

CHAPTER 9

Heredity and Evolution

Class 10 Science | NCERT Exemplar - Complete Solved Study Guide

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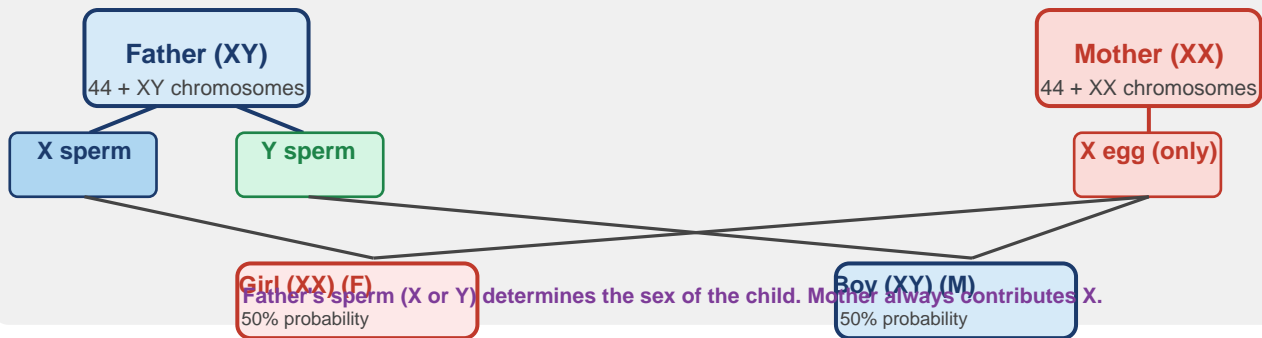
[GLOS] Key Terms / Glossary

Heredity	Transmission of traits (characteristics) from parents to offspring through genes.
Gene	A specific segment of DNA on a chromosome that codes for a particular protein/trait.
Allele	Alternative forms of a gene for the same trait (e.g., T = tall, t = short).
Dominant trait	A trait that expresses itself even in the presence of one copy (e.g., TT or Tt both tall).
Recessive trait	A trait that expresses only when both alleles are recessive (homozygous, e.g., tt = short).
Homozygous	Having two identical alleles for a gene (e.g., TT = pure tall, tt = pure short).
Heterozygous	Having two different alleles for a gene (e.g., Tt = hybrid/carrier).
Phenotype	The visible/observable trait of an organism (e.g., tall, short, yellow seed).
Genotype	The genetic constitution of an organism (e.g., TT, Tt, tt).
F1 generation	First Filial generation -- offspring of the parent (P) cross. Often all show dominant trait.
F2 generation	Second Filial generation -- offspring when F1 plants self-pollinate. Shows 3:1 ratio.
Variation	Differences in traits among individuals of the same species; raw material for evolution.
Inherited character	A character that is passed from parent to offspring through genes. E.g., eye colour.
Acquired character	A character developed during an organism's lifetime; NOT passed to offspring. E.g., muscle built by exercise.
Homologous structures	Structures with the same origin (same ancestor) but different functions. E.g., human arm and whale flipper.

Analogous structures	Structures with different origins but same function. E.g., wings of birds and insects.
Natural selection	Darwin's mechanism: organisms with beneficial variations survive and reproduce more; these traits spread.
Speciation	Formation of a new species through accumulated genetic changes over many generations, often aided by geographical isolation.
Fossils	Preserved remains or traces of once-living organisms; provide direct evidence of evolution.
Evolution	Gradual change in inherited traits of a species over generations; results in formation of new species.

Sex Determination in Humans

Human Sex Determination



Homologous vs Analogous Structures

Homologous vs Analogous Structures

HOMOLOGOUS STRUCTURES

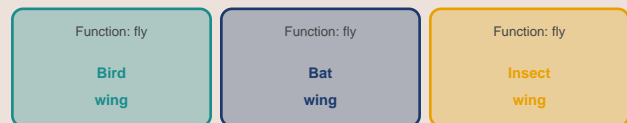
Same origin, different functions



Common ancestor -> divergent evolution
Evidence of COMMON DESCENT

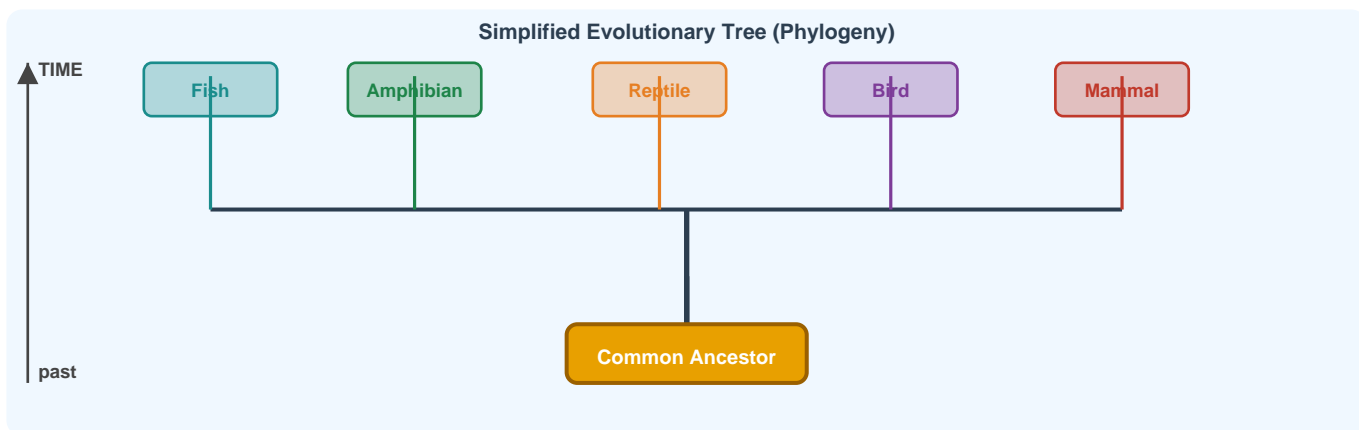
ANALOGOUS STRUCTURES

Different origin, same function



Different ancestors -> convergent evolution
Similar environment = similar adaptations

Evolutionary Tree



■ Mendel's 7 Pea Plant Characters

Character	Dominant Trait	Recessive Trait	Ratio (F2)
Seed shape	Round (R)	Wrinkled (r)	3:1
Seed colour	Yellow (Y)	Green (y)	3:1
Pod shape	Inflated (I)	Constricted (i)	3:1
Pod colour	Green (G)	Yellow (g)	3:1
Plant height	Tall (T)	Short/Dwarf (t)	3:1
Flower position	Axial (A)	Terminal (a)	3:1
Flower colour	Violet (C)	White (c)	3:1

SECTION A ♦ Multiple Choice Questions (Q. 1-25)

Q.1. Exchange of genetic material takes place in:

- (a) Vegetative reproduction
- (b) Asexual reproduction
- (c) Sexual reproduction
- (d) Budding

[ANS] Answer: (c) Sexual reproduction

In **sexual reproduction**, gametes from two parents fuse during fertilisation. Each gamete carries a unique combination of chromosomes (due to meiosis and crossing over). When they fuse, the offspring receives half its genetic material from each parent -- this constitutes an **EXCHANGE** of genetic material.

In asexual reproduction (including vegetative propagation and budding), genetic material is simply **COPIED** from one parent -- no exchange occurs.

[TIP] Exam Tip: Sexual reproduction = exchange of genetic material = variation. Asexual = copying = clones. This is why sexual reproduction creates more variation!

Q.2. Two pink flowers on crossing gave 1 red : 2 pink : 1 white progeny. The nature of the cross is:

- (a) Double fertilisation
- (b) Self pollination
- (c) Cross fertilisation
- (d) No fertilisation

[ANS] Answer: (c) Cross fertilisation

The 1:2:1 ratio of red:pink:white indicates **incomplete dominance**:

* Red (RR) x White (rr) = all Pink F1 (Rr) [neither fully dominant]

* Crossing two pink (Rr x Rr) gives: RR (red) : 2Rr (pink) : rr (white) = 1:2:1

This requires two **DIFFERENT** parent plants to cross -> this is **cross fertilisation** (not self-pollination).

Cross fertilisation = fusion of gametes from two different individuals.

[TIP] Exam Tip: 1:2:1 ratio = incomplete dominance (pink is blend). 3:1 ratio = complete dominance. The 1:2:1 is the classic incomplete dominance F2 ratio!

Q.3. A cross between a tall plant (TT) and short pea plant (tt) resulted in all tall progeny because:

- (a) Tallness is the dominant trait
- (b) Shortness is the dominant trait
- (c) Tallness is the recessive trait
- (d) Height is not governed by gene T or t

[ANS] Answer: (a) Tallness is the dominant trait

TT x tt:

All offspring = Tt (heterozygous tall)

Since ALL are tall despite having one t allele, TALLNESS

Dominant = expressed when at least ONE copy is present

Recessive = only expressed when BOTH copies are recessive

TT x tt cross (F1)

	t	t
T	Tt	Tt
T	Tt	Tt

[TIP] All F1 = same phenotype (all tall) = one trait is DOMINANT. If F1 were all blends = incomplete dominance.

Q.4. Which of the following statement is INCORRECT?

- (a) For every hormone there is a gene
- (b) For every protein there is a gene
- (c) For production of every enzyme there is a gene
- (d) For every molecule of fat there is a gene

[ANS] Answer: (d) For every molecule of fat there is a gene

Option (d) is **incorrect**. Fats (lipids) are synthesised by **enzymes** (not directly by genes). Genes code for proteins (including enzymes). Fats are built by enzymatic reactions using fatty acids and glycerol -- there is no specific gene that codes for each fat molecule.

- * (a) OK Hormones (most are proteins/peptides) -> need genes (e.g., insulin gene)
- * (b) OK Every protein is directly encoded by a gene (one gene -> one protein concept)
- * (c) OK Enzymes are proteins -> each enzyme requires a specific gene
- * (d) X Fats are synthesised indirectly via enzymes; no direct "fat gene"

[TIP] **Exam Tip:** Genes code for PROTEINS (enzymes, hormones). Fats are synthesised BY enzymes, not coded BY genes directly. Classic conceptual question!

Q.5. A round, green seeded pea plant (RRyy) is crossed with wrinkled, yellow seeded pea plant (rrYY). Seeds produced in F1 generation are:

- (a) round and yellow
- (b) round and green
- (c) wrinkled and green
- (d) wrinkled and yellow

[ANS] Answer: (a) Round and Yellow

RRyy x rrYY:

- * Parent 1 (RRyy): Round (RR = dominant) + Green (yy = recessive)
- * Parent 2 (rrYY): Wrinkled (rr = recessive) + Yellow (YY = dominant)
- * F1 genotype: All = **RrYy**
- * Phenotype: R is dominant over r -> Round; Y is dominant over y -> Yellow
- * All F1 seeds = **Round and Yellow (RrYy)**

[TIP] In F1 of a dihybrid cross, ALL offspring show BOTH dominant traits. R (round) dominant over r (wrinkled). Y (yellow) dominant over y (green).

Q.6. In human males, all chromosomes are paired perfectly except one. This/these unpaired chromosome(s) is/are:

- (i) Large chromosome (ii) Small chromosome (iii) Y-chromosome (iv) X-chromosome
- (a) (i) and (ii)
(b) (iii) only
(c) (iii) and (iv)
(d) (ii) and (iv)

[ANS] Answer: (c) (iii) and (iv) -- X and Y chromosomes

Human males have 44 autosomes (22 pairs) + **one X and one Y chromosome**.

* The X chromosome is **LARGE**; the Y chromosome is **SMALL**

* The X and Y chromosomes are **NOT** identical to each other (they differ in size and gene content)

* Therefore, X and Y are "paired" in the sense of being the sex chromosome pair, but they are **IMPERFECTLY** matched

* Human females have two identical X chromosomes (XX) which are perfectly paired

So in males, the X (large, iv) and Y (small, iii) form an imperfect pair.

[TIP] Exam Tip: Males = XY (X is large, Y is small -- imperfect pair). Females = XX (identical pair). Y chromosome makes a child male!

Q.7. The maleness of a child is determined by:

- (a) The X chromosome in the zygote
(b) The Y chromosome in the zygote
(c) The cytoplasm of germ cell which determines sex
(d) Sex is determined by chance

[ANS] Answer: (b) The Y chromosome in the zygote

The presence of the **Y chromosome** is what makes a child male:

* Y chromosome carries the **SRY** gene (Sex-determining Region of Y)

* **SRY** gene triggers development of testes -> testosterone production -> male development

* Zygote with XY -> male; Zygote with XX -> female

* Mother always gives X; father gives either X (->girl) or Y (->boy)

* The Y chromosome is **INHERITED** from the father; determines maleness

[TIP] Exam Tip: Y chromosome = male-determining chromosome. The SRY gene on Y triggers male development. Mother cannot determine sex -- she only has X chromosomes!

Q.8. A zygote which has an X-chromosome inherited from the **FATHER** will develop into a:

- (a) Boy
(b) Girl
(c) X-chromosome does not determine sex
(d) Either boy or girl

[ANS] Answer: (b) Girl

Father's genotype: **XY**

- * If the X chromosome comes from the FATHER, the zygote received X from father
- * The mother always contributes X (since mother is XX)
- * So: Father's X + Mother's X = **XX zygote = GIRL**
- * If the Y chromosome came from father: Father's Y + Mother's X = XY = boy

[TIP] Exam Tip: Father's X + Mother's X = XX = GIRL. Father's Y + Mother's X = XY = BOY. Mother always contributes X. Father determines sex!

Q.9. Select the INCORRECT statement:

- (a) Frequency of certain genes in a population changes over several generations resulting in evolution
- (b) Reduction in weight due to starvation is genetically controlled
- (c) Low weight parents can have heavy weight progeny
- (d) Traits not inherited over generations do not cause evolution

[ANS] Answer: (b) Reduction in weight due to starvation is genetically controlled

Option (b) is **incorrect**.

- * Weight loss due to starvation is an **acquired/environmental change** -- it is NOT genetically controlled
- * It is caused by lack of food (external factor), not by a change in genes
- * Acquired characters (like starvation-induced weight loss) are NOT passed to offspring
- * Other options:
 - * (a) OK Gene frequency changes = foundation of population genetics and evolution
 - * (c) OK Parents with genes for low weight can produce heavy offspring if different alleles combine
 - * (d) OK Only inherited traits can cause evolution (Weismann's principle)

[TIP] Exam Tip: Starvation weight loss = acquired character = NOT genetically controlled. Only changes in GERM CELLS (sperm/egg) can be inherited and cause evolution!

Q.10. New species may be formed if:

- (i) DNA undergoes significant changes in germ cells
 - (ii) Chromosome number changes in gametes
 - (iii) There is no change in genetic material
 - (iv) Mating does not take place
- (a) (i) and (ii)
 - (b) (i) and (iii)
 - (c) (ii), (iii) and (iv)
 - (d) (i), (ii) and (iii)

[ANS] Answer: (a) (i) and (ii)

- * (i) OK Significant DNA changes in germ cells -> inherited genetic changes -> new characteristics -> over generations -> new species
- * (ii) OK Change in chromosome number (e.g., polyploidy) in gametes -> chromosomal speciation -> new species (e.g., many plant species arose by polyploidy)
- * (iii) X NO change in genetic material -> NO new characteristics -> NO new species
- * (iv) X No mating prevents gene flow but alone does NOT create a new species; new species need genetic changes, not just reproductive isolation alone

[TIP] **Exam Tip:** New species = significant genetic changes (DNA mutations) + chromosomal changes. No genetic change = no new species. Isolation alone is not enough!

Q.11. Two pea plants: RRyy (round green) x rrYY (wrinkled yellow) -> F1 = RrYy (round yellow).

When F1 is selfed, new combinations in F2 are:

- (i) Round yellow (ii) Round green (iii) Wrinkled yellow (iv) Wrinkled green
(a) (i) and (ii) (b) (i) and (iv) (c) (ii) and (iii) (d) (i) and (iii)

[ANS] Answer: (c) (ii) Round green AND (iii) Wrinkled yellow

The PARENT plants were: Round green (RRyy) and Wrinkled yellow (rrYY)

Round yellow and Wrinkled green did NOT exist in the parents.

NEW combinations in F2 = the ones not present in parents:

- * Round GREEN (R_yy) -- Round came from parent 1, Green came from parent 1 BUT combined with R
- Wait -- Actually: Original parents = RRyy (round green) and rrYY (wrinkled yellow).
- So "Round yellow" (existed in F1) and "Wrinkled green" (rryy) are combinations that could appear but "Round green" and "Wrinkled yellow" are NEW recombinations.

F2 from RrYy x RrYy gives 9:3:3:1 ratio:

- * 9 Round Yellow (R_Y_) -- parental type from F1
- * 3 Round Green (R_yy) -- NEW combination OK
- * 3 Wrinkled Yellow (rrY_) -- NEW combination OK
- * 1 Wrinkled Green (rryy) -- parental type (from original parents)

[TIP] NEW combinations in F2 dihybrid = the combos NOT seen in ORIGINAL PARENTS. Parents were Round-green and Wrinkled-yellow. New = Round-yellow and Wrinkled-green? Actually: the question says parents were RRyy and rrYY, so Round-yellow and Wrinkled-green are new.

Q.12. A basket contains carrot, potato, radish and tomato. Which represent correct homologous structures?

- (a) Carrot and potato
(b) Carrot and tomato
(c) Radish and carrot
(d) Radish and potato

[ANS] Answer: (c) Radish and carrot

Homologous structures: same origin (modified same part) but different functions/appearance.

* **Radish:** modified TAPROOT (food storage root)

* **Carrot:** also a modified TAPROOT (food storage root)

-> Both are taproots with same origin = **homologous!**

* Potato: modified UNDERGROUND STEM (tuber) -- NOT a root

* Tomato: fruit (ripened ovary) -- completely different structure

Carrot and potato are NOT homologous (one is root, other is stem).

[TIP] Exam Tip: Radish + Carrot = BOTH taproots = homologous. Potato = stem tuber ≠ root. Tomato = fruit. Identify the ORGAN TYPE first!

Q.13. Select the correct statement:

- (a) Tendril of pea plant and phylloclade of Opuntia are homologous
- (b) Tendril of pea plant and phylloclade of Opuntia are analogous
- (c) Wings of birds and limbs of lizards are analogous
- (d) Wings of birds and wings of bat are homologous

[ANS] Answer: (b) Tendril of pea and phylloclade of Opuntia are analogous

* **Tendril of pea plant:** modified LEAF (for climbing)

* **Phylloclade of Opuntia** (cactus pad): modified STEM (for photosynthesis/water storage)

* Different origins (leaf vs stem) but both are green, flattened, photosynthetic-looking -> ANALOGOUS OK

* (c) X Bird wings and lizard limbs are HOMOLOGOUS (same bone structure: humerus, radius, ulna), not analogous

* (d) X Bird wings and bat wings are ANALOGOUS (both for flying but evolved independently; bat wing = skin between elongated fingers; bird wing = feathers on arm bone) -- NOT homologous

[TIP] Exam Tip: Bird wing vs bat wing = ANALOGOUS (both fly but different structure). Human arm vs bird wing vs whale flipper = HOMOLOGOUS (same bone plan, different function).

Q.14. If fossil of an organism is found in DEEPER layers of earth, then we can predict that:

- (a) Extinction occurred recently
- (b) Extinction occurred thousands of years ago
- (c) Fossil position is not related to time of extinction
- (d) Time of extinction cannot be determined

[ANS] Answer: (b) Extinction occurred thousands of years ago

The principle of **stratigraphy**: deeper layers of rock (sedimentary) were deposited earlier.

- * Deeper layer = older age = organism lived/died millions/thousands of years ago
- * Shallower (upper) layers = more recent organisms
- * By dating the rock layer, scientists can estimate when the organism lived and became extinct
- * Methods like radioactive carbon dating (C-14) and potassium-argon dating are used
- * Deeper fossil = older fossil = extinction long ago

[TIP] Exam Tip: Deeper layer = older fossil. Shallower layer = more recent fossil. This is the **LAW OF SUPERPOSITION** used in geology and palaeontology!

Q.15. Which statement is NOT TRUE with respect to variation?

- (a) All variations in a species have equal chance of survival
- (b) Change in genetic composition results in variation
- (c) Selection of variants by environmental factors forms basis of evolutionary processes
- (d) Variation is minimum in asexual reproduction

[ANS] Answer: (a) All variations in a species have equal chance of survival

Option (a) is **not true**. Not all variations have equal chance of survival:

- * Some variations provide **ADVANTAGES** in a specific environment -> those organisms survive and reproduce better
- * Some variations are **NEUTRAL** -> neither help nor harm
- * Some variations are **HARMFUL** -> those organisms die out

This is the core of **Natural Selection** (Darwin): only beneficial variations are "selected" -- not all have equal survival chances. Options (b), (c), (d) are all correct statements.

[TIP] Exam Tip: Natural selection = NOT all variations equal! Beneficial = selected. Harmful = eliminated. Neutral = persist but give no advantage.

Q.16. A trait in an organism is influenced by:

- (a) Paternal DNA only
- (b) Maternal DNA only
- (c) Both maternal and paternal DNA
- (d) Neither paternal nor maternal DNA

[ANS] Answer: (c) Both maternal and paternal DNA

An offspring inherits half its chromosomes (and DNA) from the **MOTHER** (via egg) and half from the **FATHER** (via sperm). Every gene in the offspring has two alleles -- one from each parent.

- * How the trait is expressed depends on the combination of both alleles
- * Example: Tt (tall) -- one T from father, one t from mother
- * Both parent's DNA contribute to every trait

Exception: mitochondrial DNA is inherited only from mother (mitochondria are in egg cytoplasm).

[TIP] **Exam Tip:** Every trait = influenced by BOTH maternal AND paternal DNA. Half chromosomes from each parent. Only mitochondrial DNA is maternal only!

Q.17. Select the group which shares the maximum number of common characters:

- (a) Two individuals of a species
- (b) Two species of a genus
- (c) Two genera of a family
- (d) Two genera of two families

[ANS] Answer: (a) Two individuals of a species

In biological taxonomy, the hierarchy is: Kingdom -> Phylum -> Class -> Order -> Family -> Genus -> Species

* Members of the **same species** share the **MAXIMUM** common characters (they can interbreed)

* As you move up the hierarchy, organisms become more and more different

* Two individuals of a species: almost identical genetically and anatomically

* Two species of a genus: share some features but have significant differences

* Two genera of a family: even fewer common features

[TIP] **Exam Tip:** SAME SPECIES = maximum common features (can interbreed). Higher up taxonomy = fewer shared features. Species is the **MOST** specific level!

Q.18. According to evolutionary theory, formation of a new species is generally due to:

- (a) Sudden creation by nature
- (b) Accumulation of variations over several generations
- (c) Clones from asexual reproduction
- (d) Movement of individuals from one habitat to another

[ANS] Answer: (b) Accumulation of variations over several generations

Darwin's theory of evolution by natural selection:

* Variations arise through mutations, genetic recombination, crossing over

* Beneficial variations are selected by the environment (natural selection)

* Over **MANY GENERATIONS**, these small changes accumulate

* Eventually, the accumulated changes are so great that the organisms can no longer interbreed with the original population -> **new species** formed

This process is called **gradualism** in evolutionary biology.

[TIP] **Exam Tip:** Evolution = gradual accumulation of variations over generations. NOT sudden creation. Clones from asexual = NO variation = no new species!

Q.19. Select the character which can be **ACQUIRED** but **NOT** inherited:

- (a) Colour of eye
- (b) Colour of skin
- (c) Size of body
- (d) Nature of hair

[ANS] Answer: (c) Size of body

Acquired character: developed during an organism's lifetime due to use/environment -- NOT in genes -- NOT passed to offspring.

* **Size of body** (especially muscle mass) can be changed by exercise, diet, lifestyle -> acquired. A bodybuilder's muscle size is NOT passed to their children -> acquired, not inherited.

* Eye colour: determined by genes (multiple pigment genes) -> inherited

* Skin colour: determined by genes (melanin production genes) -> inherited

* Nature of hair: determined by genes (keratin structure) -> inherited

[TIP] Exam Tip: Size of body (muscle mass) = acquired by exercise/diet = NOT inherited. Eye colour, skin colour, hair = all genetic = inherited!

Q.20. The two versions of a trait brought in by male and female gametes are situated on:

- (a) Copies of the same chromosome
- (b) Two different chromosomes
- (c) Sex chromosomes
- (d) Any chromosome

[ANS] Answer: (a) Copies of the same chromosome

In a diploid organism, each chromosome exists in **PAIRS** (homologous chromosomes).

* The two alleles for the same trait are located at the **same position (locus)** on **homologous chromosomes**

* One homolog came from the father (via sperm), one from the mother (via egg)

* So the two versions of a trait are on **corresponding (homologous) copies of the same chromosome**

Example: In humans, chromosome 7 carries the cystic fibrosis gene. One copy from each parent, at the same position on each chromosome 7.

[TIP] Exam Tip: Two alleles for a trait = **SAME LOCUS** on **HOMOLOGOUS CHROMOSOMES** (one from each parent). This is why we write Tt -- T on one, t on the other of the pair!

Q.21. Select the statements that describe characteristics of genes:

- (i) Genes are specific sequence of bases in DNA
 - (ii) A gene does not code for proteins
 - (iii) In a species, a specific gene is located on a particular chromosome
 - (iv) Each chromosome has only one gene
- (a) (i) and (ii)
 - (b) (i) and (iii)
 - (c) (i) and (iv)
 - (d) (ii) and (iv)

[ANS] Answer: (b) (i) and (iii)

- * (i) OK Genes ARE specific sequences of nitrogenous bases (A, T, G, C) in the DNA molecule
- * (ii) X WRONG: Genes DO code for proteins (one gene -> one polypeptide concept)
- * (iii) OK In a given species, every individual has the same gene at the same position (locus) on the same chromosome
- * (iv) X WRONG: Each chromosome has THOUSANDS of genes (not just one). Human chromosome 1 alone has about 2,000 genes!

[TIP] **Exam Tip:** Gene = specific DNA sequence = codes for protein = located at fixed locus on specific chromosome. Each chromosome has MANY genes!

Q.22. In peas, TT x tt crossed. The ratio of PURE TALL to SHORT plants in F2 is:

- (a) 1:3 (b) 3:1 (c) 1:1 (d) 2:1

[ANS] Answer: (c) 1:1

P: TT x tt -> F1: all Tt (tall)

F1 self: Tt x Tt ->

F2: 1 TT : 2 Tt : 1 tt

Genotypes: TT (pure tall), Tt (hybrid tall), tt (short)

Pure tall (TT) : Short (tt) = 1 : 1

(Note: Total tall = 3 including Tt; but PURE tall = only TT =

F1: Tt x Tt cross

	T	t
T	TT	Tt
t	Tt	tt

[TIP] F2 genotypic ratio: 1 TT : 2 Tt : 1 tt. PURE TALL (TT) : SHORT (tt) = 1:1. But TALL phenotype : SHORT phenotype = 3:1 (TT + 2Tt : tt).

Q.23. The number of pairs of sex chromosomes in the zygote of humans is:

- (a) One
(b) Two
(c) Three
(d) Four

[ANS] Answer: (a) One

Human zygote has **46 chromosomes = 23 pairs:**

* 22 pairs of autosomes (non-sex chromosomes)

* 1 pair of sex chromosomes: either XX (female) or XY (male)

There is only **ONE pair** of sex chromosomes. So the answer is 1 pair.

[TIP] **Exam Tip:** Humans: 46 chromosomes = 22 pairs autosomes + 1 pair sex chromosomes (XX or XY). **ONLY 1 PAIR** of sex chromosomes!

Q.24. The theory of evolution by natural selection was given by:

- (a) Mendel

- (b) Darwin
- (c) Morgan
- (d) Lamarck

[ANS] Answer: (b) Darwin

Charles Darwin proposed the theory of evolution by **Natural Selection** in his book "On the Origin of Species" (1859).

- * Darwin observed variation among organisms and that populations produce more offspring than can survive
- * Those with beneficial variations survive and reproduce -> "survival of the fittest"
- * Over generations, beneficial variations spread through the population -> evolution

- * Mendel: discovered laws of inheritance (genetics)
- * Lamarck: proposed use-and-disuse theory (acquired characters can be inherited -- now disproved)
- * Morgan: worked on genes in chromosomes of *Drosophila* (fruit fly)

[TIP] Exam Tip: Darwin = Natural Selection (1859). Mendel = Genetics. Lamarck = Use and disuse (disproved). Morgan = Gene linkage in *Drosophila*. All four are common in exams!

Q.25. Some dinosaurs had feathers but could not fly; birds have feathers and fly. In context of evolution this means:

- (a) Reptiles have evolved from birds
- (b) No evolutionary connection between reptiles and birds
- (c) Feathers are homologous structures in both
- (d) Birds have evolved from reptiles

[ANS] Answer: (d) Birds have evolved from reptiles

The fact that dinosaurs (reptiles) had feathers -- structures that LATER became used for flight in birds -- strongly suggests that **birds evolved from dinosaurs/reptiles**.

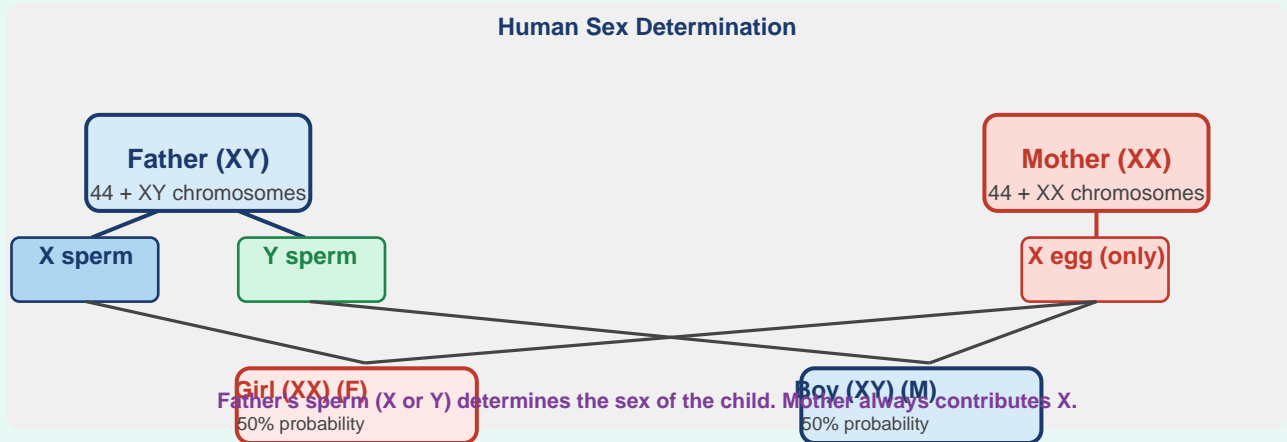
- * Feathers first evolved for purposes like insulation or display (not flight)
- * As dinosaurs evolved into birds, feathers were adapted (modified) for flight
- * This is an example of **pre-adaptation** or **exaptation**
- * Option (c) is also partially true but (d) better answers the question -- feathers in dinosaurs show the evolutionary lineage from reptiles (dinosaurs) to birds.

[TIP] Exam Tip: Feathers in dinosaurs + feathers in birds = shared evolutionary origin = birds evolved FROM reptiles (dinosaurs). This is also why birds are classified as Avian dinosaurs!

SECTION B ♦ Short Answer Questions (Q. 26-36)

Q.26. How is the sex of a newborn determined in humans?

Sex is determined by the sex chromosome contributed by the FATHER's sperm.



Explanation:

- * Human females are **XX** -- they have two X chromosomes
- * During meiosis, all eggs produced by the mother contain only **X chromosome**
- * Human males are **XY** -- they have one X and one Y chromosome
- * During meiosis, father produces two types of sperm: **X-sperm (22+X)** and **Y-sperm (22+Y)** in equal numbers

If X-sperm fertilises the egg: $X + X = \mathbf{XX} = \mathbf{Girl (F)}$

If Y-sperm fertilises the egg: $X + Y = \mathbf{XY} = \mathbf{Boy (M)}$

Both types of sperm are produced in equal numbers -> 50% chance of girl, 50% chance of boy.
The sex of the child is determined at fertilisation.

Q.27. Do genetic combinations of mothers play a significant role in determining the sex of a new born?

NO -- the mother's genetic combination has NO role in determining the sex of the newborn.

Reason:

- * All women are **XX** -- both X chromosomes are identical
- * During meiosis, ALL eggs produced by a woman carry **ONLY an X chromosome**
- * There is no possibility of a woman producing a Y-containing egg
- * Therefore, the mother's genetic contribution is ALWAYS the same (X) regardless of sex of child

The father's sperm determines sex:

- * Father (XY) produces X-sperm AND Y-sperm
- * X-sperm + X-egg = XX (girl)
- * Y-sperm + X-egg = XY (boy)

Historically, women were blamed for not producing male children -- this is genetically incorrect! The father's sperm type is entirely responsible for determining the child's sex.

[TIP] **Exam Tip:** Mother = always contributes X (cannot contribute Y). Father contributes X or Y. So **ONLY** the father's chromosome determines the sex!

Q.28. Mention three important features of fossils which help in the study of evolution.

Three important features of fossils in evolutionary studies:

1. Age estimation (Chronological evidence):

The position of fossils in rock layers (stratigraphy) indicates their age. Deeper layers = older organisms. Radiometric dating (C-14, uranium-lead) gives actual age in years. This establishes a timeline of when organisms lived and went extinct.

2. Structural evidence (Morphological comparison):

Fossils preserve hard parts (bones, shells, teeth, impressions). Comparing fossil structures with modern organisms reveals evolutionary relationships. E.g., fossil horse (Eohippus, 3 toes) → modern horse (1 toe) shows gradual evolution.

3. Missing links / Transitional forms:

Some fossils show intermediate characteristics between ancestral and modern groups. E.g., *Archaeopteryx* had features of both reptiles (teeth, claws, long tail) and birds (feathers, wings) -- showing the evolutionary transition from reptiles to birds.

[TIP] **Exam Tip:** 3 features: (1) Dating/age, (2) Structural comparison, (3) Transitional forms. *Archaeopteryx* is the classic example of a missing link fossil!

Q.29. Why do all gametes formed in human females have an X chromosome?

Because human females are genetically XX -- they have ONLY X chromosomes, no Y.

Human females have the genotype **44 + XX** (44 autosomes + 2 X chromosomes).

During meiosis (gamete formation):

- * The diploid (2n) egg cell divides into haploid (n) eggs
- * Each egg receives **ONE** sex chromosome
- * Since females only have X chromosomes, all eggs can only receive an **X chromosome**
- * There is no Y chromosome in females to be distributed into any egg

Therefore, 100% of human female gametes (eggs) contain exactly **ONE** X chromosome.

This is why the egg always contributes X to the zygote, and the sperm (X or Y) from the father determines the sex.

[TIP] **Exam Tip:** All eggs have X because females are XX -- no Y to contribute. During meiosis: XX → each egg gets one X. Simple and logical!

Q.30. In humans, the statistical probability of getting a male or female child is 50:50. Give a suitable explanation.

Because fathers produce X-sperm and Y-sperm in equal numbers (50% each).

Human males are **XY**. During meiosis:

- * Cell with XY divides -> produces TWO types of sperm in equal numbers:
- 50% carry **X chromosome** (X-sperm)
- 50% carry **Y chromosome** (Y-sperm)

Human females are **XX**. All eggs carry only X chromosome.

At fertilisation (random event):

- * P(X-sperm meets egg) = 50% -> XX zygote -> **Girl**
- * P(Y-sperm meets egg) = 50% -> XY zygote -> **Boy**

Since X-sperm and Y-sperm are produced in equal numbers, and fertilisation is random, the probability of either a male or female child is theoretically **50:50**.

[TIP] **Exam Tip:** 50:50 because: Father XY -> 50% X-sperm + 50% Y-sperm. Mother always provides X. X+X=girl (50%). X+Y=boy (50%). Equal meiotic products!

Q.31. A very small population of a species faces a greater threat of extinction than a larger population. Provide a suitable genetic explanation.

Small populations have lower genetic diversity and suffer more from genetic drift.

Genetic explanation:

1. Reduced genetic diversity (gene pool):

A small population has fewer individuals -> fewer different alleles in the gene pool. If a disease or environmental change occurs, all individuals may be equally susceptible (no resistant variants exist) -> all may die.

2. Genetic drift:

In small populations, chance events (random births/deaths) can cause certain alleles to disappear or become fixed by chance. This reduces variation further.

3. Inbreeding depression:

Small populations must mate among closely related individuals -> harmful recessive alleles that were hidden in heterozygotes become expressed in homozygous form -> reduced fitness.

4. Minimum viable population:

Below a certain population size, the species cannot maintain enough genetic diversity to adapt to changing conditions -> extinction risk increases dramatically.

[TIP] **Exam Tip:** Small population = low gene pool = genetic drift + inbreeding = less variation = less adaptability = extinction risk. Cheetahs are an example of low genetic diversity!

Q.32. What are homologous structures? Give an example. Is it necessary that homologous structures always have a common ancestor?

Homologous structures: Organs/structures that have the SAME ORIGIN and BASIC STRUCTURAL PLAN but are adapted to perform DIFFERENT FUNCTIONS due to evolution in different environments.

Example:

The forelimbs of humans, whales, bats, and horses are homologous structures:

- * Human arm: used for grasping and manipulation
- * Whale flipper: used for swimming
- * Bat wing: used for flying
- * Horse leg: used for running

All have the SAME BASIC BONE PLAN (humerus -> radius + ulna -> carpals -> metacarpals -> phalanges) but are shaped differently for different functions.

Is a common ancestor necessary for homologous structures?

YES -- Homologous structures are defined by having a COMMON EVOLUTIONARY ORIGIN. If two structures have the same basic plan, it strongly implies they share a common ancestor (divergent evolution). Without a common ancestor, the structural similarity would be coincidental -- which would make them analogous (if they serve the same function) or simply convergent. Therefore, by definition, homologous structures imply a shared ancestry.

[TIP] **Exam Tip:** Homologous = same origin, different function = evidence of COMMON ANCESTOR (divergent evolution). Analogous = different origin, same function = convergent evolution.

Q.33. Does the occurrence of diversity of animals on earth suggest their diverse ancestry also? Discuss in the light of evolution.

NO -- despite enormous diversity, all life on Earth shares a COMMON ancestry.

Evidence of common ancestry despite diversity:

1. **Biochemical unity:** All living organisms use the same genetic code (DNA/RNA), same amino acids for proteins, and ATP as energy currency -> points to a single common ancestor (universal ancestor)
2. **Homologous structures:** Despite vast morphological differences, organisms share fundamental structural similarities (e.g., vertebrate forelimb plan) -> common ancestor
3. **Fossil record:** Shows gradual progression from simple to complex organisms; transitional forms connect major groups -> common descent with modification
4. **Molecular phylogenetics:** DNA sequence comparisons show that all life is related; the more similar the DNA, the more recently they shared a common ancestor

Conclusion: Evolution (divergent evolution) from a common ancestor explains why life is both diverse (different adaptations) and unified (same molecular machinery).

Q.34. Give the pair of contrasting traits in pea plants and mention which is dominant and recessive:

- (i) Yellow seed (ii) Round seed

(i) Yellow seed:

Contrasting pair: **Yellow seed (Y) vs Green seed (y)**

* Dominant: **Yellow (Y)** -- expressed in YY or Yy genotypes

* Recessive: **Green (y)** -- expressed only in yy genotype

(ii) Round seed:

Contrasting pair: **Round seed (R) vs Wrinkled seed (r)**

* Dominant: **Round (R)** -- expressed in RR or Rr genotypes

* Recessive: **Wrinkled (r)** -- expressed only in rr genotype

In a dihybrid cross, Yellow (Y) and Round (R) are both dominant; Green (y) and Wrinkled (r) are both recessive.

[TIP] **Exam Tip:** Dominant in peas: Tall (T), Yellow (Y), Round (R), Green pod (G), Inflated pod (I), Axial flowers (A), Violet flowers (C). The FIRST trait in each pair is dominant!

Q.35. Why did Mendel choose pea plant for his experiments?

Mendel chose *Pisum sativum* (garden pea) for several excellent reasons:

1. Easily available, cheap, fast-growing:

Pea plants grow quickly (one generation per year), produce many seeds, and were easy to obtain in a monastery garden.

2. Distinct, contrasting traits:

Pea plants have 7 pairs of clearly distinguishable contrasting characters (tall/short, round/wrinkled, yellow/green, etc.) -- no intermediate forms, making classification easy.

3. Naturally self-pollinating:

Pea flowers are normally self-pollinating (closed flower structure). This allowed Mendel to maintain pure breeding lines (TT or tt) over generations.

4. Can also be artificially cross-pollinated:

Mendel could easily cross different plants by transferring pollen with a brush -- giving full control over crosses.

5. Large number of seeds:

Each plant produces many offspring -> reliable statistical analysis of ratios (3:1, 9:3:3:1, etc.).

6. Short life cycle:

Multiple generations could be studied in a relatively short time.

[TIP] **Exam Tip:** 6 reasons Mendel chose pea: distinct traits, self-pollinating, can cross-pollinate, many seeds, fast growing, cheap. At least 4 reasons for exam answers!

Q.36. A woman has only daughters. Analyse the situation genetically and provide a suitable explanation.

This situation is due to chance -- specifically because all X-sperm from her partner have fertilised her eggs.

Genetic analysis:

- * The woman is **XX** -- she contributes only X chromosomes to all eggs
- * The father is **XY** -- produces 50% X-sperm and 50% Y-sperm
- * Normally: 50% chance girl (XX) and 50% chance boy (XY) for each pregnancy

Why only daughters?

This is simply a matter of **probability and chance**. Each pregnancy is an independent event. Just as flipping a coin repeatedly can give heads several times in a row by chance, it is possible for a couple to have all daughters by statistical chance, even though the probability of each being a girl is only 50%.

Important note: The woman (mother) is NOT responsible for having only daughters -- she always contributes X only. The sex depends on the father's sperm. Having all daughters means Y-sperm did not fertilise the egg in any pregnancy -- this is chance, not genetic abnormality.

[TIP] **Exam Tip:** All daughters = chance event. NOT the mother's fault. Each pregnancy is independent (50:50). Mother CANNOT determine sex. Historically incorrect to blame women!

SECTION C ♦ Long Answer Questions (Q. 37-47)

Q.37. Does geographical isolation of individuals of a species lead to formation of a new species? Explain.

YES -- Geographical isolation is one of the most important factors leading to speciation.

Process (Allopatric Speciation):

Step 1 -- Geographical Isolation:

A population of a species gets divided by a geographical barrier (mountain, river, ocean, desert). The two groups are now physically separated and cannot interbreed.

Step 2 -- Independent genetic changes:

Each isolated group now faces different environmental conditions. Different mutations and variations arise in each group. Natural selection acts differently on each group (selecting different variants).

Step 3 -- Genetic divergence:

Over many generations, the two groups accumulate different genetic changes. Their gene pools become increasingly different. Eventually, they may develop different structural features, behaviours, or physiological adaptations.

Step 4 -- Reproductive isolation:

After enough genetic divergence, even if the geographical barrier is removed, the two groups can no longer interbreed (or produce viable/fertile offspring). They are now considered **TWO SEPARATE SPECIES**.

Example:

* Darwin's finches on the Galápagos Islands: ancestral finch species arrived from mainland; isolated on different islands -> different foods available -> different beak shapes evolved -> 13 separate species now exist, all from one ancestor.

[TIP] **Exam Tip:** Geographical isolation -> different mutations -> different selection -> genetic divergence -> reproductive isolation -> **NEW SPECIES**. This is allopatric speciation!

Q.38. Bacteria have a simpler body plan compared with human beings. Does it mean humans are more evolved than bacteria? Explain.

NO -- "more evolved" is not about complexity. Bacteria are just as evolved as humans.

Why complexity does not mean "more evolved":

1. Evolution means adaptation, not advancement:

Evolution is the change in inherited traits that helps organisms survive in their environment. Bacteria are PERFECTLY evolved for their environment -- soil, water, inside other organisms. Their simplicity is not a disadvantage; it is a fitness advantage.

2. Bacteria have evolved for 3.8 billion years:

Bacteria are the OLDEST living organisms on Earth (3.8 billion years old). They have been evolving far longer than humans (~300,000 years for Homo sapiens). In terms of evolutionary time, bacteria are ancient and highly adapted.

3. Bacteria's evolutionary success:

- * Bacteria survive in extreme environments (hot springs, deep ocean vents, radioactive waste)
- * They reproduce rapidly (some species divide every 20 minutes)
- * They can evolve resistance to antibiotics in days
- * Bacteria will likely outlast humans on Earth

4. Complexity is an evolutionary strategy, not superiority:

Complexity evolved because it was advantageous in certain environments. Complex organisms (like humans) have occupied new ecological niches. But bacteria occupy niches humans cannot -- inside other cells, extreme acidic environments, etc.

Conclusion:

Evolution does not have a direction towards "better" or "more complex." Bacteria and humans are BOTH products of billions of years of evolution, each perfectly adapted to their respective environments. Calling humans "more evolved" than bacteria is a misunderstanding of evolutionary theory.

[TIP] **Exam Tip:** Evolution = adaptation, not progress. Bacteria have been evolving for 3.8 billion years! Complexity is just one evolutionary strategy. Common exam misconception!

Q.39. All human races (Africans, Asians, Europeans, Americans) might have evolved from a common ancestor. Provide evidences in support of this view.

Multiple lines of evidence support that all humans share a common African ancestor (Out of Africa theory).

Evidence 1: Molecular genetics (DNA sequences):

- * Human mitochondrial DNA (mtDNA) analysis shows all humans trace back to a single woman in Africa (~150,000 years ago) -- called "Mitochondrial Eve"
- * Y-chromosome analysis traces all humans to "Y-chromosomal Adam" in Africa
- * Humans worldwide share 99.9% of their DNA -- far more similar than different

Evidence 2: Fossil record:

- * Oldest Homo sapiens fossils (200,000-300,000 years old) found in AFRICA
- * Fossil evidence shows gradual migration from Africa to other continents
- * No evidence of independent human evolution on multiple continents

Evidence 3: Anatomical similarity:

- * All human races have the same basic anatomy, same number of chromosomes (46), same blood groups (ABO system)
- * Can interbreed and produce fertile offspring -> prove they are one species

Evidence 4: Biochemical unity:

- * Same proteins, same blood proteins (albumin, haemoglobin) across all races
- * Immunological tests show high similarity between all human groups

Evidence 5: Cultural and linguistic evidence:

- * Oldest language families trace back to Africa
- * Archaeological evidence of stone tool making traced from Africa outward

[TIP] **Exam Tip:** Evidence for common human ancestor: mtDNA (Mitochondrial Eve), fossil record (Africa), 99.9% shared DNA, same chromosome number, interbreeding possible. 3-4 evidences for 5 marks!

Q.40. Differentiate between inherited and acquired characters. Give one example for each type.

Comparison table:

Feature	Inherited Characters	Acquired Characters
Definition	Characters present in genes; passed from parents to offspring through gametes	Characters developed during an organism's lifetime due to environment, use, or learning; NOT in genes
Location	In DNA/genes (in nucleus)	In somatic (body) cells; NOT in germ cells (sperm/egg)
Transmission	Passed to next generation	NOT passed to next generation
Basis	Genetic (DNA sequence)	Environmental, behavioural, or physiological
Example	Eye colour, blood group, skin colour, height (partly)	Muscle mass built by exercise; scar from injury; learned skills

Q.41. Give reasons why acquired characters are not inherited.

Acquired characters are not inherited because changes in somatic cells do NOT affect germ cells.

Reason 1: Weismann Barrier:

The **Weismann barrier** states that information cannot flow from somatic (body) cells back to germ cells (sperm/egg). Only changes in germ cells can be inherited.

Example: A blacksmith develops large arm muscles through use. But the muscle cells change due to physical training -- this does NOT alter the DNA in the sperm or eggs. Therefore, the blacksmith's children do NOT inherit large muscles.

Reason 2: Germ-line theory:

Only changes in the **germ line** (cells that produce gametes) can be passed to offspring. Acquired changes in somatic cells (body cells) are isolated from the germ line.

Reason 3: DNA of germ cells is not altered by somatic changes:

When a person loses a limb (body cell change), the DNA in their reproductive cells remains unchanged. Their children will still be born with normal limbs.

Historical context:

Lamarck incorrectly proposed that acquired characters could be inherited (e.g., giraffes stretching their necks -> longer-necked offspring). This was disproved by Weismann's experiments (cutting off mouse tails for many generations; offspring always had normal tails). Darwin's natural selection provides the correct mechanism.

[TIP] **Exam Tip:** Acquired \neq inherited because somatic cell changes \neq germ cell DNA changes. Weismann barrier! Lamarck was wrong about inheritance of acquired characters.

Q.42. "Evolution has exhibited a greater stability of molecular structure when compared with morphological structures." Comment.

This statement is TRUE and well-supported by evidence from molecular biology.

What it means:

While the external appearance (morphology) of organisms has changed dramatically during evolution, the molecular machinery (DNA, proteins, metabolic pathways) has remained remarkably conserved (unchanged) across diverse species.

Evidence supporting the statement:

- 1. Genetic code:** All living organisms from bacteria to humans use the SAME genetic code (64 codons coding for the same 20 amino acids). This code has been essentially unchanged for ~3.5 billion years despite vast morphological diversity.
- 2. Conserved proteins:** Cytochrome c (a protein in the electron transport chain) has changed very little between organisms as different as yeast and humans. Histone proteins (DNA packaging) are nearly identical across all eukaryotes.
- 3. ATP and metabolic pathways:** Glycolysis (breakdown of glucose) occurs in almost all living organisms with the same enzymes and same reaction steps -- despite billions of years of evolution and enormous morphological diversity.

Why this happens:

Molecular structures that work well (like the genetic code, core metabolic enzymes) are under strong **purifying selection** -- mutations that alter these critical molecules are lethal and are eliminated. Therefore, they stay conserved. Morphological structures are more plastic and can change more freely in response to environment.

Significance:

This molecular conservation supports the concept of **common ancestry** -- all life on Earth shares the same fundamental molecular toolkit, inherited from a common ancestor.

[TIP] **Exam Tip:** Molecular structures (DNA code, cytochrome c, histones) = highly conserved = stable through evolution. Morphological features = more variable. This proves COMMON ANCESTRY!

Q.43. Write characteristics of the progeny for the following crosses:

Cross	Parents	F1 Progeny Genotype	Phenotype
(a)	RRYY x RRYy (Round Yellow x Round Yellow)	All RRYy (homozygous)	All Round, Yellow (100%)
(b)	RrYy x RrYy (Round Yellow x Round Yellow)	9 R_Y_ : 3 R_yy : 3 rrY_ : 1 rryy	9 Round Yellow : 3 Round Green : 3 Wrinkled Yellow : 1 Wrinkled Green
(c)	rryy x rryy (Wrinkled Green x Wrinkled Green)	All rryy (homozygous)	All Wrinkled, Green (100%)
(d)	RRYY x rryy (Round Yellow x Wrinkled Green)	All RrYy (heterozygous)	All Round, Yellow (100%) (F1 shows both dominant traits)

[TIP] (b) $RrYy \times RrYy$ = classic dihybrid F2 cross = 9:3:3:1 ratio. MEMORISE this ratio! 9 R_Y_ : 3 R_yy : 3 rrY_ : 1 rryy

Q.44-45. Parents: $RRYY \times rryy \rightarrow F1: RrYy \times ?$ (self pollination in F1)

Q.45: What are combinations and ratios in F2?

Q.44 Answer: F1 cross is $RrYy \times RrYy$ (self-pollination)

When $RRYY \times rryy \rightarrow$ All F1 = $RrYy$.

Self-pollination in F1 = $RrYy \times RrYy$

The "?" = $RrYy$

Q.45: F2 combinations and ratios:

From $RrYy \times RrYy$ (16 combinations in 4x4 Punnett square)

	RY	Ry	rY	ry
RY	RRYY	RRYy	RrYY	RrYy
Ry	RRYy	RRyy	RrYy	Rryy
rY	RrYY	RrYy	rrYY	rrYy
ry	RrYy	Rryy	rrYy	rryy

Genotype group	Phenotype	Count in 16	Ratio
R_Y_ ($RRYY, RRYy, RrYY, RrYy$)	Round, Yellow	9	9
R_yy ($RRyy, Rryy$)	Round, Green	3	3
rrY_ ($rrYY, rrYy$)	Wrinkled, Yellow	3	3
rryy	Wrinkled, Green	1	1
TOTAL	4 phenotypes	16	9:3:3:1

[TIP] F2 Dihybrid ratio = 9:3:3:1 (ALWAYS). 9 both dominant : 3 first dominant : 3 second dominant : 1 both recessive. MUST MEMORISE!

Q.46. Give the basic features of the mechanism of inheritance.

Basic features of Mendelian inheritance:

1. Genes are the units of inheritance:

Each heritable trait is controlled by a specific gene, located at a fixed position (locus) on a specific chromosome. Genes are segments of DNA.

2. Genes exist in pairs (alleles):

In diploid organisms, each trait is controlled by two alleles -- one inherited from each parent. The two alleles may be identical (homozygous: TT or tt) or different (heterozygous: Tt).

3. Law of Dominance:

When two different alleles are present together, the dominant allele is expressed; the recessive allele is hidden. Recessive trait appears only in homozygous recessive condition (tt).

4. Law of Segregation (First Law of Mendel):

During gamete formation, the two alleles of a gene SEPARATE from each other. Each gamete receives only ONE allele. At fertilisation, two alleles come together again in the offspring.

5. Law of Independent Assortment (Second Law of Mendel):

Alleles of different genes are sorted independently into gametes (provided they are on different chromosomes). This produces new combinations of traits in offspring.

6. Chromosome theory of heredity:

Genes are carried on chromosomes. When chromosomes separate during meiosis, genes go with them. This explains the physical basis of Mendel's laws.

[TIP] **Exam Tip:** Mendel's 2 laws: (1) Law of Segregation (alleles separate in gametes). (2) Law of Independent Assortment (different genes sort independently). Both are FUNDAMENTAL!

Q.47. Give reasons for the appearance of new combinations of characters in the F₂ progeny.

New combinations in F2 arise due to independent assortment of genes during meiosis and random fertilisation.

Reason 1 -- Law of Independent Assortment:

Genes for different traits located on DIFFERENT chromosomes are sorted independently into gametes during meiosis. This means the inheritance of one trait does not influence the inheritance of another trait (when genes are on different chromosomes).

Example: RrYy parent produces gametes RY, Ry, rY, rY -- 4 different types in equal numbers.

Reason 2 -- Gamete combinations:

F1 plants (RrYy) produce 4 types of gametes (RY, Ry, rY, ry).

When two F1 plants self-pollinate: 4 types of male gametes x 4 types of female gametes = 16 possible zygote combinations. These 16 combinations give 4 phenotypes including NEW combinations (Round-green, Wrinkled-yellow) not seen in original parents.

Reason 3 -- Crossing over during Meiosis:

During prophase I of meiosis, homologous chromosomes exchange segments (crossing over). This creates new combinations of alleles on chromosomes -> further increases variation.

Result:

Original parents: RRyy (Round green) and rrYY (Wrinkled yellow)

F2 NEW combinations: Round yellow (R_Y_) and Wrinkled green (rryy) appear!

These are called **recombinants** -- combinations not present in the original parents.

[TIP] **Exam Tip:** New F2 combinations = independent assortment + random fertilisation + crossing over. The word "recombinant" is important in genetics!

[WARN] Common Mistakes & Exam Tips

[ERR] Dominant vs Recessive

Dominant = expressed in TT AND Tt. Recessive = expressed ONLY in tt. Students often say "dominant appears in pure form only" -- WRONG! Hybrid Tt is ALSO dominant phenotype.

[ERR] Mother cannot determine sex of child

All eggs from mother have X chromosome ONLY. Sex is determined by father's sperm (X or Y). Blaming the mother for "only daughters" is scientifically incorrect!

[ERR] Acquired characters are NOT inherited

Exercise muscles, scars, learned skills = acquired. Eye colour, skin colour, blood group = inherited. Lamarck was WRONG. Only germ cell (sperm/egg) DNA changes are inherited.

[ERR] Homologous \neq Analogous

Homologous = same origin, different function (human arm + whale flipper). Analogous = different origin, same function (bird wing + insect wing). Bird wing vs bat wing = ANALOGOUS (both fly, different bone structure)!

[ERR] F2 ratio: 3:1 (monohybrid) vs 9:3:3:1 (dihybrid)

Monohybrid F2: 3 dominant : 1 recessive. Dihybrid F2: 9:3:3:1 (4 phenotypes). Pure tall:short in F2 = 1:1 (NOT 3:1 -- that is phenotypic ratio).

[ERR] Deeper fossils = OLDER, not more recent

Deeper rock layers were deposited earlier = older organisms. Shallower = more recent. Law of Superposition. Carbon-14 dating gives actual age.

[ERR] Evolution = gradual accumulation, not sudden creation

New species = accumulated genetic variations over MANY generations. NOT sudden mutation. Clones (asexual) cannot create new species (no variation).

[ERR] Fat molecules do NOT have specific genes

Genes code for PROTEINS (enzymes, hormones). Fats are made BY enzymes -- there is no direct "fat gene." This is a common confusion in Q4-type questions.

[REV] Quick Revision -- Chapter 9 at a Glance

Topic	Key Facts
Mendel's Laws	Law of Segregation (alleles separate in gametes). Law of Independent Assortment (different genes assort independently).
Monohybrid F2 ratio	3 dominant : 1 recessive (phenotype). 1 TT : 2 Tt : 1 tt (genotype). Pure tall : short = 1:1.

Dihybrid F2 ratio	9 R_Y_ : 3 R_yy : 3 rrY_ : 1 rryy = 9:3:3:1.
Sex determination	Mother = XX (all eggs = X). Father = XY (50% X-sperm, 50% Y-sperm). Y-sperm + X-egg = boy. X-sperm + X-egg = girl.
Homologous structures	Same origin, different function. E.g., human arm + whale flipper + bat wing + horse leg (all forelimbs). Evidence of common ancestry.
Analogous structures	Different origin, same function. E.g., bird wing + insect wing + bat wing (all for flying but structurally different).
Fossils	Deeper = older. Used for dating, structural comparison, identifying transitional forms (Archaeopteryx).
Natural selection (Darwin)	Variation -> beneficial variants survive -> reproduce -> pass traits -> accumulated change -> new species.
Speciation	Geographical isolation -> independent genetic changes -> reproductive isolation -> new species (allopatric speciation).
Acquired vs Inherited	Acquired (muscle, scars) = NOT inherited. Inherited (eye colour, blood group) = in genes = passed to offspring.
Molecular conservation	Genetic code, cytochrome c, ATP, histones = same/similar across all life. Evidence of common ancestry.

[KEY] MCQ Answer Key Summary (Q. 1-25)

Q.No	Ans	Q.No	Ans	Q.No	Ans	Q.No	Ans	Q.No	Ans
Q.1	(c)	Q.2	(c)	Q.3	(a)	Q.4	(d)	Q.5	(a)
Q.6	(c)	Q.7	(b)	Q.8	(b)	Q.9	(b)	Q.10	(a)
Q.11	(c)	Q.12	(c)	Q.13	(b)	Q.14	(b)	Q.15	(a)
Q.16	(c)	Q.17	(a)	Q.18	(b)	Q.19	(c)	Q.20	(a)
Q.21	(b)	Q.22	(c)	Q.23	(a)	Q.24	(b)	Q.25	(d)

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