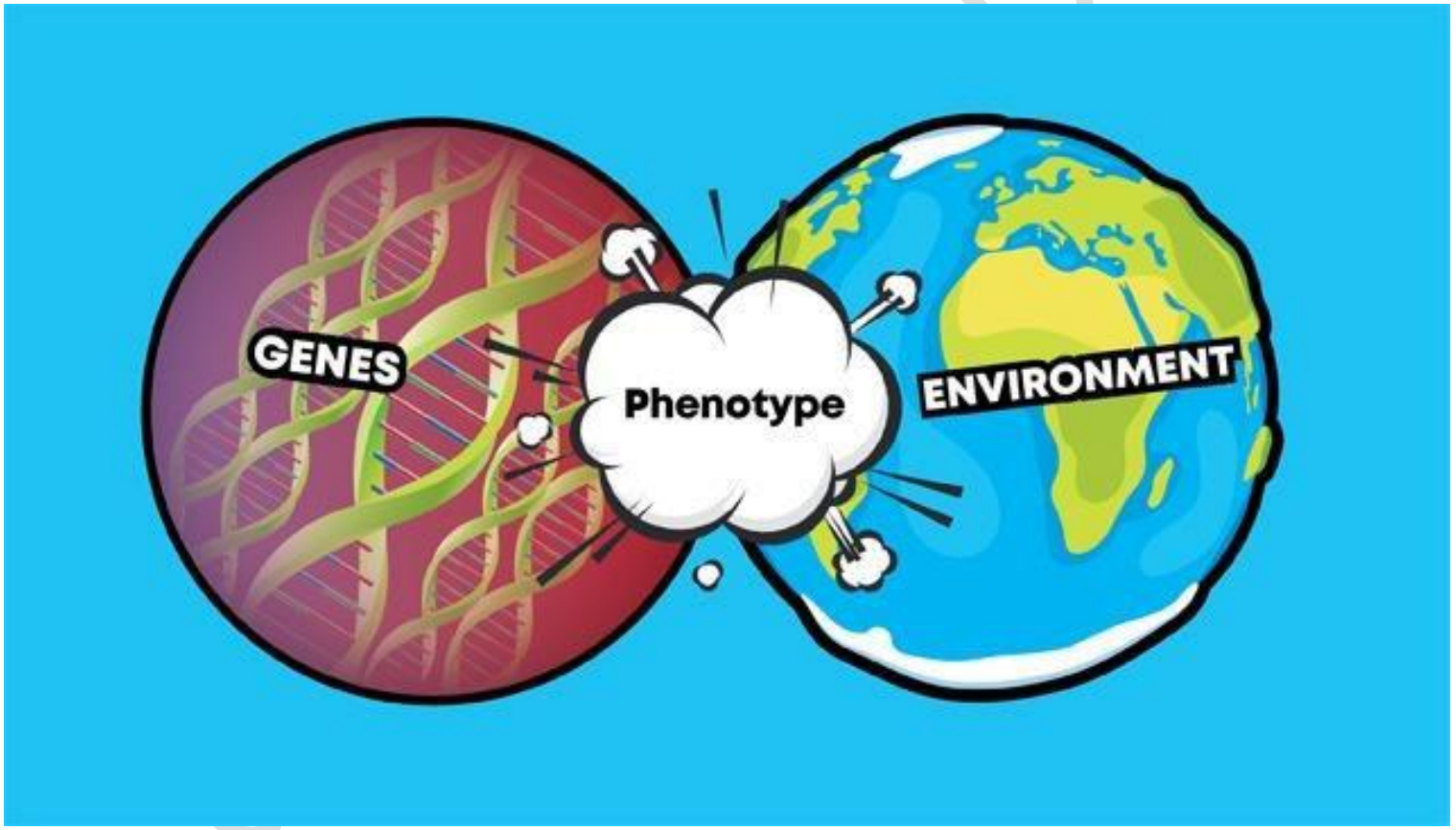
- Each gene has a uniform and regular phenotypic expression

Implications

✓ All the individuals carrying a specific gene show the same phenotype

✓ The degree of phenotypic expression of a gene is same in all the individuals carrying it.

Relationship Between Genotype, Environment & Phenotype



- Penetrance: refers to the actual manifestation of a phenotype when the gene responsible for that phenotype is present in the individual.

Or

- Penetrance refers to whether or not a particular phenotype is expressed in all the individuals possessing the appropriate genotype responsible for it.

Types of Penetrance:

1. **Full Penetrance**
2. **Incomplete Penetrance**

- A gene that expresses invariably in all the individuals carrying it is said to have **Full Penetrance**.

- If an allele expresses its phenotype in some individuals but not in others, the gene is said to have I**ncomplete Penetrance**.

- **Examples of Penetrance:**

Albino condition: homozygous recessive

If all individuals are homozygous recessive for the allele causing albino condition, then we can say that the allele responsible for albino condition fully penetrates into the phenotype

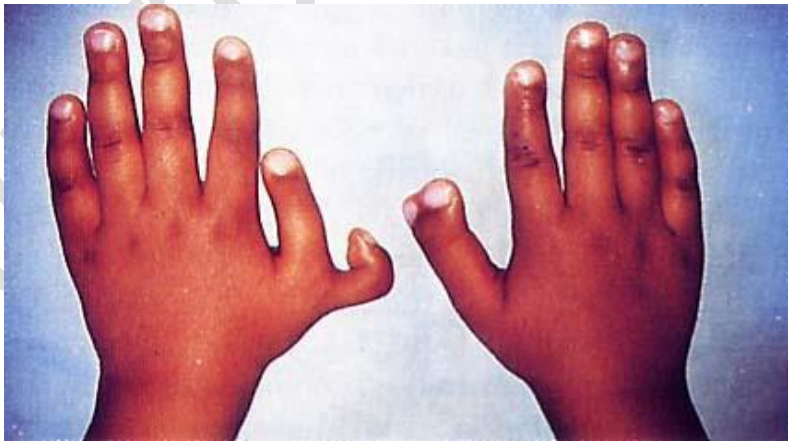
If an allele expresses its phenotype in some individuals but not in others, the gene is said to

have incomplete penetrance

Polydactyly –presence of extra digits on toes and fingers

- Polydactyly: dominant gene (P)
- Normal condition of five digits caused by recessive allele (pp) in homozygous state

All the individuals carrying allele, P, responsible for polydactyly do not exhibit the polydactyly phenotype.



- **Expressivity:** refers to the variation in the degree of phenotypic expression of a gene from one individual to the other in a group.
- A gene whose phenotypic expression varies from one individual to the other in a group of individuals is said to have variable expressivity.
- **Polydactyly:** some individuals carrying 'P' allele have an extra digit on both hands and feet, others have extra digit on one limb only and some have rudimentary extra digit. The degree of expression of polydactyl thus varies from rudimentary extra digit to extra digit in all the four limbs.

Piebald Spotting In Beagles

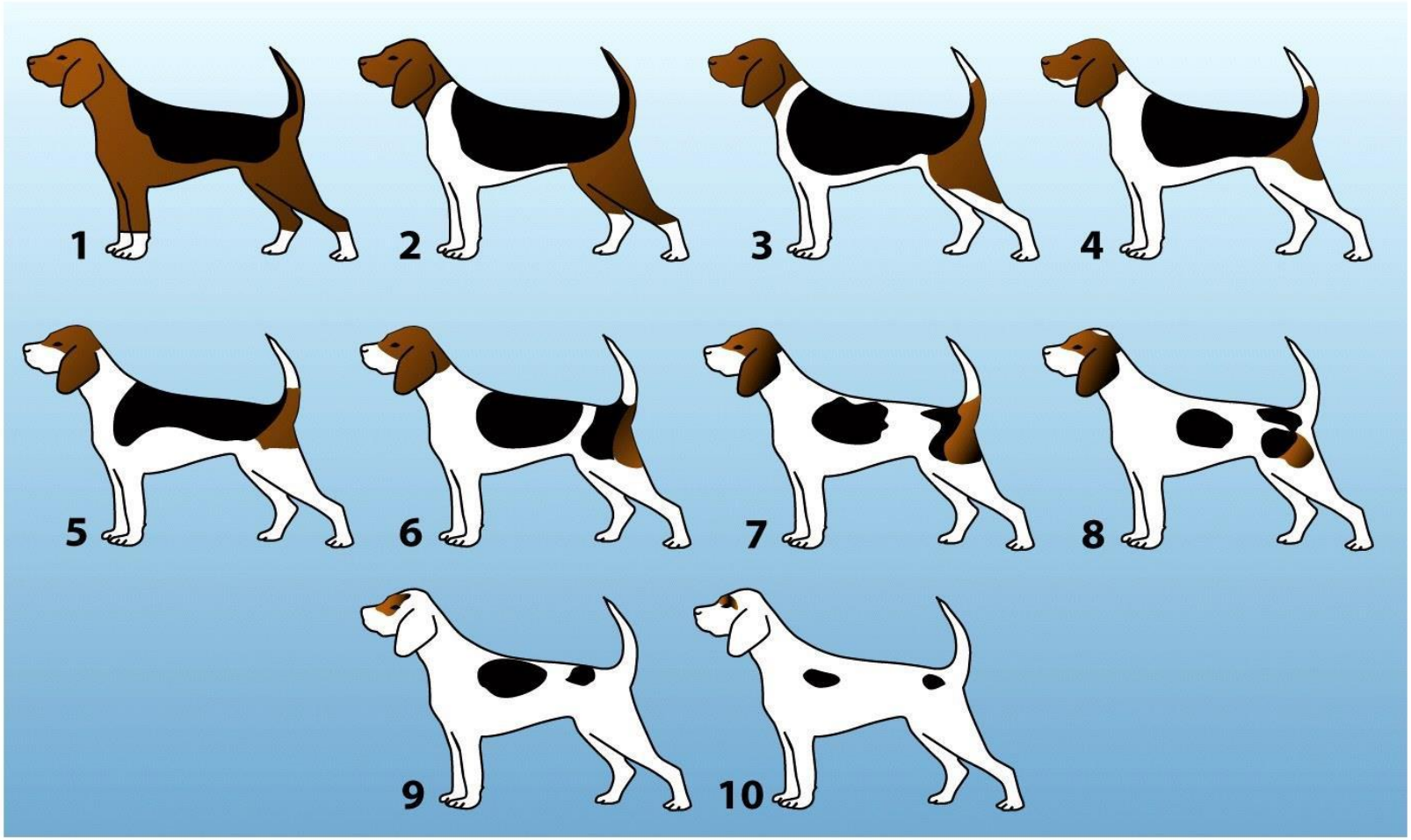


Figure 6-23
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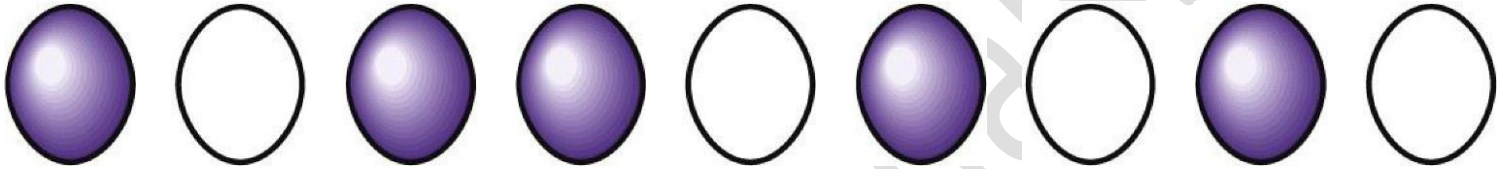
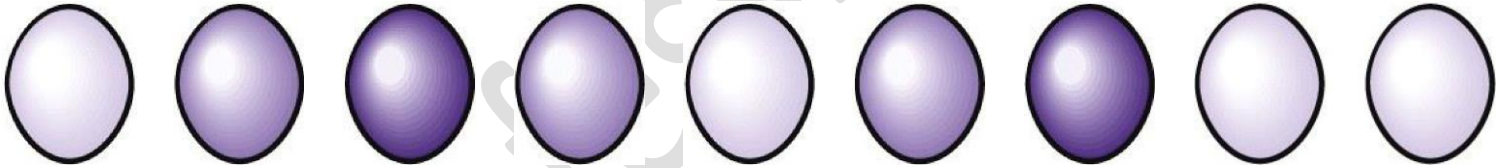
Each of these dogs has the dominant allele for piebald (black and white) spotting

The degree of spotting varies among individuals

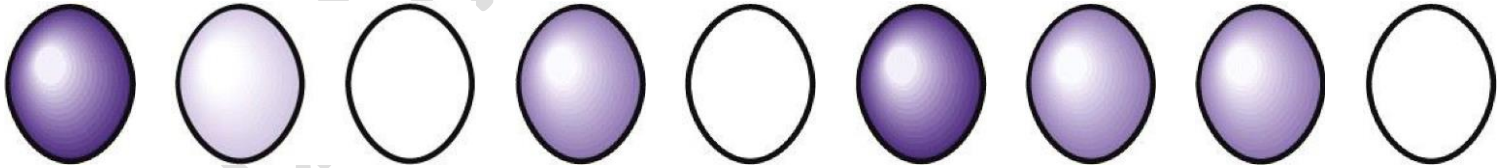
Phenotypic expression
(each oval represents an individual)



Variable penetrance



Variable expressivity



Variable penetrance and expressivity

Figure 6-22
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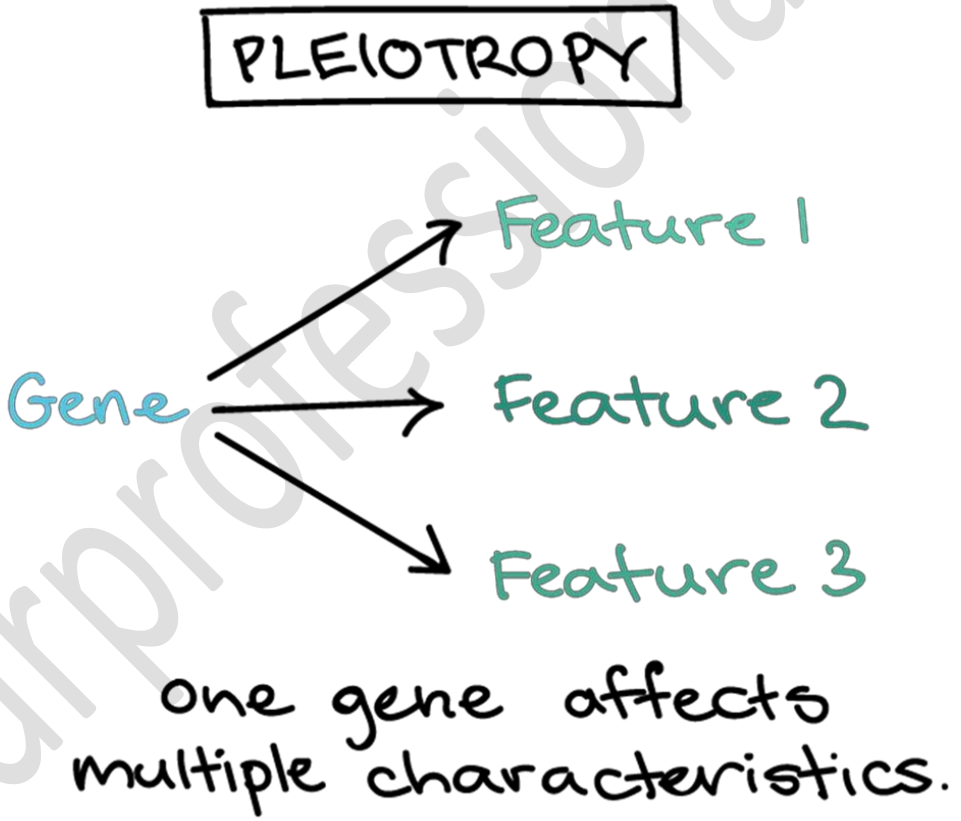
Reasons for Incomplete Penetrance

- Environment, Epistatic genes, pleiotropic genes or other genes which suppress the expression of the genotype.

- **Pleiotropy**: Phenomenon in which a single gene influences the expression of a number of distinct traits



- Mechanism of pleiotropy in most cases is the effect of a gene on metabolic pathways that contribute to different phenotypes

- Genes showing pleiotropy produce a single polypeptide just like other non pleiotropic genes

- But their polypeptide governs such a biochemical reaction, which is basic to many developmental events. As a result impairment of the function

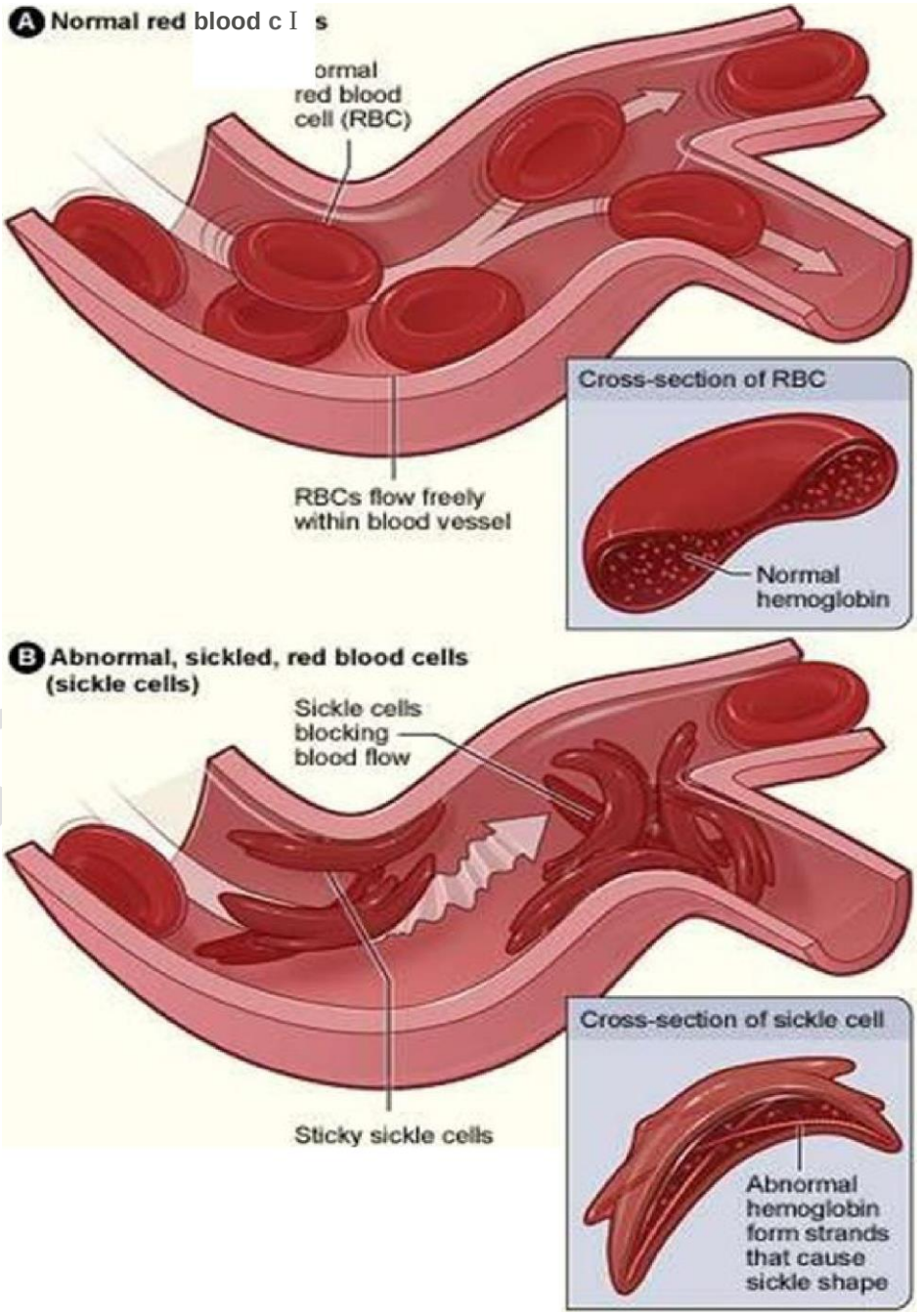
- **Example: Sickle Cell Anemia**
- Sickle cell anemia is a genetic disease that causes deformed red blood cells with a rigid, crescent shape instead of the normal flexible, round shape.
- It is caused by a change in one nucleotide, a point mutation in the beta chain of the Hb (glutamic acid to valine) which in turn leads to sickle shaped red blood cells.
- Sickle cell anemia is a pleiotropic disease because the expression of a single mutated HBB gene (Beta globulin) produces numerous consequences throughout the body.

The sickling of RBCs have two major effects:

- ➢ Sickled cells are destroyed by the liver, causing anemia
- ➢ Sickled RBCs interfere with capillary blood flow due to clumping of the odd shaped RBCs
- These two leads to number of secondary ailments like damage to numerous organs including bone, heart, lung and muscle.
- Thus a single gene leads to multiple phenotypic effects

rmal r J blood *c* II

• icklcd red blood cell



Phenylketonuria (PKU)

- This disease can cause mental retardation and reduced hair and skin pigmentation

- Phenylketonuria is due to mutation in a single gene that codes for the enzyme phenylalanine hydroxylase

- Phenylalanine hydroxylase converts the amino acid phenylalanine to tyrosine

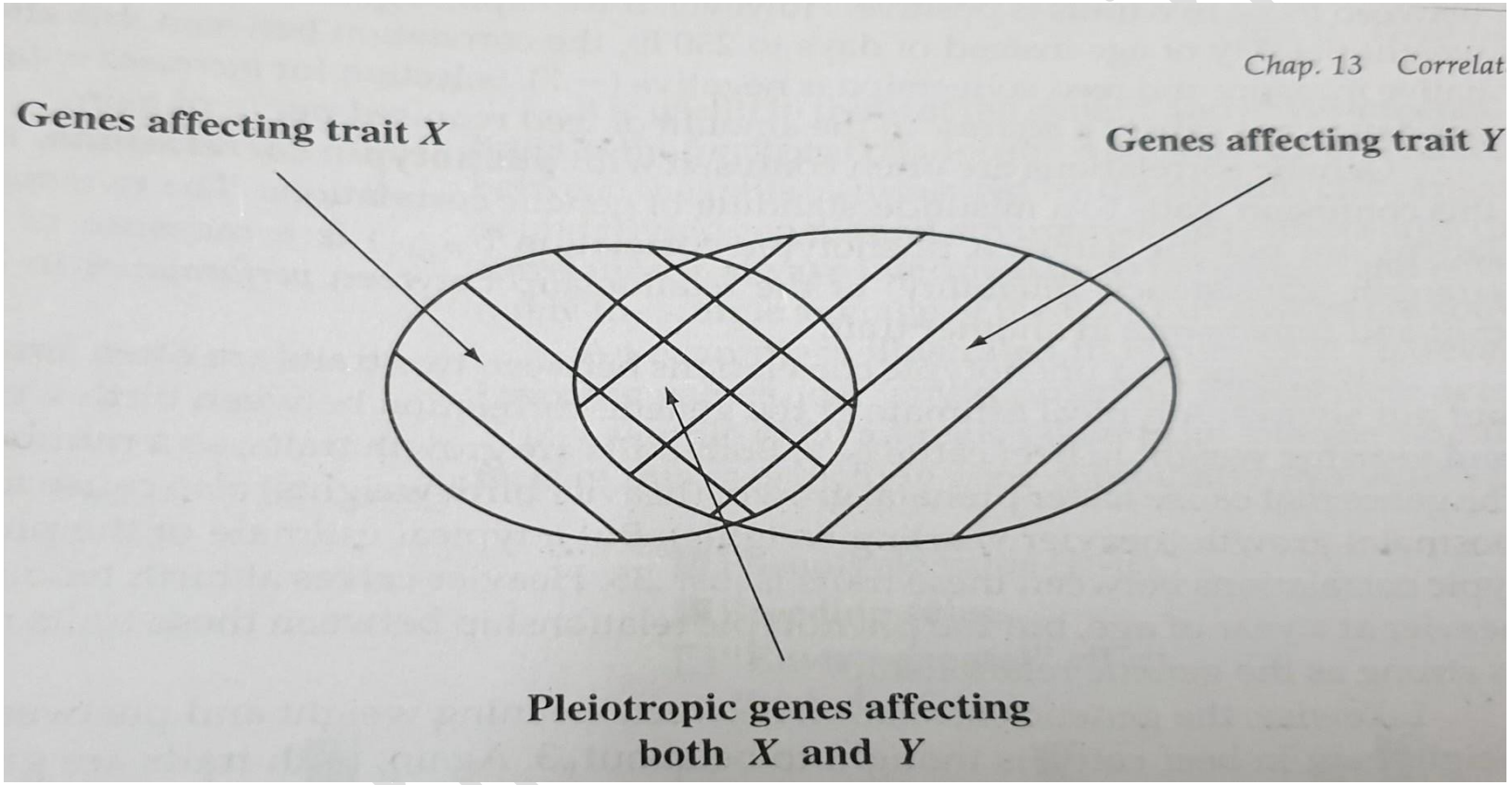
- Due to mutation, conversion of phenylalanine to

tyrosine is reduced or ceases entirely.

- Phenylalanine in the bloodstream is toxic to the developing nervous system of new-born and infant children and which causes mental retardation.

- Where as tyrosine is used by the body to make melanin (an important component of the pigment found in hair and skin)

- The failure to convert normal levels of phenylalanine to tyrosine results in less pigmentation of hair and skin.



Some genes affect trait X only. Others affect only trait Y. Pleiotropic genes affect both X & Y resulting a genetic correlation between thetwo traits

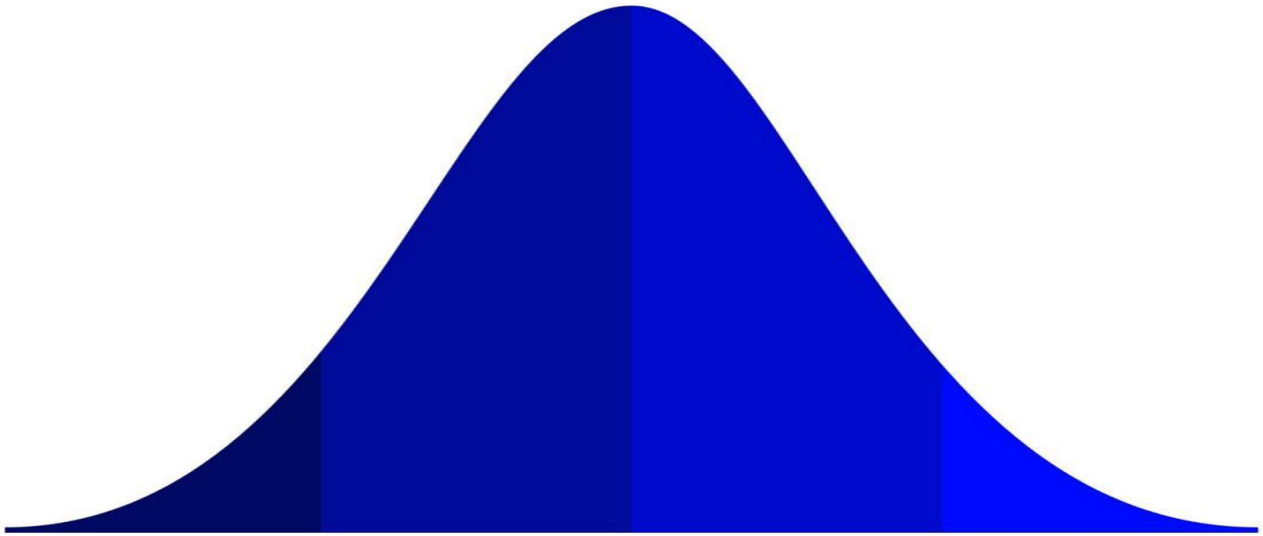
Polygenic Inheritance:

- Describes the inheritance of traits that are controlled by more than one gene
- Genes controlling polygenic inheritance are called as polygenes
- Polygenic inheritance differs from Mendelian inheritance patterns, where traits are determined by a single gene.
- Polygenic inheritance patterns normally follow a normal (bell-shaped) distribution curve - it shows continuous variation with most individuals inheriting various combinations of alleles and falling within the middle

range of the curve for a particular trait.

Polygenic Traits Distribution

- Polygenic traits tend to have a bell-shaped distribution in a population. Most individuals inherit various combinations of dominant and recessive alleles. These individuals fall in the middle range of the curve, which represents the average range for a particular trait. Individuals at the ends of the curve represent those who either inherit all dominant alleles (on one end) or those who inherit all recessive alleles (on the opposite end). Using height as an example, most people in a population fall in the middle of the curve and are average height. Those on one end of the curve are tall individuals and those on the opposite end are short individuals.

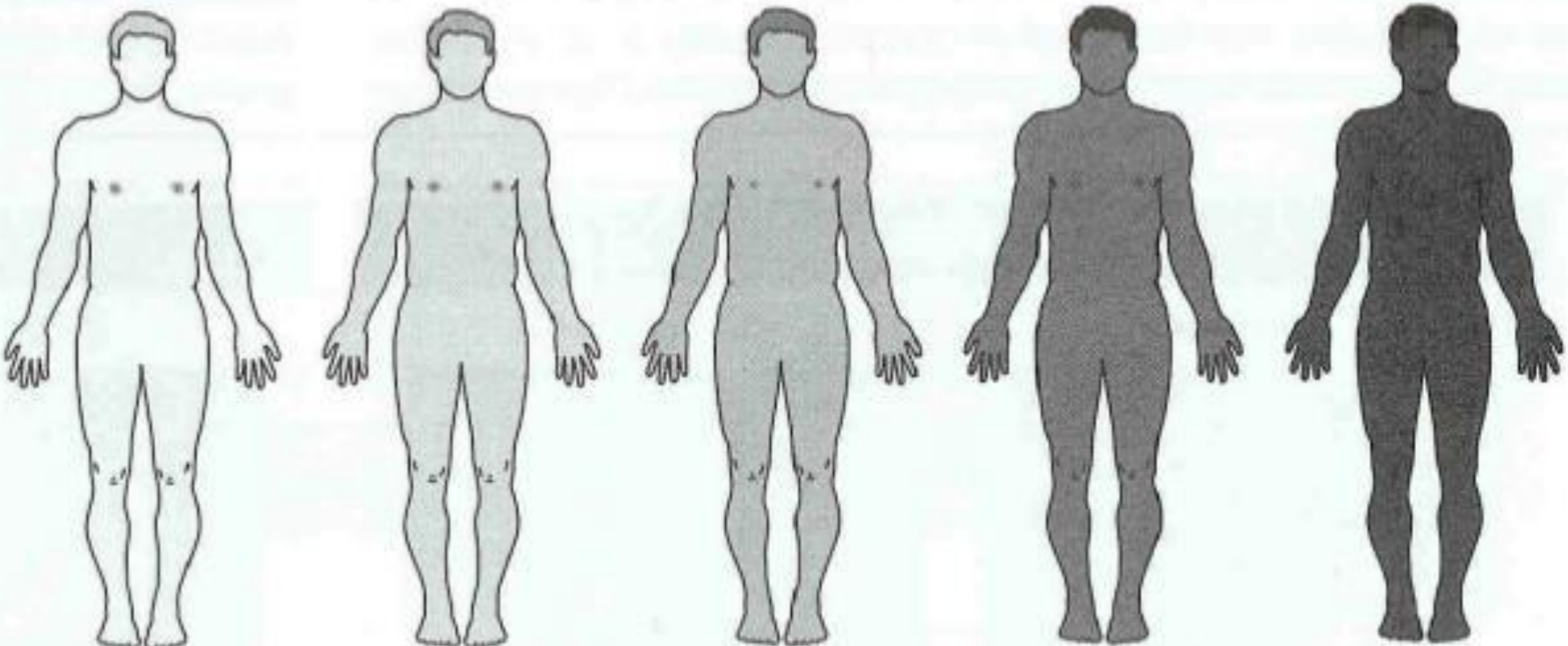


Examples of Polygenic Inheritance:

- Inheritance of skin colour – presence of melanin pigment in the skin determines skin colour. The more is the pigment the darker is the skin colour.
- Skin colour is controlled by 2 or 3 genes.
- Each gene has alleles which promote melanin production and alleles which do not.
- Thus there is a wide range of phenotypes possible ranging from all alleles promoting melanin production (black Skin) to alleles not promoting melanin production (white skin).

Continuous Variation in Human Skin Colour as a Result of Polygenic Inheritance

Ref: Yr12 Biology, Bizzone



Spotted Colour in Cattle:

- In Cattle, solid colour is dominant to spotted colour pattern. The solid colour is due to dominanat gene **S**, where spotting is due to its recessive alleles.

- Degree of spotting in **ss** individuals depends upon a large series of polygenes.

- **Penetrance:** in a population of individuals with the same genotype, the percentage who exhibit the phenotype for that genotype

- **Expressivity:** for a given genotype, the degree to which the phenotype is expressed

- **Pleiotropy:** single gene influences the expression of a number of distinct traits

- **Polygenic Inheritance:** inheritance of traits that are

controlled by more than one gene