जीव विज्ञान
Biology

कक्षा / Class XII

2026-27

विद्यार्थी सहायक सामग्री
Student Support Material

केन्द्रीय विद्यालय संगठन~Kendriya Vidyalaya Sangathan

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केन्द्रीय विद्यालय संगठन

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संदेश

शिक्षा केवल पुस्तकों तक सीमित ज्ञान नहीं है; यह स्वयं को पहचानने, अपने विचारों को विस्तार देने और जीवन की चुनौतियों का आत्मविश्वास से सामना करने की सतत् यात्रा है। केन्द्रीय विद्यालय संगठन का सदैव यह प्रयास रहा है कि प्रत्येक विद्यार्थी के लिए ऐसा शिक्षण वातावरण हो, जहाँ जिज्ञासा को प्रोत्साहन मिले, सीखना आनंददायी बने और प्रत्येक बालक अपनी अंतर्निहित क्षमताओं को पहचानकर उन्हें विकसित कर सके।

राष्ट्रीय शिक्षा नीति 2020 ने शिक्षा को सिर्फ रटने से समझने, सूचना से ज्ञान और ज्ञान से जीवनोपयोगी दक्षताओं की ओर अग्रसर किया है। आज का समय कृत्रिम बुद्धिमत्ता (Artificial Intelligence – AI), डिजिटल नवाचार और निरंतर बदलती तकनीकों का है। ऐसे युग में केवल तथ्यों का ज्ञान पर्याप्त नहीं है; आवश्यक है कि विद्यार्थी मनन- चिंतन करना सीखें, प्रश्न पूछें, समस्याओं का समाधान खोजें और नए विचारों के साथ आगे बढ़ें। यही क्षमताएँ उन्हें भविष्य के लिए तैयार करेंगी।

इन्हीं उद्देश्यों को ध्यान में रखते हुए केन्द्रीय विद्यालय संगठन के पाँचों आंचलिक शिक्षा एवं प्रशिक्षण संस्थानों (ZIETs) के माध्यम से, समर्पित एवं अनुभवी शिक्षकों द्वारा कक्षा 9 से 12 के विद्यार्थियों के लिए यह विद्यार्थी सहायक सामग्री तैयार की गई है। यह केवल परीक्षा की तैयारी की संकलन सामग्री नहीं है, बल्कि विषयों को सरलता से समझने, अवधारणाओं को स्पष्ट करने, नियमित अभ्यास करने और आत्मविश्वास के साथ आगे बढ़ने का एक विश्वसनीय साथी है।

इस सामग्री में विषय-वस्तु को विद्यार्थियों की आवश्यकताओं के अनुरूप सरल, व्यवस्थित एवं दक्षता-आधारित दृष्टिकोण से प्रस्तुत किया गया है। मुझे प्रसन्नता है कि इसे हमारे शिक्षकों के अनुभव, नवाचार और विद्यार्थियों के प्रति उनकी प्रतिबद्धता ने समृद्ध बनाया है। मुझे विश्वास है कि यह सामग्री विद्यार्थियों की सीखने की यात्रा को अधिक सहज, रोचक और प्रभावी बनाएगी तथा उन्हें बोर्ड परीक्षाओं के साथ-साथ जीवन की व्यापक चुनौतियों के लिए भी तैयार करेगी।

मेरा विश्वास है कि जब एक जिज्ञासु विद्यार्थी, प्रेरित शिक्षक और सार्थक शिक्षण संसाधन एक साथ आते हैं, तब शिक्षा केवल उपलब्धि का माध्यम नहीं रहती, बल्कि व्यक्तित्व निर्माण की एक सशक्त प्रक्रिया बन जाती है। यही भावना इस विद्यार्थी सहायक सामग्री के केंद्र में है।

मेरी हार्दिक शुभकामनाएँ हैं कि आप सभी सीखने की इस यात्रा में निरंतर आगे बढ़ें, अपने सपनों को नए आयाम दें और ज्ञान, संवेदनशीलता तथा नवाचार के साथ राष्ट्र निर्माण में अपना महत्वपूर्ण योगदान दें।

शुभकामनाओं सहित।

(विकास गुप्ता)

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COURSE STRUCTURE
CLASS XII (2026 - 27)
(THEORY)

Time: 03 Hours **Max. Marks: 70**

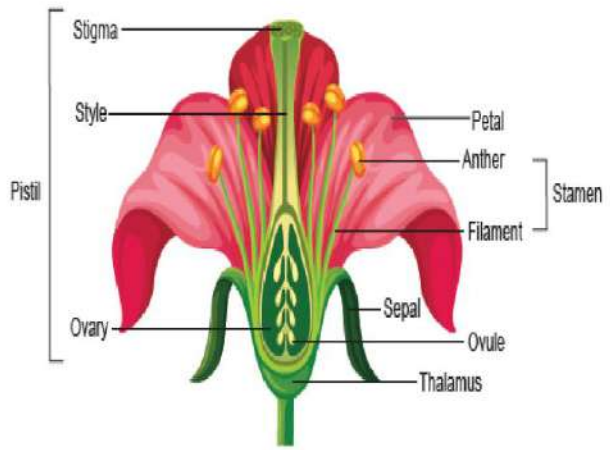
Unit	Title	Marks
VI	Reproduction	16
VII	Genetics and Evolution	20
VIII	Biology and Human Welfare	12
IX	Biotechnology and its Applications	12
X	Ecology and Environment	10
	Total	**70**

CHAPTER -1 SEXUAL REPRODUCTION IN FLOWERING PLANTS

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

Syllabus(2026-27) :Marks(6-8) Flower structure; development of male and female gametophytes; pollination - types, agencies and examples; out breeding devices; pollen-pistil interaction; double fertilization; post fertilization events - development of endosperm and embryo, development of seed and formation of fruit; special modes- apomixis, parthenocarpy, polyembryony; Significance of seed dispersal and fruit formation.

Parts of flower



All flowering plants show sexual reproduction.
A complete flower consists of calyx, corolla, androecium and gynoecium.

Androecium is the male reproductive structure that consists of a whorl of stamens.

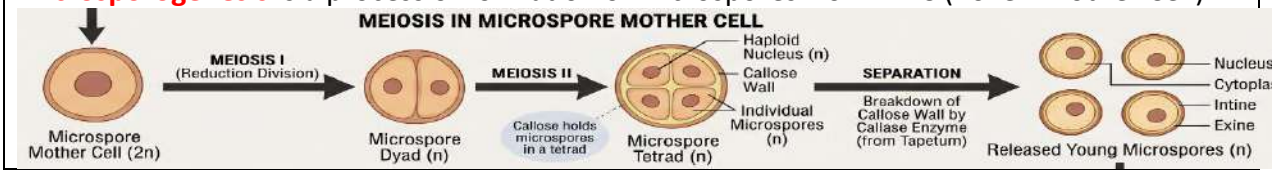
Gynoecium is the female reproductive structure that consists of a whorl of carpels (pistils)

Each carpel has three parts
Stigma: Landing platform for pollen grains.
Style: It is the elongated slender part beneath the stigma,
Ovary: Basal bulged part of pistil, has ovarian cavity (locule). Placenta is located inside ovarian cavity.

A typical stamen is composed of filament and anther. Filament: It is a long slenderstalk. The proximal end of the filament is attached to the thalamus or the petal of the flower. Anther is terminal and generally bilobed structure and each lobe having two theca ie., they are dithecous.

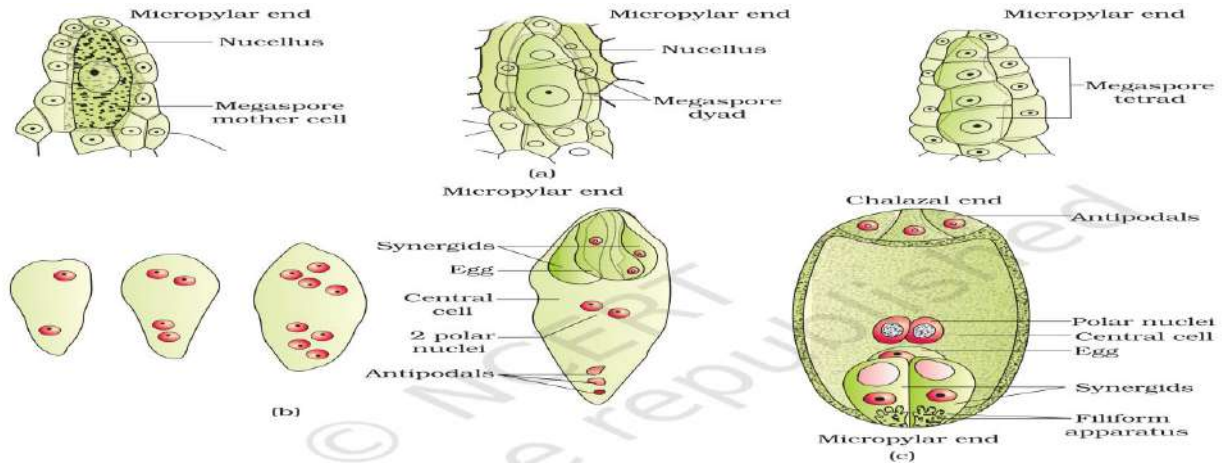
Anther is a four-sided (tetragonal) structure consisting of four microsporangia located at the corners, two in each lobe. The microsporangia develop further & become pollen sacs, They extend longitudinally all through the length of an anther and are packed with pollen grains.
Structure of Microsporangium: A typical microsporangium is generally surrounded by four wall layers.

Name and Function: 1. Epidermis (outermost mono layer) – protection
2. Endothecium (Hygrscopic mono layer): Dehiscence of anther.
3. Middle Layers (3-5 thick cell layer) – Nutrition of tapetum.
4. Tapetum (ameboid mono layer)- nourishment of developing pollen grain.
Microsporogenesis is a process of formation of microspores from PMC (Pollen Mother Cell).



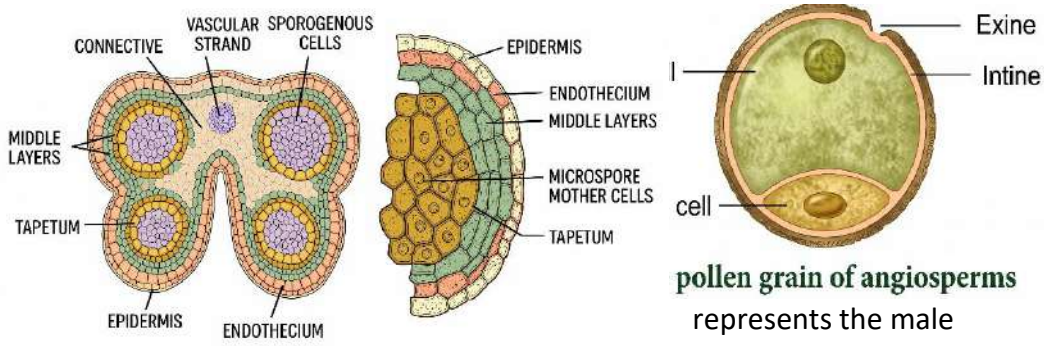
Megasporogenesis

It is the process of formation of megaspores from the megaspore mother cell is called megasporogenesis. Ovules generally differentiate a single megaspore mother cell (MMC) in micropylar region of the nucellus. MMC undergoes meiotic division and results in production of four megaspores. In majority of flowering plants one of the megaspores is functional while the other three degenerate. Only functional megaspore develops into the female gametophyte (embryo sac). This method of embryo sac formation from a single megaspore is termed monosporic development.



Pollen Grain

It



pollen grain of angiosperms represents the male gametophyte

It has prominent two layered wall: exine and intine.

* The outer layer exine is made up of **sporopollenin** and the intine is made up of pectin and cellulose.

- Pollen grains of many species cause severe allergies.
- Pollen grains are rich in nutrients
- Pollen viability: depends on both temperature and humidity,

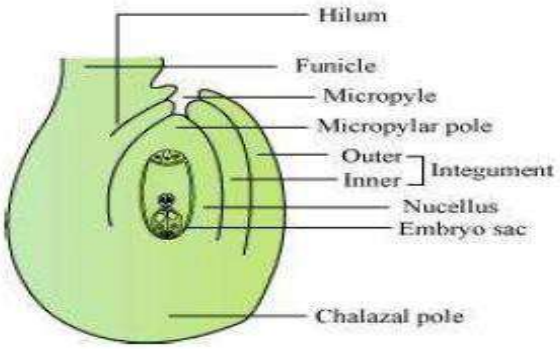
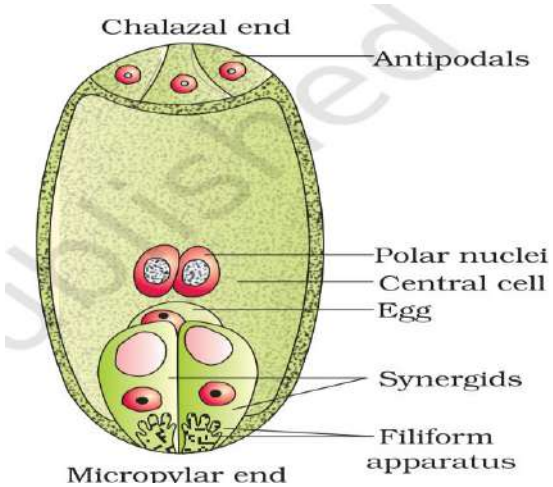
Pollen of a large number of species can be stored for years in liquid nitrogen (-196°C) in pollen banks for crop breeding programme.

Q 1. A plant has 6 flowers with 1 pistil contains 5 ovules. All flowers are pollinated and all ovules are fertilized. How many seeds and fruits will be formed?

Difference between Microsporogenesis and Megasporogenesis

S.No	Microsporogenesis	Megasporogenesis
1	In this process, haploid microspore are formed from diploid mother cell or pollen mother cells (MMC or PMC).	In this process, haploid megaspore are formed from diploid mother cell (MMC).
2	It occurs inside the microsporangium or pollen sac of an anther.	It occurs inside the nucellus of ovule or megasporangium.
3	There are many microspore mother cells in a microsporangium.	There are generally a single megaspore mother cell in a megasporangium.
4	The four microspore formed from a single microspore mother cell are generally arranged in a tetrahedral structure.	The four megaspore formed from a megaspore mother cells are arranged in the form of a linear tetrad.
5	All the four microspores arranged in a tetrahedral tetrad are functional.	Only one megaspore remains functional while the other three degenerates.
6	The microspores give rise to male gametophytes.	The functional megaspore gives rise to female gametophytes.

Difference between megaspore and embryo sac

The Megasporangium (Ovule) – Nucellar cell(one) generally differentiate into a single megaspore mother cell (MMC) towards micropylar region of ovule. In majority of flowering plants, one megaspore remains functional and three degenerate.  	**Female Gametophyte (Embryo sac)** **It is 7-celed and 8-nucleated** 

Q.2 A flower of brinjal plant following the process of sexual reproduction procedure 260 viable seeds. (HOTs)

Answer the following questions giving a reason:

(a) How many ovules minimally involved?

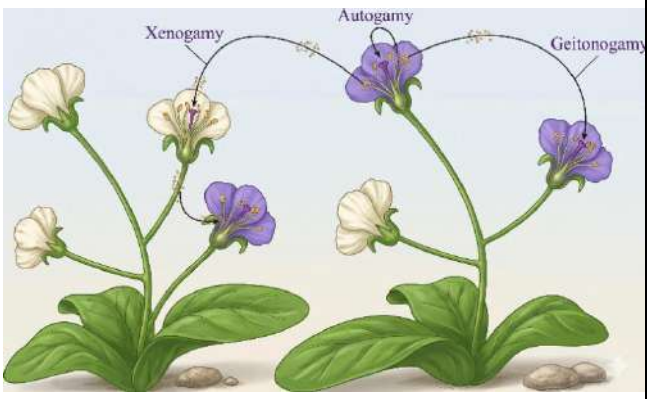
(b) How many megaspore mother cells are involved?

(c) What is the minimum number of pollen grains that must land on stigma for pollination?

(d) How many male gametes are involves in the above case?

(e) How many microspore mother cells must have undergone reduction division prior to dehiscence of anther in the above case?

Pollination



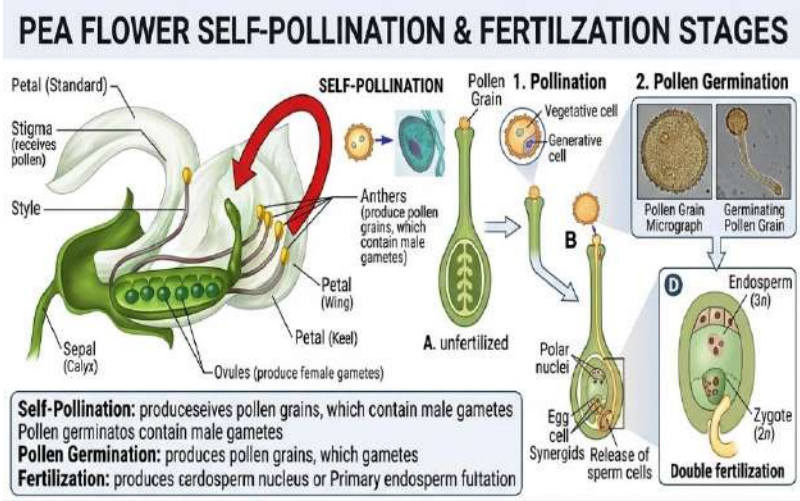
Self-pollination is of two types i.e., autogamy and geitonogamy (genetical autogamy and functional cross pollination). Autogamy can be promoted by cleistogamy.

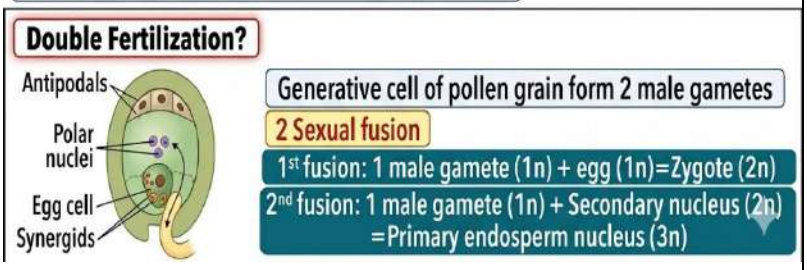
Xenogamy can be promoted by chasmogamous flower.

Outbreeding Devices: Mechanisms to avoid self-pollination like:

i) pollen release and stigma receptivity non-synchronized. ii) Different positioning of anther and stigma. iii) Self-incompatibility (regulated by genetic mechanism) iv)Unisexual flowers e.g. papaya, cucumberetc.

Pollen-pistil interaction is a chemical-mediated dynamic process. Following compatible pollination, pollen tube grows through the tissues of the stigma and style, the contents of pollen grain move into pollen tube. The growing pollen tube carrying two non-motile male gametes, reaches the ovary, enters the ovule through micropyle & then enters one of the synergids through the filiform apparatus, which guides the entry of pollen tube.





Artificial hybridization

1. Desired pollen is selected and used for controlled pollination.
2. Emasculation
— removal of anthers from bisexual flowers to prevent self-pollination.
3. Bagging
— stigma is covered/protected from unwanted pollen contamination.
4. If flower is unisexual (female) , emasculation is not needed (no stamens present).

Double Fertilization

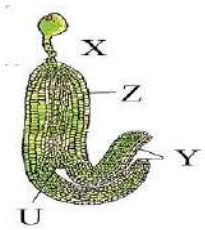
Syngamy & triple fusion are called double fertilization, an event unique to flowering plants. The central cell after triple fusion becomes primary endosperm cell (PEC) and develop into endosperm

Endosperm

Endosperm development precedes embryo development, as it is filled with reserve food materials and used by developing embryo. Embryo develops at micropylar end of embryo sac where the zygote is situated.

Early stages of embryo development (**Embryogeny**) are similar in both monocotyledons and dicotyledons.

Zygote --Proembryo Globular Embryo-- Heart-shaped Embryo --- Mature Embryo



Q.3 Identify 'U', 'X', 'Y' and 'Z' in a developing dicot embryo.

Seed

In angiosperms, seed (fertilized ovule) is the final product of sexual reproduction, formed inside fruits.
A seed typically consists of seed coats, cotyledon(s) & an embryo axis.
Significance: 1.Biological Significance (Ecological) -Better Adaptive Strategies:
2.Protection and Nourishment: necessary nourishment for initial growth.
3. Dispersal and Colonization
4.Genetic Variation: essential for adaptation and evolution.
5.Dormancy for Survival: helping the species survive through droughts or harsh winters.
6.Agricultural and Economic Significance
Lupinus arcticus seed germinated and flowered after estimated record 10,000 years of dormancy.
Phoenix dactytifera (date palm) seed remained viable for 2000 years.

Q.4 (a)How does a farmer use the dormancy of seeds to his advantage?
b) What advantages a seed provides to a plant?

Types of seeds

Seed Type	Description	Key Characteristic	Examples
Non-albuminous (Ex-albuminous)	No residual endosperm remains in the mature seed.	Endosperm is completely consumed during embryo development.	Pea, Groundnut, Beans
Albuminous	The seed retains a significant portion of the endosperm.	Endosperm is not completely used up during embryo development.	Wheat, Maize, Barley, Castor, Coconut
Perispermic	Seeds where the remnants of the nucellus are persistent.	Presence of Perisperm (persistent nucellus).	Black Pepper, Beet

True fruits develop from ovary.
In apple, strawberry, cashew, etc., thalamus also contributes to form fruit called false fruit.
Parthenocarpic fruit develop without fertilization eg. Banana.

Apomixis

- Formation of seed without fertilization is Apomixis.
- Apomixis is asexual form of reproduction but mimics sexual reproduction in term of seed formation.
- Apomixis maintain the gene combination from parent to offsrings.
- If hybrid seeds are made apomictic there will not be loss of superior characters in the next generation so farmers need not to buy new hybrid seed every year (cost effective).

Polyembryony

- Formation of more than one embryo within a single embyosac(female gametophyte)
- Some species of Asteraceae & grasses have evolved a special mechanism to produce seeds without fertilisation called apomixis.

- In Citrus and mango, nucellar cells protrude into embryo sac & develops into embryos, so each ovule contains many embryos (polyembryony)

Q.5 Write the ploidy of apomictic embryo developed from the integument cells and megaspore mother cell without reduction division respectively?

SEXUAL REPRODUCTION IN FLOWERING PLANTS
(NCERT Class 12)

1. FLOWER – REPRODUCTIVE ORGAN
A typical flower has four whorls:
Calyx, Corolla, Androecium and Gynoecium.

2. GAMETOPHYTE FORMATION
- Male gametophyte (Pollen grain) is formed in the pollen sacs of anthers.
- Female gametophyte (Embryo sac) is formed in the ovule inside the ovary.

MALE GAMETOPHYTE (POLLEN GRAIN)

a) In each pollen sac (microsporangium), microspore mother cells (2n) undergo meiosis to form microspores (n).

b) Each microspore undergoes mitosis to form a pollen grain (male gametophyte) with 2 cells – a vegetative cell and a generative cell.

c) The generative cell divides mitotically to form two male gametes.

FEMALE GAMETOPHYTE (EMBRYO SAC)

a) In the ovule, a megaspore mother cell (2n) undergoes meiosis to form 4 megaspores (n); one functional megaspore remains.

b) The functional megaspore undergoes three successive mitotic divisions to form an embryo sac (female gametophyte) with 7 cells and 8 nuclei.

c) Embryo sac structure:
1 egg cell, 2 synergids, 3 antipodals, and a central cell with 2 polar nuclei.

3. POLLINATION
Transfer of pollen grains from anther to stigma.
(May be self or cross pollination)

4. FERTILISATION (DOUBLE FERTILISATION)
- Pollen grain germinates on the stigma and pollen tube grows through the style to the ovule.
- The generative cell divides to form two male gametes.
- One male gamete fuses with the egg cell to form a diploid zygote (2n) – Syngamy.
- The other male gamete fuses with the two polar nuclei in the central cell to form a triploid primary endosperm nucleus (3n) – Triple fusion.

5. POST-FERTILISATION EVENTS

Zygote (2n) develops into Embryo → Primary endosperm nucleus (3n) develops into Endosperm → Ovule develops into Seed → Ovary develops into Fruit → Seed contains embryo and endosperm

6. SIGNIFICANCE
Leads to the formation of seeds and fruits, ensures genetic variation, and maintains continuity of species.

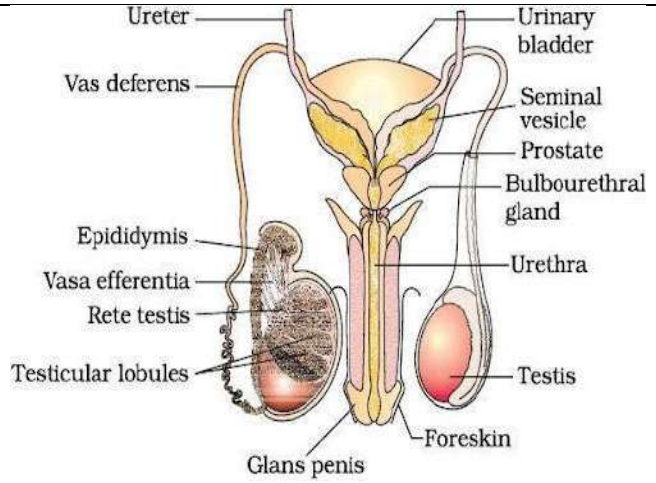
CHAPTER 2 HUMAN REPRODUCTION

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus (2026-27) Marks(4-6) : Male and female reproductive systems; microscopic anatomy of testis and ovary; gametogenesis -spermatogenesis and oogenesis; menstrual cycle; fertilization, embryo development up to blastocyst formation, implantation; pregnancy and placenta formation (elementary idea); parturition (elementary idea); lactation (elementary idea) **Reproduction**

The Biological Process by which organisms produce offsprings of their own Kind.

Male Reproductive System



Accessory Glands – Seminal vesicles(1 pair), prostate gland(1), and bulbourethral glands(1 pair) produce seminal plasma rich in fructose, calcium, and enzymes.

Penis and Urethra – Penis is the external genital organ for insemination, and the urethra carries semen outside through the urethral meatus.

The path of sperm in human males,

(inside of testis) Seminiferous tubules → Rete testis → Vasa efferentia → Epididymis →(outside testis) Vas deferens → Ejaculatory duct → Urethra → Urethral meatus

Location – The male reproductive system is in the pelvic region.

Main Parts – It includes testes, accessory ducts, glands, and external genitalia (penis).

Scrotum – Testes are present in the scrotum, which keeps them 2–2.5°C cooler than body temperature for spermatogenesis.

Testes – Each testis is oval-shaped and divided into about 250 testicular lobules.

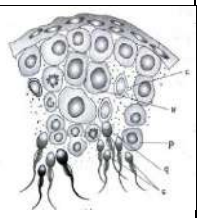
Seminiferous Tubules – Present inside lobules; they are the site of sperm production.

Sertoli Cells – Provide nourishment and support to developing sperms.

Leydig Cells – Present between seminiferous tubules and secrete male hormones called androgens (testosterone).

Accessory Ducts – Rete testis, vasa efferentia, epididymis, and vas deferens help in storage and transport of sperms.

Q.1 In the given figure, an enlarged section view of a seminiferous tubule, study the figure and answer the questions.



a. State the functions of part 'c'

b. What is the genetic makeup of a cell e'

c. Identify the parts 'a' and 'b

Q. 2 Read the passage carefully and answer the following questions:

A group of biology students visited a research lab studying male fertility. The scientist explained the process of spermatogenesis, which begins at puberty under hormonal control. Inside the seminiferous tubules, undifferentiated spermatogonia undergoes mitosis and meiosis to form spermatozoa. The process is regulated by hormones like FSH, LH, and testosterone, and supported by Sertoli cells and Leydig cells. The scientist also explained that factors like hormonal imbalance or testicular damage can impair spermatogenesis and reduce male fertility.

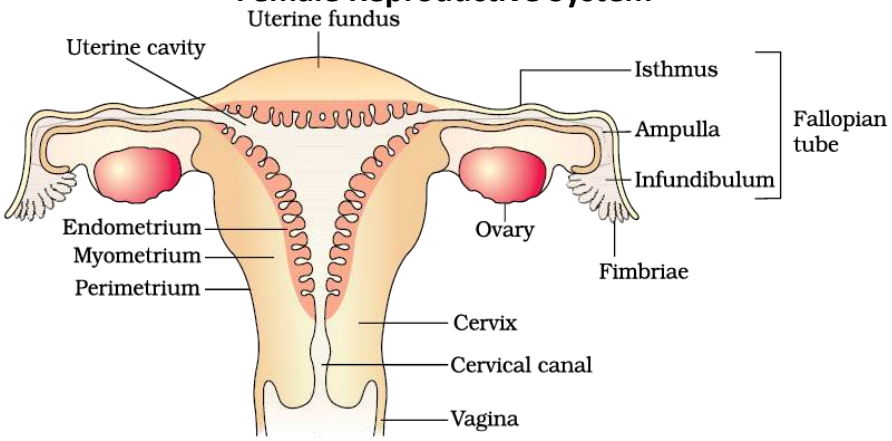
Questions:

a. **State the role of Sertoli cells in spermatogenesis.**
b. **Illustrate the role of the pituitary hormone that acts on the Leydig cell.**
c. **Describe the sequence of stages involved in spermatogenesis from spermatogonia to spermatozoa.**

OR

d. **Mention the role of testosterone in this process.**

Female Reproductive System



- **Layers of Uterus** –
- **Perimetrium** – Outer layer
- **Myometrium** (middle smooth muscles) – Middle muscular layer for childbirth contractions
- **Endometrium** – Inner glandular layer showing menstrual changes
- **Birth Canal** – Cervical canal together with vagina forms the birth canal.
- **External Genitalia** –
- Mons pubis
- Labia majora
- Labia minora
- Hymen
- Clitoris

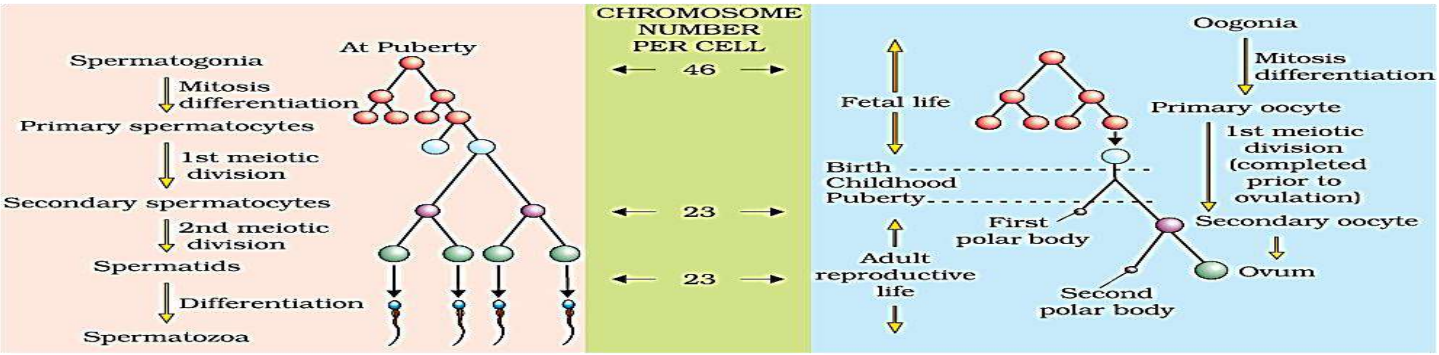
- **Mammary Glands** – Produce and secrete milk for nourishment of baby.

- **Main Parts** –consists of ovaries, oviducts (fallopian tubes), uterus, cervix, vagina, external genitalia, and mammary glands.
- **Functions** – It helps in ovulation, fertilisation, pregnancy, childbirth, and child care.
- **Ovaries** – Primary female sex organs that produce ova (eggs) and ovarian hormones.
- **Structure of Ovary** – Each ovary is 2–4 cm long and has:
  - Outer cortex
  - Inner medulla
- **Fallopian Tubes (Oviducts)** – About 10–12 cm long; transport ovum to uterus.
- **Parts of Oviduct** –
  - **Infundibulum** – Funnel-shaped part near ovary
  - **Fimbriae** – Finger-like projections that collect ovum
  - **Ampulla** – Wider middle part
  - **Isthmus** – Narrow part joining uterus

• **Milk Pathway/Lactation pathway** – Alveoli → Mammary tubules → Mammary ducts → Mammary ampulla → Lactiferous duct.	• **Uterus (Womb)** – Pear-shaped organ where embryo develops; opens into vagina through cervix.

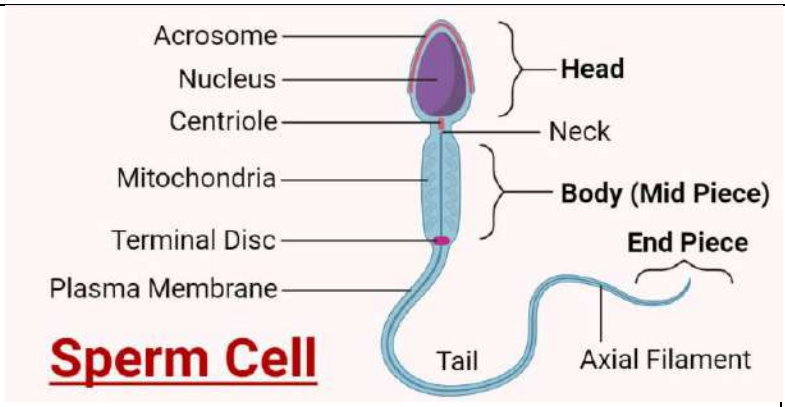
Gametogenesis :The process of formation of sperms and ova (eggs) in organisms.

Oogenesis(formation of ova (eggs))	**Spermatogenesis(**formation of sperms)
• Oogonia (2n = 46 chromosomes) multiply by mitosis during fetal life to form primary oocytes. • Primary oocyte begins first meiotic division and remains arrested until puberty. • At puberty, first meiotic division completes to form a secondary oocyte and first polar body. • Secondary oocyte undergoes second meiotic division to form ovum and second polar body. • One functional ovum (n = 23) is formed along with polar bodies.	• Spermatogonia (2n = 46 chromosomes) divide by mitosis to form primary spermatocytes at puberty. • Each primary spermatocyte undergoes first meiotic division to form two secondary spermatocytes (n = 23). • Secondary spermatocytes undergo second meiotic division. • This produces four haploid spermatids (n = 23). • Spermatids differentiate into mature spermatozoa (sperms).



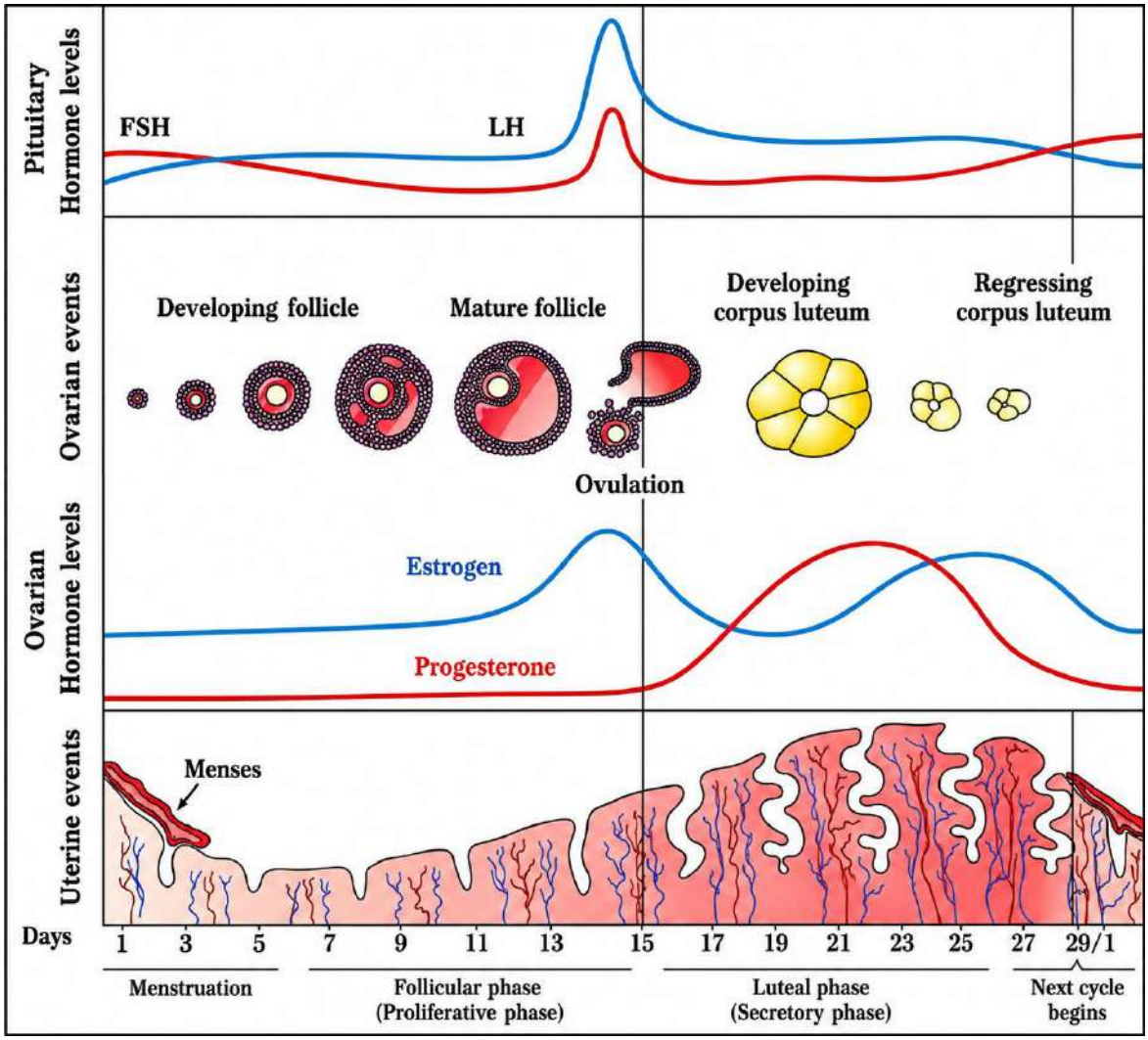
Q.3 Mention the difference between spermiogenesis and spermiation.

Q.4 The Correct number of Chromosomes in Human spermatogonia, Primary spermatocytes, and Spermatids is respectively



- Sperm is a microscopic male gamete covered by a plasma membrane.
- It has four parts – **head, neck, middle piece and tail**.
- The head contains an elongated **haploid nucleus**.
- The anterior part of the head has an **acrosome** with hydrolytic enzymes for fertilisation.
- The middle piece contains many **mitochondria** that provide energy for movement of the tail.

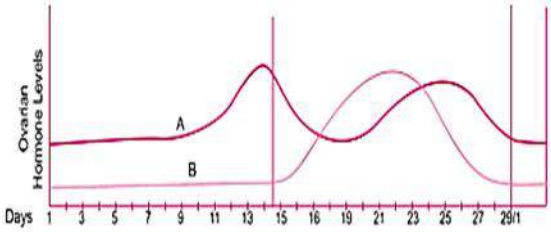
Menstrual Cycle



Days of Menstrual Cycle	Uterine Events	Ovarian Events	Hormones Involved

Day 1–5 (Menstrual Phase)	Breakdown and shedding of endometrium; menstrual flow occurs	Old corpus luteum degenerates	Low estrogen and progesterone
Day 6–13 (Follicular / Proliferative Phase)	Endometrium regenerates and thickens	Primary follicles grow; one develops into mature Graafian follicle	Increasing FSH and LH; estrogen secretion increases
Day 14 (Ovulatory Phase)	Endometrium continues thickening	Rupture of Graafian follicle and release of ovum (ovulation)	LH surge; peak of LH and FSH
Day 15–28 (Luteal / Secretory Phase)	Endometrium becomes thick, vascular and ready for implantation	Formation of Corpus luteum	Progesterone mainly; some estrogen
If Fertilization Does Not Occur	Endometrium breaks down leading to menstruation	Corpus luteum degenerates	Progesterone and estrogen decrease
If Fertilization Occurs	Endometrium maintained for pregnancy	Corpus luteum persists	Progesterone remains high
Days of Menstrual Cycle	Uterine Events	Ovarian Events	Hormones Involved

Q.5 The graph given below shows the variation in the levels of ovarian hormones during various phases of the menstrual cycle:



a. **Identify 'A' and 'B'.**
b. **Specify the source of the hormone marked in the diagram.**
c. **Reason out why A peaks before B.**
d. **Compare the role of A and B.**
e. **Under which condition will the level of B continue to remain high on the 28th day?**

Fertilisation and Implantation

1. During copulation, semen is released into the vagina and sperms travel to the ampullary region of the fallopian tube.
2. Fertilisation is the fusion of sperm and ovum, forming a diploid zygote (46 chromosomes).
3. Acrosomal enzymes help the sperm penetrate the ovum; only one sperm enters due to changes in zona pellucida.
4. The zygote undergoes cleavage divisions forming 2, 4, 8, 16 blastomeres and then a morula.
5. Morula changes into blastocyst which gets embedded in the uterine endometrium; this is called implantation.

Pregnancy and Embryonic Development

1. After implantation, chorionic villi (from Trophoblast) and uterine tissue form the placenta.
2. Placenta supplies oxygen and nutrients to the foetus and removes wastes.
3. Placenta acts as an endocrine tissue and secretes hormones like hCG, hPL, estrogen and progesterone.
4. The embryo forms three germ layers – ectoderm, mesoderm and endoderm.
5. Human pregnancy lasts about 9 months; by the ninth month the foetus becomes fully developed.

Parturition and Lactation

1. Parturition is the process of childbirth after about 9 months of gestation.
2. Foetal ejection reflex and oxytocin hormone cause strong uterine contractions for delivery.
3. After delivery of the baby, the placenta is expelled out.
4. Mammary glands produce milk after childbirth by the process called lactation.
5. The first milk called colostrum contains antibodies (IgA) important for the newborn baby.

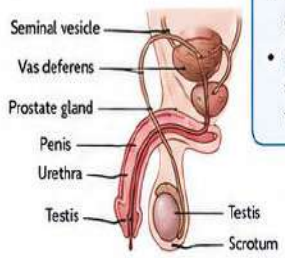
Important Hormones Produced by Placenta and Their Functions

Hormone	Function
hCG (Human Chorionic Gonadotropin)	Maintains Corpus luteum and supports pregnancy
hPL (Human Placental Lactogen)	preparation of mammary glands
Estrogens	Help growth of uterus and mammary glands
Progesterone	Maintains endometrium and pregnancy
Relaxin	Relaxes pelvic ligaments and softens cervix during childbirth

HUMAN REPRODUCTION

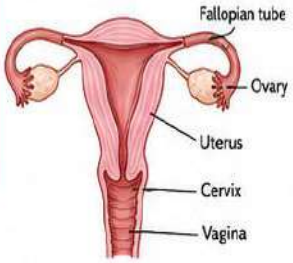
1. MALE REPRODUCTIVE SYSTEM

- Pair of testes, accessory ducts, accessory glands and penis.
- Functions – production of sperms, secretion of male hormones and transport of sperms.



2. FEMALE REPRODUCTIVE SYSTEM

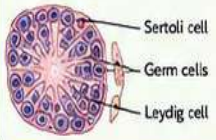
- Pair of ovaries, fallopian tubes (oviducts), uterus, cervix, vagina and external genitalia.
- Functions – production of ova, secretion of female hormones, transport of gamete, supporting fertilisation, pregnancy and childbirth.



3. MICROSCOPIC ANATOMY

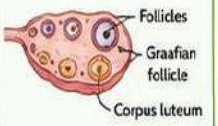
Testis

- Seminiferous tubules – site of spermatogenesis
- Sertoli cells – support and nourishment to germ cells
- Leydig cells – secrete testosterone



Ovary

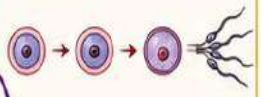
- Ovarian follicles at different stages
- Graafian follicle – mature follicle
- Corpus luteum – temporary endocrine structure



4. GAMETOGENESIS

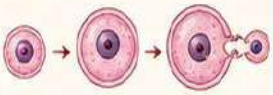
Spermatogenesis (in testes)

- Spermatogonia (2n) → Primary spermatocyte → Secondary spermatocyte → Spermatid → Spermatozoa (n)
- Occurs in seminiferous tubules after puberty.

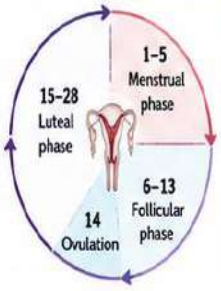


Oogenesis (in ovaries)

- Oogonia (2n) → Primary oocyte → Secondary oocyte + 1st polar body → Ovum + 2nd polar body (n)
- Begins in fetal life, one ovum released in each cycle after puberty.



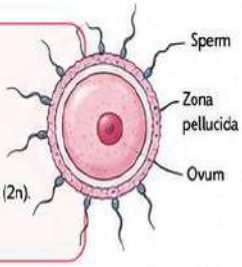
5. MENSTRUAL CYCLE (≈ 28/29 DAYS)



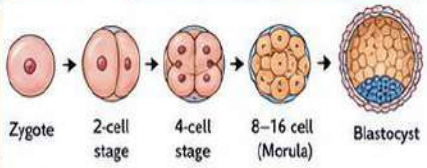
- **Menstrual phase**: Shedding of endometrium (1–5 days).
- **Follicular phase**: Growth of follicle and regeneration of endometrium (6–13 days).
- **Ovulation**: Release of ovum around 14th day (LH surge).
- **Luteal phase**: Corpus luteum secretes progesterone; prepaes endometrium for implantation (15–28 days).

6. FERTILISATION

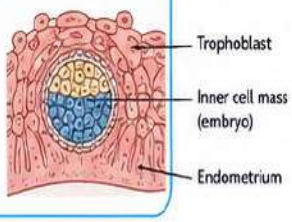
- Occurs in ampullary region of fallopian tube.
- Sperm penetrates ovum with the help of acrosomal enzymes.
- Fusion of male and female gametes → diploid zygote (2n).
- Sex of the baby determined by the sperm (X or Y).



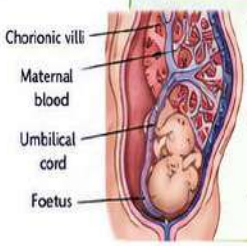
7. EMBRYO DEVELOPMENT (UPTO BLASTOCYST) & IMPLANTATION



- Zygote divides by cleavage during its passage through isthmus of oviduct.
- 8–16 celled morula transforms into blastocyst.
- Blastocyst reaches uterus and gets implanted in the endometrium. (Implantation)



8. PREGNANCY & PLACENTA FORMATION (ELEMENTARY IDEA)



- Trophoblast forms chorionic villi which interdigitate with maternal tissues.
- Placenta acts as a link between foetus and mother.
- Functions – supply of O_2 and nutrients, removal of CO_2 and wastes, and hormone secretion.
- Hormones: hCG, hPL, estrogens, progestogens.

9. PARTURITION (ELEMENTARY IDEA)

- Full term pregnancy ≈ 9 months (gestation period).
- Signals from foetus and placenta induce uterine contractions.
- Oxytocin from maternal pituitary increases contractions (positive feedback).
- Expulsion of baby through birth canal.
- Placenta is expelled after the baby.

10. LACTATION (ELEMENTARY IDEA)

- Mammary glands develop during pregnancy and begin milk production after delivery.
- First milk (colostrum) – rich in antibodies, provides immunity to newborn.
- Prolactin – milk production.
- Oxytocin – ejection of milk.

Flow of the chapter: Structure → Function → Gamete formation → Cycle → Fertilisation → Early development → Implantation → Pregnancy → Birth → Lactation

CHAPTER-3 REPRODUCTIVE HEALTH

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

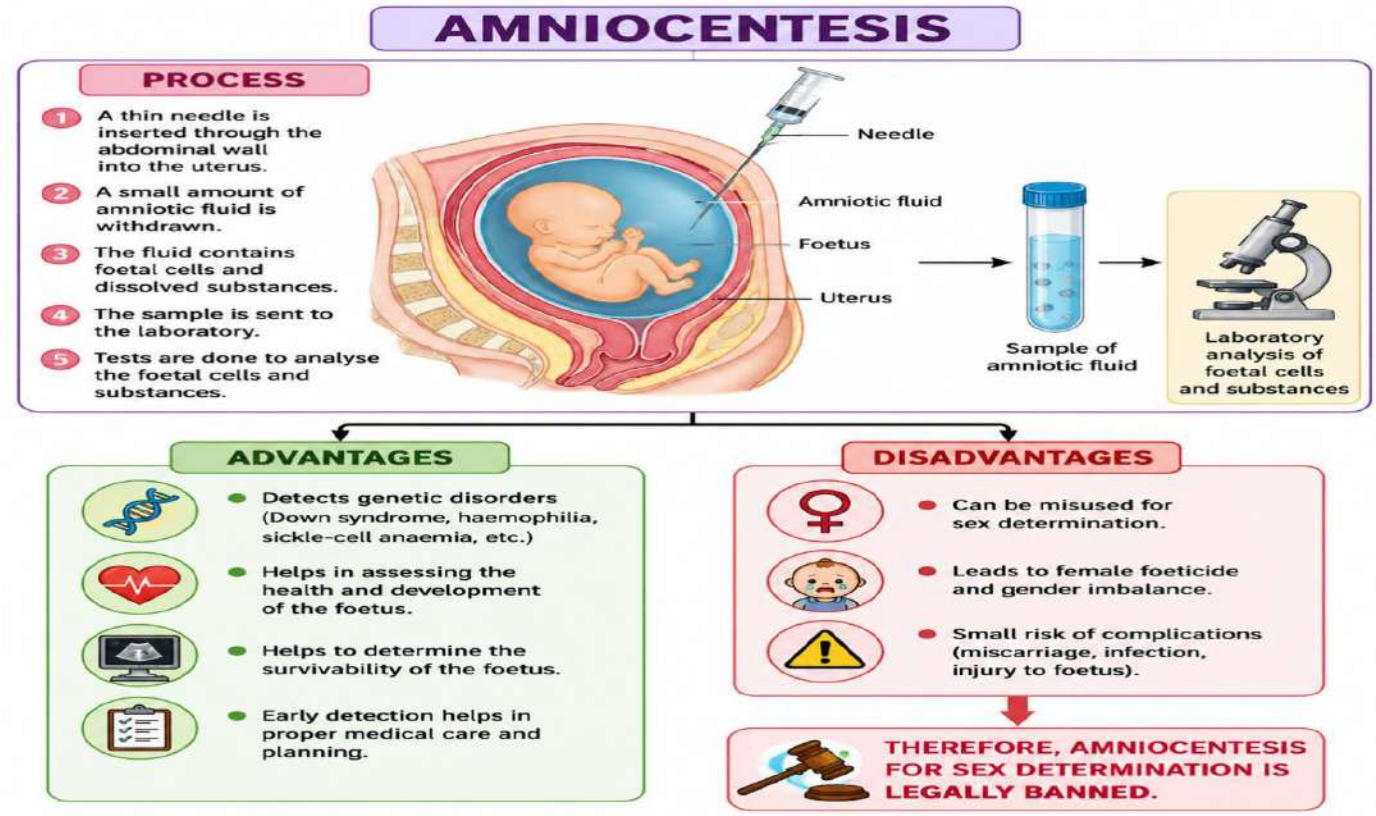
CBSE Syllabus (2026-27): Marks (2-4) Need for reproductive health and prevention of Sexually Transmitted Diseases (STDs); birth control - need and methods, contraception and medical termination of pregnancy (MTP); amniocentesis; infertility and assisted reproductive technologies - IVF, ZIFT, GIFT (elementary idea for general awareness).

Problems of Reproductive Health	Strategies / Solutions
• Lack of awareness about reproductive health	• Awareness programmes through media, NGOs and government
• Myths and misconceptions about sex	• Sex education in schools
• Unsafe sexual practices	• Education about safe and hygienic sex
• Spread of STDs and AIDS	• Information, prevention and treatment facilities
• Uncontrolled population growth	• Family planning and birth control awareness
• Poor maternal and child health	• Proper pregnancy and post-natal care
• Female foeticide	• Ban on sex determination by amniocentesis
• Sex abuse and sex-related crimes	• Social awareness and education
• Infertility and menstrual problems	• Medical assistance and counselling
• Lack of medical facilities	• Better hospitals, infrastructure and trained professionals
• High maternal and infant mortality	• Improved medical care and immunisation
• Gender inequality	• Equal opportunities for male and female child

Points to go through	
• **Population Explosion**	• Rapid increase in population due to better health care and living conditions.
• **World Population Growth**	• 2 billion (1900) → 6 billion (2000) → 7.2 billion (2011).

● **Indian Population Growth**	● 350 million (1947) → 1 billion (2000) → 1.2 billion (2011).
● **Reasons for Population Growth**	● ↓ Death rate, ↓ MMR, ↓ IMR, ↑ reproductive-age population, ↑life span
● **RCH Programme**	● Helped reduce population growth marginally.
● **Population Growth Rate**	● Less than 2% (20/1000/year) in 2011 census.
● **Problems Due to Overpopulation**	● Scarcity of food, shelter, clothing and natural resources
● **Government Measures**	● Promote small families and birth control methods.
● **Hum Do Hamare Do**	● Slogan promoting two-child norm.
● **One Child Norm**	● Adopted by many young urban couples.
● **Marriageable Age**	● Female – 18 years; Male – 21 years.
● **Incentives for Small Families**	● Government rewards couples with fewer children.
● **Ideal Contraceptive**	● User-friendly, effective, reversible, fewer side effects.
● **Types of Contraceptive Methods**	● Natural, Barrier, IUDs, Oral pills, Injectables, Implants, Surgical methods.

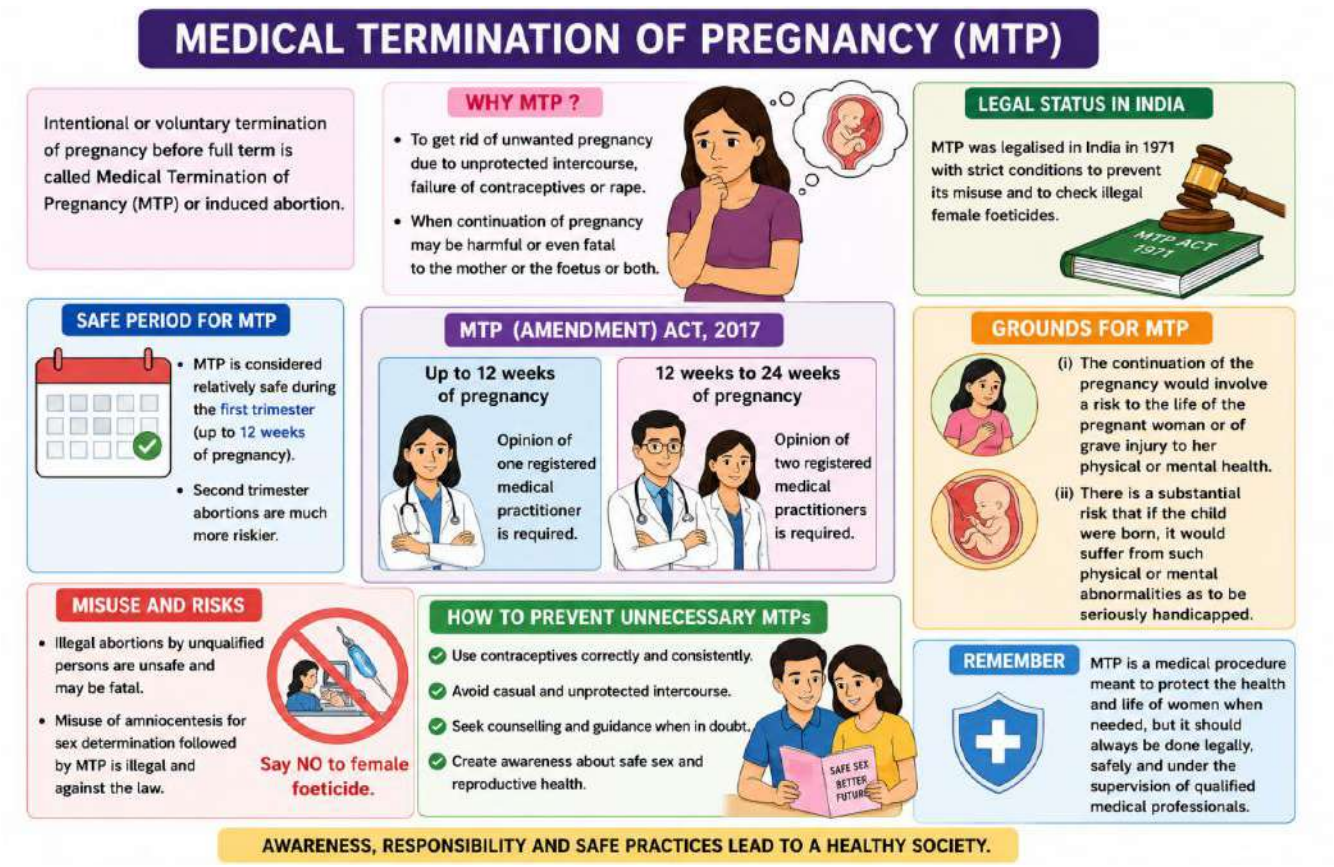
Q.1 How will the population be affected if there is increase in IMR and decrease in MMR?



Category	Mechanism of Action	Specific Types / Examples	Key Features / Advantages
Natural Methods	Prevent physical meeting of sperm and ovum without chemicals or devices.	Periodic abstinence, Withdrawal method, Lactational amenorrhea.	Zero side effects; high failure rate; no cost.
Barrier Methods	Physical blockades that prevent sperm from reaching the ovum.	Condoms (e.g., Nirodh), Diaphragms, Cervical caps, Vaults.	Protects against STDs and AIDS; disposable and user-friendly.
IUDs (Intra Uterine Devices)	Inserted into the uterus to affect sperm motility or implantation.	Non-medicated: Lippes loop; Copper-releasing: CuT, Cu7; Hormonal: LNG-20.	Ideal for spacing children; Copper ions suppress sperm motility.
Oral Pills	Hormonal preparation that inhibits ovulation and implantation.	Saheli (Non-steroidal), Daily pills (Progestogen-estrogen).	Saheli is a "once-a-week" pill with high contraceptive value and few side effects.
Injectables & Implants	Hormones administered under the skin or via injection.	Subcutaneous implants, Hormonal injections.	Provides long-lasting protection compared to daily pills.
Emergency Contraceptives	High-dose hormones used to prevent pregnancy post-intercourse.	Progestogens or IUDs (within 72 hours).	Used to avoid pregnancy due to unprotected coitus or rape.
Surgical Methods	Permanent sterilization by blocking gamete transport.	Vasectomy (Males), Tubectomy (Females).	Highly effective; terminal method; very poor reversibility.
Q.2 A mother of one-year old daughter wanted to space her second child. Her doctor suggested Cu-T. Explain its contraceptive actions.			

Type of STI	Disease	Causative Organism
Bacterial STI	Gonorrhoea	*Neisseria gonorrhoeae*
Bacterial STI	Syphilis	*Treponema pallidum*
Bacterial STI	Chlamydiasis	*Chlamydia trachomatis*
Viral STI	AIDS	HIV (Human Immunodeficiency Virus)
Viral STI	Genital Herpes	Herpes Simplex Virus (HSV)
Viral STI	Hepatitis-B	Hepatitis-B Virus (HBV)
Viral STI	Genital Warts	Human Papilloma Virus (HPV)

Q.3 Which one of the following groups includes sexually transmitted diseases caused by bacteria only?



Sexually Transmitted Infections (STIs)/Venereal diseases (VD) / reproductive tract infections (RTIs)

High vulnerability/risk group: 15-24 years.

Bacterial and protozoan diseases are completely curable if detected early and treated properly.

Mode of Transmission:

+ Sexual intercourse.

Sharing of injection needle, surgical instruments with infected persons.

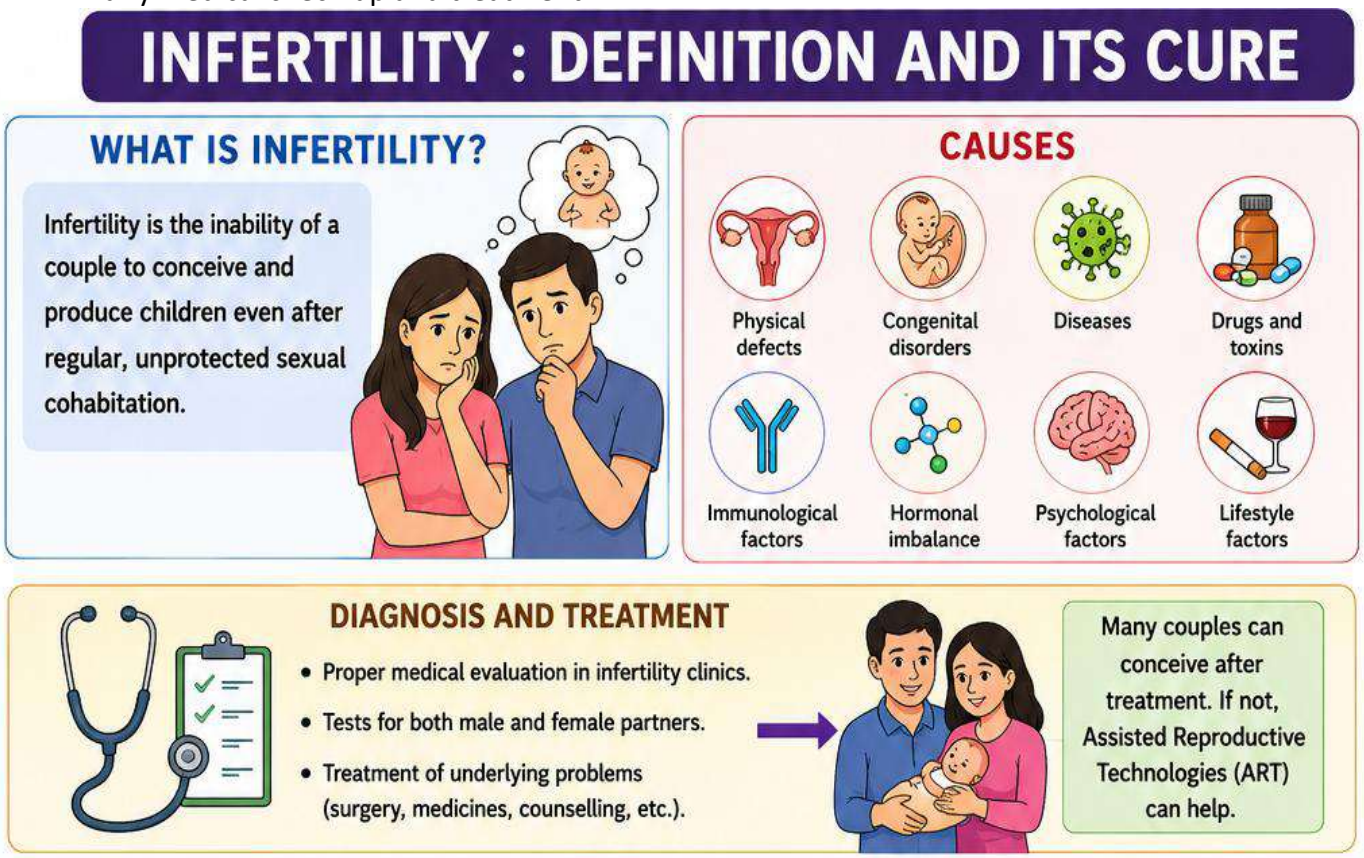
Transfusion of blood.

From infected mother to foetus.

Prevention

- Avoid multiple/unknown partners.
- Use condoms.

- Early medical check-up and treatment.



ART Technique	Definition	Uses / Purpose
IVF-ET (In Vitro Fertilisation – Embryo Transfer)	Fertilisation occurs outside the body in laboratory conditions followed by embryo transfer.	Helps infertile couples to conceive; called test tube baby technique.
ZIFT (Zygote Intra Fallopian Transfer)	Transfer of zygote or early embryo (up to 8 blastomeres) into fallopian tube.	Helps further development of embryo in female body.
IUT (Intra Uterine Transfer)	Transfer of embryo with more than 8 blastomeres into uterus.	Supports implantation and pregnancy.
GIFT (Gamete Intra Fallopian Transfer)	Transfer of ovum from donor into fallopian tube of another female.	Used when female cannot produce ova but can support development.
ICSI (Intra Cytoplasmic Sperm Injection)	Direct injection of sperm into ovum in laboratory.	Helps in cases of very low sperm count or male infertility.
AI (Artificial Insemination)	Artificial introduction of semen into female reproductive tract.	Helps when male cannot inseminate properly.
IUI (Intra Uterine Insemination)	Semen introduced directly into uterus.	Increases chances of fertilisation in infertile couples.

Q.4 Name two hormones that are constituents of contraceptive pills. Why do they have high and effective contraceptive value? Name a commonly prescribed non-steroidal oral pill.

Flow Chart

CHAPTER SUMMARY – REPRODUCTIVE HEALTH

1. POPULATION STABILISATION AND BIRTH CONTROL

- Rapid population growth is a global concern.
- Balanced population is essential for economic and social development.
- Government promotes small family norm
  - 'Hum Do Hamare Do', incentives, raising marriageable age (females – 18 yrs, males – 21 yrs).
- Contraceptives help prevent unwanted pregnancies.

2. CONTRACEPTIVE METHODS

Natural/ Traditional Methods
- Avoid the meeting of ovum and sperm.
- Periodic abstinence (safe period: day 10–17)
- Withdrawal (coitus interruptus)
- Lactational amenorrhea (effective up to 6 months after delivery)

Barrier Methods
- Prevent physical meeting of gametes.
- Condoms (male & female) – also protect from STIs and AIDS.
- Diaphragms, cervical caps, vaults.
- Spermicidal creams, jellies, foams.

IUDs (Intra Uterine Devices)
- Inserted in uterus by doctor.
- Non-medicated (Lippes loop)
- Copper releasing (CuT, Cu7, Multiload 375)
- Hormone releasing (Progestasert, LNG-20)
- Help in spacing and delaying pregnancy.

Oral Contraceptives
- Pills taken for 21 days, repeat after 7 days gap.
- Inhibit ovulation & implantation.
- Saheli – non-steroidal, once a week pill with few side effects.

Injectables and Implants
- Progestogens alone or in combination.
- Given as injections or implants under skin.
- Long acting and effective.

Emergency Contraceptives
- Taken within 72 hours of unprotected coitus.
- Prevents pregnancy in emergency (such as rape or failed contraception).

Surgical Methods (Sterilisation)
- Permanent methods.
- Vasectomy (in males) – vas deferens cut/tied.
- Tubectomy (in females) – fallopian tube cut/tied.
- Highly effective but poor reversibility.

REPRODUCTIVE HEALTH

Complete well-being in all aspects of reproduction and sexual life.

3. MEDICAL TERMINATION OF PREGNANCY (MTP)

- Intentional termination of pregnancy before full term.
- Legalised in India in 1971 with strict conditions.
- Safe during first trimester (up to 12 weeks).
- MTP Amendment Act, 2017:
  - Up to 12 weeks – opinion of one registered medical practitioner.
  - 12 to 24 weeks – opinion of two registered medical practitioners.
- Grounds:
  - Risk to life or health of mother.
  - Substantial risk of serious abnormalities in foetus.
- Misuse leads to illegal abortions and female foeticide.
- Counselling, awareness and proper healthcare are essential.

4. SEXUALLY TRANSMITTED INFECTIONS (STIs)

- Infections transmitted through sexual contact (also called VDs or RTIs).
- **Common STIs:** Gonorrhoea, Syphilis, Chlamydiasis, Genital herpes, Genital warts, Trichomoniasis, Hepatitis-B, HIV/AIDS.
- Spread by sexual contact, infected needles, blood transfusion, mother to foetus.
- **Symptoms:** Itching, pain, discharge, swelling in genital area (often mild or absent in early stages).
- **Complications:** PID, infertility, ectopic pregnancy, abortions, still births, cancer.
- **Prevention:**
  - Avoid multiple/unknown partners.
  - Always use condoms.
  - Early detection and complete treatment.

5. INFERTILITY AND ASSISTED REPRODUCTIVE TECHNOLOGIES (ART)

- Inability to conceive despite unprotected cohabitation.
- **Causes:** Physical, congenital, diseases, drugs, immunological, psychological or unexplained.
- Diagnosis and treatment in infertility clinics.
- ART Techniques:
  - IVF-ET
  - IUT
  - ICSI
  - ZIFT
  - GIFT
  - AI
  - IUI
- Adoption is a noble option for childless couples.

6. KEY TAKEAWAYS

- Reproductive health is essential for individual well-being and healthy society.
- Awareness, responsible behaviour and timely medical help are crucial.
- Contraception prevents unwanted pregnancies and STIs.
- Safe motherhood, prevention of STIs, proper treatment of infertility and ethical use of MTP improve quality of life.

Abbreviations

- IVF-ET – In Vitro Fertilisation – Embryo Transfer
- ZIFT – Zygote Intra Fallopian Transfer
- IUT – Intra Uterine Transfer
- GIFT – Gamete Intra Fallopian Transfer
- ICSI – Intra Cytoplasmic Sperm Injection
- AI – Artificial Insemination
- IUI – Intra Uterine Insemination

CHAPTER-4: PRINCIPLES OF INHERITANCE AND VARIATION

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus (2026-27) : Marks (6-8) Heredity and variation: Mendelian inheritance; deviations from Mendelism – incomplete dominance, co-dominance, multiple alleles and inheritance of blood groups, pleiotropy; elementary idea of polygenic inheritance; chromosome theory of inheritance; chromosomes and genes; Sex determination - in humans, birds and honey bee; linkage and crossing over; sex linked inheritance - hemophilia, color blindness; Mendelian disorders in humans - thalassemia; chromosomal disorders in humans; Down's syndrome, Turner's and Klinefelter's syndromes.

Genetics: Is a branch of biology concerned with the study of inheritance, as well as the variation of characters from parents to offspring.

Heredity: The process of genetic inheritance of characteristics from one generation to another;

Inheritance: The process by which characters are passed on from parent to progeny; it is the basis of heredity.

Variation: Is the degree by which progeny differ from their parents.

MENDEL'S LAWS OF INHERITANCE

- Gregor Johann Mendel is considered as 'father of genetics'
- Gregor Mendel conducted hybridization experiments on garden peas for seven years (1856-1863) and proposed the laws of inheritance in living organisms.
- Mendel conducted artificial pollination/cross pollination experiments using several true-breeding pea lines. A true-breeding line is one that, having undergone continuous self-pollination, shows the stable trait inheritance and expression for several generations.

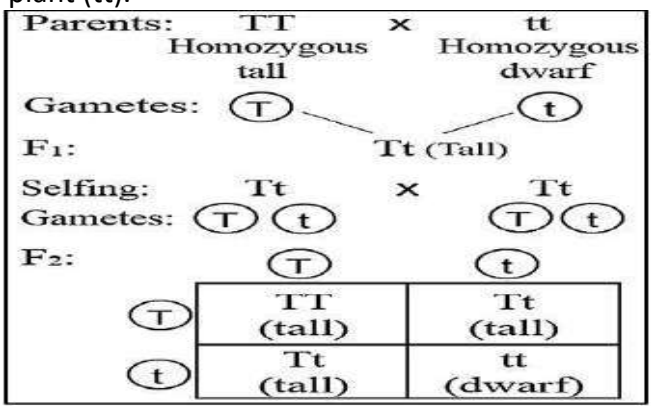
Why Mendel selected garden pea (*Pisum sativum*) plant for his hybridization experiments?

- They can be grown easily in open ground or even in pots.
- They have a short period of growth cycle.
- They produce self-pollinating flowers, large number of seeds and fertile hybrids on cross-pollination.
- They show contrasting heritable characters.

MONOHYBRID CROSS

The crossing between two plants, with respect to a single contrasting character is called monohybrid cross.

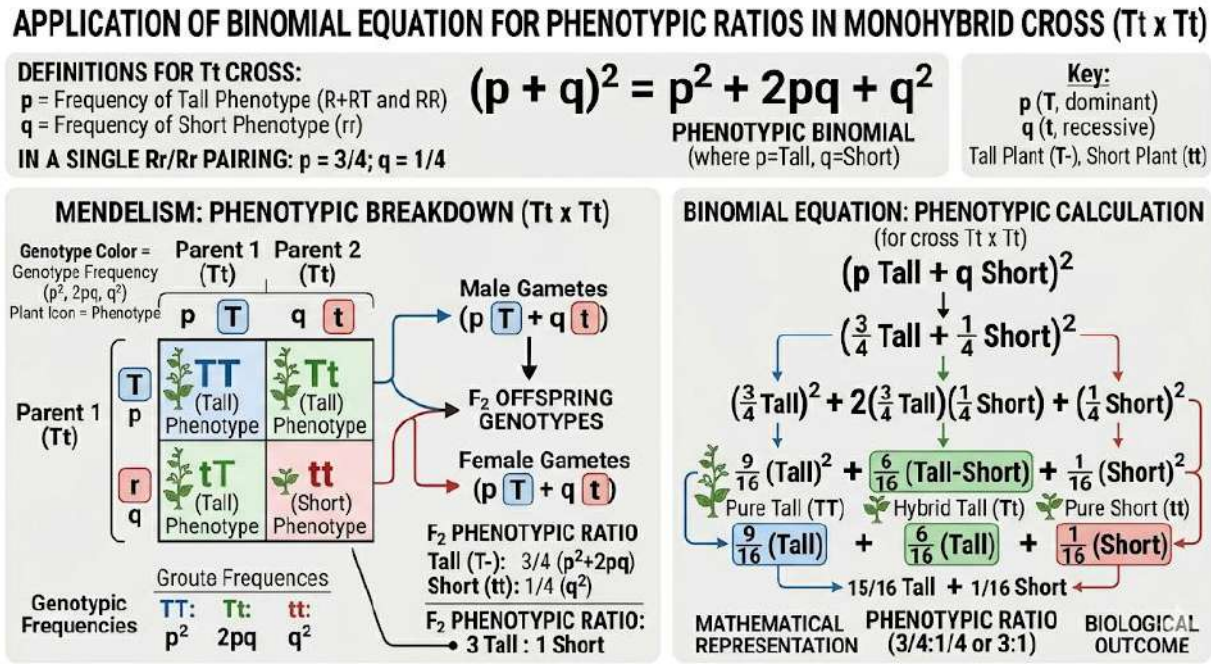
- Mendel conducted hybridization experiment by crossing true-breed tall pea plant (TT) with true-breed dwarf pea plant (tt).



Phenotypic ratio	**Genotypic ratio**
Tall : Dwarf	Pure tall : Hybrid Tall : Pure Dwarf

3 : 1 1 TT : 2 Tt : 1t

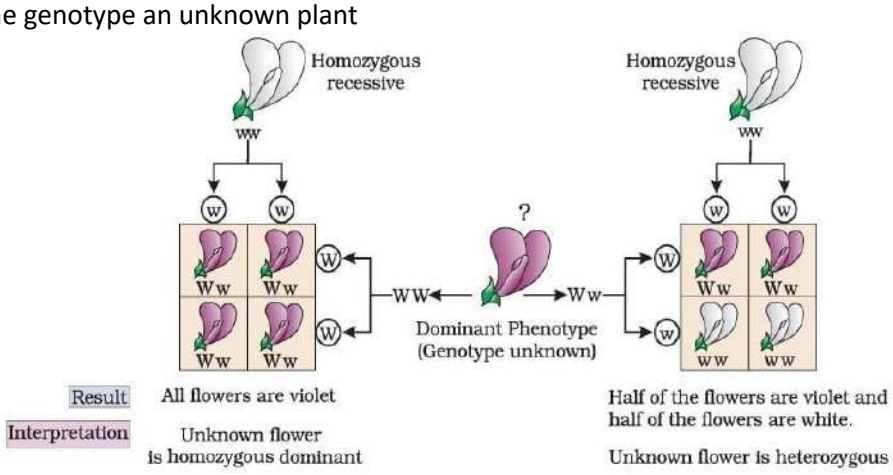
Binomial expression – It can be used to calculate genotype.



Q.1 A heterozygous tall plant is crossed with a similar genotype, what percentage of plants should possess TT, Tt genotype?

TEST CROSS

The cross made between unknown plant (or F1 hybrids) with the recessive parent is called test cross. It is used to find the genotype an unknown plant



Genotypic ratio – Ww : ww
1 : 1
Phenotypic ratio – Violet : White
1 : 1

- Based on his observations on monohybrid crosses Mendel proposed two general rules to consolidate his understanding of inheritance in monohybrid crosses.

Law of dominance: It states that "In a dissimilar pair of factors one member of the pair dominates (dominant) the other one (recessive).

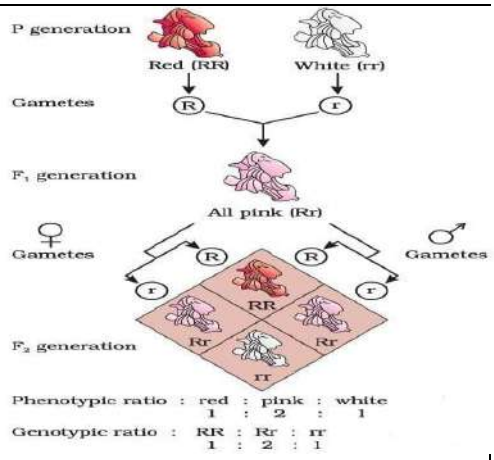
Law of Segregation: This law states "A pair of alleles segregate from each other during gamete formation, such that a gamete receives only one of the two factors".

Q.2 A tall pea plant bearing violet flower is given with unknown genotypes. Explain how would you find the correct genotypes.

INCOMPLETE DOMINANCE

- It's a phenomenon in which the F1 hybrid exhibits intermediate characters of the parental gene
- It is seen in flower colours of Mirabilis jalapa (4 O'clock plant and Antirrhinus majus (Snapdragon).
- In a cross between true breeding red flowered (RR) and true breeding white flowered plants (rr), the F1 (Rr) was pink.
- When the F1 was self-pollinated the F2 resulted in the following ratio 1 Red (RR) : 2 Pink (Rr) : 1 White (rr).
- Here the phenotypic ratio deviates from the Mendel's monohybrid cross.

Both phenotypic and genotypic ratio will be the same 1:2:1.



- Homozygous Dominant (BB): These plants synthesize starch effectively, resulting in large starch grains and round seeds.
- Homozygous Recessive (bb): These plants have low efficiency in starch synthesis, resulting in small starch grains and wrinkled seeds.
- Heterozygous (Bb): These plants produce round seeds, which suggests that the B allele is dominant over the b allele for seed shape.
- Intermediate Phenotype: While the seeds are round, the starch grains within Bb seeds are of intermediate size, showing that dominance is not absolute for every trait.
- So, if starch grain size is considered as the phenotype, then from this angle, the alleles show incomplete dominance.

  Note - The modified allele could be responsible for production of –

  (i) the normal/less efficient enzyme, or

  (ii) a non-functional enzyme, or

  (iii) no enzyme at all

CO-DOMINANCE:

- The Alleles which are able to express themselves independently, even when present together are called co-dominant alleles and this biological phenomenon is called co-dominance.
- A good example is different types of red blood cells that determine ABO blood grouping in human beings.
- ABO blood groups are controlled by the gene I.
- The gene (I) has three alleles I^A, I^B and i. The alleles ^{IA} and ^{IB} produce a slightly different form of the sugar while allele i does not produce any sugar on plasma membrane.
- In other words when I^A and i are present only I^A expresses (because i does not produce any sugar), and when I^B and i are present I^B expresses. But when I^A and I^B are present together they both express their own types of sugars: this is because of co-dominance. Hence red blood cells have both A and B types of sugars. Following table Shows the Genetic Basis of Blood Groups in Human Population.

Allele from Parent 1	Allele from Parent 2	Genotype of offspring	Blood types of offspring
I^A	I^A	I^AI^A	A
I^A	I^B	I^AI^B	AB
I^A	i	I^Ai	A
I^B	I^A	I^AI^B	AB
I^B	I^B	I^BI^B	B
I^B	i	I^Bi	B
i	i	ii	O

Q.3 The inheritance pattern of human ABO blood grouping is an example of

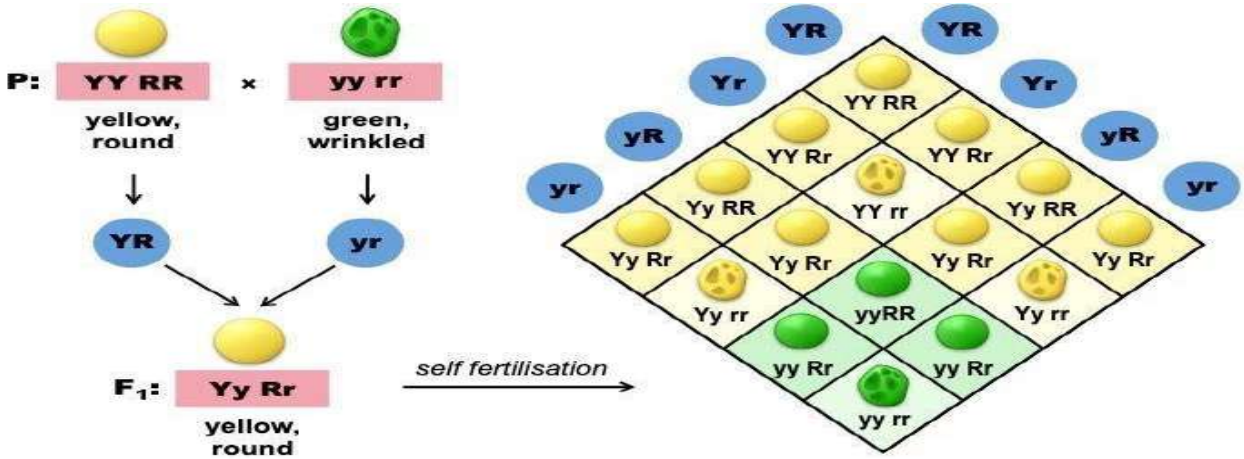
MULTIPLE ALLELISM:

Multiple allelism describes a genetic situation where more than two alleles exist for a single trait in a population. While individuals typically inherit only two alleles for each gene (one from each parent), multiple allelism indicates that a gene has multiple variations, leading to a wider range of possible phenotypes. A classic example is the ABO blood group system in humans, where there are three alleles (IA, IB, and i) for the same gene, resulting in four different blood types (A, B, AB, and O).

Q.4 A child with blood group A has father of blood group B and mother with blood group AB. What would be the possible genotypes of parents and the child? Choose the correct option:

DIHYBRID CROSS (INHERITANCE OF TWO GENES)

The cross between two parents differed in two pairs of contrasting traits; is called dihybrid cross. Mendel also worked with and crossed pea plants that differed in two characters, as is seen in the cross between a pea plant that has seeds with yellow colour and round shape and one that had seeds of green colour and wrinkled shape. The genotype of the parents can then be written as RRYY and rryy.



Phenotypic ratio: Round Yellow: **Round Green : Wrinkled yellow** : Wrinkled green

9 **3** **3** 1

Law of Independent assortment: The law states that "When two pairs of traits are combined in a hybrid, segregation of one pair of characters is independent of the other pair of characters".

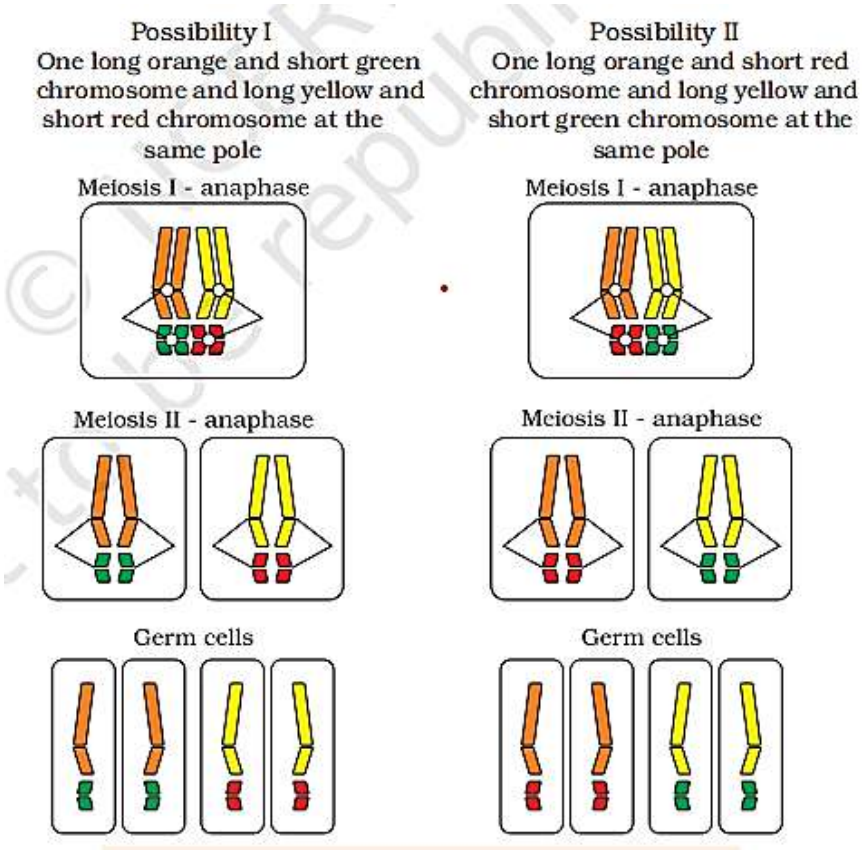
Note : - In 1900, three Scientists (de Vries, Correns and von Tschermak) independently rediscovered Mendel's results on the inheritance of characters.

CHROMOSOMAL THEORY OF INHERITANCE

It was proposed independently by Walter Sutton and Theodore Boveri in 1902. They united the knowledge of chromosomal segregation with Mendelian principles and called it chromosomal theory of inheritance. The main points are as follow:

(i) Gametes (sperm and egg) transmit hereditary characters from one generation to another.

(ii) Nucleus is the site of hereditary characters.
(iii) Chromosomes as well as genes are found in pairs.
(iv) The two alleles of a gene pair are located on homologous sites on the homologous chromosomes.
(v) The sperm and egg having haploid sets of chromosomes fuse to regain the diploid state.
(vi) Homologous chromosomes synapse during meiosis and get separated to pass into different cells and is the basis of segregation and independent assortment during meiosis.



A Comparison between the Behaviour of Chromosomes and Genes

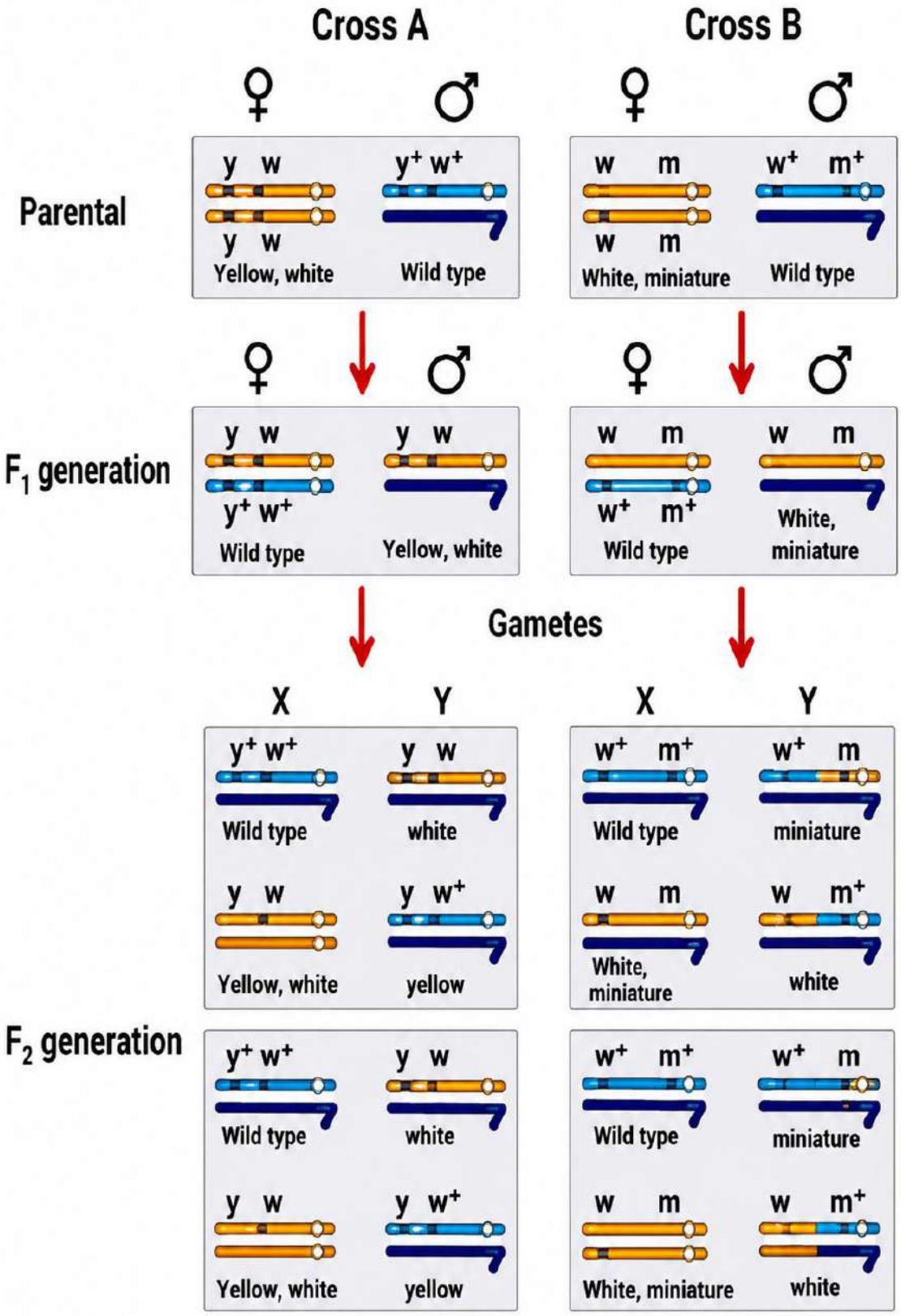
A	B
Occur in pairs	*Occur in pairs*
Segregate at the time of gamete formation such that only one of each pair is transmitted to a gamete	*Segregate at gamete formation and only one of each pair is transmitted to a gamete*
Independent pairs segregate independently of each other	*One pair segregates independently of another pair*
Can you tell which of these columns A or B represent the chromosome and which represents the gene? How did you decide?	

A – Gene, B- Chromosome

LINKAGE AND RECOMBINATION

Thomas Hunt Morgan, experimentally verify the chromosomal theory of inheritance. Morgan worked with tiny fruit flies, *Drosophila melanogaster.* Morgan selected fruit fly, *Drosophila melanogaster* for his experiments because:

(a) They could be grown on simple artificial medium in the laboratory.
(b) Their life cycle is only about two weeks.
(c) A single mating could produce a large number of flies.
(d) There was a clear differentiation of the sexes, i.e. male (smaller) and female (bigger).
(e) It has many types of hereditary variation that can be easily seen through low power microscopes.



The physical association of two genes on a chromosome is called **linkage**.

- **Recombination** explains the generation of non-parental gene combinations.
- To explain the phenomena of linkage and recombination, Morgan carried out several dihybrid crosses in Drosophila to study genes that were sex-inked, i.e. the genes are located on X chromosome. He observed that two genes did not segregate independently of each other.
- He observed that the proportion of parental gene combinations were much higher than the non-parental type, when two genes in a dihybrid cross were situated on the same chromosome. Morgan concluded this a physical association or linkage.
- Morgan and his group also found that even when genes were grouped on the same chromosome, some genes were very tightly linked (very low recombination), while others were loosely linked (higher recombination).
- Recombination of linked genes is by crossing over (exchange of corresponding parts between the chromatids of homologous chromosomes). Linkage results of two dihybrid crosses conducted by Morgan. Cross 'A' shows crossing between genes y and w. Cross 'B1 shows crossing between genes w and m. Here, dominant wild type alleles are represented with (+) sign.
- Alfred Sturtevant (Morgan's student) used the frequency of recombination between gene pairs on the same chromosome as a measure of the distance between genes and 'mapped' their position on the chromosome.
- The unit of distance between genes is the centimorgan (cM), often referred to as a map unit (m.u.). One centimorgan is equivalent to a 1% chance of recombination frequency, not physical distance in base pairs.

POLYGENIC INHERITANCE/QUANTITATIVE INHERITANCE

- In this inheritance pattern, traits are controlled by more than two genes. These traits are called polygenic traits.
- The phenotype shows participation of each allele and is also influenced by the environment and is called quantitative inheritance as the character/phenotype can be quantified
- Example, human skin colour which is caused by a pigment melanin. The quantity of melanin is due to three pairs of polygenes (A, B and C). If it is black or very dark (AA BB CC) and white or very light (aa bb cc) individuals marry each other, the offspring shows intermediate colour often called mulatto (Aa Bb Cc).

PLEIOTROPY

- It is the phenomenon in which a single gene exhibits multiple phenotypic expressions.
- A single pleiotropic gene may produce more than one effect. For example-Phenylketonuria, a disorder caused by mutation in the gene coding the enzyme phenylalanine hydroxylase. The affected individuals show hair and skin pigmentation and mental problems.

1. Difference between Multiple allelism and Pleiotropy

Multiple allelism	Pleiotropy
It is the phenomenon in which a gene for a trait exists in more than two allelic forms. The alleles can show codominance. e.g. the gene for human blood groups exists in three allelic forms, I^A, I^B and i.	It is the phenomenon of the ability of a single gene to have more than one phenotypic effect. Codominance is not exhibited. e.g. a single gene in garden pea controls seed shape and size of starch grains.

2. Difference between Multiple allelism and Polygenic inheritance.

Basis	Multiple Allelism	Polygenic Inheritance
Definition	A trait controlled by more than two alleles of a single gene	A trait controlled by many genes acting together
Number of genes involved	Only one gene	Two or more genes
Number of alleles	More than two alleles exist in a population	Usually, two alleles for each gene pair
Effect on trait	Produces different forms of a trait	Produces continuous variation in a trait
Pattern of inheritance	Follows Mendelian inheritance with multiple alleles	Shows additive effect of genes

SEX DETERMINATION

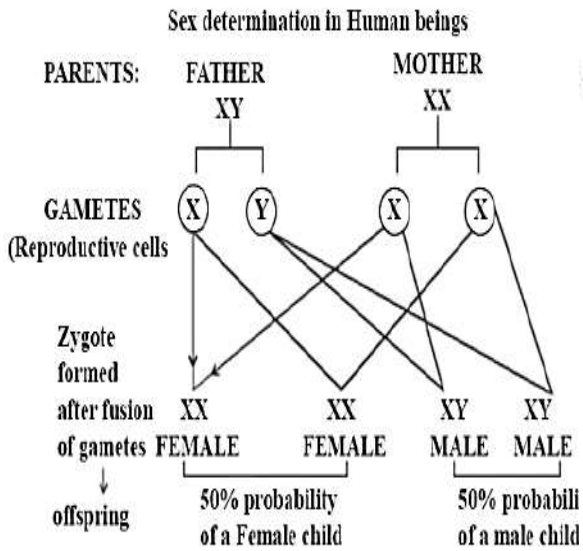
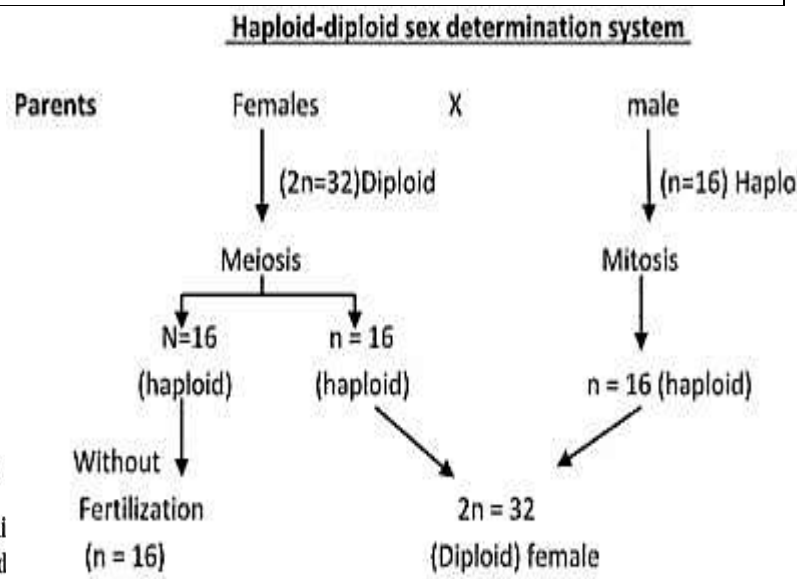
- Finalization of sex at the time of zygote formation is called sex determination.

I. **XX-XY type**	II. **XX-XO type**	III. **ZZ-ZW type**
This type of sex determination seen in mammals including humans. Males have X and Y chromosomes along with autosomes and females have a pair of X chromosomes. Male heterogamety: Males produce two different types of gametes in term of the sex chromosomes.	This type of sex determination seen in grasshopper(insect). Males have only one X chromosomes along with autosomes and females have a pair of X chromosomes.	This type of sex determination seen in birds (eg.- fowl). Females have one Z and one W chromosome whereas males have a pair of Z chromosomes. Female heterogamety: Females produce two different types of gametes in term of the sex chromosomes.

MUTATION

- Mutation is a phenomenon which results in alteration of DNA sequences and consequently results in changes in the genotype and the phenotype of an organism.

- The sudden, stable, inheritable change in genetic material of an organism is termed as mutation.
- The organism which undergoes mutation is called mutant.
- The agent of mutation is called mutagen. E.g., UV radiations and some chemicals.
- When mutation takes place due to change in a single base pair of DNA is called point mutation. E.g., Sickle-cell anaemia.
- When mutation takes place due to deletion or insertion of a segment of DNA, alteration of chromosomes is called chromosomal aberration. It's common in cancer cells.

SEX DETERMINATION IN HUMANS	SEX DETERMINATION IN HONEYBEE
	

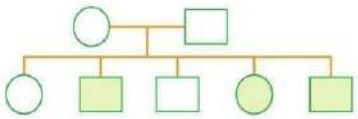
Q.5 Assertion (A): In honey bees, female is diploid and male is haploid.
Reason (R): Gametes are formed by meiosis in female and by mitosis in male.

PEDIGREE ANALYSIS

The study of Inheritance of genetic traits in several generations of human family in the form of a family tree diagram is called pedigree analysis.

- It helps in genetic counselling to avoid disorders.
- It shows the origin of trait and flow of trait in a family.
- It is possible to know the expressive recessive allele that can cause genetic disorders.
- It predicts the harmful effects of marriage between close relatives.

Q.6 The pedigree chart given below, present a particular generation which shows a trait irrespective of sexes (*i.e.*, present in both male and female). Neither of the parents of the particular generation shows the trait. Draw your conclusion on the basis of the pedigree.



GENETIC DISORDERS

Genetic disorders may be grouped into two categories Mendelian disorders and chromosomal disorders.

MENDELIAN DISORDERS

Mendelian disorders are mainly caused due to the alteration or mutation in the single gene.

Haemophilia	• Sex linked (X-linked) recessive disease. • Blood clotting protein is affected • The disease is controlled by two alleles, X^H (normal) & X^h (haemophilic). • In females haemophilia is very rare because it happens only when mother is atleast carrier and father haemophilic.
Colour blindness	• It is a sex-linked (X-linked) recessive disorder. • It results in defect in either red or/and green cone cells of eye, resulting in failure to determinate between red and green colour. • The gene for colour blindness is present on X-chromosome. • It is observed more in males (X^cY) because of presence of only one X-chromosome in males as compared to two X chromosomes in female.
Sickle-cell anaemia	• Autosome linked recessive disease. (RBC becomes sickle shape) • Homozygous dominant (Hb^AHb^A): normal • Heterozygous (Hb^AHb^S) carrier for sickle cell trait • Homozygous recessive (Hb^SHb^S):affected • It is due to substitution of Glutamic acid by Valine at the 6th position of the β-globin chain of the haemoglobin molecule. • It is due to the single base substitution at the sixth codon of the beta globin gene from GAG to GUG
Thalassemia	• It is an autosome-linked recessive disease. • It is due to a mutation which results in reduced synthesis of α or β globin chains of haemoglobin. It forms abnormal haemoglobin and causes anaemia. • Based on the chain affected, thalassemia is 2 types: (i) α Thalassemia: Here, production of α globin chain is affected. It is controlled by two closely linked genes HBA1 & HBA2 on chromosome 16 of each parent. Mutation or deletion of one or more of the four genes causes the disease. (ii) β Thalassemia: Here, production of β globin chain is affected. It is controlled by a single gene HBB on chromosome 11 of each parent. **Thalassemia is a quantitative problem (synthesize very less globin molecules). Sickle-cell anaemia is a qualitative problem (synthesize incorrectly functioning globin).**

Phenylketonuria	● It is an in born error of metabolism and is inherited as the autosomal recessive trait. ● The affected individual lacks an enzyme called phenylalanine hydroxylase that converts the amino acid phenylalanine into tyrosine in liver. ● Phenylalanine is accumulated and converted into phenyl pyruvic acid and other derivatives. This affects the brain results in mental retardation. These are also excreted through urine because of its poor absorption by kidney.

Chromosomal Aberration:

1.Loss (deletion) or gain (insertion/ duplication) of DNA segment cause Chromosomal abnormalities (aberrations).

2.When there is a change in chromosomal number that leads to

a. Aneuploidy-Gain or loss of one or two chromosomes (due to failure of chromosome separation during meiosis)

This may be i.Nullisomy- 2n – 2 ii. Monosomy-2n – 1

iii. Trisomy- 2n + 1 iv. Tetrasomy-2n + 2

b. Polyploidy-Gain of one or more sets of chromosomes. It may be

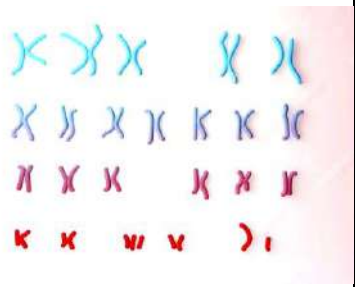
i. Triploidy- 2n + n ii. Tetraploidy- 2n + 2n

Karyotype

A **karyotype** is the complete set of chromosomes of an organism, arranged in pairs according to their size, shape, and position of the centromere.

Karyotyping helps in:

- detecting genetic disorders
- studying evolution
- identifying species
- prenatal diagnosis



Q.7 Study the karyotype image and answer the following questions:

a. **Identify the chromosomal disorder.**
b. **Name the chromosomal anomaly observed.**
c. **Mention two symptoms of the disorder.**
d. **Is this a Mendelian or chromosomal disorder? Justify your answer**

Example Disorders Detected by Karyotyping (Also example of Chromosomal Aberration/ Aneuploidy**) is as followings -**

Down's syndrome	● Down's syndrome is caused by an extra copy of chromosome number 21 (trisomy of 21). ● This disorder was first discovered by Langdon Down (1866). ● Short statured with small round head. ● Partially open mouth with protruding furrowed tongue. ● Palm is broad with characteristic palm crease. ● Physical, psychomotor and mental development is retarded.
Klinefelter's syndrome	● Klinefelter's syndrome is caused by the presence of an additional copy of X-chromosomes, resulting in the karyotype of 44+XXY. ● Sex of the individual is masculine but possess feminine characters.

	● Gynaecomastia i.e., development of breasts. ● Poor beard growth and sterile. ● Feminine pitched voice
Turner's syndrome	● Turner's syndrome is caused by the absence of one of the X-chromosomes. i.e., 44+XO ● Sterile female with rudimentary ovaries. ● Shield shaped thorax. ● Short stature and webbed neck. ● Poor development of breasts.

Flow Chart Of The Chapter

PRINCIPLES OF INHERITANCE AND VARIATION

1 Genetics

- Study of heredity and variation
- Heredity = passing traits from parents to children
- Variation = differences among offspring

2 Gregor Mendel – Father of Genetics

- Worked on pea plants
- Chose 7 contrasting traits
- Used true breeding plants
- Gave Laws of Inheritance

3 Important Terms

- Gene → unit of inheritance
- Alleles → different forms of same gene
- Genotype → genetic makeup (TT, Tt)
- Phenotype → visible character (Tall)
- Homozygous → same alleles (TT, tt)
- Heterozygous → different alleles (Tt)

4 Monohybrid Cross

Tall (TT) X Dwarf (tt)

- Cross involving one trait
- Example: Tall × Dwarf pea plant
- F_1 generation → all Tall (Tt)
- F_2 generation → 3 Tall : 1 Dwarf

5 Mendel's Laws

Law of Dominance
- Dominant trait appears in F_1
- Recessive trait remains hidden

Law of Segregation
- Alleles separate during gamete formation
- Each gamete gets only one allele

Tt → T, t

Law of Independent Assortment
- Two traits assort independently
- Dihybrid ratio = 9 : 3 : 3 : 1

6 Dihybrid Cross

Round Yellow (RRYY) X Wrinkled Green (rryy)

- Cross involving two traits
- F_1 generation → all Round Yellow (RrYy)
- F_2 generation → 9 : 3 : 3 : 1

9 Round Yellow | 3 Round Green | 3 Wrinkled Yellow | 1 Wrinkled Green

7 Types of Dominance

Complete Dominance
Tall over dwarf

Incomplete Dominance
Red × White flower
Pink flower in F_1

Co-dominance
Both alleles express equally
Example: AB blood group

8 ABO Blood Group

- Alleles = I^A, I^B, i
- I^A and I^B are co-dominant
- Blood Groups:

A	B	AB	O
I^AI^A or I^Ai	I^BI^B or I^Bi	I^AI^B	ii

9 Chromosomal Theory of Inheritance

- Given by Sutton and Boveri
- Genes are present on chromosomes
- Chromosomes carry hereditary information

10 Linkage and Recombination

- Linked genes stay together
- Recombination forms new combinations
- Morgan worked on Drosophila (fruit fly)

11 Polygenic Inheritance

- Trait controlled by many genes
- Examples:
  - Human skin colour
  - Human height
- Environment also affects

12 Pleiotropy

- One gene controls many traits
- Example: Phenylketonuria (PKU)

13 Sex Determination

Humans:
Female XX | Male XY

- Father determines sex of child
- 50% chance of boy or girl

14 Mutation

- Sudden change in DNA
- Creates variation
- Point mutation → change in one base
- Example: Sickle cell anaemia

15 Genetic Disorders

Mendelian Disorders (single gene)
- Haemophilia
- Colour blindness
- Sickle-cell anaemia
- Thalassemia
- Phenylketonuria

Chromosomal Disorders
- Down's Syndrome → Trisomy 21
- Turner's Syndrome → XO
- Klinefelter's Syndrome → XXY

16 Pedigree Analysis

- Study of family inheritance pattern
- Used to trace genetic diseases

CHAPTER: 5 MOLECULAR BASIS OF INHERITANCE

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

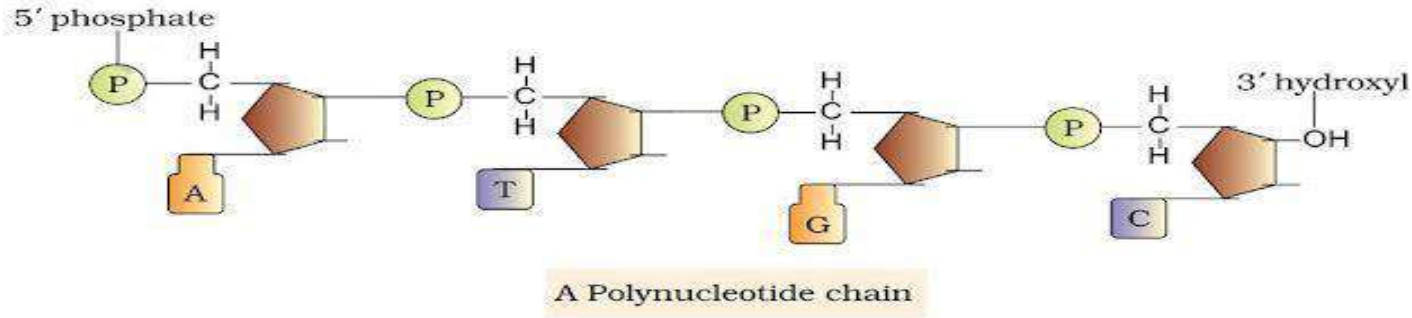
CBSE Syllabus (2026-27): Marks (8-10) : Search for genetic material and DNA as genetic material; Structure of DNA and RNA; DNA packaging; DNA replication; Central Dogma; transcription, genetic code, translation; gene expression and regulation - lac operon; Genome, Human and rice genome projects; DNA fingerprinting.

DNA and RNA are two nucleic acids. The DNA is a long polymer of deoxyribonucleotides. A pair of nucleotides is also known as base pairs. Length of DNA is usually defined as number of nucleotides present in it. E. coli has 4.6×10^6 bp and haploid content of human DNA is 3.3×10^9bp. ϕ X 174 virus has 5,386 bp nucleotides

Structure of Polynucleotide Chain

Component	Specific Variants	Functional Role
Pentose Sugar	Ribose (RNA) or 2'-Deoxyribose (DNA)	Structural framework; the absence of the 2'-OH group in DNA increases chemical stability.
Nitrogenous Base	Purines (Adenine, Guanine); Pyrimidines (Cytosine, Thymine, Uracil)	The primary information carrier. Note: **Thymine is 5-methyl uracil**, a modification that enhances DNA's resilience.
Phosphate Group	Linked to the 5'-OH of the pentose sugar	Provides the acidic nature and forms the repeating backbone via phosphodiester linkages.

A polynucleotide chain



- A nitrogenous base is linked to pentose sugar with N-glycosidic linkage to form a nucleoside. When phosphate group is linked to 5'-0H of a nucleoside through phosphoester linkage nucleotide is formed. Two nucleotides are linked through 3'-5' phosphodiester linkage to form dinucleotide. More nucleotide joins together to form polynucleotide.

Structural differences

DNA	RNA
a) The sugar present in DNA is deoxyribose.	(a)The sugar present in RNA is ribose.
(b) DNA contains cytosine and thymine as pyrimidine bases and guanine and adenine as purine bases.	(b) RNA contains cytosine and Uracil as pyrimidine bases and guanine and adenine as purine bases.
(c) DNA has double stranded-helix structure.	(c) RNA has a single stranded helix structure.
(d) DNA molecules are very large their molecular mass may vary from **6X10^6 - 16X10^6 µ.**	(d) RNA molecules are comparatively much smaller with molecular mass ranging from 20,000 -40,000.

Functional differences

(a) DNA has unique property of replication.	(a) RNA usually does not replicate
(b) DNA controls the transmission of hereditary effects.	(b) RNA controls the synthesis of proteins
(c) DNA is genetic material in all organism except RNA Virus	(d) RNA is genetic material in RNA Virus

Double Helix Model for Structure of DNA-

James Watson and Francis Crick, based on X-ray diffraction data produced by Maurice Wilkins and Rosalind proposed this model of DNA. The salient features of this model are-

Salient Features of the Double Helix

1. **Dual Polynucleotide Chains:** The structure consists of two strands where the sugar-phosphate backbone is situated on the exterior and the nitrogenous bases project inward.
2. **Anti-parallel Polarity:** The strands run in opposite directions (one 5'→3', the other 3'→5').
3. **Strict Complementary Base Pairing:** Adenine (A) pairs with Thymine (T) via two hydrogen bonds; Guanine (G) pairs with Cytosine (C) via three hydrogen bonds. This ensures a purine always faces a pyrimidine.
4. **Right-Handed Helical Coiling:** The polymer twists in a right-handed fashion.
5. **Thermodynamic Stability:** The helix is stabilized by H-bonds and the stacking of base pair planes, which protects the genetic code from chemical insult.

A structural visualization of DNA reveals a "twisted ladder" with highly conserved dimensions:

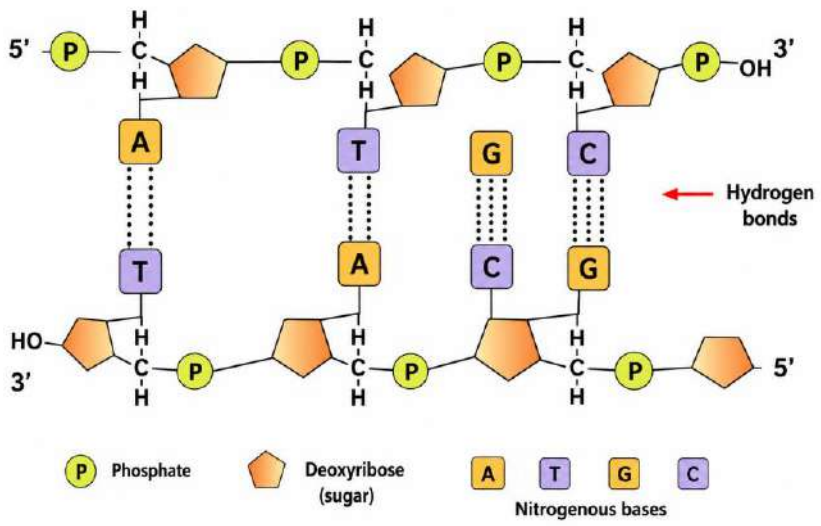
- **Pitch of the Helix:** 3.4 nm per complete turn.
- **Base Pair Frequency:** Approximately 10 base pairs per turn.
- **Rise per Base Pair:** The vertical distance between consecutive base pairs is 0.34 nm.

- **Strand Distance:** The purine-pyrimidine pairing ensures a constant distance between the two backbones.

Analytical Significance: Chargaff's Rule

Chargaff's Rule—stating that the ratios of A:T and G:C are equal to one—is the cornerstone of the model. **A+G=T+C**

This complementarity provides a built-in mechanism for high-fidelity copying: the sequence of one strand automatically dictates the sequence of the other



Q.1 DNA is a polymer of nucleotides which are linked to each other by 3'→ 5' phosphodiester bond. To prevent polymerisation of nucleotides, which of the following modifications would you choose?

Central Dogma in Molecular Biology:

Francis Crick proposed the Central dogma in molecular biology, which states that the genetic information flows from DNA-----> RNA--------> Protein.

Special case For Retro virus

Viral RNA--------> DNA-----> RNA ----->Protein.

DNA Packaging

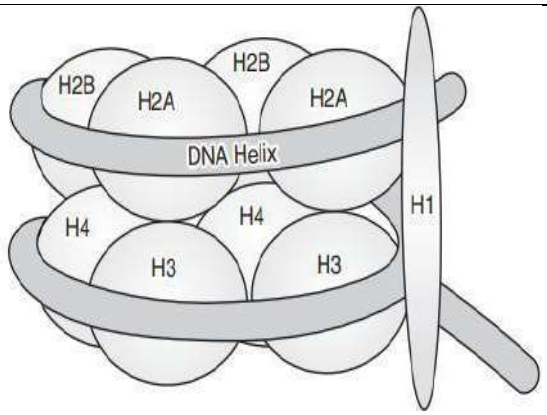
The distance between two consecutive base pairs as 0.34 nm (0.34×10–9 m), if the length of DNA double helix in a typical mammalian cell is calculated (simply by multiplying the total number of bp with distance between two consecutive bp, that is, 6.6 × 109 bp ×0.34 × 10-9m/bp), it comes out to be approximately 2.2 meters. A length that is far greater than the dimension of a typical nucleus (approximately 10^{-6} m).

Prokaryotic vs. Eukaryotic Models

- **Prokaryotes (e.g., E. coli):** Lacking a nucleus, the negatively charged DNA is organized into large loops held by positively charged proteins in a region called the **nucleoid**.

  Eukaryotes: Utilize a sophisticated system involving **histones**, which are basic proteins rich in the positively charged amino acids **lysine** and **arginine**. Histones protein organized to form 8 molecules

unit called histone octamer. Negatively charged DNA is wrapped around the histone octamer to form nucleosome. Single nucleosome contains about 200 base pairs. Chromatin is the repeating unit of nucleosome.



Packaging (Process Flow)

1. **Wrapping:** Negatively charged DNA wraps around a **Histone Octamer** (8 molecules).
2. **Nucleosome Formation:** This core unit encompasses approximately **200 bp** of DNA.
3. **"Beads-on-String":** Repeating nucleosomes form the basic structure of **chromatin**.
4. **Coiling:** Chromatin fibers coil and condense further with **Non histone chromosomal protein (NHC)**
5. **Metaphase Chromosome:** Maximum condensation reached during cell division.

Q.2 A researcher observed chromatin under an electron microscope and found that it appeared like a "string of beads." Each bead represented a nucleosome formed by DNA associated with specific proteins. Based on this observation, identify the correct composition of each bead-like structure.

Seach for genetic material

Griffith's Transforming Principle (1928)

Frederick Griffith's "transforming principle" refers to the specific substance derived from dead bacteria that is capable of permanently altering the genetic characteristics of a living recipient bacterium.

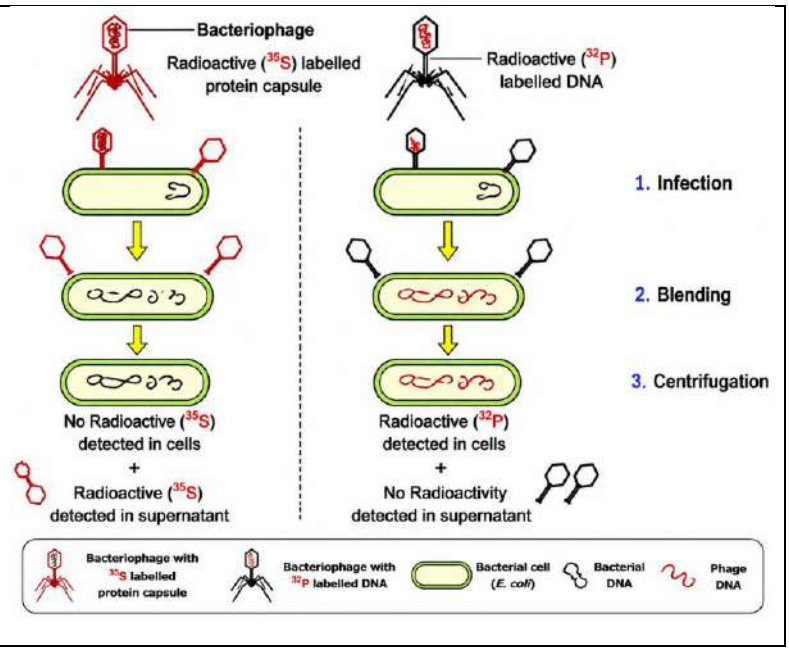
S strain	Inject → mice	→ died	
R strain	Inje → to mice	→ lived	
S strain(heat-killed)	Inje → to mice	Mi → ved	
S strain(heat-killed) + R strain(live)	In → in to mice	→ e died	

- **Avery, MacLeod, and McCarty (1933-44):** Through systematic enzymatic digestion, they showed that **Proteases** and **RNases** did not inhibit transformation, but **DNase** did. This identified DNA as the biochemical basis of the transforming principle.

Hershey-Chase Experiment (1952)

Using bacteriophages, they labeled viral protein with S^{35} and viral DNA with P^{32}. After infection and centrifugation, only P^{32} was found within the bacteria. His experiment shows that protein does not enter the bacterial cell and only DNA is the genetic material.

Note-Sulphur is the component of protein and phosphorus is component of DNA



Q.3 a. State the 'Central dogma' as proposed by Francis Crick. Are there any exceptions to it? Support your answer with a reason and an example.

b. Explain how the biochemical characterization (nature) of 'Transforming Principle' was determined, which was not defined from Griffith's experiments.

Properties of Genetic Material:

a) It should be able to generate its replica (replication)

b) It should chemically and structurally be stable.

c) It should provide the scope for slow changes (mutation) that are required for evolution.

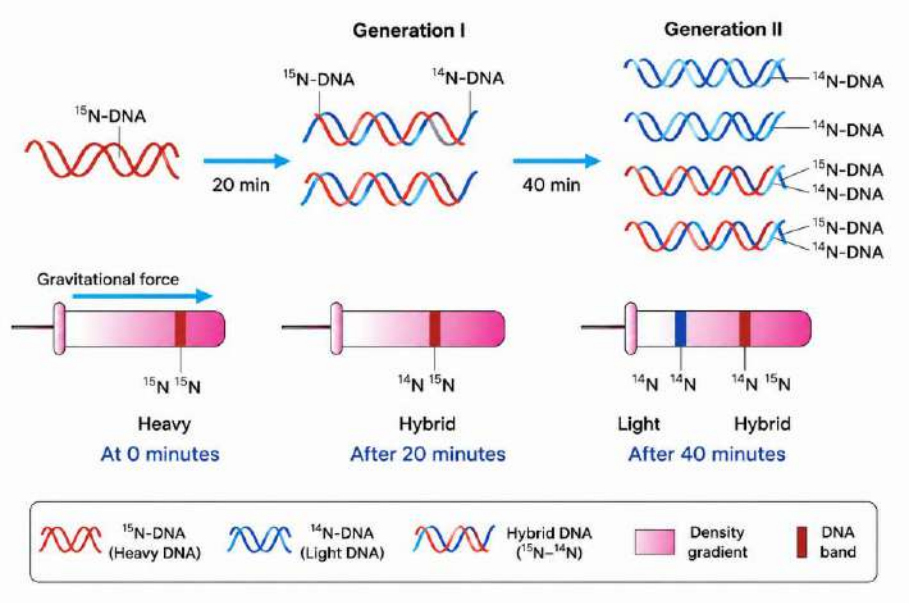
d) It should be able to express itself in the form of 'Mendelian Characters'.

DNA is better choice as genetic material because its chemically less reactive but structurally more stable as compare to RNA.
RNA is used as genetic material as well as catalyst, more reactive so less stable. Therefore, DNA has evolved from RNA.

Semiconservative mode of Replication of DNA

Meselson and Stahl's shows experimental evidence of semi conservative replication by growing E. coli on nutrient media containing nitrogen salts ($^{15}NH_4Cl$) labelled with heavy isotope ^{15}N.^{15}N was incorporated into both the strands of DNA and such a DNA was heavier than the DNA obtained from E. coli grown on a medium containing ^{14}N.Then they transferred E. coli cells on to a medium containing ^{14}N.

- After one generation, when one bacterial cell has multiplied into two, they isolated the DNA and evaluated its density. Its density was intermediate between that of the heavier ^{15}N-DNA and the lighter ^{14}N-DNA.
- This is because during replication, new DNA molecule with one ^{15}N-old strand and a complementary ^{14}N-new strand was formed (semi-conservative replication) and so its density is intermediate between the two.



Generation	No. of DNA	Strand	Heavy DNA strand	Heavy DNA Percentage
1	1	2	2	100
2	2	4	2	50
3	4	8	2	25

Q.4 A group of biology students performed an experiment similar to the one conducted by Matthew Meselson and Franklin Stahl to study the mode of DNA replication in *E. coli*. The bacteria were first grown in a medium containing heavy nitrogen N^{15} and later shifted to a medium containing normal nitrogen N^{14}. DNA samples were collected after different time intervals and analysed using density gradient centrifugation.

Based on the above case, answer the following questions:

a. **Name the technique used by the scientists to separate DNA molecules containing different isotopes of nitrogen.**
b. **What type of DNA band was observed after one generation (20 minutes) of bacterial growth in the N^{14}medium?**
c. **How many DNA bands were observed after two generations (40 minutes)? Name them.**
d. **Which mode of DNA replication was proved by this experiment? Explain briefly.**

Replication

1. Initiation and Unwinding

- **Origin of Replication (ori):** Replication does not start randomly; it initiates at specific sites called *ori*.
- **Replication Fork:** Because long DNA molecules cannot be fully separated (due to high energy requirements), replication occurs within a small opening called the replication fork.
- **Enzymes:**
  - **Helicase:** Unwinds the helix.
  - **DNA-dependent DNA Polymerase:** The main enzyme that uses a DNA template to catalyze the polymerization of deoxynucleotides.

2. Directionality and Synthesis

The DNA polymerase catalyzes polymerization only in **one direction: 5' to 3'**. This creates a complication at the replication fork:

- **Continuous Synthesis:** On the template strand with polarity 3' to5', replication is continuous. This is the **leading strand**.

- **Discontinuous Synthesis:** On the template strand with polarity 5' to 3', replication is discontinuous. This is the **lagging strand**.
- **Okazaki Fragments:** The small segments produced on the lagging strand.
- **DNA Ligase:** Joins the discontinuously synthesized fragments together.

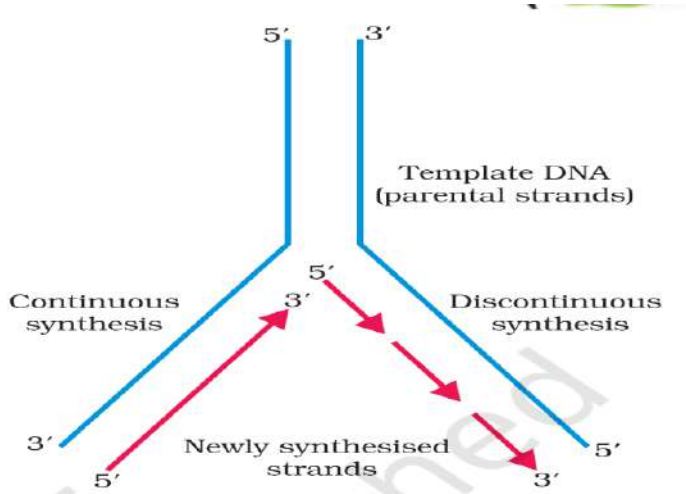


Figure 5.8 Replicating Fork

3. Important Requirements

- **Energy Source:** Deoxyribonucleoside triphosphates (dNTPs) serve a dual purpose: they act as **substrates** and provide **energy** for polymerization (from the two terminal phosphates).
- **Accuracy:** The process must be very fast and highly accurate; any mistake results in mutations.

Differences between leading and Lagging strands for DNA replication.

Characters	Leading strand	Lagging strand
1. Fragments	It is formed continuously as single fragment.	In the beginning it is formed in the form of small fragments called okazaki segments.
2.RNA primer	It requires only one primer to initiate the growth.	Every fragment requires separate RNA primer to initiate.
3.DNA ligase	Not required.	Required to join DNA fragments.
4.Direction of growth	5' 3'	Of complete strand it is 3' 5'. However, for Okazaki fragments it is 5' 3'.

Transcription

- **Definition:** The process of copying genetic information from one strand of DNA into RNA.
- **Scope:** Only a specific segment of DNA and **only one strand** is copied.
- **Why only one strand?**
  1. If both strands were copied, they would produce two different RNA sequences leading to two different proteins from one gene, complicating information transfer.
  2. Two complementary RNA molecules would pair to form **double-stranded RNA**, preventing translation.

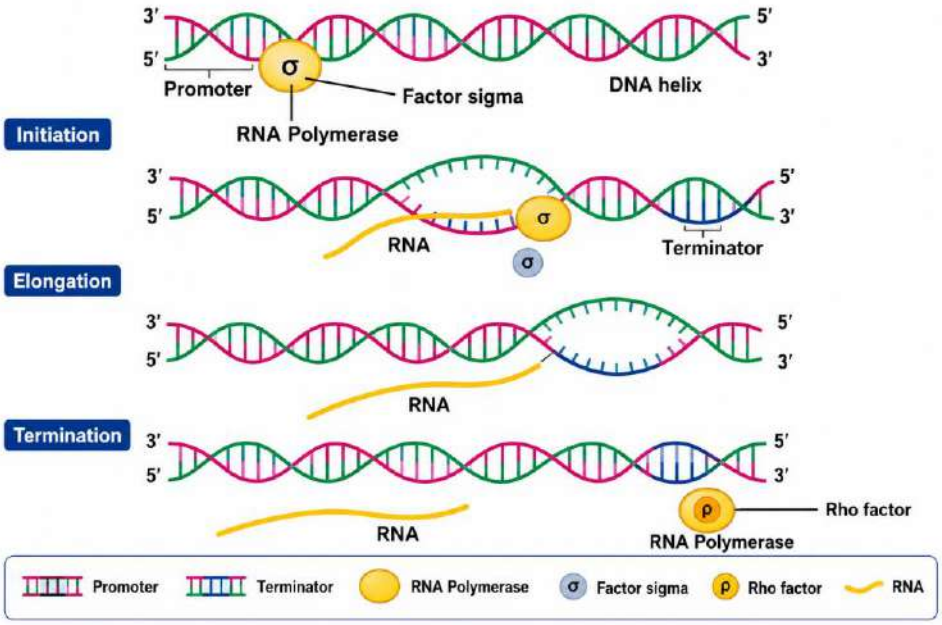
2. The Transcription Unit

1. **Promoter:** Located at the **5'-end (upstream)** of the coding strand. Provides the binding site for **RNA polymerase**.

2. **Structural Gene:** The area between the promoter and terminator being transcribed.
3. **Terminator:** Located at the **3'-end (downstream)** of the coding strand. Defines the end of transcription.

Strand Convention

- **Template Strand:** Polarity **3' to 5'**. Acts as the actual template for RNA synthesis.
- **Coding Strand:** Polarity **5' to 3'**. Its sequence is identical to the produced RNA (except T is replaced by U). All reference points (upstream/downstream) are made relative to this strand.



3. The Process of Transcription in Prokaryotes

Occurs in three steps catalyzed by a single **DNA-dependent RNA polymerase**:

- **Initiation:** RNA polymerase binds to the promoter. It requires the **initiation factor (σ- sigma)** to start.
- **Elongation:** The polymerase moves along the DNA, opening the helix and adding nucleotides.
- **Termination:** Upon reaching the terminator, the nascent RNA and enzyme fall off. This requires the **termination factor (ρ - rho)**.

  Note: In bacteria, transcription and translation are often **coupled** because there is no nuclear membrane and no processing is required.

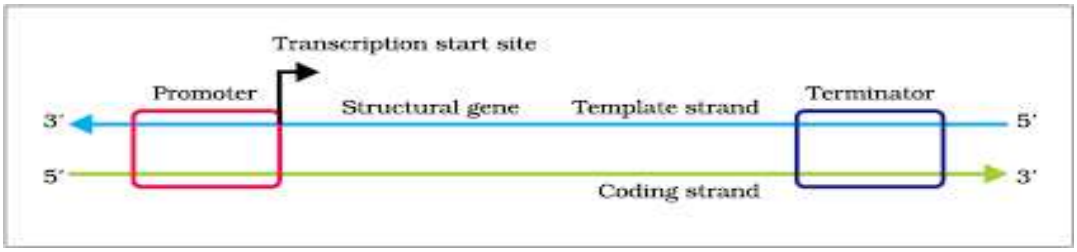
Exons are those sequences that appear in mature and processed RNA. Exons are interrupted by introns. Introns do not appear in mature and processed RNA.

Transcription in Eukaryotes

The Transcription Unit

Defined by three critical regions:

1. **Promoter:** Upstream (5'-end) binding site for RNA polymerase; defines the template/coding strands.
2. **Structural Gene:** The segment coding for a polypeptide (mono cistronic in eukaryotes, polycistronic in bacteria).
3. **Terminator:** Downstream (3'-end) site defining the end of transcription.



Q.5 Both the strands of DNA are not copies during transcription. Give reasons.

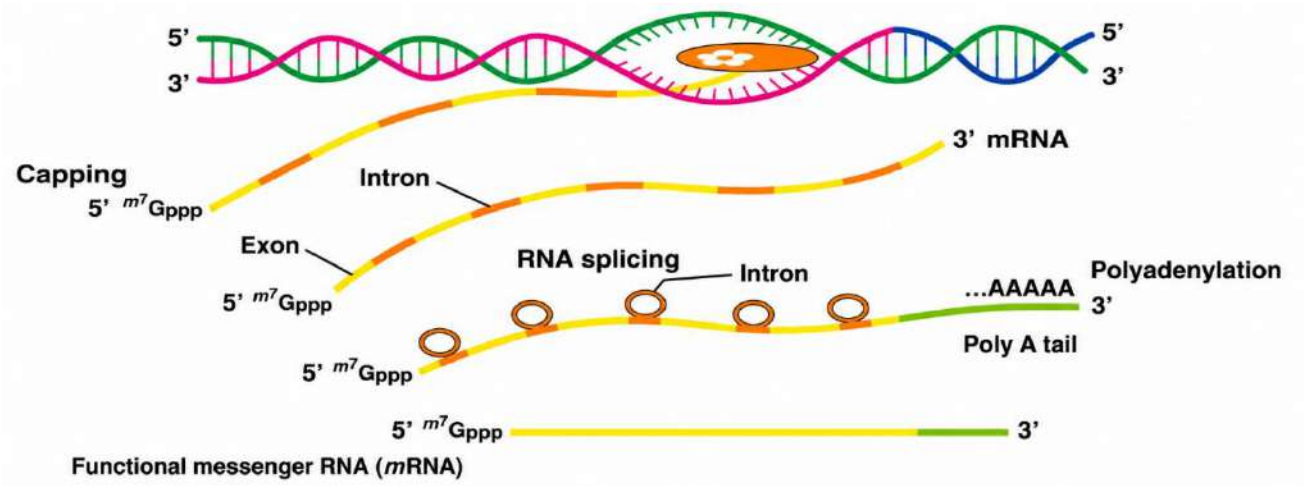
In eukaryotes, there are three different RNA polymerase enzymes I,IIand III, they catalysethe synthesis of all types of RNA.

RNA Pol I: transcribes rRNAs (28S, 18S, 5.8S).

RNA Pol II: transcribes hnRNA (precursor of mRNA).

RNA Pol III: transcribes tRNA, 5srRNA, and snRNAs.

Post Transcriptional Modification in Eukaryotes



- The primary transcript contains both exon and intron and is non-functional. It undergoes the process of splicing in which introns are removed and exons are joined in a defined order.
- The hnRNA (heterogeneous nuclear RNA) undergo additional processing called as capping and tailing. In capping an unusual nucleotide (methyl guanosine triphosphate) to the 5'end of hnRNA. In tailing polyadenylate tail is added at 3' end in a template at independent manner.

Q.6 Protein synthesis requires the services of all three types of RNAs, namely t-RNA, m-RNA and r- RNA. Explain the role of each of them during the process of protein synthesis in prokaryotes.

Genetic Code:

Genetic Code is the relationship of amino acids sequence in a polypeptide and nucleotide /base sequence in hn-RNA. It directs the sequence of amino acids during synthesis of proteins. George Gamow suggested that genetic code should be combination of 3 nucleotides to code 20 amino acids. H.G. Khorana developed chemical method to synthesizing RNA molecules with defined combination of bases. Marshall Nirenberg's cell free system for protein synthesis finally helped the code to be deciphered. Severo Ochoa enzyme (polynucleotide phosphorylase) was also helpful in polymerising RNA with defined sequences in a template independent manner (enzymatic synthesis of RNA).

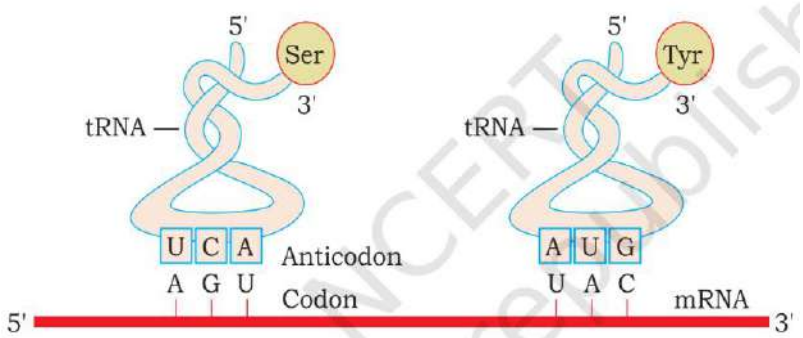
Salient Features:

- **Triplet:** 61 codons code for amino acids; 3 are **stop codons** (UAA, UAG, UGA).

- **Degenerate:** Some amino acids are coded by more than one codon.
- **Contiguous:** Read without punctuations.
- **Universal:** Same from bacteria to humans (with minor exceptions).
- **Initiator: AUG** codes for Methionine and acts as the start codon.

tRNA - The Adapter Molecule:

- Has an **anticodon loop** complementary to the mRNA code.
- Has an **amino acid acceptor end**.
- Secondary structure: clover-leaf; Actual structure: inverted L.



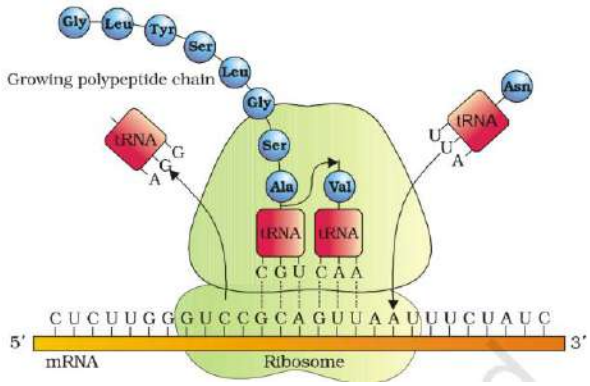
Q.7 Which one is the correct product of DNA dependent RNA polymerase to the template?
3'TACATGGCAAATATCCATTCA5'

Mutations and Genetic code

- Point Mutation: - A change of single base pair (point mutation) in the 6th position of Beta globin chain of Hemoglobin results due to the change of amino acid residue glutamate to valine. These results into diseased condition called sickle cell anemia.
- Frameshift Mutation: -Insertion and deletion of three or its multiple bases insert or delete one or multiple codons hence one or more amino acids and reading frame remain unaltered from that point onwards. Such mutations are called frame-shift insertion or deletion mutations.

Translation process:

1. **Charging of tRNA:** Amino acids are activated (ATP) and linked to tRNA (Aminoacylation).
2. **Initiation:** Small ribosome subunit binds to mRNA at the start codon (AUG).
3. **Elongation:** Ribosome moves codon-to-codon; peptide bonds form between amino acids.
    - **Ribozyme:** 23S rRNA in bacteria acts as a catalyst for peptide bond formation.
4. **Termination:** Release factor binds to the stop codon, releasing the polypeptide.



Regulation of Gene Expression

The Lac Operon (Jacob and Monod)

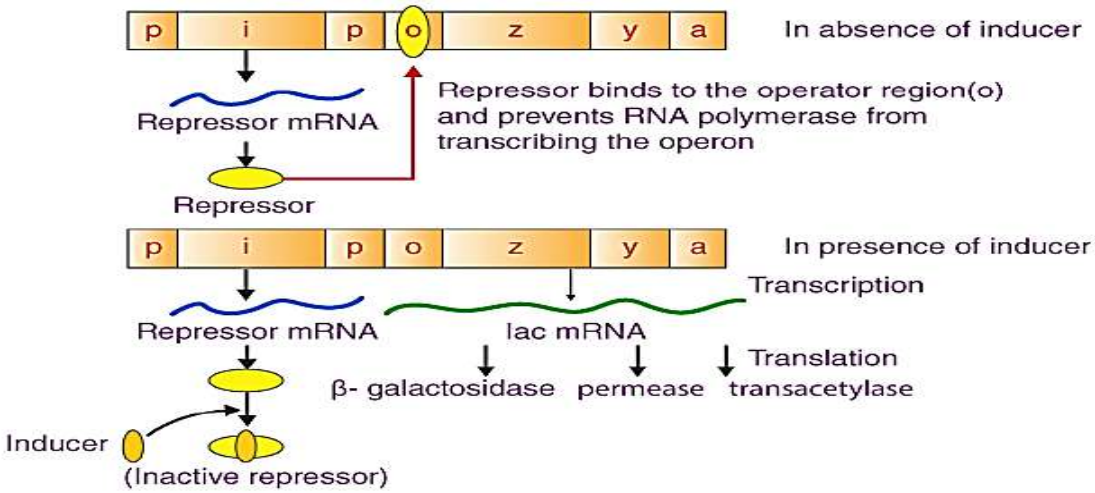
A polycistronic structural gene regulated by a common promoter and regulatory genes.

Components:

- **i gene (inhibitor):** Codes for the repressor protein.
- **z gene:** Codes for beta-galactosidase (hydrolyzes lactose).
- **y gene:** Codes for permease (increases cell permeability to lactose).
- **a gene:** Codes for transacetylase.

Function:

- **Absence of Inducer:** Repressor binds to the **operator**, blocking RNA polymerase.
- **Presence of Inducer (Lactose):** Inducer inactivates the repressor; RNA polymerase accesses the promoter; transcription proceeds.



- Lactose is the substrate for enzyme beta-galactosidase and it regulates switching on and off of the operon, so it is called inducer.
- Regulation of Lac operon by repressor is referred as negative regulation. Operation of Lac operon is also under the control of positive regulation.

Goal of HGP

a) Identify all the genes (20,000 to 25,000) in human DNA.

b) Determine the sequence of the 3 billion chemical base pairs that make up human DNA.

c) Store this information in database.

d) Improve tools for data analysis.

e) Transfer related information to other sectors.

f) To address the legal, ethical and social issues that may arise due to project.

The method involved the two major approaches- first identifying all the genes that expresses RNA called **Express sequence tags (EST).** The second is the sequencing the all set of genomes that contained all the coding and non-coding sequence called **sequence Annotation**. (SA)

Salient features of Human Genome:

a) The human genome contains 3164.7 million nucleotide bases.

b) The average gene consists of 3000 bases, but sizes vary greatly, with the largest known human gene being dystrophin at 2.4 million base pairs.

c) Less than 2 percent of the genome codes for proteins.

d) Repeated sequences make up very large portion of the human genome.

e) Repetitive sequences are stretches of DNA sequences that are repeated many times, sometimes hundred to thousand times.

f) Chromosome 1 has most genes (2968), and the Y has the fewest (231).

g) Scientists have identified about 1.4 million locations where single base DNA differences (SNPs-single nucleotide polymorphism) occur in humans.

DNA finger printing

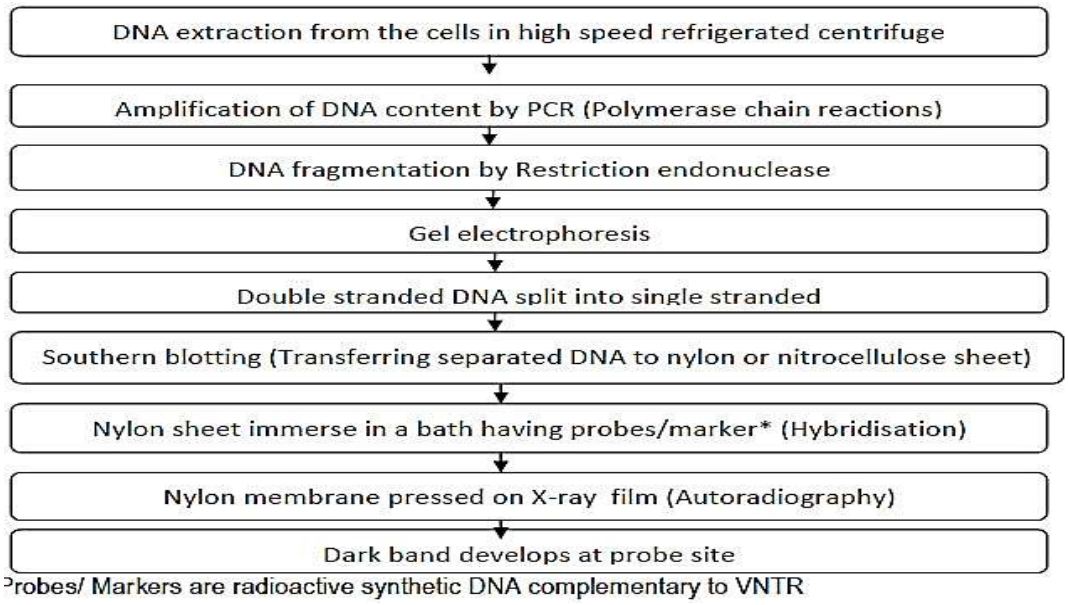
The Basis of DNA Fingerprinting

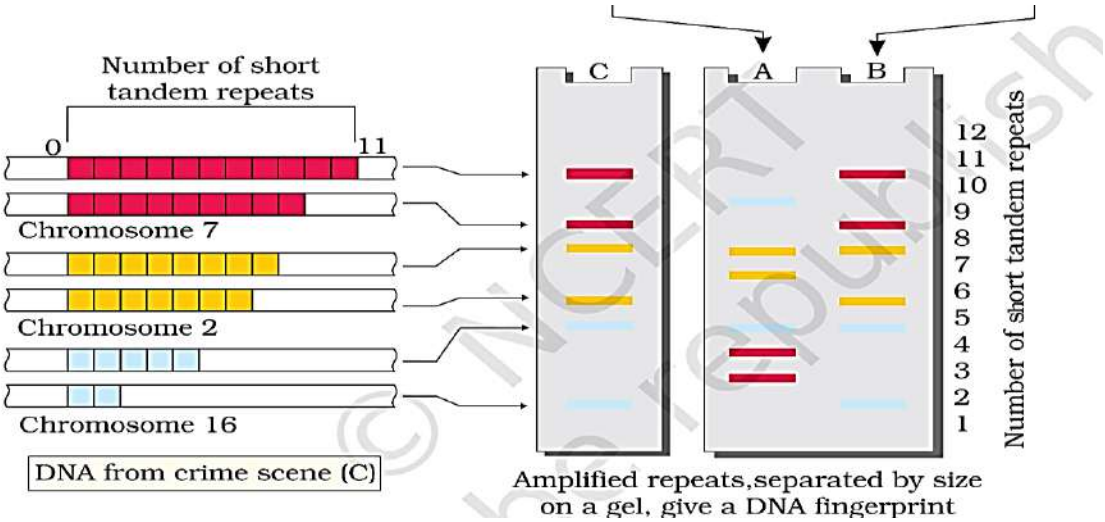
- **Repetitive DNA:** Specific regions where a small stretch of DNA is repeated many times.
- **Satellite DNA:** During **density gradient centrifugation**, repetitive DNA separates from bulk genomic DNA as smaller "satellite" peaks.
    - **Classification:** Based on base composition (A:T vs G:C rich), length, and number of repeats (e.g., **micro-satellites**, **mini-satellites**).
- **Polymorphism:** Variations at the genetic level due to mutations.
    - Found largely in **non-coding DNA** because mutations there don't immediately affect survival/reproduction.
    - Defined as a variation at a locus with a frequency in the population **greater than 0.01**.
    - Inheritable from parents to children, forming the basis for paternity testing.

DNA Polymorphism in Identification

- Every tissue (blood, hair, skin, bone, saliva, sperm) from an individual shows the **same degree of polymorphism**.
- This makes it an ideal tool for forensic applications.
- The pattern is unique to every individual except **monozygotic (identical) twins**.

The Technique (Alec Jeffreys) Initially developed using **VNTR (Variable Number of Tandem Repeats)** as a radiolabelled probe. VNTRs are a type of **mini-satellite**.





Use of DNA Fingerprinting

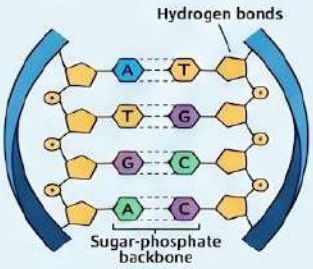
1. Forensic Science and Crime Investigation
2. Paternity and Maternity Disputes
3. Immigration and Family Reunification
4. Medicine and Genetics:
5. Disease Diagnosis
6. Organ Transplantation

7. Wildlife Research and Conservation
8. Anthropology and Biodiversity

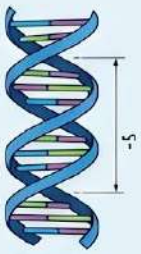
Q.8 a. Name and write two characteristics of the type of DNA that forms the basis of DNA fingerprinting technique.
b. Mention any two applications of this technique.

THE BLUEPRINT OF LIFE:
A GUIDE TO THE MOLECULAR BASIS OF INHERITANCE

DNA STRUCTURE AND PACKAGING

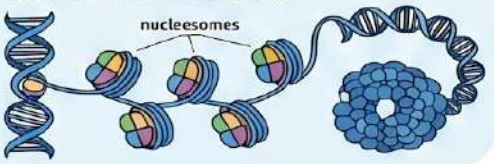


THE WATSON-CRICK DOUBLE HELIX (1955):
Features two ontiperchel chains with a sugar-phosphate backbone and base pairs.



UNIFORM DIMENSIONS:
Pitch of 3.4 nm, ~10 base pairs per turn, 0.34 nm between consecutive pairs.

PACKAGING 2.2 METERS OF DNA

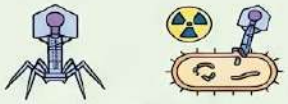


THE SEARCH FOR GENETIC MATERIAL

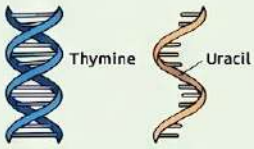
1928

GRIFFITH'S TRANSFORMING PRINCIPLE
Experiments with Streptoxoccus pnoumnnive showed a "transforming principle" could transfer xitulence.

1952



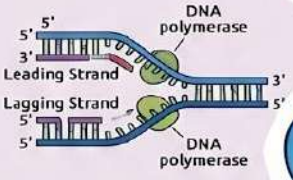
UNEQUIVOCAL PROOF BY HERSHEY AND CHASE
Used rodinective isotopes to prove only DNA enters bacteria to direct viral reproduction.



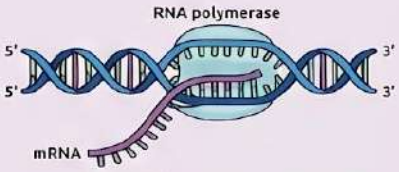
DNA vs. RNA STABILITY
DNA is more steble due to its double-stranded structure and thymine (vs, uracll), despite RNA's likely earher role.

THE CENTRAL DOGMA: REPLICATION & TRANSCRIPTION

SEMICONSERVATIVE REPLICATION
As proved by Meselson and Stahl using heavy nitrogen reli strand and one newly synthesized strand.



THE REPLICATION FORK



TRANSCRIPTION: DNA TO RNA
Genetic information couled from DNA into RNA by RNA polymerase, using complementarity (0 replaces 7).

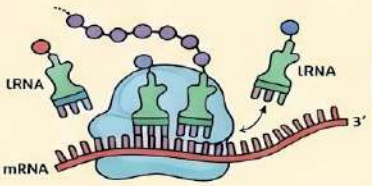
TRANSLATION AND REGULATION

THE TRIPLET GENETIC CODE

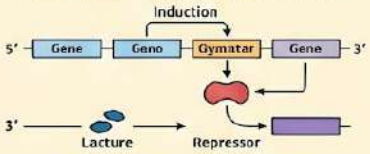
AUG AUC AUG	Generic Base Triplet	UUC UUC UUG	Generic Triplet 2
UUG UUC UUG	Generic Triplet 2	UAC UAC UAG	Generic Triplet 3
GOG GOG GOG	Generic Triplet 5	GGA GGG GGG	Generic Triplet 3

Genetic sede consists of base triplets specifying amino acids, nearly universal ocross organisms.

TRANSLATION: SYNTHESIZING PROTEINS



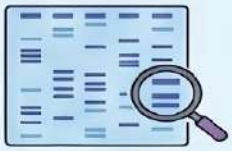
REGULATION AND THE LAC OPERON



Gene expression is highly regulated; exemplified by the cnordmoted lac operon control in bacteria.

GENOMICS AND APPLICATIONS

THE HUMAN GENOME PROJECT (HGP)
A "inage project" to sequence every base in the human genome, opening new eras in genomics and personalized medicine.



DNA FINGERPRINTING
Technique used to identify individuals by analyzing DNA sequence variations (polymerphismc) for forontic science and evolutionary biology.

NotebookLM

CHAPTER: 6 EVOLUTION

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus (2026-27): Marks (3-5) - Origin of life, evolution of life forms-a theory, evidences of evolution, adaptive radiation, biological evolution, mechanism of evolution, Hardy-Weinberg principle, a brief account of evolution, origin and evolution of man.

Condition of early earth:

- The Earth is believed to have been formed about 4.5 billion years back in the solar system of the Milky Way galaxy.
- Water vapor, methane, carbon dioxide and ammonia released from molten mass covered the surface. The UV rays from the sun caused decomposition of water into hydrogen and oxygen. Hydrogen gas being lighter escaped into space.
- Oxygen that remained behind combined with ammonia and methane to form water, CO2 and other compounds. The ozone layer was formed.
- As the water vapor cooled, it fell as rain, to fill all the depressions and form oceans.

Origin of Life (theories):

- Early Greek believed that units of life called **spores** were brought to different planets including earth. This theory is called as **Panspermia** and is still favored by many astronomers.
- For a long time, it was also believed that life could originate from decaying and rotting matter like straw, mud etc.
- This was the **theory of spontaneous generation.** It was disproved by Louis Pasteur by his swan-neck flask experiment.

Q.1 Match the scientists listed under column 'I' with ideas listed column 'II'.

Column I	Column II
A. Darwin	(*i*) Abiogenesis
B. Oparin	(*ii*) Use and disuse of organs
C. Lamarck	(*iii*) Continental drift theory
D. Wagner	(*iv*) Evolution by natural selection

a. **A-(*i*); B-(*iv*); C-(*ii*); D-(*iii*)** ***b.*** **A-(*iv*); B-(*i*); C-(*ii*); D-(*iii*)**
c. **A-(*ii*); B-(*iv*); C-(*iii*); D-(*i*)** ***d.*** **A-(*iv*); B-(*iii*); C-(*ii*); D-(*i*)**

Q.2 A certain species of bacteria became resistant to an antibiotic after repeated exposure to the drug. A student concluded that the bacteria 'developed resistance because they needed to survive'.
Based on the concept of Evolution, answer the following:

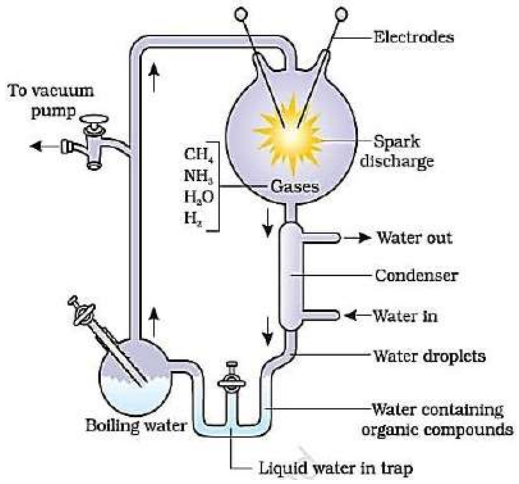
a. **Is the student's conclusion scientifically correct? Give reason.**
b. **Explain how antibiotic resistant bacteria actually become more common in the population through Natural Selection.**

Oparin–Haldane theory of origin of life:

- Oparin of Russia and Haldane of England proposed that the first forms of life originated from pre-existing non- living organic molecules (e.g. RNA, protein etc.).
- Formation of life was preceded by chemical evolution i.e. formation of diverse organic molecule from inorganic constituents.

Urey and Miller Experiment:

- In1953, S.L. Miller, an American scientist demonstrated the same experimentally in a laboratory scale
- Miller observed the synthesis of amino acids from simple inorganic chemicals. He did this by recreating the conditions that were believed to exist on primitive earth in the laboratory.
- In similar experiments formation of sugars,nitrogen bases,pigment and fats were also observed by other scientists.



Diagrammatic representation of Miller's experiment

Theory of Origin of Species by Natural Selection: -

Survival of the fittest: The fitness according to Darwin refers ultimately to the ability to survive a change. Therefore, only the fittest organisms survive and produce more progeny than others.

- These, therefore, have better survival capacities and hence are selected by nature. He called it as natural selection.
- Alfred Wallace, a naturalist who worked in Malay Archipelago had also come to similar conclusions around the same time.

EVIDENCES FOR EVOLUTION

Paleontological evidence:

- Fossils are remains of life-forms found in rocks.
- Different-aged rock sediments contain fossils of different life-forms that probably died during the formation of the particular sediment.
- They represent the extinct organisms (e.g. Dinosaurs).

Biochemical evidences:

- Similarities in proteins and genes performing a specific function among different organisms give clues regarding common ancestry.

Embryological evidence:

- Ernst Heckel proposed this evidence as evolution based on observation of certain common features during embryonic stage of all vertebrates but are absent in adult.
- All vertebrate embryos including human embryo develop a row of vestigial gill slits just behind the head. It is seen that it is a functional organ only in fish. Gills are not found in any other adult vertebrates.

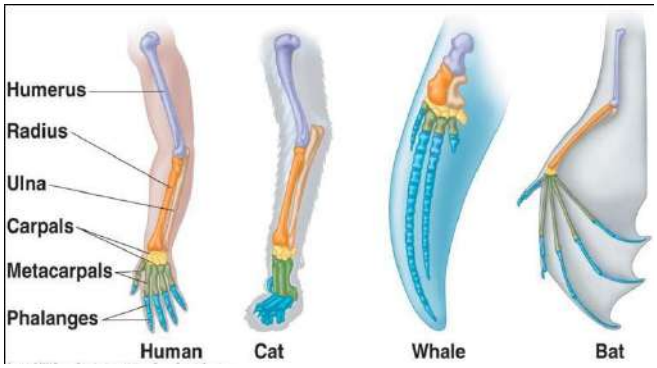
Homologous Organs: Organs that have a similar basic anatomical structure and origin due to common ancestry, but perform different functions based on environmental adaptations.

- Forelimbs of Mammals
- Vertebrate Hearts/Brains
- Thorns and Tendrils

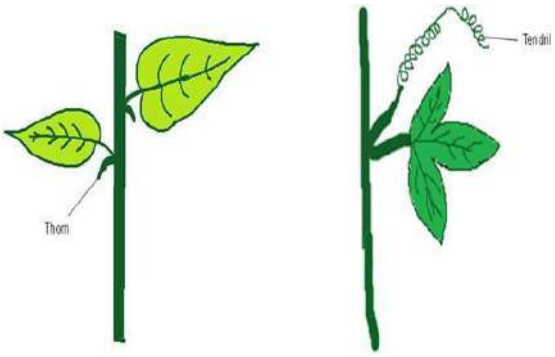
Analogous Organs: Organs that have different anatomical structures and origins but perform similar functions because the organisms have adapted to similar habitats or need.

- Wings of Insects and Birds
- Eyes of Octopus and Mammals
- Flippers of Penguins and Dolphins
- Storage Organs (Sweet Potato and Potato

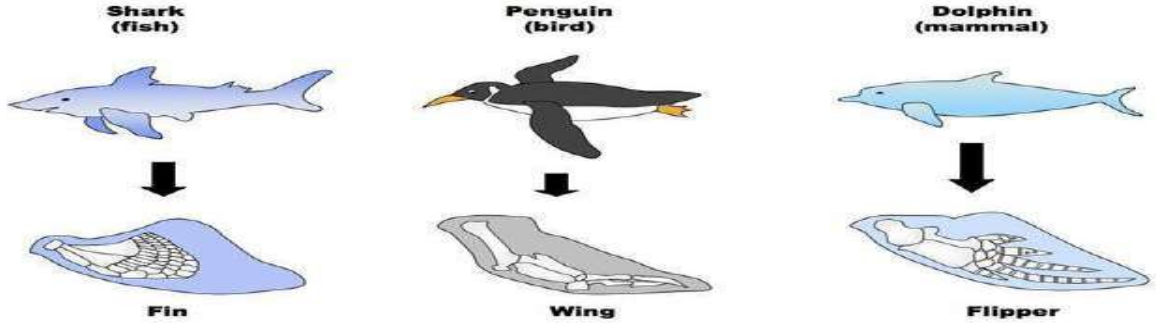
Feature	Divergent Evolution	Convergent Evolution
Basic Definition	Closely related species evolve different traits to adapt to different environments.	Unrelated species evolve similar traits because they live in similar environments.
Type of Organs	Homologous Organs	Analogous Organs
Anatomy	Similar basic internal structure.	Different internal structures.
Function	Different functions.	Similar functions.
Indicates	Common Ancestry.	Adaptation to similar niche.
Animal Examples	Forelimbs: Whale, Bat, Cheetah, and Human (similar bone pattern).	
Plant Examples	Axillary Bud Modifications: Thorns of Bougainvillea and Tendrils of Cucurbita.	Food Storage: Sweet Potato (Root) and Potato (Stem).



Homologous organs: Forelimbs of mammals



Homologous organs in Plants



Evolution by natural selection:

- A popular example is the change in frequency of moth population in England in 1850, phenomenon known as 'industrial melanism'.

- Before industrialization set in more white-winged moths were observed on trees than dark winged or melanized moths as they camouflaged on trees which were covered with light colored lichens.
- After industrialization *i.e.*1920,
- the proportion was reversed as there were more dark-winged moths in the same area as industrial pollution killed lichens and tree trunks became dark. As a result, white-winged moths were unable to camouflage and got eaten by predator birds. Thus, industrial melanism is a classical example of 'natural selection'.

Evolution by anthropogenic action:

Excess use of herbicides, pesticides etc., has resulted in selection of the resistant varieties in a much lesser time scale. This has also been observed for microbes against which we use antibiotics or drugs.

- These are the examples of evolution by **anthropogenic action.**

Q.3 Explain the increase in the numbers of melanic (dark winged) moths in the urban areas of post-industrialisation period in England.

ADAPTIVE RADIATION

Darwin's Finches: Darwin's theory was based on observation of certain birds in the Galapagos Islands. The small black birds he observed have since been called Darwin's Finches.

- He observed that there were many varieties of finches in the same island which were originally adapted with seed-eating features. From these many other forms evolved with altered beaks depending on the food habit.
- This process of evolution of different species in a given geographical area starting from a point and radiating to other areas of geography is called as **adaptive radiation.**

Figure 7.5 Variety of beaks of finches that Darwin found in Galapagos Island

Australian marsupial:

- In Australia it was seen that a number of marsupials had evolved from an ancestral stock.These marsupials were all different from each other.
- When more than one adaptive radiation appears to have occurred in an isolated geographical area (representing different habitats), it can be called as **convergent evolution.**

- **Placental mammals** in Australia were also seen to exhibit adaptive radiation.

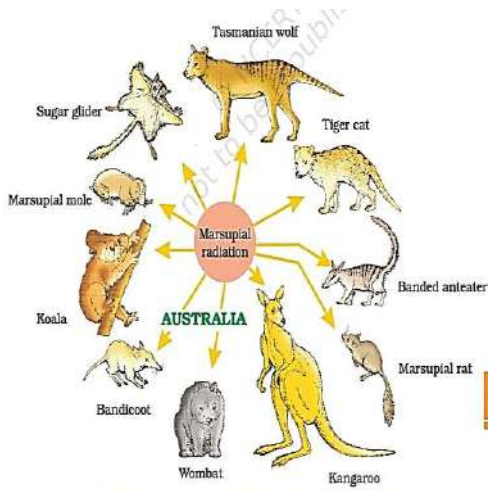
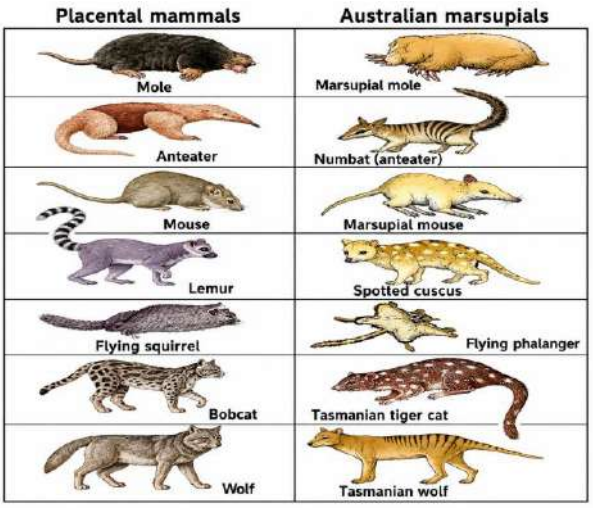


Figure 7.6 Adaptive radiation of marsupials of Australia



BIOLOGICAL EVOLUTION:

- **Natural selection** is the essence of Darwinian Theory about evolution.
- Organisms with favorable variations are better adapted to survive in a hostile environment.
- The key concepts of Darwinism are:

1. **Natural selection:** Survival of the fittest by the nature in face of changing environment.
2. **Theory of Common Descent:** Organisms are descended from common ancestors due to accumulation of variations.
3. **Branching descent theory (Darwin's concept of evolution)** : It explains that all organisms are related through common ancestry. New species arise when populations diverge from a common ancestor over time. This divergence forms a branching pattern, like a tree of life, rather than a straight line. It shows that evolution occurs through gradual splitting and modification of species.

MECHANISM OF EVOLUTION:

- **Hugo de Vries** worked on **evening primrose.** He gave the idea of **mutations**. Mutation is the difference arising suddenly in a population.

Hugo de Vries theory of mutation differs from Darwin's theory of natural selection.

- He stated that mutation causes evolution and not the minor variations that as suggested by Darwin.
- Mutations are sudden, random and directionless while Darwinian variations are small and directional.
- Evolution according to Darwin was slow and gradual whereas Hugo de Vries believed that mutation caused large changes that led to speciation. He therefore called it **saltation** (single step large mutation).

HARDY–WEINBERG PRINCIPLE:

- For given population the frequency of occurrence of alleles of a particular gene present on a specific locus can be calculated.
- This frequency is usually fixed and remains the same throughout different generations.
- Hardy-Weinberg principle expressed the same using algebraic equations. This is called as the

Hardy-Weinberg Principle.

- The principle states that allele frequencies in a population are stable and are constant from generation to generation.
- The **genepool** (total genes and their alleles in a population) remains a constant.This is called **genetic equilibrium**.
- Sum total of all the allelic frequencies is 1.
- The principle can be represented mathematically as follows:
- **$(p+q)^2 = p^2 + 2pq + q^2 = 1$.**
- p and q represent the individual allele frequencies.

  Therefore, p^2= frequency of homozygous condition represented by p

  And q^2 = frequency of homozygous alleles represented by q And pq = frequency of heterozygous condition
- Disturbance in genetic equilibrium (Hardy Weinberg equilibrium) or change of frequency of alleles in a population can then be interpreted as accumulation or change in variations that results in evolution.

  Five factors are known to affect Hardy- Weinberg equilibrium:
- **Gene migration:** When a section of population migrates to another place gene frequencies will change in the original as well as in the new population. New genes /alleles will be added to the new population and the same are lost from the old population.
- **Genetic recombination:** crossing over
- **Gene flow:** When gene migration occurs frequently it is termed as geneflow.
- **Genetic drift:** Change in gene frequency that occurs due to a random event or by chance.
- **Founder effect:** Sometimes the change in allelic frequency is so drastic that in the new sample of population the variants form a different species. The original drifted population from which the variants arose becomes founder species and this effect is called **founder effect**.

Q.4 In a population of 5,000 individuals, 25% show a recessive trait controlled by allele a. The population is in Hardy–Weinberg equilibrium. Calculate:
a. frequency of alleles p and q
b. number of homozygous dominant individuals (AA)
c. number of heterozygous individuals (Aa)

Operation of natural selection on different trait:

- Natural selection can lead to:
  - **Stabilization:** In which more individuals acquire mean character value.
  - **Directional changes**: Occurs when more individuals acquire value other than the mean character value.
  - **Disruption:** more individuals acquire peripheral character value at both ends of the

distribution curve.

A BRIEF ACCOUNT OF EVOLUTION:

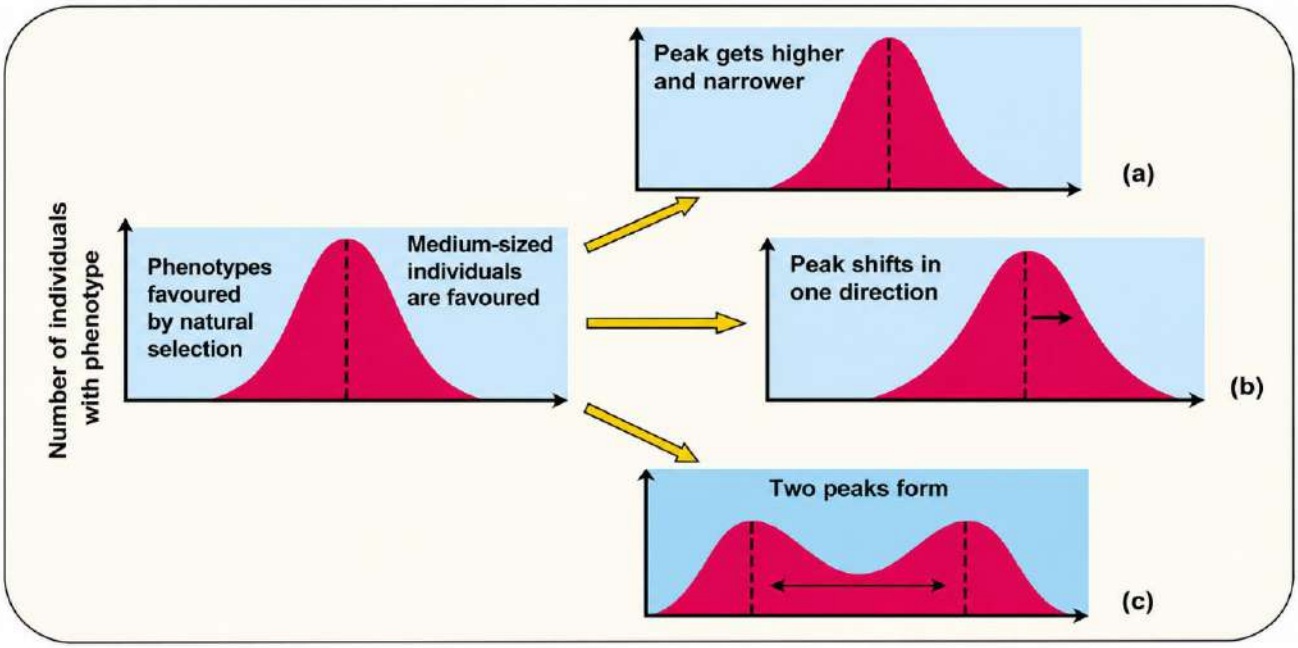
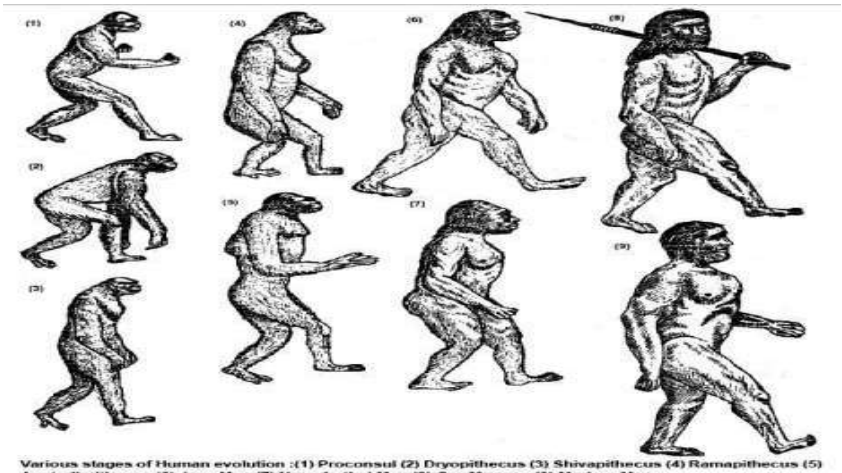


Figure 7.8 Diagrammatic representation of the operation of natural selection on different traits : (a) Stabilising (b) Directional and (c) Disruptive

- Approximately 2000 million years ago (mya) the first forms of life appeared on earth.They were cellular. Certain cellular forms developed the ability to photosynthesize and thus release O_2. The atmosphere slowly became rich in oxygen.This inturn promoted the development and evolution of more aerobic forms of organisms. Slowly and gradually the single cell organisms started to form multi-cellular life forms.

ORIGIN AND EVOLUTION OF MAN:

- About 15 mya primates such as ***Dryopithecus*** and ***Ramapithecus*** existed.They appeared to be similar to gorillas and chimpanzees in their appearance and walking.
- *Ramapithecus* was more similar to man whereas *Dryopithecus* was more similar to apes.
- Few fossils of bones that resemble human bones have been discovered in Ethiopia and Tanzania



Various stages of Human evolution :(1) Proconsul (2) Dryopithecus (3) Shivapithecus (4) Ramapithecus (5) Australbpithecus (6) Java Man (7) Neanderthal Man (8) Cro-Magnon (9) Modern Man

Q.5 Rearrange *Ramapithecus, Australopithecus* and *Homo habilis* in the order of their evolution on the

Earth. Comment on their evolutionary characteristics.

Two mya ***Australopithecines*** existed. They most likely lived in East African grasslands.

- They used stone weapons for hunting.
- Essentially had a fruit-based diet.

- The first human-like organism was the hominid and was called **Homo habilis.**
- Brain capacity was 650–800 cc.
- They also survived on plant-based diet and did not eat meat.

- Fossils discovered in Java in 1891 seemed to be of the next stage i.e. ***Homoerectus***. They evolved about 1.5 mya.
- Had large brain with capacity around 900 cc.
- Probably ate meat.

- **<u>Neanderthal man:</u>**
- Brain size was around 1400cc.
- Lived in east and central Asia between 1,00,000-40,000 years back.
- They developed use of animal hides to protect their body.
- Buried their dead.

- **<u>Homo sapiens:</u>**
  - Arose in Africa and migrated across continents and developed distinct races.
  - During ice age75,000-10,000 years ago modern Homo sapiens arose.
  - Prehistoric cave art developed about 18,000 years ago.
  - Agriculture came around 10,000 years back and human settlement started.

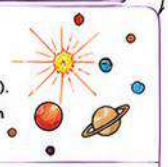
EVOLUTION

Origin of life, Diversity of life and Change over time

1. ORIGIN OF UNIVERSE & EARTH

* Big Bang Theory

- Universe originated from a single point (~13.8 billion years ago).
- Expansion of universe → formation of galaxies, stars and planets.



* Formation of Earth (~4.5 billion years ago)

- Hot, molton surface.
- Gradual cooling → crust formation.
- Outgassing → primitive atmosphere (CH_4, NH_3, H_2O, CO_2, NO_2, H_2S)
- No free oxygen.

* Early Earth Conditions

- Volcanic activity, lightning, UV radiation.
- Oceans formed, temperature decreased.

2. ORIGIN OF LIFE

* Theory of Spontaneous Generation (Abiogenesis)

- Life arises from non-living matter.
- Example: maggots from decaying meat.
- Disproved by experiments of Redi, Spallanzani and Pasteur.

* Biogenesis Principle

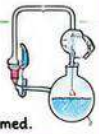
- Life comes only from pre-existing life.

* Oparin–Haldane Hypothesis

- Primitive Earth had reducing atmosphere.
- Simple inorganic molecules → complex organic molecules ("Primordial soup").
- Coacervates or protobionts formed.

* Miller–Urey Experiment (1953)

- Simulated early Earth conditions.
- Electric sparks in gases + water → amino acids and other organic molecules formed.



* First Life Forms

- Anaerobic, unicellular, prokaryotic.
- Heterotrophic → then autotrophic organisms.

3. THEORIES OF EVOLUTION

* Lamarckism (Jean Baptiste Lamarck)

- Use and disuse of organs.
- Inheritance of acquired characters.
- Example: Long neck in giraffe.

* Darwin's Theory of Natural Selection

- Overproduction of offspring.
- Struggle for existence.
- Variation exists in population.
- Survival of the fittest.
- Accumulation of favorable variations → new species.

* Mutation Theory (Hugo de Vries)

- Evolution occurs through sudden and discontinuous changes (mutations).
- New species arise by mutations.

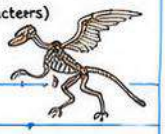
* Modern Synthetic Theory

- Combines Darwinism + Genetics + Palaeontology.
- Evolution = change in gene frequency in a population.
- Variation arises by mutation and recombination.
- Natural selection acts on variation.

4. EVIDENCES OF EVOLUTION

* Fossil Evidence (Palaeontology)

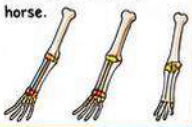
- Remains or impressions of past organisms.
- Show gradual change over geological time.
- Transitional fossils (Connecting links): Archaeopteryx (reptile + bird characters)



* Comparative Anatomy

Homologous Organs

- Same basic structure and origin but different function.
- Example: Forelimbs of human, whale, bat, horse.

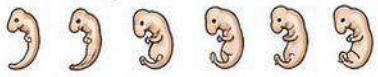


Analogous Organs

- Different origin but similar function.
- Example: Wings of bird and insect, bird and bat
- eyes of octopus and human.

* Embryological Evidence

- Early embryos of vertebrates are similar.
- More similarities in early stages → common ancestry.



Fish Salamander Tortoise Chick Pig Human

* Biochemical Evidence

- Similarity in DNA, RNA and proteins.
- Universal genetic code.
- Cytochrome c similarity in species.

* Connecting Links

- Organisms having characters of two groups.
- Example: Peripatus (Annelida + Arthropoda), Lung fish (fish + amphibian).

5. ADAPTIVE RADIATION & SPECIATION

* Adaptive Radiation

- Evolution of one ancestral species into many forms to occupy different niches.
- Example: Darwin's finches in Galapagos.

* Speciation

- Formation of new and distinct species.

* Isolation Mechanisms

- Geographical isolation (physical barrier).
- Reproductive isolation (behavioral, temporal, mechanical, gametic).

6. POPULATION GENETICS

* Hardy–Weinberg Principle

- In a large population, allele and genotype frequencies remain constant from generation to generation in the absence of evolutionary forces.
- $p^2 + 2pq + q^2 = 1$

* Conditions for Equilibrium

1. Large population size
2. Random mating
3. No mutation
4. No migration (gene flow)
5. No natural selection
6. No genetic drift

* Factors causing evolution (change in allele frequency)

9. ORIGIN & EVOLUTION OF MAN

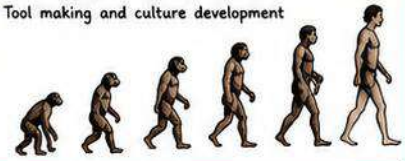
Primates → Hominids → Homo sapiens

* Stages in Human Evolution

1. Australopithecus (ape-like ancestors)
2. Homo habilis (tool maker)
3. Homo erectus (erect posture, brain development)
4. Neanderthal (advanced tools, social life)
5. Homo sapiens sapiens (modern human)

* Key Trends in Human Evolution

- Bipedalism (upright posture)
- Increase in brain size and intelligence
- Complex language and communication
- Tool making and culture development



8. EVOLUTION OF ANIMALS

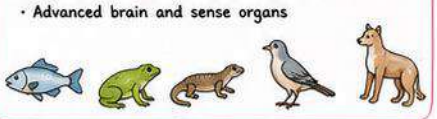
Invertebrates → Vertebrates

* Vertebrate Evolution Line

Fish → Amphibians → Reptiles → Birds → Mammals

* Key Trends

- Development of notochord → backbone
- Adaptation from water to land
- Development of lungs
- Warm-bloodedness in birds and mammals
- Advanced brain and sense organs



7. EVOLUTION OF PLANTS

Algae → Bryophytes → Pteridophytes → Gymnosperms → Angiosperms

* Key Trends

- Adaptation to land
- Development of vascular tissue
- Seed formation
- Flowers and fruits development
- Angiosperms dominate the Earth

SUMMARY / CONCLUSION

- Evolution is the gradual change in living organisms over millions of years.
- It is supported by strong evidences from fossils, anatomy, embryology, biochemistry and molecular biology.
- Evolution results in the origin of new species and biodiversity of present Earth.

CHAPTER-7: HUMAN HEALTH & DISEASE

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus(2026-27):- **Marks (8-10)** Pathogens; parasites causing human diseases (malaria, dengue, chikungunya, filariasis, ascariasis, typhoid, pneumonia, common cold, amoebiasis, ring worm) and their control; Basic concepts of immunology - vaccines; cancer, HIV and AIDS; Adolescence - drug and alcohol abuse.

HEALTH:

Definition: A state of complete physical, mental, and social well-being.

Factors affecting health: Genetic Disorders, Infections, Lifestyle.

Disease: Any adverse effect on normal functioning of organ(s) or systems of body is known as disease. Disease is characterised by appearance of sign and symptoms.

A group of symptoms is known as **Syndrome.** E.g. AIDS – acquired immunodeficiency syndrome

Groups of Diseases:

1. Infectious/Communicable diseases: Transmitted from one person to another. E.g. AIDS
2. Non-infectious/Non communicable diseases: e.g. Cancer

Pathogen: Disease causing organisms. Belong to groups such as Bacteria, Virus, Fungi, Protozoan, Helminths.

Q.1 The 'good humor' health hypothesis was discarded as a consequence of which significant discovery by William Harvey?

INFECTIOUS/COMMUNICABLE DISEASES

Disease	*Causal organism*	Organ(s) affected	Symptoms	Spread	Prevention & Control
I. Bacterial Diseases					
Typhoid	*Salmonella typhii*	Small Intestine Stomach	Headache, sustained fever (39-40°C loss of appetite intestinal perforations & death in severe cases	Through contaminated food and water	Widal test (Confirmatory test) Screening of water and food sources Sanitation TAB vaccine
Pneumonia	*Streptococcus pneumonia*	Alveoli of lungs (*become filled with fluid*)	Difficulty in breathing Fever, chills, cough, Headache Lips & fingernails may turn gray to bluish (*in severe cases)*	Droplet infection Sharing utensils	Isolation of infected person
Other bacterial diseases: Dysentery, plague, diphtheria					
II. VIRAL DISEASES					
Common Cold	Rhinovirus	Affects upper respiratory tract **Lungs not affected**	Sneezing, runny nose, Nasal congestion Sore throat Coughing Headache *(Lasts 3-7 days)*	Droplet infection Through Contaminated objects	Isolation of infected person Antibiotics
Chikungunya & Dengue: Vector – Aedes mosquito					
Other viral diseases: Chicken pox, smallpox, polio, AIDS					
III. **PROTOZOAN DISEASES**					
Malaria	*Plasmodium vivax* *P. ovale* ***P. falciparum –***	Liver, RBCs	Muscular pain Alternate cycle of chill & high fever (every 3-4 days)	Through bite of female mosquito anopheles	Elimination of mosquitoes & their breeding places: Wire mesh on doors &

	causes malignant malaria (most serious & fatal)				Windows, Use of mosquito nets, insecticides and mosquito repellents. Avoiding stagnant water Introducing ***Gambusia* fish** (feeds on mosquito larva)
Amoebic dysentery (amoebiasis)	*Entamoeba histolytica*	Large Intestine	Constipation, abdominal cramps, pain; mucous and blood clots in stool	Contaminated food and water (Mechanical carriers: Houseflies)	Sanitary conditions Covering of food, Washing of fruits and vegetables before eating
HELMINTH DISEASES					
Ascariasis	*Ascaris* (common round worm) *Wuchereria* (Filarial worm)	Intestine	Internal bleeding Fever Muscular pain Anaemia Blockage of intestinal passage	Contaminated fruits, vegetables and water	Proper handwashing & washing of fruits and vegetables. Proper discard of faeces Regular Deworming
Elephantiasis	*Wuchereria bancrofti* *W. malayi*	Lymphatic vessel of lower limbs	Swelling of body parts including genital organs. Gross deformity	Bite of female mosquito vectors	Mosquito control (same as Malaria) Mass medication
V. **Fungal Diseases**					
Ringworm	*Microsporum, Trichophyton, Epidermophyton*	Skin, Nail & Scalp. Between skin fold such as Groin & between toes	Dry and scaly lesions, itching	From soil OR Sharing towels, combs, clothes of infected person	Isolation Sterilization of objects used by patients

Measures for prevention and control of infectious diseases –

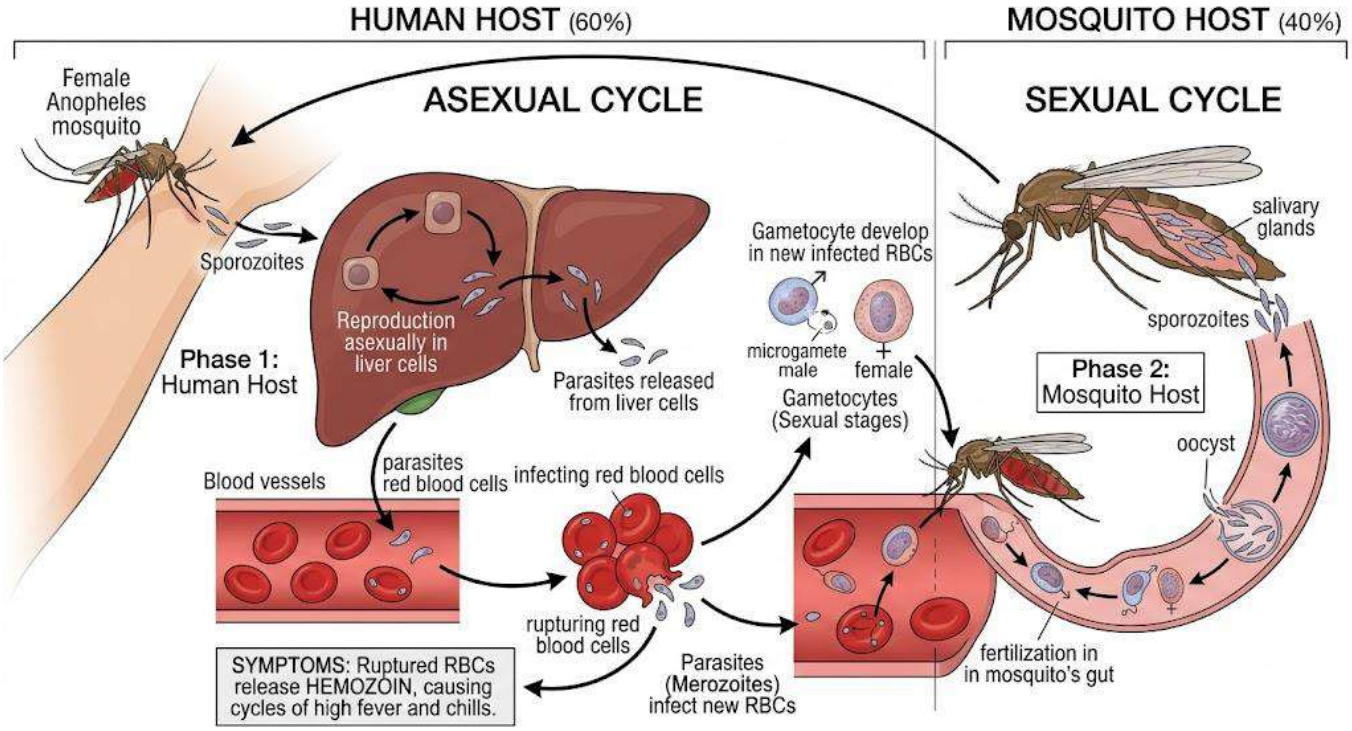
- **Personal hygiene:** It includes cleanliness of body, drinking of clean water, etc.
- **Public hygiene:** It includes cleaning of water reservoirs, proper disposal of sewage, etc.

Q.2 Pathogen such as *Samonella* & *Entamoeba,* that enter through contaminated food and water need to survive inside the host. They need adaptations to resist which of the following in the host:

Life cycle of plasmodium:

Human Host (Asexual Phases) - Secondary Host	**Female Anopheles Mosquito Host (Sexual Phases) - Primary Host**
1. Sporozoites injection: Mosquito injects sporozoites into bloodstream; they travel to liver	1. Gametocytes ingestion: Mosquito ingests gametocytes during blood meal
2. Liver stage: Sporozoites infect liver cells, & multiply.	2. Fertilization: In mosquito gut, gametes fertilize to form zygote
3. Blood stage: Pathogen invade RBCs, Breakdown haemoglobin to form haeomozoin.	3. Zygote enters gut
Pathogen multiply, burst RBCs to release haemozoin (every 3-4 days) Heamozoin is toxin causing chill & fever	4. Sporozoite release and migrate to salivary glands

4. Gametocyte formation: male/female gametocytes formed in blood, ready for mosquito uptake	5. Sporozoites injected into human blood when mosquito bites



Key Steps of Life Cycle:

Immunity – the ability of host to fight the disease-causing microorganism due to is called immunity. This ability is provided by our immune system. The immune system has two characteristics:

1. Differentiation between self & non-self
2. Specificity 3. Memory

Types of Immunity:

INNATE IMMUNITY: Types of barriers

-Physical barrier: Example, skin covering of the body, secretion of mucous in the respiratory tract --
Physiological barrier: Example, acid in the stomach, saliva in mouth, .tears from the eyes
-Cellular barrier: Cells such as:

a. WBCs in blood: PMNL Leukocytes (Polymorpho-nuclear Neutrophils), Monocytes, Natural Killer T Lymphocytes
b. Macrophages – In tissues

Mechanism of action: Phagocytose and kill pathogen
Cytokine barrier: Interferon – Released by virus infected cells. Protect non-infected cells from viral infection.

ACQUIRED IMMUNITY

Acquired immunity is characterised by pathogen - Specificity & memory.

Due to memory, two types of responses are shown:

A. Primary Response: At first encounter with pathogen. It is slow, and of low intensity.
B. Secondary or **anamnestic** response: At next encounter with pathogen. It is faster and of high intensity.

Cells Involved in Acquired Immunity:

B lymphocytes: Produce Antibodies

T Lymphocytes: types

i. Helper T Lymphocytes: Signal B Lymphocytes in antibody production (Humoral Immune Response)
ii. Killer T Lymphocytes: Phagocytose and kill pathogen (Cell Mediated Immune Response)

T Lymphocytes help in identification of self and non-self. Responsible for graft rejection.

Innate vs Acquired Immunity:

	Innate Immunity	Acquired Immunity
1.	Present since birth	Developed after exposure to pathogen
2.	Non-specific defense	Pathogen Specific defense
3.	Incapable to keep memory	Shows memory of immunity
4.	Faster response	Slower Primary response

Humoral Immune Response vs Cell Mediated Immune Response

	Humoral immune Response	Cell Mediated Immune Response
1.	Through antibodies in blood	Through Cells
2.	B Lymphocytes involved	T Lymphocytes involved

Antibody:

i. The antibodies are protein molecules produced by B Lymphocytes.
ii. They are of many types such as:

- IgA – In colostrum
- IgE – involved in allergy
- Also IgM and IgG etc.

iii. Each antibody molecule consists of four polypeptide chains and is represented by H2L2.
iv. H2 represents two longer heavy chains
v. L2 represents two short chains called light chains.
vi. Both are arranged in the shape of 'Y'.

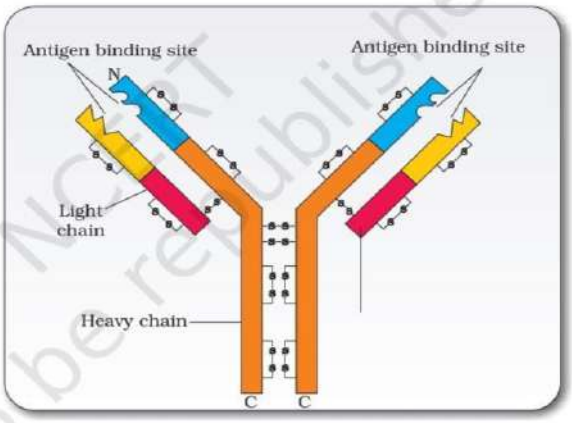


Figure 7.4 Structure of an antibody molecule

Active Vs Passive Immunity

	ACTIVE IMMUNITY	PASSIVE IMMUNITY
1.	Developed by host cells in response to infection or vaccine	Readymade antibodies introduced in host
2.	Relief after some time	Immediate relief
3.	Longer lasting	For Short duration
4.	No side effect	May have side effects

Unique example of Natural Passive Immunity: IgA by colostrum of mother's milk

Vaccination vs Immunisation

Vaccines are

a. Weakened/inactive pathogen
b. Antigenic proteins of pathogen in host

Injection of vaccines into human body is known as vaccination or immunisation.

Vaccines cause production of antibodies against the pathogen. Vaccination is based on memory of T and B Lymphocytes to produce faster reaction in subsequent infections.

Passive Immunisation: injection of preformed antibodies or antitoxin. Used when quick response is required, eg. In case of snakebite.

Use of rDNA technology for vaccine production: For Hepatitis B using Yeast cell.

Allergies – the exaggerated response of immune system to certain antigens present in the environment.

Allergen: The substance to which cause allergy. E.g. Dust pollen

Symptoms: Sneezing, watery eyes, difficulty in breathing

Antibodies produced due to allergy: **IgE**

Chemicals produced during allergy: **Histamine and serotonin** from the **mast cells**.

Treatment: Antihistamine, adrenaline, serotonin

Auto Immunity : When immune system attacks self-cells causing damage of body – known as **Autoimmune Diseases**. E.g. Rheumatoid Arthritis

Cause: Due to genetic or other unknown reasons.

Components: Lymphoid organs, Tissues, Cells, soluble molecules like Antibodies

Roles:

Recognises foreign antigens
Acts against them
Remembers them
Involved in allergic reactions, autoimmunity & organ transplantation

IMMUNE SYSTEM IN THE BODY:

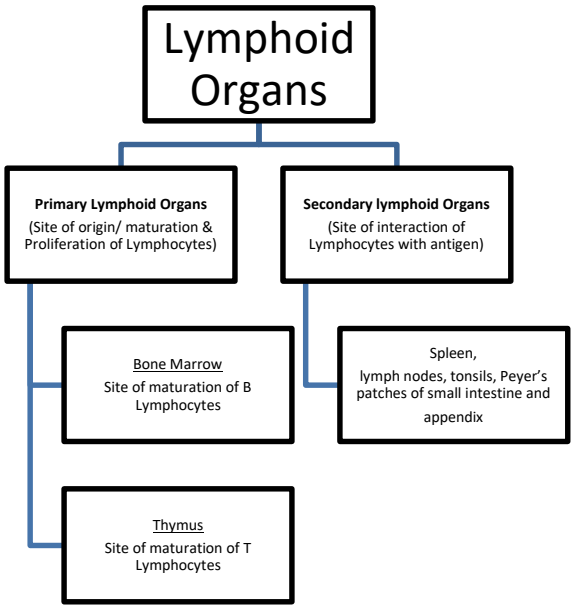
Thymus: Gland near heart. Large at birth, decreases in size with age.

Spleen: contains lymphocytes and phagocytes. It acts as a filter of the blood by trapping blood-borne microorganisms.

Spleen also has a large reservoir of erythrocytes

Lymph Nodes: Trap microbes & antigens from the lymph and tissue fluid and cause immune response.

MALT: Mucose Associated Lymphoid tissue. located within the lining of the major tracts (respiratory, digestive and urogenital tracts). 50% of lymphoid tissue in human body.



AIDS (Acquired Immuno Deficiency Syndrome):

Causal Organism: HIV (human Immuno deficiency virus), a retrovirus.

Incubation Period: Few months to many years (5-10 yrs)

First cell infected: macrophages – HIV Factory

Site of attack: Helper T lymphocytes

Symptoms: fever, diarrhoea and weight

Modes of Transmission of HIV:

Sexual contact with infected person

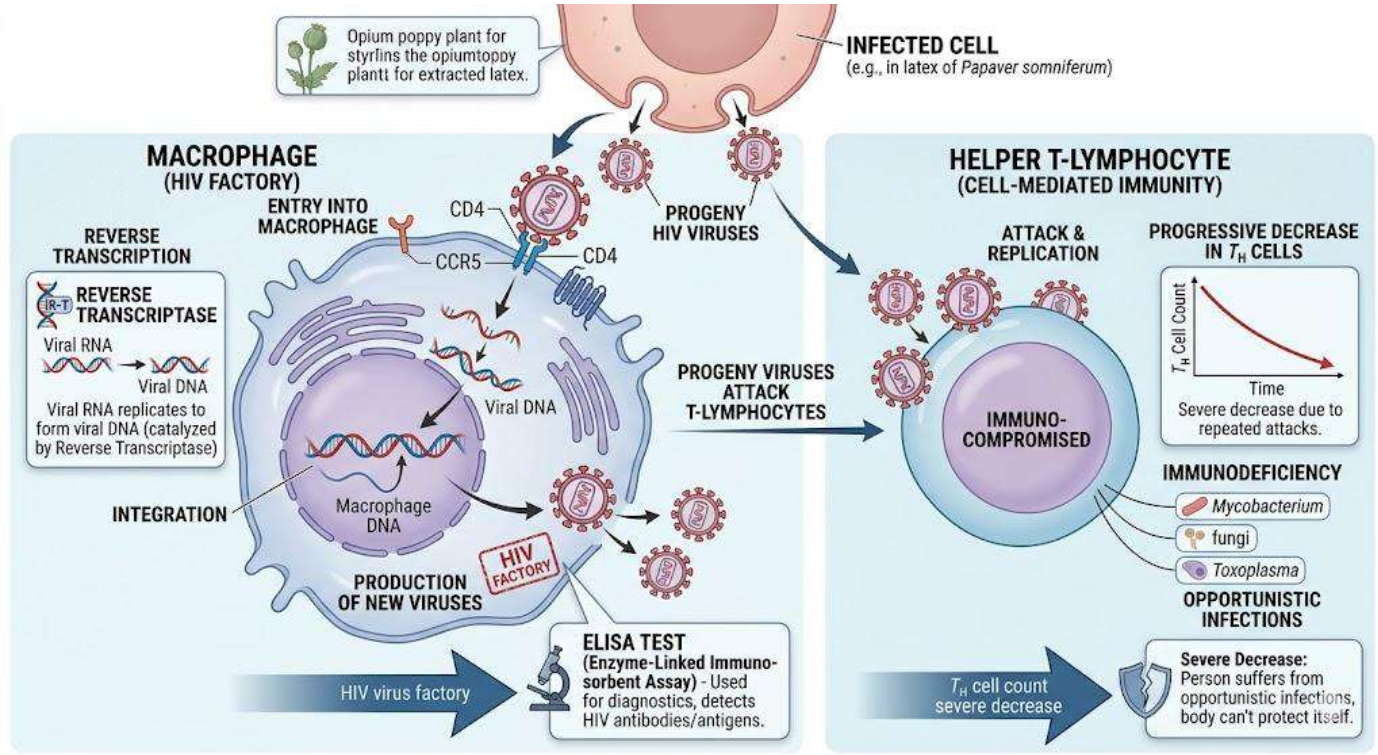
Transfusion of contaminated blood and blood products

Sharing infected needles as in intravenous drug abusers

Infected mother to her child through placenta.

Loss. Immuno-deficiency leading to the person suffering from infections of bacteria, viruses, fungi etc.

Diagnosis	Treatment
ELISA: Enzyme Linked Immunosorbent Assay	No complete cure, only partially effective – Antiretroviral Drugs



Prevention:

1. Awareness Drives: NACO (National AIDS Control Organisation), World AIDS Day: December 11.
1. Efforts by WHO: Making blood (from blood banks) safe from HIV, ensuring the use of only disposable needles and syringes in public and private hospitals and clinics, free distribution of condoms, controlling drug abuse, advocating safe sex and promoting regular check-ups for HIV in susceptible populations

Cancer

Uncontrolled growth and multiplication of cells due to loss of **Contact Inhibition.**

Contact Inhibition: Property of normal cells. Normal dividing cells when come in contact with other cells, their growth & division is inhibited.

Two kinds of tumours

(a)Benign tumours (b) Malignant tumours

Tumours

Benign Tumour
1. It remains confined to the affected organ.
2. Rate of growth is usually slow
3. It causes limited damage to the body.
4. There is no metastasis.
5. It is non-cancerous

Malignant Tumour
1. It also spreads to other organs of the body.
2. Rate of growth is usually rapid.
3. The cancer cells migrate to other sites of the body.
4. There is metastasis.
5. It is cancerous

Causes of cancer	Cancer detection and diagnosis	Treatment of cancer---
Cancerous neoplastic cell may be induced by physical, chemical and biological agents called carcinogens	Cancer detection is based on biopsy and histopathological study, Radiography, CT (computed Tomography), MRI (magnetic resonance imaging).	Surgical, Radiotherapy, Chemotherapy, Immunotherapy etc. **A-interferons** – Biological response modifiers (help in destroying cancer cells.

Drug and alcohol abuse

Drugs and alcohol abuse includes –

- **Opioids:** Opioids bind with opioid receptor of Central Nervous system & Gastrointestinal tract. E.g. Morphine is obtained from latex of **Poppy plant** *Papaver somniferum*). It is a sedative (depressant) and pain killer.

Heroin (*smack*) is chemically diacetylmorphine. It is taken by snorting & injection. It slows down body functions.

- **Cannabinoids:** It is obtained from *Cannabis sativa*. These are taken by inhalation and oral ingestion. They affect the cardiovascular system of the body. Example, marijuana, hashish, *charas*, *ganja* (obtained from *Cannabis sativa*),
- **Coca alkaloids / Cocaine**: it is obtained from *Erythroxylon coca*. It is taken by smoking. It is a stimulant and activates central nervous system.
- **Hallucinogens:** It is obtained from *Atropa belladonna* and *Datura sp*. LSD (Lysergic acid Diethylamide) is obtained from fungus.
- **Tobacco:** It contains nicotine, which is stimulant. It stimulates adrenaline and increases the secretion of adrenaline. Smoking of tobacco leads to lung cancer, bronchitis, emphysema, coronary heart diseases.

Adolescence and Drug abuse

Causes of drug abuse –	Effects of drug/alcohol abuse –	Prevention and control
Curiosity Adventure Excitement Experimentation Stress or pressure to	Reckless behaviour Malicious mischief Violence Drop in academic performance Depression, isolation,	Avoid peer pressure Counselling and education Take help from teachers, parents and peers Take professional and

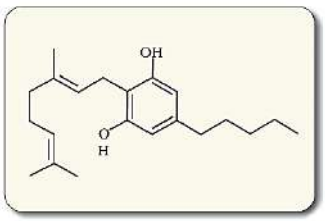


Figure 7.9 Skeletal structure of cannabinoid molecule

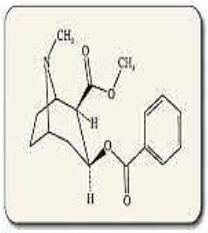
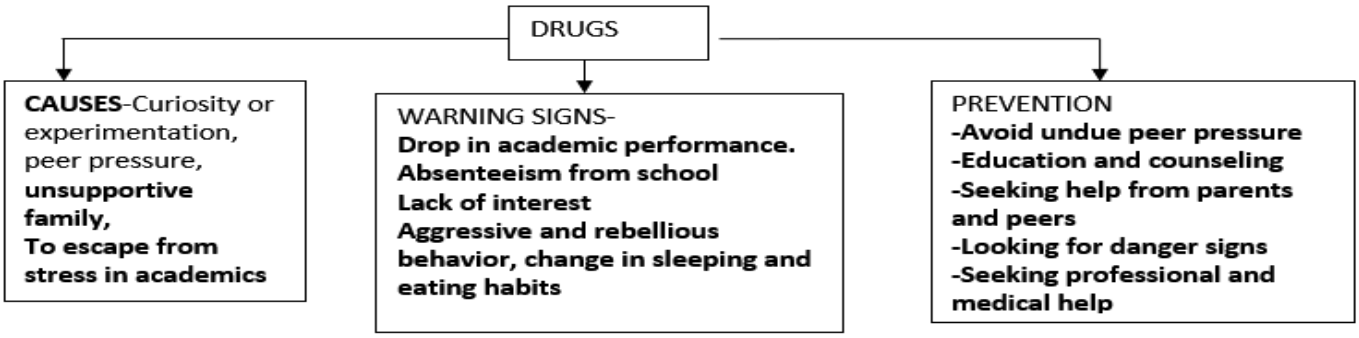


Figure 8.7 Chemical structure of Morphine

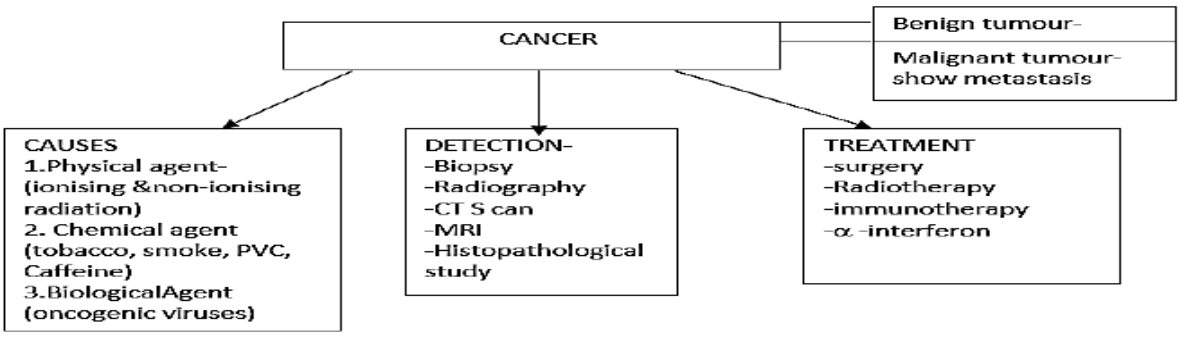
Figure 8.8 Opium poppy

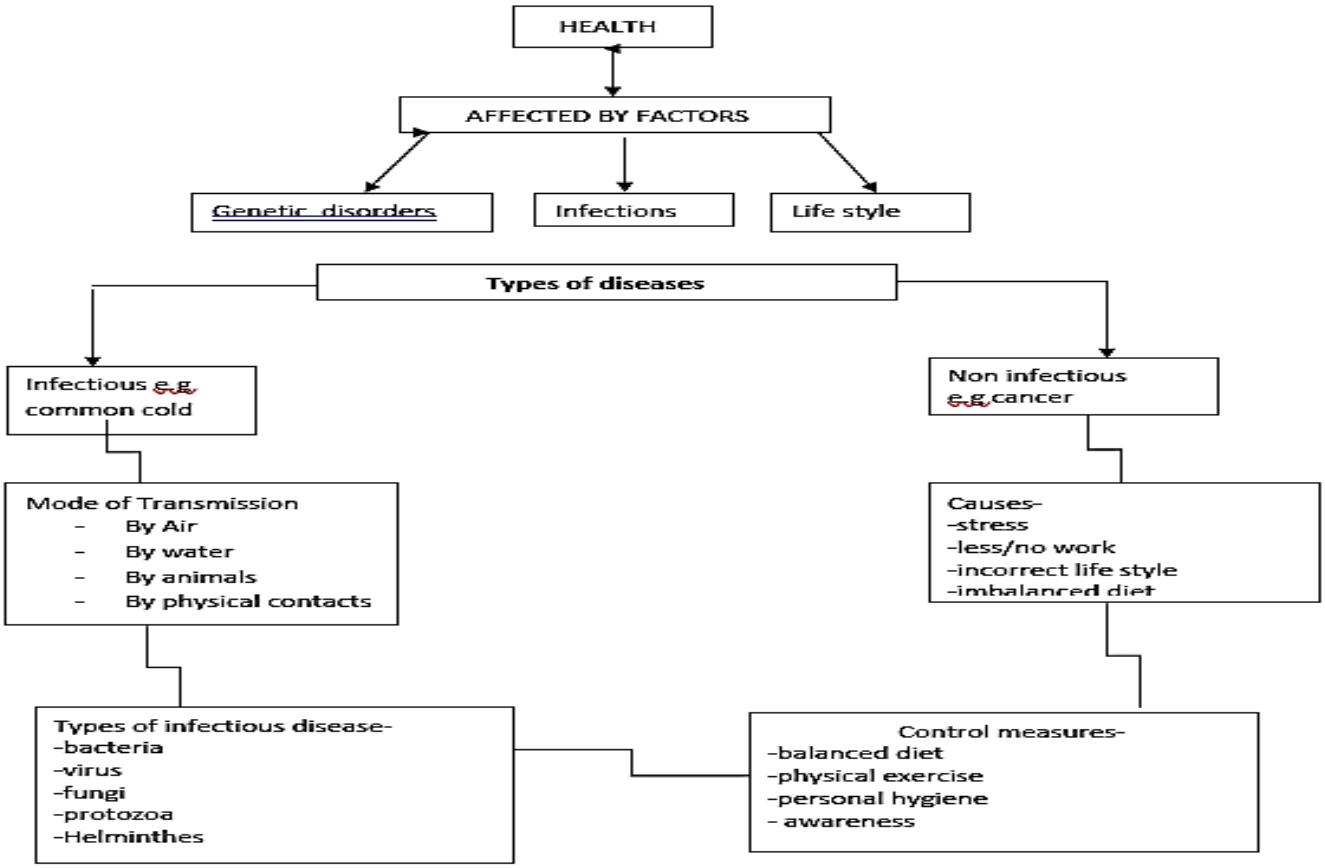
7.10 Leaves of *Cannabis sativa*



- Addiction: Temporary good feeling after taking the drug- euphoria. Habitual & psychological attachment to drug effects.
- Dependence: Tendency of body to manifest unpleasant withdrawal symptoms if drug is discontinued.
- Withdrawal syndrome: anxiety, shakiness, nausea, sweating.

Addiction is Psychological ; Dependence is Physiological





Q.3 Alcohol is among the most addictive and widely used drugs. Adolescence are most vulnerable to alcohol abuse often due to peer pressure, and sometimes due to curiosity. Most alcohol is absorbed by stomach and small intestine, and is broken down into water and CO_2 in liver. However, this process takes certain time, and during this period alcohol circulates in blood. The blood alcohol levels (BAL) of an individual who had taken 6 units of alcohol, was measured experimentally over a period. The data collected is shown in table below:

Time since drinking / hours	BAL / mg of alcohol per 100 cm^3 of blood
0.0	0.0
0.5	70
1.0	135
1.5	140
2.0	115
3.0	75
4.0	50
5.0	40

Based on data available, answer the following questions:

a. The legal limit of BAL in India is 30mg/100cc of blood. After approximately how long can the individual drive back home?

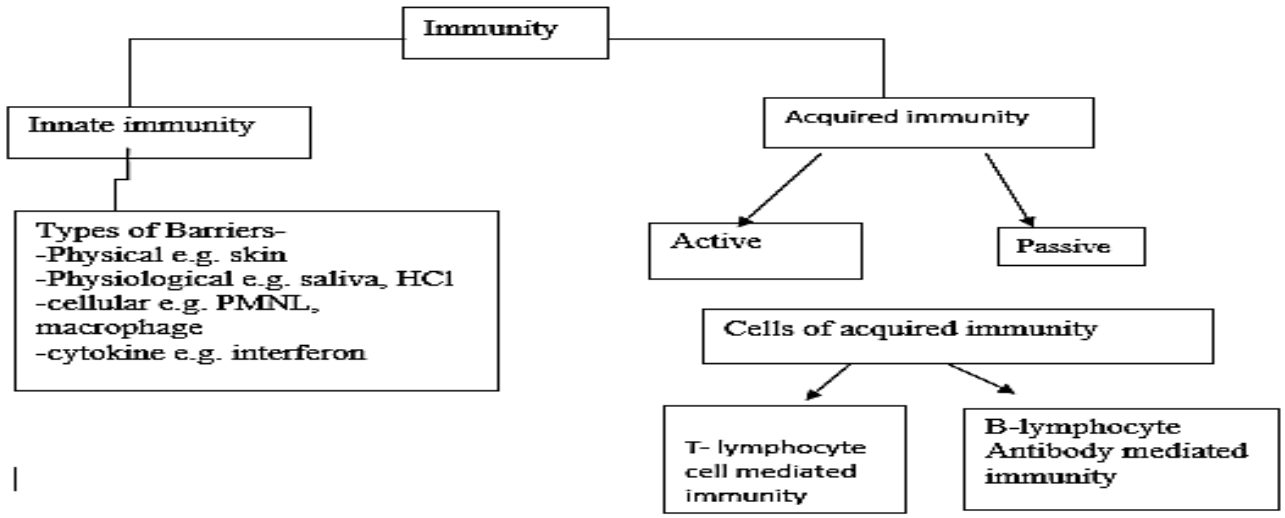
b. Liver detoxifies alcohol, however long-term use of alcohol may have adverse impact on liver. Provide one damaging effect of long-term use of alcohol on liver.

c. How is psychological attachment to alcohol different from physiological habituation? Provide specific terms and differentiate between the two conditions.

OR

d. Suggest 2 strategies that you as an adolescent can follow for prevention and control of alcohol abuse.

Types of immunity



Q.4 Primary immune response is of slow intensity than secondary immune response. Justify the statement.

Q.5 Vaccination is a form of active immunity. Justify.

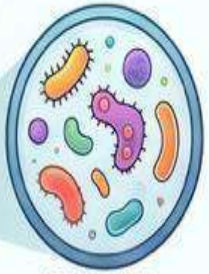
Human Health & Disease: A Biological Perspective

DEFINING HEALTH AND DISEASE

THREE PILLARS OF HEALTH INFLUENCE

- GENETIC DISORDERS (Innartiali)
- INFECTIONS (Pathogene)
- LIFESTYLE HABITS (Diet, Exercise, Rest)

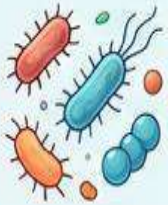
SOCIAL WELL-BEING
A state of complete well-being, increasing productivity and longevity, reducing mortality.



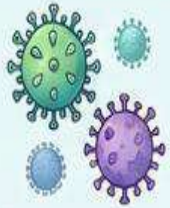
PATHOGENS: THE AGENTS OF DISEASE
Disease-causing organisms

adapt to the host environment.

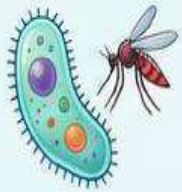
THE PATHOGEN GALLERY



BACTERIAL INFECTIONS
Typhold (*Yeimonella typld*): Contaminated food/water. Sustained high fever.
Pneumonia (*Stroptococcus posumoines*): Infects long alveoil, Ruid-filled, chills.



VIRAL INFECTIONS
Common Cold (Rhino viruses): Infects noso/ respiratory passage. Nasal congostion, sore throst. Spreads via aerosols.



PROTOZOAN PARASITES
Malaria (*Plasmodium*): Carried by Anopheles mosquito. Recurring chills, high fever.
Amooblasis (Entamoobe *instotylies*): Large intastine, Constipation, abdominal pain.

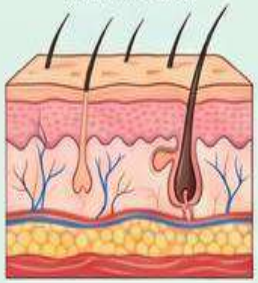
HELMINTHS AND FUNGI
Filarial worms (*Kiuchereria*): Causes elephantipsis, physical deformines.
Ringwarm (*Microsporum, Trishophyton*): Thrives in heat/moisture. Dry, scaly lesions, itohing.

ALLERGY: Exaggerated response to allergen. **IgE**

AUTOIMMUNITY: Immune system active against self cells - **Rheumatoid Arthritis**

THE BODY'S DEFENSE: IMMUNITY

INNATE IMMUNITY: THE FIRST LINE



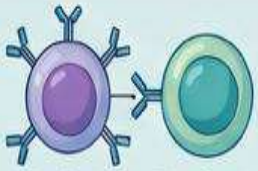
SKIN

PHYSICAL BARRIERS

PHYSIOLOGICAL BARRIERS
Non-specific defense present at birth.

ACQUIRED IMMUNITY: PATHOGEN MEMORY

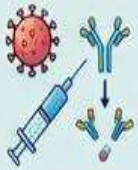
CELLULAR BARRIERS | **CYTOKINE BARRIERS**



B-lymphocytes T-lymphocytes

Specific defense.
B-lymphocytes produce antibodies.
I-lymphocytes facilitate response.
Creates memory.

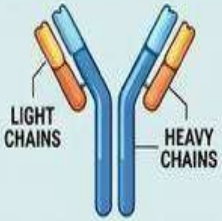
ACTIVE VS. PASSIVE IMMUNITY



VS.

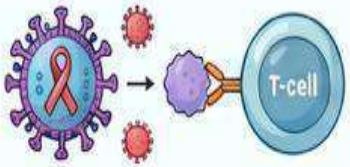
ACTIVE
Induced by antigens (slow)

PASSIVE
Ready-made antibodies (e.g., Colostrum)

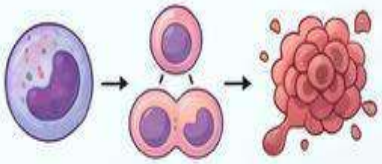


ANTIBODY STRUCTURE (H2L2)
Four peptide chains (e.g., IgA, IgB, IgE).

MODERN MEDICAL CHALLENGES



AIDS: THE IMMUNE DEFICIENCY
Caused by HIV (retrovirus).
Replicates in macrophages, destroys helper T-lymphocytes, leaving patient vulnerable.



CANCER: UNCONTROLLED PROLIFERATION
Breakdown in cell growth regulation. Malignent tumors show "metastacis," spreading through blood.

Common Carcinogans:
- Physical (X-roys/UV)
- Chemicols (tobacoe smoha)
- Biological (oncogenic viruses).

DRUG AND ALCOHOL ABUSE IN YOUTH
Rising abuse of opioids, cannabinoide, and coce alkaloids. Driven by cariosity, stress, or "cool" factor.

NotebookLM

CHAPTER-8 MICROBES IN HUMAN WELFARE

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus(2026-27):- **Marks (6-8)** Microbes in food processing, industrial production, sewage treatment, energy generation and microbes as bio-control agents and bio-fertilizers. Antibiotics; production and judicious use.

1) Microbes are diverse.
   Ex-protozoa, bacteria, fungi, microscopic plants, viruses, viroids and also prions (proteinaceous infectious agents).
2) Microbes like bacteria and fungi can be grown in nutrient media in the laboratory to form colonies and can be seen in naked eyes.
3) Some microbes' causes diseases and some are useful for human being.

Where used	Microbes Type	Use
Household products	LAB (Lactic acid bacteria)	Curd + increasing vitamin B12
	Propionibacterium sharmanii(Bacterium)	Swiss chess
	Saccharomyces cerevisiae (Fungi)	Idli , dosa , toddy, bread
	Penicillium roqueforti (Fungi)	Roquefort cheese
Industrial Products	*Saccharomyces cerevisiae (Fungi)*	Ethanol
	Aspergillus niger (Fungi)	Citric acid
	Penicillium notatum (Fungi)	Antibiotics
	Acetobacter aceti (Bacterium)	Acetic acid
	Clostridium butylicum(Bacterium)	Butyric acid
	Lactobacillus (Bacterium)	Lactic acid
Enzymes	**Streptokinase**- *Streptococcus (*Bacterium)	Clot buster
	Lipases- *Bacillus and pseudomonas (Bacterium)*	Removes stains of grease and oil
	Pectinases & Proteases- *Aspergillus niger (Fungi)* *Bacillus subtilis (Bacterium)*	Clearing bottled juice
Bioactive molecules	*Trichoderma polysporum (Fungi)*	Cyclosporin-A (Immunosuppressant)
	Monascus purpureus (Fungi)	Statins (Blood cholesterol lowering agents)
Biocontrol-agents	*Nucleopolyhedrovirus(Virus)*	Caterpillar & insect -resistant
	Bacillus thuringiensis (Bacteria)	Insect resistant plant
	Ladybird	Eradicates Aphids
	Dragonflies	Eradicates Mosquito
	Trichoderma sp.	Several plant pathogens in root system

Q.1 Lactic acid bacteria are a kind of microorganisms that can ferment carbohydrates to produce lactic acid, and are currently widely used in the fermented food industry. They are used to improve the flavor of fermented foods, increase the nutrition of foods, reduce harmful substances, increases shelf life, and so on. They can also be used as probiotics to promote health in the body.

a. **Give the full form of LAB.**
b. **Which type of food would have lactic acid bacteria? Give 2 example.**
c. **How is curd formed? ii. What happens to the milk protein during formation of the curd?**

Q2. Match the following columns:

Column I	Column II
A.Statin	1. Aspergillus
B.Cyclosporin A	2. Monascus
C.Streptokinase	3. Streptococcus
D.Citric acid	4. Trichoderma

Q.3 Assertion: Fermentation by microbes is used in the production of alcoholic beverages.
Reason: During fermentation, microbes convert sugars into water and carbon dioxide.

MICROBES IN SEWAGE TREATMENT

This municipal waste-water is also called sewage. Sewage treatment is done in two stages- primary treatment and secondary biological) treatment

Primary Treatment -This involves physical removal of particles through filtration and sedimentation. The effluent from the primary settling tank is taken for secondary treatment.

Secondary treatment (Biological treatment)-The primary effluent is passed into **large aeration tanks** where air is pumped into it. This allows vigorous growth **flocs.** These microbes consume the major part of the organic matter reduces the BOD. Once BOD reduced the effluent is then passed into a **settling tank** where the bacterial 'flocs' are allowed to sediment. This sediment is called **activated sludge**. A small part of the activated sludge is pumped back into the **aeration tank**. The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge Digesters**. Here anaerobic bacteria produce biogas (methane, hydrogen sulphide and carbon di oxide).

BOD: It represents the amount of dissolved O_2 required for the complete oxidation of all the organic matter present in one litre of H_2O by bacteria at 20^0C.

PROCESS OF SEWAGE TREATMENT

SEWAGE (Wastewater)

↓

Primary Treatment Tank
(Physical removal of large particles)

↓

Primary Effluent

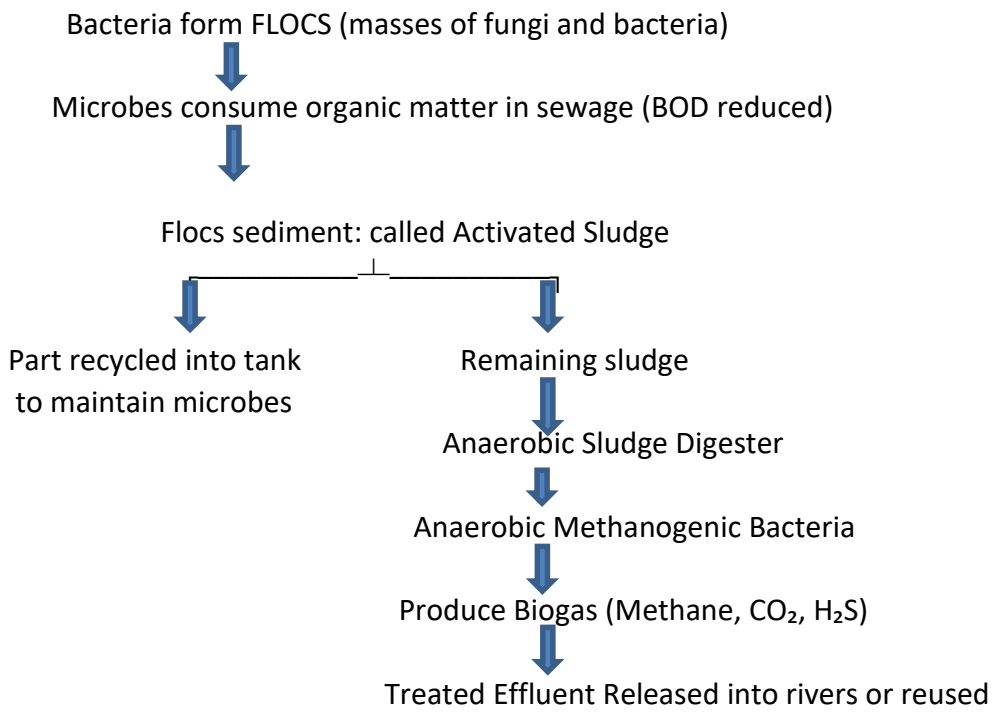
↓

Secondary Treatment Tank
(Role of Microbes Begins Here)

↓

Aerobic Bacteria + Air Pumping (Aeration)

↓



Key Points to Remember

Aerobic bacteria help in breaking down organic matter.
Flocs are clumps of bacteria and fungal filaments.
BOD reduction indicates purification of sewage.
Methanogens work anaerobically and produce biogas.

MICROBES IN PRODUCTION OF BIOGAS-

Biogas is (containing methane) produced by the microbial activity of methanogen on cow dung and cellulosic waste. Cow dung is common source of methanogens e.g. **Methanobacterium.** These bacteria are commonly found in the anaerobic sludge during sewage treatment and rumen of the cattle. The biogas is used for cooking and lightning.

Microbes as Biopesticides (Biological Control of Pests)

Biopesticides are biological agents (bacteria, fungi, viruses) used to control weeds, insects, and pathogens instead of harmful chemical pesticides. This approach is a key component of Integrated Pest Management (IPM).

A. Bacteria: Bacillus thuringiensis (Bt)

- Target: Used to control butterfly caterpillars, insect larvae, and beetles.
- Mechanism of Action: In the alkaline pH of the insect's gut, the toxin (Cry protein) becomes active. It creates pores in the midgut epithelial cells, leading to cell lysis, swelling, and eventually the death of the insect.

B. Fungi: Trichoderma

- Target: Controls several soil-borne plant pathogens (fungi and bacteria affecting roots).
- Features: Trichoderma species are free-living fungi that are very common in the root ecosystem (rhizosphere).
- They act as highly effective biocontrol agents by suppressing plant diseases through antibiosis, competition, or mycoparasitism.

C. Viruses: Baculoviruses (Genus: Nucleopolyhedrovirus)

- Target: Excellent choice for controlling insects and other arthropods.
- Key Characteristics:
  - Species-specific
  - Narrow-spectrum insecticidal applications
  - Ideal for IPM

D. Microbes as Bioherbicides

Bioherbicides (or mycoherbicides when fungal) are biological agents used to selectively eliminate weeds (unwanted plants) without damaging the crop or polluting the soil.

- Fungal Pathogens (Mycoherbicides): Specific fungi are used to target and destroy weed species.
  - Example 1: Phytophthora palmivora – Used as a mycoherbicide to control the growth of milkweed vines in citrus orchards.
  - Example 2: Alternaria crassa – Used to control specific broadleaf weeds.
- Bacterial Herbicide: Certain strains of bacteria (e.g., specific strains of Pseudomonas species) are used to suppress the growth of weeds like wild oats and downy brome by colonizing their root systems.

Q.4 a. Organic farmers prefer biological control of diseases and pests to the use of chemicals for the same purpose. Justify.

b. Give an example of a bacterium, a fungus and an insect that are used as biocontrol agents.

MICROBES AS BIOFERTILISERS-

Bacteria- Rhizobium in the root nodule of leguminous plants fixes atmospheric nitrogen into organic forms. Azospirillum and Azotobacter (free living bacteria) are also used as nitrogen enriching bio fertilizers. Some other examples-Fungi form Mycorrhiza (a symbiotic association with root nodules of higher plants) .e.g.- Genus Glomus form mycorrhiza. The role of fungus in this association is to absorb phosphorus and develop resistance to root borne disease, tolerance to salinity and drought. Cyanobacteria (Anabaena, Nostoc, Oscillatoria etc)

Q.5 The given diagram shows the root system of a leguminous plant.

a. Name the microbe present inside the root nodule and mention the role of it.

b. How is this microbe differing from Nostoc?

Microbe / Group	Used For	Main Function	Crop / Plant Example
Bacteria (Rhizobium)	Nitrogen fixation	Converts atmospheric nitrogen into usable form for plants	Leguminous plants like pea, gram, beans
Free-living Bacteria (Azotobacter)	Soil fertility	Fixes nitrogen independently in soil	Wheat, maize, cotton
Cyanobacteria (Blue Green Algae) Anabaena, Nostoc	Paddy field fertility	Adds organic matter and fixes nitrogen	Rice field
Symbiotic Association Azolla-Anabaena)	Green manure	Improves nitrogen content in waterlogged fields	Paddy cultivation
Fungi (Mycorrhiza) (Glomus)	Mineral absorption	Increases absorption of phosphorus and water	Forest tree

Q.6 a. Organic farmers prefer biological control of diseases and pests to the use of chemicals for the same purpose. Justify.
b. Give an example of a bacterium, a fungus and an insect that are used as biocontrol agents.

Antibiotics: Production and Judicious Use

Antibiotics are chemical substances produced by some microorganisms that can kill or stop the growth of disease-causing microbes. They are mainly produced by bacteria and fungi.
Example: Penicillin Streptomycin Tetracycline etc.
Discovery of Antibiotics
Penicillin – The First Antibiotic

- Discovered by Alexander Fleming in 1928.
- Fleming observed that the fungus *Penicillium notatum* prevented the growth of bacteria (*Staphylococci*) on a culture plate.
- The substance released by the fungus was named **Penicillin**.

Production and use of antibiotics:
Microbe Selected ➡ Cultured in Fermenter ➡ Fermentation Process ➡ Antibiotic Produced ➡ Extraction & Purification ➡ Medicinal Use ➡ Judicious Use Necessary.

Judicious use means the **careful and proper use** of antibiotics. Improper use can make bacteria resistant to antibiotics. This is called **antibiotic resistance**.

Guidelines for Judicious Use
- Use antibiotics only when prescribed by a doctor
- Complete the full course
- Do not use antibiotics for viral diseases like cold and flu
- Avoid self-medication
- Do not overuse antibiotics

Q.7 Alexander Fleming observed that in the presence of *Penicillium notatum* a particular species "A" cannot grow. Identify A and give the reason for the observation.

ROLE OF MICROBES IN HUMAN WELFARE

Microbes are tiny living organisms (bacteria, fungi, algae, protozoa, viruses) that are extremely useful to humans in many ways.

1. MICROBES IN FOOD PRODUCTION

Microbes help in fermentation and improve the taste, texture and nutritional value of food.

(a) Dairy Products

- *Lactobacillus* converts lactose into lactic acid.
- Used in curd, yogurt, buttermilk, cheese.

(b) Fermented Foods

- Idli, dosa (using *Leuconostoc*).
- Pickles, sauerkraut (using lactic acid bacteria).
- Helps in preservation and adds flavour.

(c) Beverages

- Yeast (*Saccharomyces*) is used in bread making.
- Yeast and bacteria are used in wine, beer and other alcoholic beverages.

(d) Other Products

- Vinegar (acetic acid bacteria – *Acetobacter*)
- Cocoa, coffee and tea fermentation.

2. MICROBES IN INDUSTRIAL PRODUCTS

Microbes are used as cell factories to produce useful industrial products.

(a) Antibiotics

- Penicillin (from *Penicillium*), *Streptomycin* (from *Streptomyces*).

(b) Organic Acids

- Citric acid (from *Aspergillus niger*)
- Lactic acid (from *Lactobacillus*).

(c) Enzymes

- Microbial enzymes are used in detergents, starch processing, textile, leather and food industries.

(d) Vitamins

- Vitamin B_2 (Riboflavin) from *Ashbya gossypii*.
- Vitamin B_{12} from *Propionibacterium shermanii*.

(e) Amino Acids

- Microbes are used for the production of amino acids like glutamic acid, lysine etc.

3. MICROBES IN AGRICULTURE

Microbes improve soil fertility and help in increasing crop yield sustainably.

(a) Nitrogen Fixation

- *Rhizobium* in root nodules of legumes (pea, gram, beans, groundnut).
- *Azotobacter* and cyanobacteria (*Anabaena*, *Nostoc*) fix atmospheric nitrogen.

(b) Phosphate Solubilization

- Phosphate solubilizing bacteria (e.g., *Bacillus megaterium*) make insoluble phosphates available to plants.

(c) Biofertilizers

- Microbial inoculants (*Rhizobium*, *Azotobacter*, *Azospirillum*, PSB, BGA) are used as biofertilizers to enrich soil fertility.

(d) Biopesticides

- *Bacillus thuringiensis* produces a protein toxin (Bt toxin) used as a biopesticide against pests.

4. MICROBES IN ENVIRONMENTAL MANAGEMENT

Microbes help in maintaining a clean and healthy environment.

(a) Decomposition

- Microbes decompose dead plants and animals and recycle nutrients in nature.

(b) Sewage Treatment

- Microbes are used in sewage treatment plants to degrade organic waste and reduce pollution.

(c) Bioremediation

- Microbes degrade pollutants like oil spills, pesticides, plastics and heavy metals.

5. MICROBES IN MEDICINE AND HEALTH CARE

- **Antibiotics:** Penicillin, Streptomycin, Tetracycline, Erythromycin etc.
- **Vaccines:** Produced using microbes (e.g., BCG, Hepatitis B vaccine).
- **Probiotics:** *Lactobacillus* and *Bifidobacterium* maintain healthy gut flora and aid digestion.
- **Diagnosis:** Microbes and their products are used in diagnostic tests (e.g., ELISA, PCR).

6. MICROBES IN RESEARCH AND BIOTECHNOLOGY

- Microbes are used as model organisms to study genes and cellular processes.
- Tools of rDNA technology (e.g., restriction enzymes from bacteria, plasmids).
- Production of recombinant products like Insulin, Growth hormone, Interferons, Vaccines.

7. MICROBES AS BIOCONTROL AGENTS

- Microbes are used to control pests and pathogens.
- Example: Baculoviruses (for insects), *Trichoderma* (against plant pathogens).
- Reduces the use of chemical pesticides and promotes eco-friendly agriculture.

IN SUMMARY

Microbes contribute enormously to human welfare by providing food, medicines, industrial products, improving agriculture, maintaining environmental balance and supporting research and biotechnology.

They are tiny but mighty partners in our lives!

CHAPTER-09 BIOTECHNOLOGY: PRINCIPLES AND PROCESSES

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus 2026-27: (Marks 8-10) Principles of biotechnology, plasmid as a vector, restriction enzymes, recombinant DNA technology, gel electrophoresis, cloning vector, insertional inactivation, competent host, processes of recombinant DNA technologic, selectable marker, bioreactor and downstream processing.

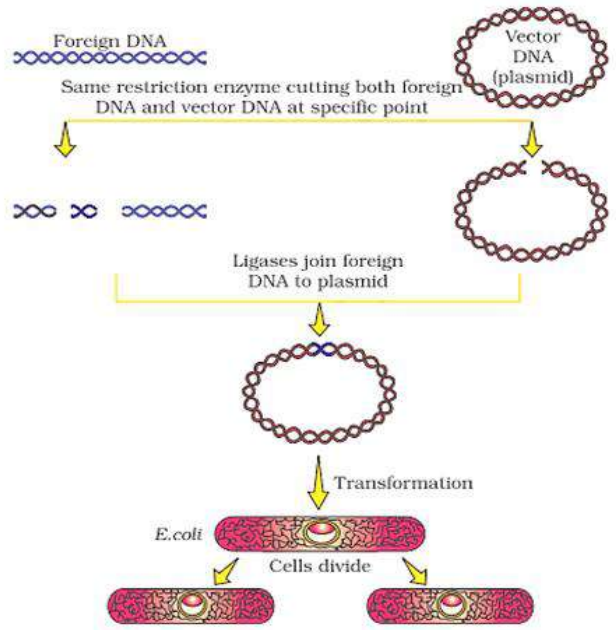
Biotechnology Definition: The European Federation of Biotechnology (EFB) defines biotechnology as "The integration of natural science and organisms, cells, parts thereof and molecular analogues for products and services".

Principles of Biotechnology:

1. Genetic engineering – Technique to introduce foreign genetic material (DNA/RNA) into the host's genome and altering its phenotype.

2.Bioprocess engineering- Maintenance of sterile (microbial contamination free) ambience in chemical engineering processes for manufacture of products such as protein, antibiotics, vaccines, etc .

Plasmid: It is a self-replicating, double stranded, circular DNA used as a vector in Recombinant DNA technology. Plasmids are generally isolated from bacterial cells like *E. coli*.



Basic steps in Recombinant DNA Technology.

a)Identification of desired gene or DNA.

b)Isolation of DNA with desirable genes using restriction endonuclease: Gene of interest (e.g., disease resistant gene).

b)Ligation of foreign DNA into the vector plasmid to form recombinant DNA(rDNA).

d)Transformation of host with rDNA.

e)Selection of recombinants

f)Maintenance of introduced rDNA in the host.

Construction of First Recombinant DNA Molecule

- First recombinant DNA (rDNA) was produced by Stanley Cohen & Herbert Boyer (1972).
- They isolated an antibiotic resistance gene (piece of DNA) from a plasmid of Salmonella typhimurium.
- It was linked with a plasmid vector and transferred into E. coli
- As a result, the gene was expressed & multiplied in E. coli and makes the E.coli cell resistant against that antibiotic.

Tools of Recombinant DNA Technology

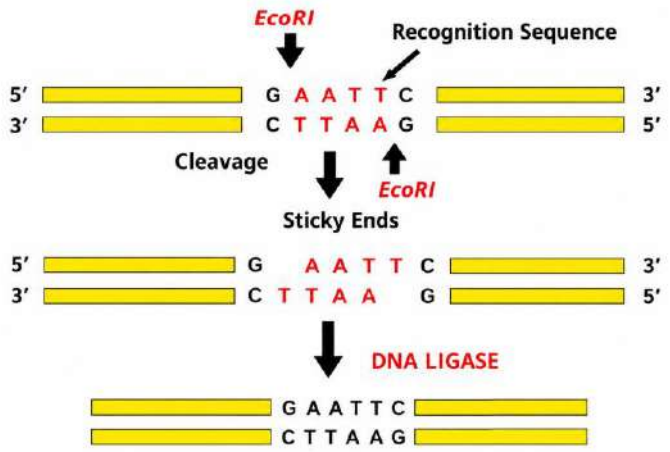
1.Restriction Enzymes:

Discovered in 1963; enzymes that cut DNA at specific sequences.
Restriction enzymes belong to Nucleases and are of two kinds:
Endonucleases – Cut the DNA at specific positions within the Restriction sites.
Exonucleases – Cut the DNA at the ends (Remove the nucleotides at the ends of the DNA)
Over 900 restriction enzymes have been isolated, all of which recognize different DNA sequences. (Recognition sequences) These sequences are Pallindromic in DNA.

- **Restriction enzymes** cut a little away from the center of palindrome site, but between the same two bases on the opposite strands. As a result, overhangs (called sticky ends) are generated on each strand.
- **Sticky ends** form hydrogen bonds with their complementary counter parts with help of DNA ligases to form rDNA molecule.

E.g., Palindromic nucleotide sequence for EcoRI (cleaves the H-H bonds between the bases G-A of the palindrome sites GAATTC of both the strands) is

5' —— GAATTC —— 3'
3' —— CTTAAG —— 5'



Naming/Nomenclature of the Restriction enzymes:

- First letter indicates the Genus of source microbes.
- The second two letters indicate species. The third letter indicates the strain source microbes.
- Roman numbers is the order in which the enzymes were isolated from that strain of bacteria).
- "EcoRI' is isolated from the bacteria ***Escherichia coli***

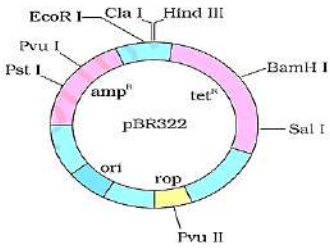
E from Escherichia, **co** from coli, **R** from 'RY13', **'I'** isolated first from that bacteria

Q.1 Why is the same restriction enzyme used for both DNA molecules?

2.Cloning Vectors: Following features are required to facilitate cloning into a vector:-

1. Origin of Replication (ori):	It is a sequence from where the replication starts .Initiates replication, controls copy number.
2. Selectable Markers:	Identify transformed cells, e.g., antibiotic resistance genes.

3. rop	Controls initiation of plasmid replic
4. Cloning Sites:	Restriction sites for inserting foreig ligated at BAM HI site of tetracycli



Q.2 A scientist transforms bacteria be **with plasmid pBR322 carrying a foreign gene inserted into the tetR region. The bacteria are first grown on ampicillin-containing medium and then transferred to tetracycline-containing medium. Which colonies are most likely recombinant?**

E.coli cloning vector PBR322

● **Plasmids and Bacteriophages**: Capable of replicating independently within bacterial cells.

Vectors for Plants and Animals:

1.Agrobacterium tumefaciens (Ti plasmid) for plants, 2. Retroviruses for animals.

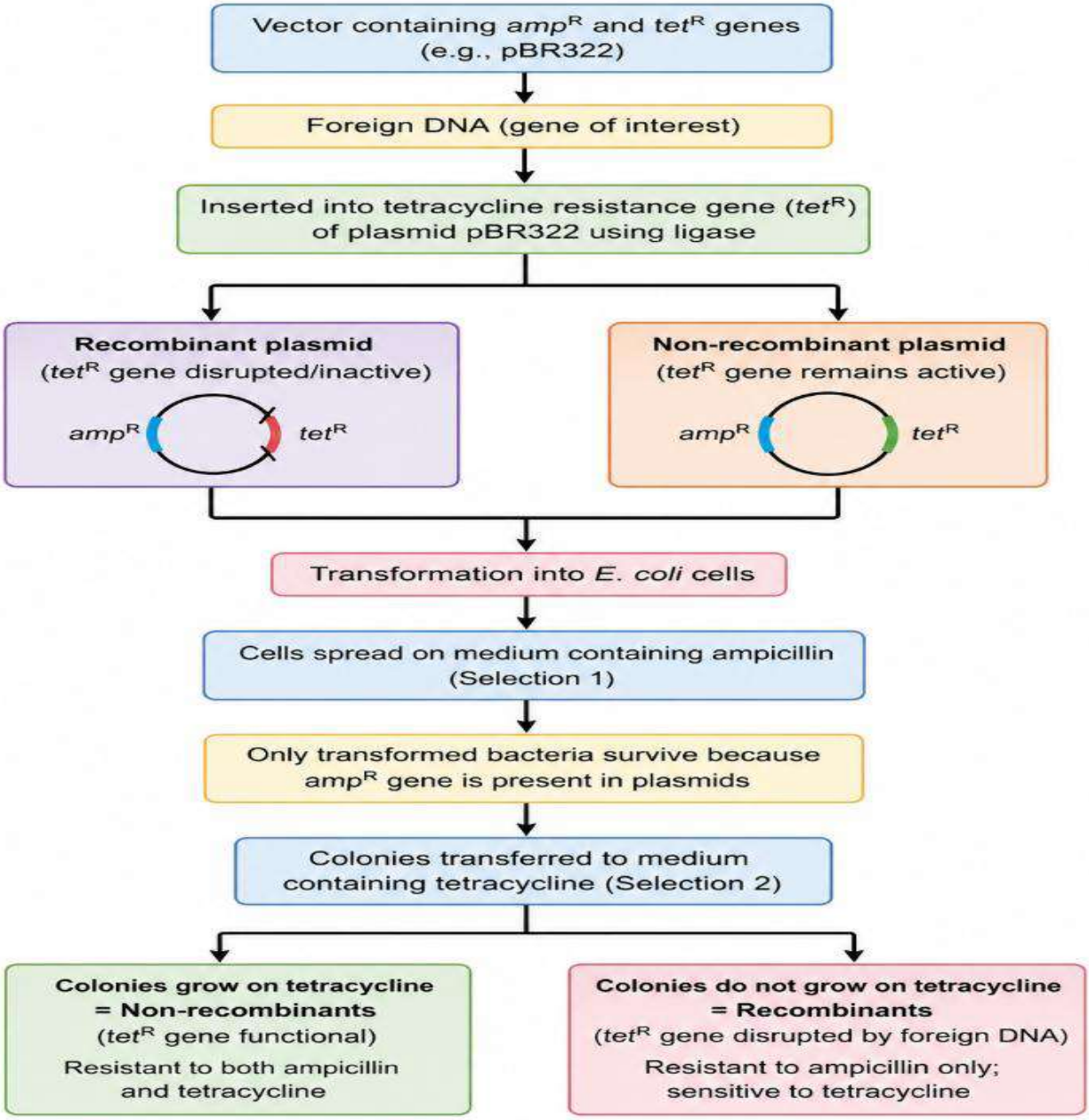
Q.3 Assertion: A piece of DNA inserted into an alien organism generally does not replicate if not inserted into a chromosome.

Reason: Chromosomes have specific sequences called 'ori' region where DNA replication is initiated.

Selection of Recombinants using antibiotic resistance genes: Selection of recombinants is the process of identifying bacteria that contain recombinant DNA.

It is done using marker genes, such as antibiotic resistance genes, to distinguish recombinants from non-recombinants.

Selection of recombinants through insertional inactivation: It is a method used to identify recombinants by inserting a foreign DNA into β-galactosidase (lac z) gene, which inactivates it. Recombinants form **white**



colonies while non-recombinants form **Blue** colonies in the medium (Blue-white screening). It is done using pUC18 as a vector.

3.Competent Host: It is a host cell that has the ability to take up foreign DNA or recombinant DNA from the surroundings (transformation with recombinant DNA). A host is made competent artificially by following methods:-

Method	**Explanation**
Divalent Cation	Treating a cell with a specific concentration of a divalent Cation, such as calcium ion, increases the cell's efficiency to take DNA.
Heat and shock	incubating the host cell under heat and then ice, create pores on the wall through which DNA enters the bacterium.
Micro-injection	rDNA is directly injected into the nucleus of an animal cell
Biolistic/ Gene gun method	plant cells are bombarded with high-velocity micro-particles of gold or tungsten coated with DNA.
Disarmed pathogen vectors	Infect host cell and transfer r- DNA into them

Processes of Recombinant DNA Technology

• Isolation of Genetic Material (DNA):	Breaking cells open to release DNA using enzymes like lysozyme (bacteria), cellulase (plants), chitinase (fungi). Removing RNA and proteins to purify DNA.
• Cutting of DNA at Specific Locations:	Using restriction enzymes to cut DNA at specific sites. Visualizing DNA fragments using agarose gel electrophoresis.
• Amplification of Gene of Interest using PCR:	In vitro synthesis of multiple DNA copies using PCR
• Insertion of Recombinant DNA into Host Cells:	Introducing ligated DNA into host cells to transform them, e.g., E. coli with antibiotic resistance genes. Selecting transformed cells using selective media.
• Obtaining the Foreign Gene Product:	Cloning genes into vectors and transferring into host cells for expression. Producing recombinant proteins in large scale using bioreactors
• Downstream Processing:	Purification and formulation of the product after biosynthesis. Clinical trials and quality control testing.

Gel Electrophoresis:-

It is a technique used to separate DNA bands on a gel under the applied electric field.

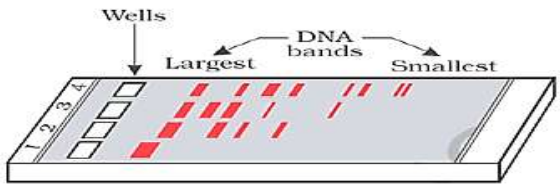
Principle: Seperation on DNA bands takes place on the basis of their molecular weight and size.

Steps:

a) The fragments of DNA obtained after cutting with restriction enzymes are separated by using gel electrophoresis.

b) Electric field is applied to the electrophoresis matrix (commonly agarose gel) and negatively charged DNA fragments move towards the anode.

c) Fragments separate according to their size by the sieving properties of agarose gel. Smaller the fragment, farther it moves.



e) DNA fragments are visible as bright orange coloured bands in the agarose matrix.

f) These bands are cut from the agarose gel and extracted from the gel piece (elution).

d) Staining dyes such as ethidium bromide followed by exposure to UV radiations are used to visualize the DNA fragments.	g) DNA fragments are purified and these purified DNA fragments are used in constructing recombinant DNAs.

Q4. Nowadays says which matrix is used in gel electrophoresis? From which source one can get gel used in electrophoresis?

Q.5. Bacterial cells are treated with $CaCl_2$ and subjected to heat shock before adding plasmid DNA.

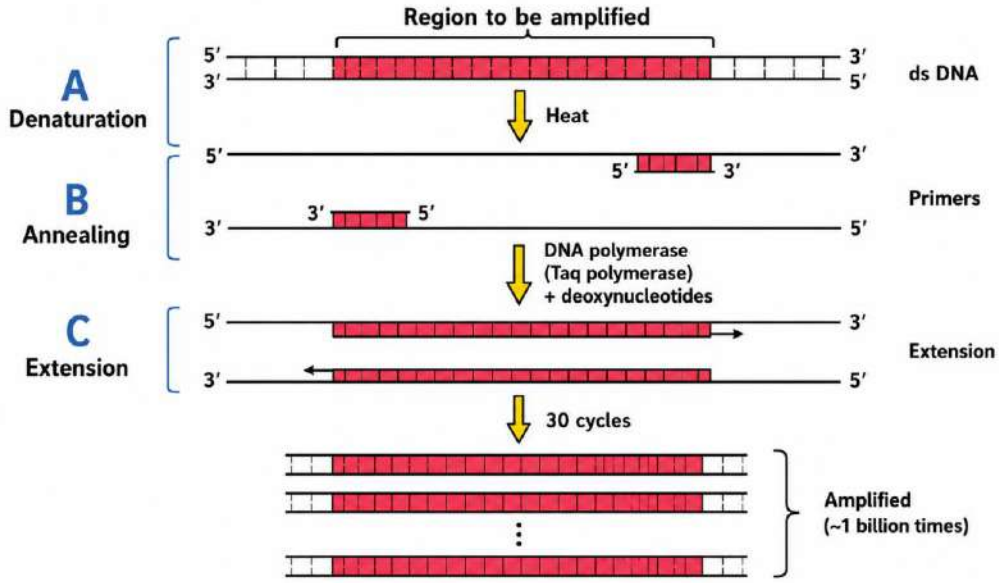
a. **Why is $CaCl_2$ treatment necessary?**
b. **What is the function of heat shock?**
c. **What is meant by competency?**

Polymerase Chain Reaction (PCR)

It is a technique used to make multiple copies of a specific segment of DNA. PCR consists of 3 steps:

Denaturation	Double helical DNA is denatured by providing high temperature (94 °C
Annealing	Joining of the two Primers at the 3' end of DNA template (at about 52 °C).
Extension	Addition of nucleotides to the primer and extending the chain (at about 72 °C). DNA polymerase get degraded in such high temperatures hence the thermostable Taq DNA polymerase used in this reaction as it is isolated from thermophilic bacteria, *Thermus aquaticus* (Taq).

This cycle is repeated several times to generate up to 1 billion identical copies of the DNA.



Q.6 During PCR, denaturation at high temperature helps to:

Q.7 a. Explain the correct sequential step of polymerase chain reaction.

b. Which enzyme is used for PCR and why?

C. What is the source of that enzyme?

Q.8 How and why is the bacterium Thermus aquaticus employed in recombinant DNA technology? Explain.

Bioreactors

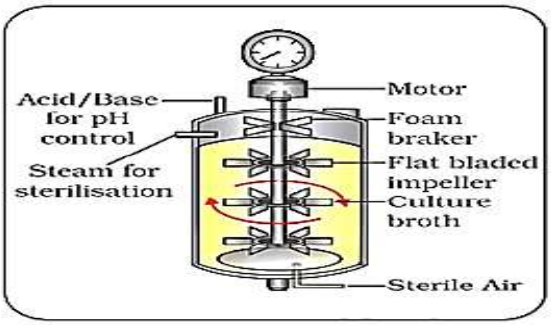
- These are the vessels in which raw materials are biologically converted to specific products, enzymes

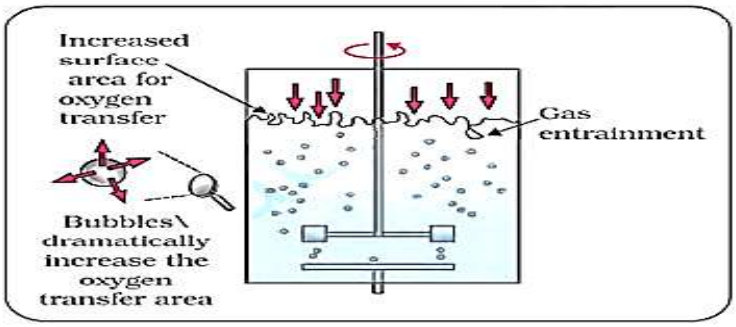
etc., using microbial, plant, animal, or human cells.

- Bioreactors are used to produce large quantities of products. They can process 100-1000 litres of culture.
- A bioreactor provides the optimal growth conditions (pH, temperature, substrate, salts, and vitamins, oxygen) to get desired product.
- The most used bioreactors are of stirring type (stirred-tank bioreactor). It is usually cylindrical or with a curved base to facilitate the mixing of the reactor contents. The stirrer facilitates even mixing and oxygen availability. Alternatively, air can be bubbled through the reactor.

The bioreactor has the following facilities.

- 1. An agitator system 2. An oxygen delivery system
- 3. A foam control system 4. A temperature control system
- 5. pH control system 6. Sampling ports (for periodic withdrawal of the culture)





Downstream Processing: – It is a series of processes such as separation and purification of products after the biosynthetic stage.

– The product is formulated with suitable preservatives. Such formulation undergoes thorough clinical trials and strict quality control testing.

BIOTECHNOLOGY: PRINCIPLES AND PROCESSES

MAIN TOPICS

1. Recombinant DNA Technology

1.1 Restriction Endonuclease
- Enzymes that recognise specific palindromic (reverse repeat) sequences in DNA and cut both the strands at or near these sites.
- Generate sticky or blunt ends.

1.2 Plasmid as Cloning Vector
- Plasmids are small, circular, double-stranded DNA molecules in bacteria.
- Have an origin of replication (ori) for autonomous replication.
- Contain selectable marker genes.
- Used to carry foreign DNA into host cells.

1.3 Selectable Marker
- Genes that confer resistance to antibiotics or other agents.
- Help in identifying transformants (recombinant cells) from non-transformants.
- Only cells with the marker gene survive under selective conditions.

1.4 Selection of Recombinants
- Host cells are plated on medium containing appropriate antibiotic.
- Only recombinant cells carrying the selectable marker grow.
- Non-recombinant cells die.
- Recombinants are identified and isolated.

1.5 Gene Transfer
- Introduction of recombinant DNA into a host cell.
- Methods: Transformation ($CaCl_2$ method, heat shock, electroporation), microinjection, biolistics, viral vectors.
- Transformed cells replicate and express the cloned gene.

2. Isolation of DNA

2.1 Cell Lysis
Cells are broken using detergents (SDS), enzymes (lysozyme) or physically to release DNA.

2.2 Removal of Proteins
Proteins are removed by treatment with proteases (proteinase K) and by phenol–chloroform extraction.

2.3 DNA Precipitation
DNA is precipitated by anding cold alcohol (ethanol/isopropanol) and salt.

2.4 Spooling and Washing
DNA strands are spooled out using glass rod, washed with 70% ethanol and dried.

2.5 Dissolution
DNA is dissolved in TE buffer (Tris–EDTA) and stored.

3. Agarose Gel Electrophoresis

3.1 Principle
Separation of DNA fragments based on their size and charge in an electric field through agarose gel matrix.

3.2 Procedure
- Agarose is dissolved in buffer and poured in a tray with comb to form wells.
- DNA samples mixed with loading dye are loaded into wells.
- Electric current is applied; DNA (fregments move towards positive electrode.
- Smaller fragments move faster and travel farther.

3.3 Staining
Gel is stained with ethidium bromide (or safer dye) which intercalates with DNA.

3.4 Visualization
DNA bands are visualized under UV light and photographed.

3.5 Uses
- Check purity of DNA
- Determine size of DNA fragments using DNA ladder
- Confirm results of PCR and recombinant DNA experiments

4. PCR (Polymerase Chain Reaction)

4.1 Principle
In vitro amplification of a specific DNA segment using repeated cycles of temperature changes and DNA polymerase.

4.2 Components
- Template DNA
- Two primers (forward and reverse)
- dNTPs
- Thermostable DNA polymerase (e.g., Taq polymerase)
- Buffer with Mg^{2+}

4.3 Steps (One Cycle)
- Denaturation (94–95 °C): Double-stranded DNA separates.
- Annealing (50–65 °C): Primers bind to complementary sequences.
- Extension (72 °C): DNA polymerase extends primers and synthesizes new DNA strands.

4.4 Amplification
Repeated for 25–35 cycles resulting in exponential amplification (2^n copies) of the target DNA fragment.

4.5 Uses
- Cloning and diagnostics
- Detection of pathogens
- DNA fingerprinting
- Forensic applications
- Research studies

5. Bioreactor

5.1 Definition
A vessel or system designed to provide an optimal environment for the growth of microorganisms or cells to produce desired products.

5.2 Components
- Vessel
- Agitator (stirrer)
- Aeration system
- Sparger
- pH and temperature control system
- Sensors and probes

5.3 Types
- Stirred-tank bioreactor
- Air-lift bioreactor
- Bubble column bioreactor

5.4 Parameters Controlled
- Temperature
- pH
- Dissolved oxygen
- Agitation
- Nutrient supply
- Foam control

5.5 Uses
Large-scale production of biopharmaceuticals, enzymes, vaccines, organic acids, antibiotics, etc.

Integration and Outcome

These techniques and tools are integrated in biotechnology to isolate genes, construct recombinant DNA, amplify and analyse DNA, and produce desired products at large scale using bioreactors.

Overall Significance

- Form the basis for modern biotechnology and genetic engineering.
- Enable production of valuable products for healthcare, agriculture, industry and research.

CHAPTER-10-BIOTECHNOLOGY AND ITS APPLICATIONS

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE SYLLABUS 2026-27(Marks-6-8) Application of biotechnology in health and agriculture: Human insulin and vaccine production, stem cell technology, gene therapy; genetically modified organisms - Bt crops; transgenic animals; biosafety issues, biopiracy and patents.

The critical research areas in biotechnology are:

1. Improved Catalysts: Using enhanced organisms or pure enzymes.
2. Optimal Conditions: Engineering the best environment for catalysts to act.
3. Downstream Processing: Technologies to purify proteins or organic compounds.

APPLICATION IN AGRICULTURE

Involves three aspects for increasing food production:

- Agrochemical-based agriculture
- Organic agriculture
- Genetically engineered crop-based agriculture

Green revolution succeeded in tripling the food supply by the use of:

- Improved crop varieties
- Better management practices
- Agrochemicals (fertilisers and pesticides)

Tissue Culture

Technique of regenerating whole plant from any explants, i.e., any part of a plant taken out and grown in a test tube under sterile conditions.

The capacity to generate a whole plant from any cell/explant is called **totipotency**.

Techniques of Tissue Culture

Micropropagation	Meristem Culture
– Technique for growing thousands of plants in a shorter time by providing proper nutrients – Each grown plant will be genetically identical to the parent plant, i.e., somaclones – Examples: Tomato, banana, apple, etc.	– Recovering a healthy plant from a diseased plant (infected with a virus) by removing the meristem (apical and axillary) and growing them under in vitro conditions
Somatic Hybridisation – Process of fusing the protoplasts of different varieties or species of plants in a suitable nutrient medium under in vitro conditions to develop a somatic hybrid – For e.g., Pomato is the somatic hybrid produced by the protoplasmic fusion of tomato and potato	

Genetically Modified Organisms (GMOs)

- Plants, bacteria, fungi, and animals whose genes have been altered by **gene manipulation**

Genetic modification of crops has resulted in:

- Crops more tolerant to abiotic stress
- Reduced reliance on chemical pesticides
- Reduced post-harvest loss
- Increased efficiency of mineral usage by plants
- Enhanced nutritional value of food, e.g., **golden rice** (enriched in vitamin A)

Insect-resistant Plants

Bt Cotton

- Genetically modified crops like Bt cotton and Bt corn are engineered with a gene from Bacillus thuringiensis and produce CRY proteins to reduce insecticide use
- The bacterium produces CRY proteins, which act as biopesticides by killing insects

Pathway of action:

- Bt toxins (inactive form present in the genetically modified plant) are ingested by insects
- Alkaline pH in the insect's gut solubilises the crystal proteins

Bt COTTON — Insect-Resistant Transgenic Crop

Bacillus thuringiensis and the Insecticidal Protein

Some strains of *Bacillus thuringiensis* produce proteins that kill certain insects such as:

Lepidopterans	Coleopterans	Dipterans
Tobacco budworm, armyworm	Beetles	Flies, mosquitoes

- *B. thuringiensis* forms **protein crystals** during a particular phase of their growth. These crystals contain a **toxic insecticidal protein**.
- Genetically modified crops like Bt cotton and Bt corn are engineered with a gene from Bacillus thuringiensis and produce CRY proteins to reduce insecticide use
- The bacterium produces CRY proteins, which act as biopesticides by killing insects

Pathway of action:

- Bt toxins (inactive form present in the genetically modified plant) are ingested by insects
- Alkaline pH in the insect's gut solubilises the crystal proteins

Why Does the Toxin Not Kill the Bacillus?

In the Bacterium	In the Insect's Gut
– Bt toxin protein exists as **inactive protoxin** — harmless to the host – The inactive form does not damage the bacterium's own cells	– Insect ingests inactive toxin – Alkaline pH of the gut **solubilises the crystals** – Converted into **active form of toxin**

Mode of Action of Bt Toxin

1	**Ingestion**	Insect ingests the inactive Bt toxin (protoxin) crystals present in the transgenic plant	*Inactive protoxin*
2	**Activation**	Alkaline pH of the insect midgut solubilises the crystal proteins and converts protoxin to active toxin	*Active toxin formed*
3	**Binding**	Activated toxin binds to the surface of midgut epithelial cells	*Specific receptor binding*
4	**Pore formation**	Toxin creates pores in the epithelial cell membrane causing cell swelling and lysis	*Cell rupture*
5	**Insect death**	Disruption of midgut cells leads to eventual death of the insect	*Pest eliminated*

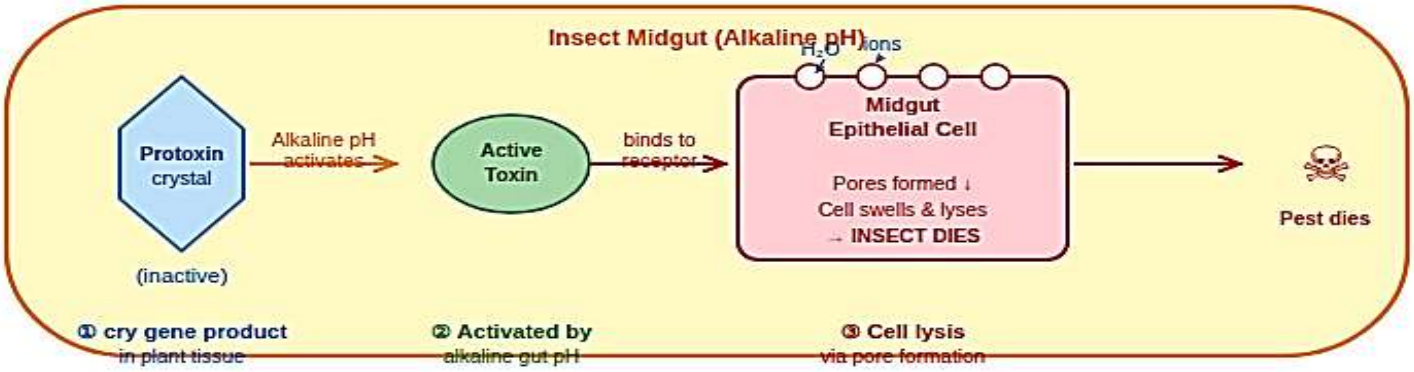
Bt Cotton and cry Genes

- Specific Bt toxin genes were isolated from *Bacillus thuringiensis* and incorporated into several crop plants such as **cotton** (Figure 10.1).
- The choice of genes depends upon the **crop** and the **targeted pest**, as most Bt toxins are insect-group specific.
- The toxin is coded by a gene named ***cry***.

cry genes and their targets:

Gene	Crop	Pest Controlled
cryIAc & cryIIAb	Cotton (Bt cotton)	Cotton bollworms
cryIAb	Corn (Bt corn)	Corn borer

Diagram: Bt Toxin Action in Insect Midgut



RNA Interference (RNAi) Strategy

Introduction — The Problem

Nematodes are tiny roundworms that parasitise a wide variety of plants, animals, and even human beings. One such nematode causes serious damage to a major cash crop.

Aspect	Detail
Pest (Nematode)	Meloidogyne incognita
Host Plant	Tobacco (Nicotiana tabacum)
Mode of Attack	Infects the roots of tobacco plants
Effect on Crop	Causes a great reduction in yield — significant economic loss
Challenge	Traditional pesticides are ineffective inside root cells

RNAi - RNA interference (RNAi) is a natural cellular defense mechanism present in ALL eukaryotic organisms. It was discovered by Andrew Fire and Craig Mello (Nobel Prize, 2006).

Core Principle: RNAi silences the expression of a specific gene (mRNA) by using a complementary double-stranded RNA (dsRNA) molecule.

Key Definition: RNAi = Silencing of a specific mRNA due to a complementary dsRNA molecule that binds to it and prevents its translation.

Natural Sources of dsRNA

- **Viral infection:** Viruses with RNA genomes produce dsRNA inside host cells
- **Mobile genetic elements:** Transposons that replicate via an RNA intermediate

Mechanism of RNAi (Steps)

1	**dsRNA Enters the Cell** A double-stranded RNA (dsRNA) molecule enters or is produced inside the eukaryotic cell.
2	**Dicer Cuts the dsRNA** An enzyme called Dicer cleaves the dsRNA into small fragments called siRNA (small interfering RNA), about 21–23 nucleotides long.
3	**RISC Formation** siRNA is incorporated into a protein complex called RISC (RNA-Induced Silencing Complex).
4	**mRNA Targeting** The antisense strand of siRNA guides RISC to bind to the complementary target mRNA sequence.
5	**mRNA Degradation** RISC cleaves and degrades the target mRNA, preventing its translation into protein — gene is effectively SILENCED.

Strategy to Protect Tobacco Plants (RNA i)

Q.1 Assertion: RNAi takes place in all eukaryotic organisms as a method of cellular defiance.
Reason: RNAi silences specific mRNA of the pathogen through a complementary dsRNA and protects the plant.
Q.2.How did the process of RNA interference help to control the nematode from infecting roots of tobacco plants? Explain.

The Approach — Overview

Scientists used the RNAi pathway as a weapon against the nematode. The goal was to silence a gene essential for the nematode's survival, from inside the plant cell itself.

Step-by-Step Process

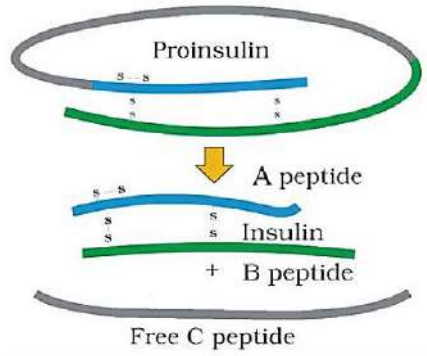
1	**Identify Nematode-Specific Genes** Scientists identified genes that are specific to Meloidogyne incognita and essential for its survival.
2	**Use Agrobacterium as Vector** These genes were cloned into Agrobacterium tumefaciens — a commonly used plant genetic engineering vector (Ti plasmid).
3	**Introduce DNA into Host Plant** The recombinant Agrobacterium was used to introduce the nematode gene DNA into tobacco plant cells (transgenic plant created).
4	**Both Sense & Antisense RNA Produced** The DNA was engineered so that BOTH sense RNA and antisense (complementary) RNA were produced in the host plant cells simultaneously.
5	**dsRNA Formed Inside Plant** The sense and antisense RNA strands, being complementary to each other, hybridised to form a double-stranded RNA (dsRNA).
6	**RNAi Triggered** This dsRNA initiated the RNAi pathway inside the plant cell, targeting and silencing the specific nematode mRNA.
7	**Nematode Cannot Survive** When the nematode feeds on the transgenic plant roots, the siRNA enters the nematode. Its essential gene is silenced → nematode dies. Plant is protected!

Q.3 Which bacterium is the source of the gene suggested by the scientist?
***Q4.Cry* gene is extensively used in genetic engineering to develop transgenic plants like cotton. Name the source organism from which one can get the *cry* gene.**

GENETICALLY ENGINEERED INSULIN

Human Insulin is a hormone produced by the pancreas that regulates blood sugar levels. In individuals with diabetes, the body either does not produce enough insulin (Type 1 diabetes) or cannot effectively use the insulin it produces (Type 2 diabetes). Traditionally, insulin for medical use was extracted from the pancreas of slaughtered cattle and pigs.

However, this animal-derived insulin could cause allergic reactions in some patients. The advent of recombinant DNA technology has enabled the production of human insulin in bacteria, providing a more effective and safer alternative.



Structure of Insulin

Insulin consists of two short polypeptide chains: Chain A and Chain B.

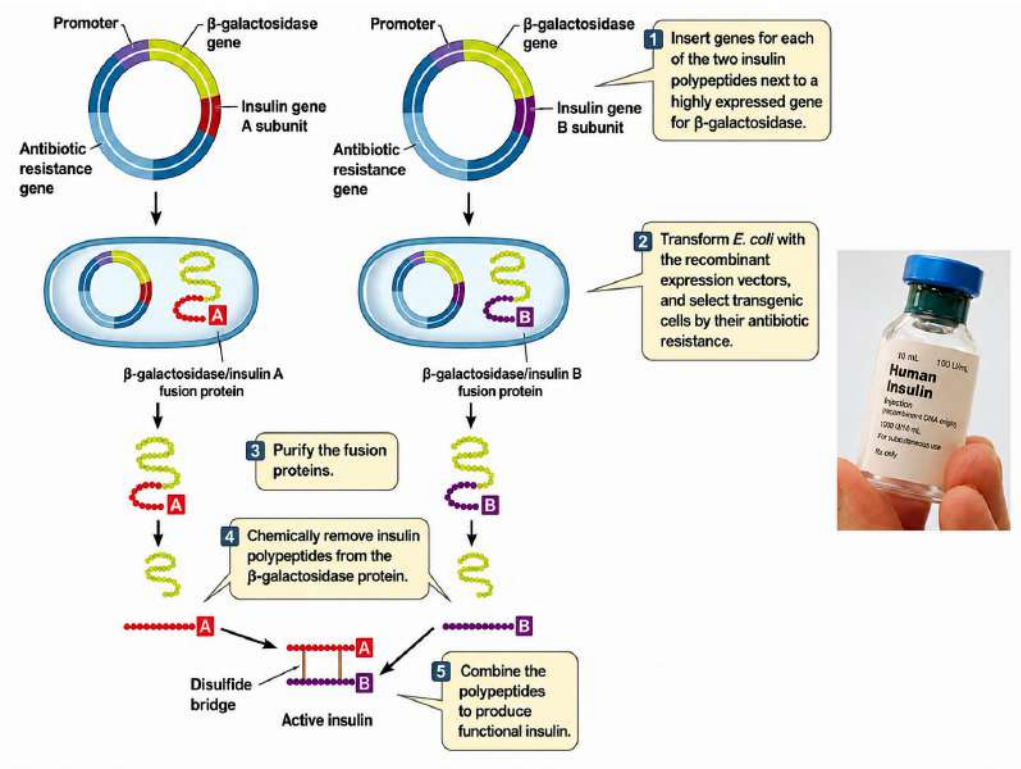
- These chains are linked together by disulfide bridges.
- In mammals, including humans, insulin is initially synthesized as a prohormone called proinsulin.
- Proinsulin contains an extra stretch called the C peptide, which is removed during maturation to form functional insulin.

Challenges in Insulin Production

- The primary challenge in producing insulin using recombinant DNA technology was assembling the insulin chains into a mature form.
- Human insulin needs to be identical to the natural molecule to avoid immunological responses.

Q.5 Insulin from an animal source is discontinued in use because

Production of Genetically Engineered Insulin



1. **Gene Cloning**:

- The genes encoding the A and B chains of human insulin were identified and cloned.
- These genes were inserted into plasmids, which are circular DNA molecules used as vectors to introduce foreign genes into host cells.

2. **Transformation**:

- The recombinant plasmids carrying the insulin genes were introduced into *Escherichia coli* (E. coli) bacteria through a process called transformation.
- E. coli cells took up the recombinant plasmids and began to produce the insulin chains.

3. **Expression**:

- In the 1980s, Eli Lilly, an American pharmaceutical company, developed a method to produce human insulin in bacteria.
- The company prepared two separate DNA sequences corresponding to the A and B chains of human insulin and inserted them into different plasmids.
- These plasmids were then introduced into separate cultures of *E. coli*, leading to the production of the individual A and B chains.

4. **Purification and Assembly**:

- The A and B chains were produced separately and then extracted from the bacterial cultures.
- The extracted chains were purified to remove any bacterial contaminants.
- Finally, the A and B chains were combined and chemically bonded through disulfide bridges to form functional human insulin.

GENE THERAPY

Gene therapy is a collection of methods that allows the correction of a gene defect diagnosed in a child or embryo. It involves the delivery of a normal gene into the individual's cells and tissues to take over the function of and compensate for the non-functional gene.

Types of Gene Therapy

1. <u>Somatic Gene Therapy</u>:
   Targets somatic (body) cells. Genetic changes are not passed on to the next generation.
2. <u>Germ line Gene Therapy</u>:
   Targets germ cells (sperm / eggs/zygote or early embryos). Genetic changes are heritable and passed on to future generations. Currently not practiced in humans due to ethical and technical issues.

- The first clinical gene therapy was given in 1990 to a four years old girl with adenosine deaminase deficiency.
- This disorder is caused due to the deletion of the gene for adenosine deaminase enzyme responsible for the production of normal functional T- lymphocyte for normal immunity.

<u>Possible cure for the ADA disorder</u>

- Bone Marrow Transplantation: Can cure some children but has limitations.

- Enzyme Replacement Therapy: Functional ADA enzyme is given to the patient by injection but is not a permanent cure.
- Gene Therapy:-Lymphocytes from the blood of patient are grown in a culture. A functional ADA cDNA is then introduced into these lymphocytes and subsequently retured into the patients' body.As these cells are not immortal, the patient required periodic infusion of such genetically engineered lymphocytes.
- It could be a Permanent Cure if a functional gene is introduced into a bone marrow cells at early embryonic stage.

MOLECULAR DIAGNOSIS

Molecular Diagnosis: For effective treatment of a disease, early diagnosis and understanding its pathophysiology is crucial.

Molecular diagnosis uses techniques that identify diseases by detecting specific genes or gene products. These techniques are more sensitive and specific than traditional methods.

Techniques of Molecular Diagnosis

1. Recombinant DNA Technology

o Involves the manipulation of DNA to identify genetic mutations or the presence of pathogens.

o Allows for the detection of specific DNA sequences associated with diseases.

2. Polymerase Chain Reaction (PCR)

o PCR is a powerful technique to amplify a specific segment of DNA.

o It can detect very low amounts of DNA in a sample, making it useful for early diagnosis.

o Application:

▪ Used to detect the presence of HIV in suspected AIDS patients.

▪ Helps in identifying genetic mutations in cancer patients.

▪ Can detect pathogens in various infectious diseases.

o Procedure:

▪ A small DNA sample is mixed with primers, nucleotides, and DNA polymerase.

▪ The mixture is subjected to repeated cycles of heating and cooling to denature the DNA, anneal primers, and extend new DNA strands.

▪ The result is the exponential amplification of the target DNA sequence.

3. Enzyme-Linked Immunosorbent Assay (ELISA)

o Based on the principle of antigen-antibody interaction.

o Used to detect the presence of antigens (proteins, glycoproteins) or antibodies in a sample.

o Application:

▪ Used to diagnose infections by detecting antibodies against pathogens like viruses and bacteria.

▪ Can be used to monitor the immune response to infections and vaccines.

o Procedure:

▪ The sample is added to a plate coated with a specific antigen or antibody.

▪ If the target antigen or antibody is present in the sample, it will bind to the coating.

▪ A secondary antibody conjugated to an enzyme is added, which binds to the target.
▪ A substrate for the enzyme is added, leading to a colour change that indicates the presence of the target antigenor antibody.

4. Autoradiography and DNA Probes

A single-stranded DNA or RNA, tagged with a radioactive molecule (probe), is used to detect its complementary DNA.

Procedure:
▪ The probe hybridizes to its complementary DNA in a sample.
▪ The sample is then subjected to autoradiography.
▪ The presence of the probe is visualized as bands on a photographic film, indicating the presence of the target DNA sequence.

Application:
▪ Used to identify specific genes or mutations.
▪ Helps in the diagnosis of genetic disorders and infections.

Advantages of Molecular Diagnosis

1. Early Detection:
Molecular techniques can detect diseases at a very early stage, even before symptoms appear.
Early diagnosis allows for timely treatment and better management of diseases.
2. High Sensitivity and Specificity:
These techniques can detect low levels of pathogens or genetic mutations with high accuracy.
They reduce the chances of false positives and false negatives.
3. Wide Range of Applications:
Molecular diagnosis is applicable to various fields, including infectious diseases, genetic disorders, cancer, and monitoring immune responses.

Molecular diagnosis has revolutionized the field of medical diagnostics by providing highly sensitive, specific, and early detection methods. Techniques like recombinant DNA technology, PCR, ELISA, and DNA probes have become indispensable tools in the diagnosis and management of diseases, enabling more effective treatment and improved patient outcomes

Technique	Principle	Application	Detects	Result
rDNA Technology	DNA manipulation	Genetic mutations, Pathogens	DNA sequence	Gene mutation
PCR	DNA amplification	HIV, Cancer genes, any pathogen	DNA fragment	Gel bands
ELISA	Ag–Ab interaction	Viral/bacterial infections	Antigen/Antibody	Colour change
DNA Probe	Hybridization	Genetic disorders, mutations	DNA sequence	Autoradiograph band
Q.6 How is a probe used in molecular diagnostics?				

Ans: A probe is a ss DNA or RNA used to search for its complementary sequence in a sample genome. By the process of hybridization and autoradiography, the probes can be identified.

Q.7. How have transgenic animals proved to be beneficial in:

a. Production of biological products?

b. chemical safety testing?

Ans. a. Rosie–the transgenic cow, produced human proteins containing human a-lactalbumin. Transgenic animals have been made to produce a-1-antitrypsin used to treat emphysema.

b. Toxicity testing – Transgenic animals are more sensitive to toxic substances, so the results are obtained in less time.

TRANSGENIC ANIMALS

Animals whose DNA is **manipulated** to possess and express an extra (foreign) gene. E.g., transgenic rats, rabbits, pigs, etc. Reasons for developing transgenic animals are:

Study normal physiology and development	Study of diseases
– Useful to study gene regulation, their effect on the normal functioning and development, for e.g., study of insulin-like growth factor	– Study of genes that are responsible for diseases in humans and transgenic models have been developed for many human diseases like cancer, cystic fibrosis, rheumatoid arthritis and Alzheimer's disease.

Biological products	– Produced by introducing a portion of DNA into transgenic animals to produce a particular product – For e.g., α-1-antitrypsin (human protein) used to treat emphysema – In 1997, the first transgenic cow, Rosie, produced human protein-enriched milk (2.4 g/L). The milk contained the human alpha-lactalbumin and was more balanced for human babies than natural cow milk.
Vaccine safety	– Transgenic mice are developed to test the safety of vaccines before they can be used on humans, for e.g., polio vaccine
Chemical safety testing	– Used for testing the toxicity of drugs – Transgenic animals are made to carry genes which make them more sensitive to toxic substances than non-transgenic animals – Toxicity testing in such animals will allow us to obtain results in less time

Q.8 A biotechnological product human protein (a-1-antitrypsin) from transgenic animals is used to treat

Ethical issues: The manipulation of living organisms by humans, particularly through genetic engineering, raises several ethical issues. These concerns revolve around the morality, safety, and potential consequences of such activities on living organisms and the environment.
GMOs can have unpredictable results when such organisms are introduced into the ecosystem.
The modification/usage of living organisms for public services has also created problems with patents
Therefore Regulatory bodies like
Genetic Engineering Approval Committee (GEAC) in India oversee the validity of GM research and the safety of introducing GMOs for public services
There is a need for transparency, public engagement, and education to address concerns and build trust in biotechnological advancements.
Biopatent:-It is the Right given to the Inventor or a country about his invention or a biological resource to prevent the illegal use by others.
Biopiracy:- It refers to the unauthorized/illegal use of biological resources by multinational companies and organizations without proper compensation to the countries and people concerned.
An example of biopiracy is the case of Indian Basmati rice, where an American company was granted a patent on Basmati rice lines and grains, derived from Indian farmer's varieties. This patent allowed the company to sell Basmati rice in the US and abroad, potentially restricting the rights of Indian farmers and traditional practices
Q.9 What is biopiracy?

Mind Map

• BIOTECHNOLOGY IN AGRICULTURE			
Tissue Culture	**GMO Crops**	**Bt Cotton**	**RNAi / Pest Resistance**
Totipotency → Explants Micro-propagation Somaclones Virus-free via Meristem Somatic Hybridisation (Pomato example)	Made crops tolerant to abiotic stress (cold, drought) Reduced pesticides Enhanced nutrition (Golden Rice – Vit. A) Increased mineral efficiency	Bacillus thuringiensis cry genes (cryIAc, cryIIAb) Protoxin → Active toxin (alkaline gut pH) Kills lepidopterans, coleopterans, dipterans	Meloidegyne incognita nematode in tobacco Agrobacterium vectors dsRNA → RNAi silencing Parasite cannot survive in transgenic host

Q.10 Assertion: The Green Revolution succeeded in tripling the food supply but yet it was not enough to meet the demands of the growing population.
Reason: Agrochemicals were very expensive and it was not possible to increase the

· BIOTECHNOLOGY IN MEDICINE		
Genetically Engineered Insulin	**Gene Therapy**	**Molecular Diagnosis**
Earlier: animal pancreas → allergic reactions Insulin = Chain A + Chain B (disulphide bonds) Eli Lilly (1983): E. coli produced human insulin ~30 recombinant therapeutics approved worldwide	First clinical therapy: 1990 4-year girl with ADA deficiency ADA crucial for immunity Lymphocytes + ADA cDNA (retroviral vector) Bone marrow transplant or enzyme replacement Permanent cure if embryonic	PCR – detects HIV, cancer mutations, genetic disorders DNA/RNA probe + autoradiography ELISA – antigen-antibody detects pathogen proteins or antibodies Early detection before symptoms

· TRANSGENIC ANIMALS (95% are Mice)				
Normal Physiology & Development	**Study of Disease**	**Biological Products**	**Vaccine Safety**	**Chemical Safety Testing**
Study gene regulation Insulin-like growth factor Biological role of genes	Models for: Cancer Cystic Fibrosis Rheumatoid Arthritis Alzheimer's	α-1-antitrypsin (emphysema) Rosie (1997): 1st transgenic cow Human alpha-lactalbumin in milk (2.4g/L)	Test vaccines before human use Polio vaccine tested May replace monkeys	Toxicity/safety testing Carry sensitive genes Results faster than normal animals

ETHICAL ISSUES		
GEAC (India)	**Biopiracy**	**Patent Issues**
Genetic Engineering Approval Committee	Use of bio-resources by multinationals without proper	Basmati rice patent (1997) by US company – derived from Indian

Evaluates GM research and safety of GMOs for public services	authorisation or compensatory payment Developed vs Developing country imbalance	varieties Turmeric, Neem patents Indian Patents Bill amended to protect bio-resources

Q.11 a. What is a disadvantage of the traditional hybridisation procedure?

b. How has rDNA technology overcome the disadvantage identified in (a)?

Biotechnology: Engineering a Better Future

Innovative solutions in agriculture and medicine, addressing ethical regulation

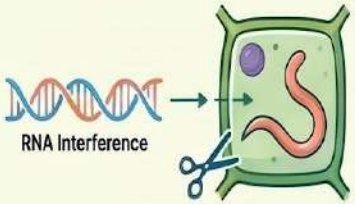
Revolutionising Agriculture

The Rise of GM Crops

GMOs engineered for abiotic stress tolerance and enhanced nutritional value.

Bt Cotton: The Natural Bio-pesticide

Bacillus thuringiensis genes produce toxins that activate in insect guts, reducing need for chemical sprays.



RNA Interference (RNAi)

A cellular defence mechanism used to silence specific nematode genes and protect tobacco plant roots.

Agricultural Approaches Comparison

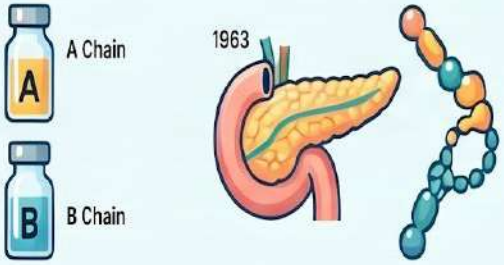
Method	Key Features	Impact
Agro-chemical	Fertilisers and Pesticides	Expensive for developing nations; high environmental cost.
Organic	Natural processes	Environmentally friendly but often lower yields.
GM-based	Genetic manipulation	Increased efficiency, stress tolerance, and nutrient enrichment.

Breakthroughs in Modern Medicine

30 Approved Recombinant Therapeutics

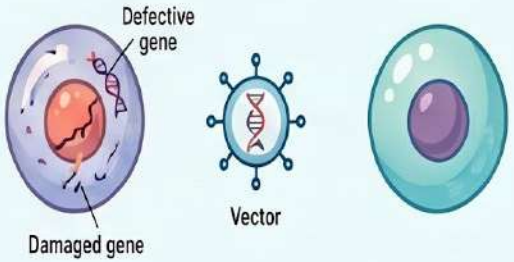
12 of these safe, effective biotech drugs are currently being marketed in India.

Genetically Engineered Insulin



Eli Lilly (1983) successfully produced human insulin by combining separately grown A and B peptide chains.

Gene Therapy for ADA Deficiency



A corrective technique involving the delivery of functional genes into cells to treat hereditary disorders.

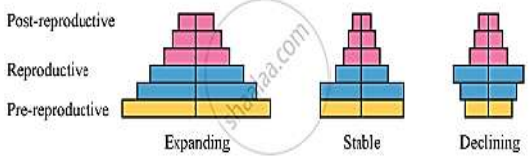
NotebookLM

CHAPTER-11: ORGANISMS AND POPULATIONS

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

CBSE Syllabus(2026-27)- (Marks 4-6) Population interactions - mutualism, competition, predation, parasitism; population attributes - growth, birth rate and death rate, age distribution.

Population: A group of species— -livingin a well-defined geographical area, -share or compete for similar resources, -potentially interbreed In nature. -Population ecology links ecology to population genetics and evolution.	**Example**s: All the cormorants (water birds) in a wetland, Rats in an abandoned dwelling, Teakwood trees in a forest tract, Bacteria in a culture plate and Lotus plants in a pond etc.
Population Attributes OR Characteristics of Population	**1.** Birth rates and death rates**2**.Sex ratio. **3**. Age distribution **4**. Population size (population density)
Birth rates/natality rate number of births per 1,000 individuals of a population per year. per capita births	**Death rates/mortality rate** number of deaths per 1,000 individuals of a population per year. per capita deaths
For example- Original population of lotus plants in a pond= 20 New plants added through reproduction=08 So, birth rate= 8/20 = 0.4 offspring per lotus per year.	For example- Original population of fruit flies in a laboratory = 40 No. of flies died during a week, = 04 So, the death rate in the population during those period = 4/40 = 0.1 individuals per fruitfly per week.
Sex ratio: number of females per 1,000 males of a population in given time. Percentage of male and female individuals in a population (e.g., 60 per cent of the population are females and 40 per cent males)	There are 2 common ways to express it: -Male to female ratio: Example: sex ratio of 105 means there are 105 males for every 100 females. -Female to Male ratio: Example: sex ratio of 95 means there are 95 females for every 100 males

Age distribution: Per cent individuals of a given age or age group in a population at any given time is called age distribution	**Age pyramid** structure that is obtained when per cent individuals of a given age / age group is plotted for the population at any given time, For human population, the age pyramids generally show age distribution of males and females in a diagram.	The shape of the pyramids reflects the growth status of the population - (a) Expanding /growing, - (b) stable - (c) declining. 

Population size (Population density= N): Population Density=Number of unit area in a region / Number of unit area in a region ----- Changes with time. ----- Depends on various factors including food availability, predation pressure and adverse weather.	**Example or Range of Population Size in Nature** <10 Siberian cranes at Bharatpur wetlands in any year. -Millions of *Chlamydomonas* in a pond.

Methods of Measuring Population Density			
1. Total Number **-Most common** and appropriate measure -Not always practical or meaningful	**2. Per Cent Cover / Biomass** -Used when total number is **misleading** -Example: 1 Banyan tree vs. 200 *Parthenium* plants — Banyan's ecological role is vastly underestimated by number alone	**3. Relative Density** - Used when absolute count is unnecessary - Example: Number of fish caught per trap → reflects total lake population	**4. Indirect Estimation** -Used when direct counting is impossible -Example: Tiger census via pug marks & fecal pellets
The best measure of population density depends on the organism, habitat, and purpose of the study — no single method fits all situations.			

<u>**Population Growth**</u> The density of a population in a given habitat during a given period, fluctuates due to changes in 4 basic processes-			
1. Natality (B)	Growth increases (+)	3.Mortality (D)	Growth decreases (-)
2. Immigration (I)		4.Emigration (E)	

	Immigration (I) The number of individuals of the same species that have come from elsewhere.	
Natality(B)+ The number of births	**+** **POPULATION DENSITY (N)**	**-** **Mortality (D)** -The number of deaths
	- **Emigration (E)** The number of individuals of the population who left the habitat and gone elsewhere.	

So, if N is the population density at time t, then its density at time t +1 is-

$$N_{t+1} = N_t + [(B + I) - (D + E)]$$

N_{t+1} = population density at time t,
B = birth rate,
I = immigration,
D = death rate,
E = emigration,

N_t = population in the beginning.

Growth Models

Q.1 Which of the following is the most accurate comment on Earth's carrying capacity (K)?
Q.2 If a population of 50 Paramecium present in a pool increases to 150 after an hour, what would be the growth rate of population?
Q.3 Which curve would depict the population of a species of deer if there are no predators in the habitat? Why is it so?

Population Interactions

S.No.	Interaction	Effect on Species 1	Effect on Species 2	Meaning	Common Examples
1	Mutualism	+	+	Both species are benefited	Lichen (Algae + Fungus), Bee and Flower
2	Commensalism	+	0	One species benefits, the other is unaffected	Orchid on Mango Tree, Cattle Egret and Cattle
3	Parasitism	+	–	Parasite benefits while host is harmed	Tapeworm in Humans, Cuscuta on Plants
4	Predation	+	–	Predator kills and eats prey	Tiger and Deer, Frog and Insects
5	Competition	–	–	Both species are harmed due to struggle for resources	Weeds and Crops, Animals competing for food
6	Amensalism	–	0	One species is harmed while the other is unaffected	Penicillium and Bacteria

Q.4 Predators in nature are said to be 'prudent'. Can you give reason why is it so?

Predation

Role of Predators: Predators act as 'conduits' for energy transfer	
They keep prey populations under control. prickly pear cactus in Australia (1920s) → controlled only after introducing a cactus-feeding moth.	
Predators also help in maintaining species diversity in a community by reducing the intensity of competition among competing prey species.	Example: When all the starfish Pisaster of American Pacific coast were removed from an intertidal area, more than 10 species of invertebrates became extinct within a year, because of interspecific Competition)

Defense mechanisms developed by prey:	**Defenses evolved by Plants (Morphological and chemical) against herbivores**:

Exponential growth: When resources (food and space) in the habitat are unlimited.

dN / dt = (b – d) × N Let (b–d) = r, then $dN/dt = rN$	N= Population Size b=birth rate d=death rate r= intrinsic rate e of natural increase (Reproductive fitness)

The above equation describes the exponential or geometric growth pattern of a population and results in a **J-shaped curve** when we plot N in relation to time.
The integral form of the exponential growth equation is

$N_t = N_0 e^{rt}$	Where N_t= Population density after time t N_0 = Population density at time zero r = intrinsic rate of natural increase (Reproductive fitness) e = the base of natural logarithms (2.71828)

Illustrative Examples

Darwin's Elephant: Even slow-reproducing elephants, left unchecked, would eventually reach enormous numbers — demonstrating that *rate* matters less than *time*.

The Chess Board Anecdote: A minister bet the king wheat grains — 1 on square 1, doubling each square up to 64. The king agreed, thinking it trivial. By the halfway point, the total exceeded the entire kingdom's wheat production — a vivid demonstration of how doubling compounds explosively.

Paramecium: A single individual dividing by binary fission daily — doubling every day — would reach a mind-boggling population in just 64 days under unlimited food and space.

Logistic growth: When resources (food and space) in the habitat are limited.

- Nature's **carrying capacity(K)** is described as the limit beyond which no further growth is possible.
- A plot of N in relation to time (t) results in a sigmoid curve.
- This type of population growth is called **Verhulst-Pearl Logistic Growth** and is described by the following equation-

$$\frac{dN}{dt} = rN[K - N/K]$$

Where N = Population density at time t
r = Intrinsic rate of natural increase
K = Carrying capacity

The 'r' Value

'r' is called the **intrinsic rate of natural increase** — a key parameter used to assess the impact of biotic and abiotic factors on population growth.

Species	r value
Norway rat	0.015
Flour beetle	0.12
Human (India, 1981)	0.0205

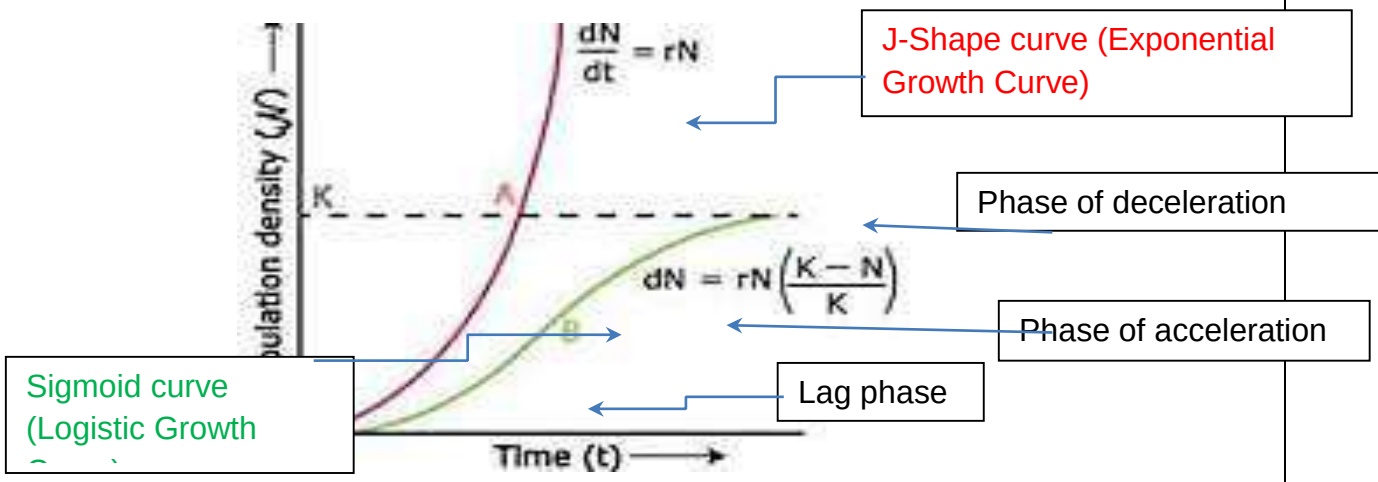
Life History Strategies & Reproductive Fitness

Darwinian Fitness

-Ability to survive and reproduce = high r value
-Populations evolve toward the most efficient reproductive strategy under given selection pressures.

Feature	Semelparity	Iteroparity
Meaning	Single breeding	Multiple breeding
Breeding frequency	Only **once** in lifetime	**Many times** during lifetime
Survival after breeding	Usually **dies** after reproduction	**Survives** to breed again
Energy investment	All energy in **one massive effort**	Energy **spread** across lifetime

Offspring number	Usually **large number** at once	**Fewer** per breeding event	
Examples	Pacific salmon, Bamboo	Most birds, Mammals	



Some species of insects and frogs are cryptically-coloured (camouflaged) to avoid being detected easily by the predator.		~25% of all insects are **phytophagous** (feed on plants). Plants cannot flee, so they evolved special defences. Thorns — *Acacia*, Cactus	
Poisonous prey are avoided by the predators The Monarch butterfly is highly distasteful to its predator (bird) because they acquires toxic chemicals by feeding on poisonous weed during caterpillar stage → avoided by birds.		Calotropis produces highly poisonous cardiac glycosides. Nicotine, caffeine, quinine, strychnine, opium Various plants — defence against grazers/browsers	

<u>Predator–Prey Balance</u>

- Overexploitation of prey → prey extinction → predator extinction (lack of food).
- Therefore, predators in nature are **"prudent"** — they don't overexploit.

Competition:

<u>Competition-</u> a process where the fitness (measured by 'r' — intrinsic rate of increase) of one species is significantly lowered in the presence of another species.

Common Misconceptions & Corrections **Darwin's View**

Misconception	Reality	

Only closely related species compete.	Totally unrelated species can also compete.	Interspecific competition = potent force in **organic evolution**. "Struggle for existence" and "survival of the fittest."
Resources must be limiting for competition.	Competition can occur even when resources are abundant (interference competition).	

Gause's '*Competitive Exclusion Principle*'
It states that two closely related species competing for the same resources cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. This may be true if resources are limiting, but not otherwise.

Evidences in support: <u>Competitive Exclusion-</u> 1.The **Abingdon tortoise** in Galapagos Islands (less browsing efficiency)-became extinct **Goats**(greater browsing efficiency)- → Survived Tortoise excluded / eliminated		
2. **Connell's Elegant field experiment-** In rocky sea coasts of Scotland, **Balanus**(the larger and competitively superior barnacle) dominates and excludes **Chathamalus**(the smaller barnacle) from that zone.(called **'competitive release')**	 larger superior barnacle	 Smaller barnacle chathamalus

Evidences not in support: 1.**Competition for the same resource b/w totally unrelated species** Visiting flamingoes and resident fishes compete for the zooplankton, their common food, in the lake.		
2. 'Resource partitioning mechanism'. Competition can be avoided b/w two species by different foraging patterns. 5 closely related species of warblers living on the same tree are able to avoid competition and **co-exist** due to differences in their foraging activities.		

Parasitism :		
Parasites involve <u>one or two intermediate hosts or vectors</u>	The human liver fluke parasite depends on two intermediate hosts (a snail and a fish)	The malarial parasite needs a vector (mosquito) to spread to other hosts.

Ecto parasites : Parasites that feed on the external surface of the host organism. The lice on humans and ticks on dogs, Copepods on marine fish. Cuscuta,a parasitic plant.	**Endo parasites :** (live inside the host body) Malarial parasite-plasmodium in human blood.
Brood parasitism: Parasitismin birds in which the <u>parasitic bird lays its eggs in the nest of its host and lets the host incubate them</u>.. Brood parasitism in action is seen in the movements of the **cuckoo (koel)** and the **crow** during the breeding season (spring to summer.	

Commensalism:

This is the interaction in which one species benefits and the other is neither harmed nor benefited.			
<u>An orchid growing as an *epiphyte* on a mango branch</u>, benefit while the mango tree does not get any benefit.	<u>Barnacles growing on the back of a whale</u> benefit while the whale does not derive any apparent benefit.	<u>The cattle egret and grazing cattle</u> The cattle,when move, stir up and flush out insects from the vegetation those egrets catch.	<u>sea anemone and the clown fish</u> t The fish gets protection from predators which stay away from the stinging tentacles of sea

			anemone.

Amensalism:

In amensalism, one species is harmed whereas the other is unaffected.		
Moulds: *Penicilliumnotatum*, a mould, produces an antibiotic, **penicillin**, which checks the growth of a variety of bacteria.	Bacteria: *streptomycesgriseus*, produce the antibiotic **streptomycin**, which inhibit the growth of many bacteria.	Plants : Walnut tree produces a substance **juglone** that inhibits the growth of seedlings including its own. Such chemicals are called **allomones** and the phenomenon is called allelopathy. Sunflower, sorghum and barley check the growth of weeds near them Ocimum sanctum (Tulsi) checks the growth of plants near it.

Mutualism:

This interaction confers benefits on both the interacting species	
Lichens Mutualistic relationship between a fungus and photosynthesizing algae or cyanobacteria. 	The mycorrhizae Associations between fungi and the roots of higher plants
Plant-animal relationships: Pollinators and seed dispersers. 	Fig-wasp relationship: The wasp pollinates the fig inflorescence while searching for suitable egg-laying sites.

Orchids- bees relationship: ➢ Orchid *Ophrys*employs 'sexual deceit' to get pollination done by a species of bee. ➢ One petal of its flower bears resemblance to the female bee in size, colour and markings. ➢ The male bee is attracted and 'pseudocopulates' with the flower, ➢ When this same bee 'pseudocopulates' with another flower, it transfers pollen to it and thus, pollinates the flower. (**Note**: Co-evolution- If the female bee's colour patterns change even slightly for any reason during evolution, pollination success will be reduced unless the orchid flower co-evolves to maintain the resemblance of its petal to the female bee).	

Q.5 Predation is usually referred to as a detrimental association, then how can you explain their positive role in an ecosystem. Give any three ideas.

Q.6 An ecologist studying an area with population A thriving on unlimited resources and showing exponential growth, introduced population B and C to the same area. What will be the effect on the growth pattern of population A, B and C when living together in the same habitat?

Q.7 How does the Mediterranean orchid Ophrys ensure its pollination by bees?

Q.8 An organic farmer relies on natural predation for controlling plant pests and diseases. Justify giving reasons why this is considered to be a holistic approach.

ORGANISMS AND POPULATIONS

1. ECOLOGY

Study of relationships of living organisms with the abiotic (physical & chemical) and biotic (other species) components of their environment.

Levels of ecological organisation

- Organism
- Population
- Community
- Ecosystem
- Biome

2. POPULATION

Group of individuals of the same species living in a particular area, sharing or competing for similar resources.

Attributes of Population

Birth rate (Natality)	Death rate (Mortality)	Sex ratio

Age Pyramid

Growing population	Stable population	Declining population
More young	More adults	More old

Population Density (N)

Ecological effect on population is reflected in its size (density).
Measured as:
- Number of individuals
- Biomass
- Percent cover

3. POPULATION GROWTH

Increase : Natality (+) and Immigration (+)
Decrease : Mortality (–) and Emigration (–)

(i) Exponential Growth

- Unlimited resources
- J-shaped curve
- Growth doubles in a fixed time.

$$\frac{dN}{dt} = rN$$

N — Time (t)

(ii) Logistic Growth

- Limited resources
- S-shaped (sigmoid) curve
- Growth levels off at carrying capacity (K).

$$\frac{dN}{dt} = rN\frac{(K-N)}{K}$$

K — N — Time (t)

Carrying Capacity (K)

Maximum population size that a particular environment can sustain indefinitely.

4. LIFE HISTORY VARIATION

Breed once in a lifetime
e.g., Pacific salmon, Bamboo

Breed many times in a lifetime
e.g., Most birds and mammals

Offspring strategy
- Many small-sized offspring
  e.g., Oysters, fishes
- Few large-sized offspring
  e.g., Birds, mammals

5. POPULATION INTERACTIONS

Interspecific interactions (between two species)

Type of Interaction	Effect on Species A	Effect on Species B	Example
Mutualism	+	+	Lichen, Fig tree & Wasp
Competition	–	–	Plants for light, Nutrients
Predation	+	–	Tiger – Deer, Bird – Seed
Parasitism	+	–	Cuscuta on plant, Mosquito on human
Commensalism	+	0	Orchid on Mango tree, Cattle egret & Cattle
Amensalism	–	0	Penicillium inhibits bacteria

(+) Benefit (–) Harm (0) No effect

DETAILS OF SOME IMPORTANT INTERACTIONS

(i) PREDATION

- Predator kills and eats prey.
- Transfers energy to higher trophic levels.
- Controls prey population.
- Maintains species diversity.

(ii) COMPETITION

- Occurs when species compete for the same resources.
- Competitive exclusion principle (Gause): one species may eliminate the other.
- Coexistence possible by resource partitioning (e.g., different time, space, food).

Competition for light, water, nutrients

(iii) PARASITISM

- One benefits (parasite), other harmed (host).
- Ectoparasites: live on body surface (e.g., lice, ticks).
- Endoparasites: live inside the host (e.g., liver fluke, tapeworm).
- Brood parasitism in birds (e.g., Koel lays egg in crow's nest).

Louse (ectoparasite) — Liver fluke (endoparasite) — Koel egg in crow's nest

(iv) COMMENSALISM

- One benefits, other is neither harmed nor benefited.

Barnacles on whale — Cattle egret & grazing cattle

(v) MUTUALISM

- Both species benefit.
- Lichen (alga + fungus)
- Mycorrhiza (fungus + plant roots)
- Plant–pollinator (bees, butterflies)
- Fig tree and wasp (obligate mutualism).

Lichen — Mycorrhiza — Bee on flower — Fig & wasp

(vi) AMENSALISM

- One is harmed, other unaffected.

Penicillium fungi inhibits bacteria

Key Equations

- Exponential growth: $\frac{dN}{dt} = rN$
- Logistic growth: $\frac{dN}{dt} = rN\frac{(K-N)}{K}$

Important Terms

- r (intrinsic rate of natural increase): inherent potential of a population to grow.
- K (carrying capacity): maximum population size an environment can sustain.

Life History Traits evolve to maximize Darwinian fitness (high r value) in a particular habitat under given selection pressures.

CHAPTER 12. ECOSYSTEM

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

Ecosystems: Patterns, components; productivity and decomposition; energy flow; pyramids of number, biomass, energy.

Ecosystem- It is the functional unit of nature where biotic component interacts among themselves and also with the abiotic component.

Ecosystem	Natural	Terrestrial	Forest, grassland and desert
		Aquatic	Pond, lake, wetland, river and estuary
	Man-made		Crop fields and an aquarium

ECOSYSTEM– STRUCTURE AND FUNCTION:

Ecosystem (A pond)	Structure	Biotic components	Autotrophic components	Phytoplankton, some algae, floating, submerged and marginal plants
			Heterotrophic components	Zooplankton, the free swimming and bottom dwelling forms
			The decomposers	Fungi, Bacteria and Flagellates
		Abiotic components	Water with all the dissolved inorganic and organic substances The rich soil deposit at the bottom of the pond. The solar input, the cycle of temperature, day-length and other climatic conditions.	
	Function	1. Productivity	Conversion of inorganic into organic material with the help of the radiant energy of the sun by the autotrophs and consumption of the autotrophs by heterotrophs.	
		2.Decomposition	Decomposition and mineralization of the dead matter	
		3. Energy flow	There is unidirectional movement of energy towards the higher trophic levels and its dissipation and loss as heat to the environment	
		4. Nutrient cycling.	Release of minerals back to the system for reuse by the autotrophs.	

Ecosystem services:

The products of ecosystem processes are named as ecosystem services, for example, healthy forest ecosystems purify air and water, mitigate droughts and floods, cycle nutrients, generate fertile soils, provide wildlife habitat, maintain biodiversity, pollinate crops, provide storage site for carbon and also provide aesthetic, cultural and spiritual values.

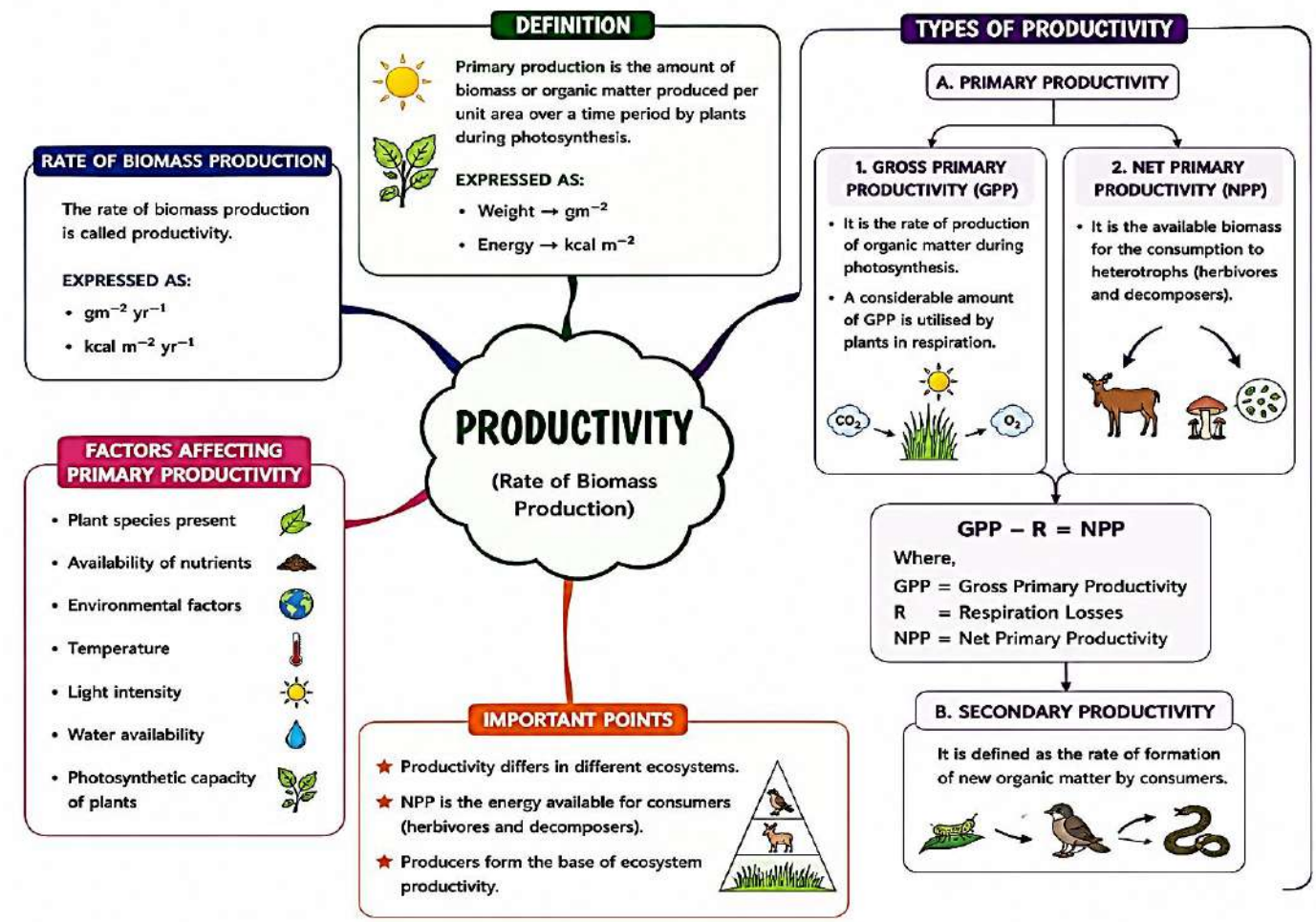
Stratification :

Vertical distribution of different species occupying different levels is called stratification. For example, trees occupy top vertical strata or layer of a forest, shrubs the second and herbs and grasses occupy the bottom layers.

Functions of Ecosystem:

The components of the ecosystem are seen to function as a unit when you consider the following aspects:
(i) Productivity;
(ii) Decomposition;
(iii) Energy flow; and
(iv) Nutrient cycling.

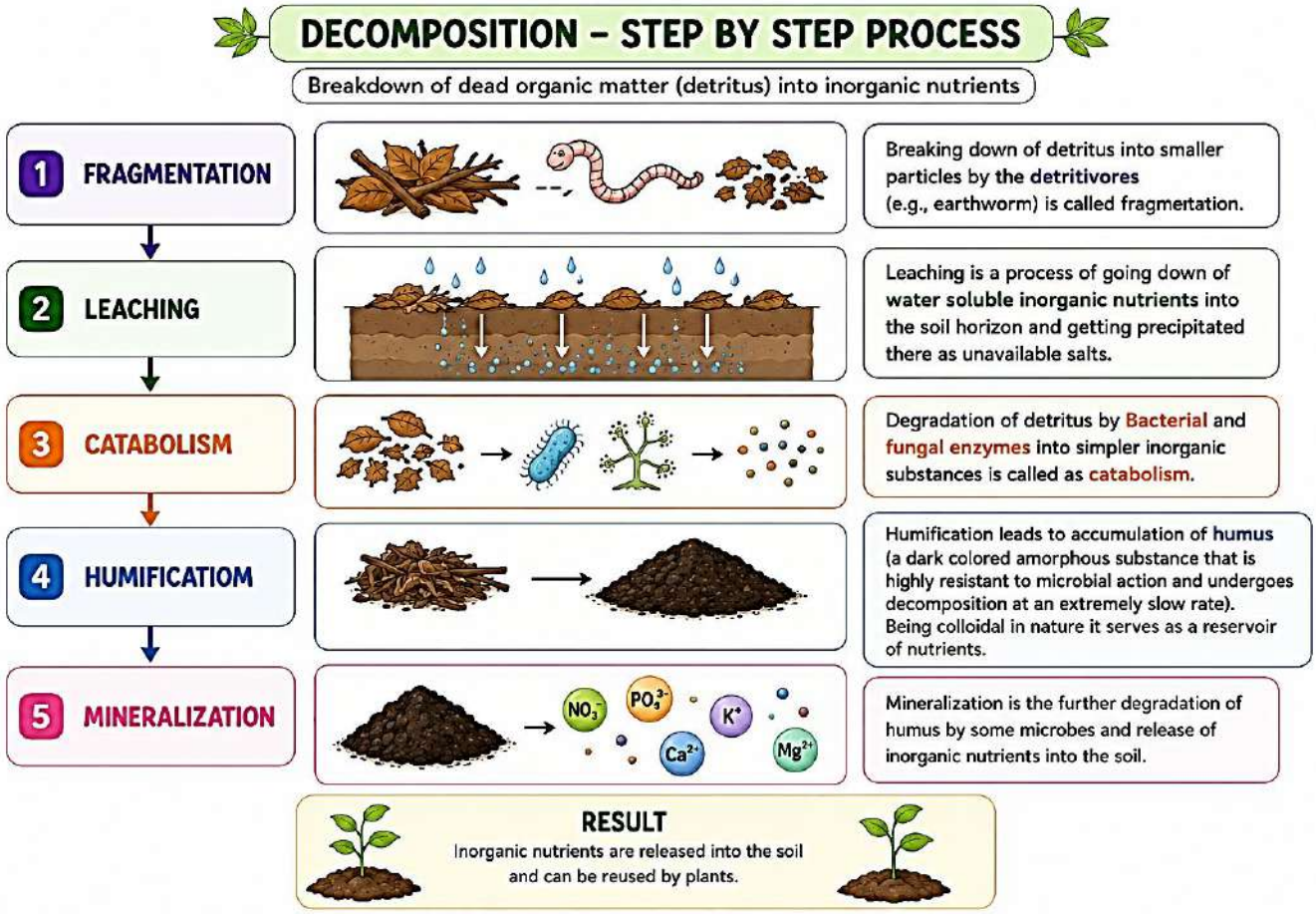
1. Productivity:



2. **Decomposition**: Breaking down complex organic matter into inorganic substances like carbon dioxide, water and nutrients by and the decomposers is called decomposition.

Detritus: The raw material for decomposition such as dead plant remains-leaves, bark, flowers and dead remains of animals, including fecal matter, is called detritus.
Decomposition is largely an oxygen-requiring process. The rate of decomposition is controlled chemical composition of detritus and climatic factors. In a particular climatic condition, decomposition rate is slower if detritus is rich in lignin and chitin, and quicker, if detritus is rich in nitrogen and water-soluble substances like sugars.
Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes. Warm and moist environment favour decomposition whereas low temperature and anaerobiosis inhibit decomposition resulting in build up of organic materials.

Steps of decomposition

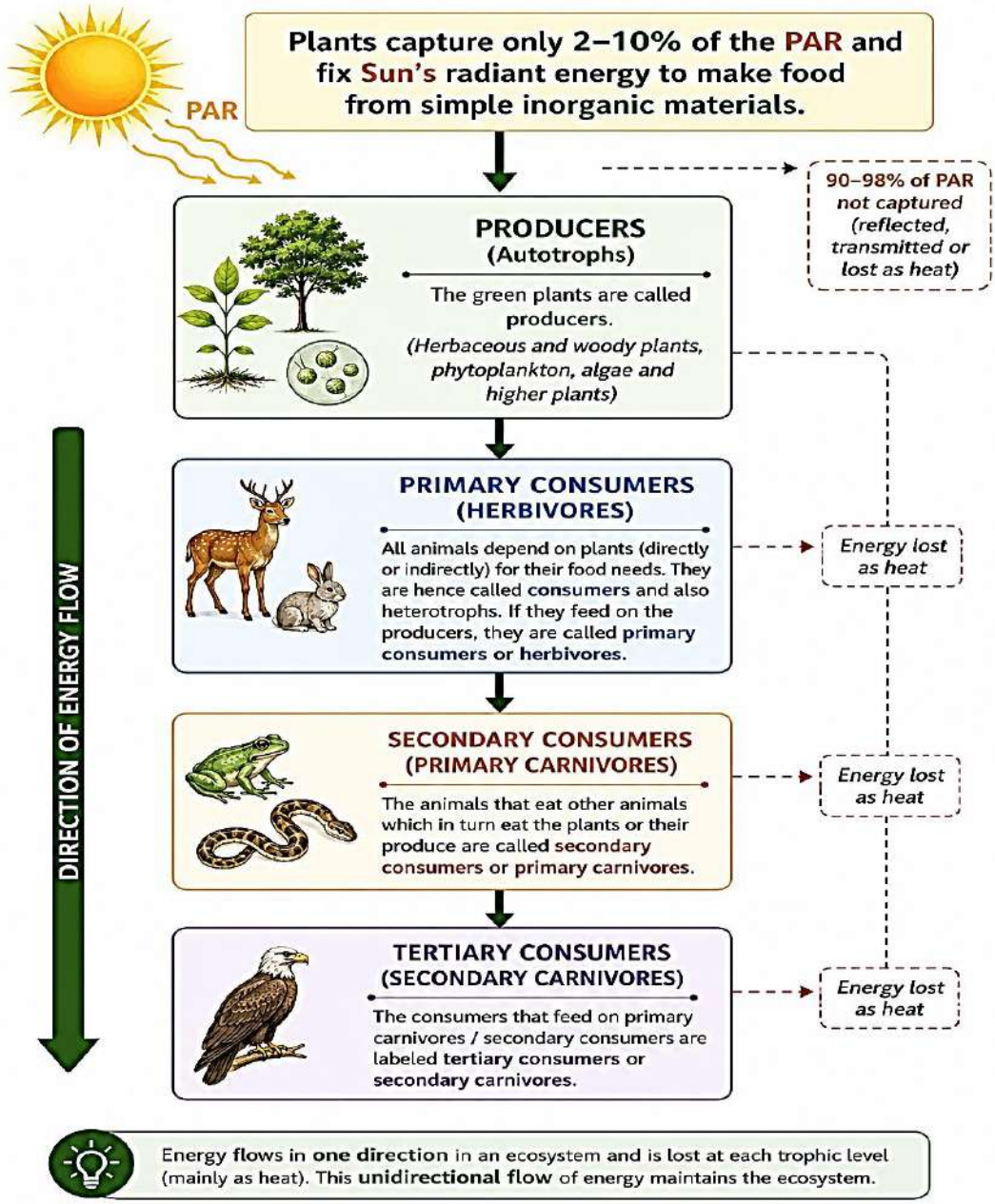


When any organism dies it is converted to detritus or dead biomass that serves as an energy source for decomposers.

<u>The detritus food chain (DFC) begins with dead organic matter</u>. It is made up of decomposers which are heterotrophic organisms, mainly fungi and bacteria. They meet their energy and nutrient requirements by degrading dead organic matter or detritus. Decomposers secrete digestive enzymes that breakdown dead and waste materials into simple, inorganic materials, which are subsequently absorbed by them.

3.Energy Flow:

Sun is the only source of energy for all ecosystems on Earth except for the deep sea hydro-thermal ecosystem. Of the incident solar radiation less than 50 per cent of it is photosynthetically active radiation (PAR)



Energy flow through different trophic levels in a food chain & Laws of Themodynamics

- Transfer of energy follows **10 per cent law** in the grazing food chain – **only 10 % of the energy** is transferred to each trophic level from the lower trophic level.
- This large expenditure of energy in the ecosystem is based on two basic laws of thermodynamics. In accordance with the **first law of thermodynamics** (which states that energy is neither created nor destroyed, but can be transformed from one state to another), energy of sunlight can be transformed into energy of food and heat.
- According to **second law of thermodynamics**, no transfer of energy occurs unless and until it is accompanied by degradation or dissipation of energy from concentrated to dispersed form. The transfer of energy from one organism to another is accompanied by degradation and loss of major part of food energy as heat. Energy of food is concentrated form while it is highly dispersed form is heat.

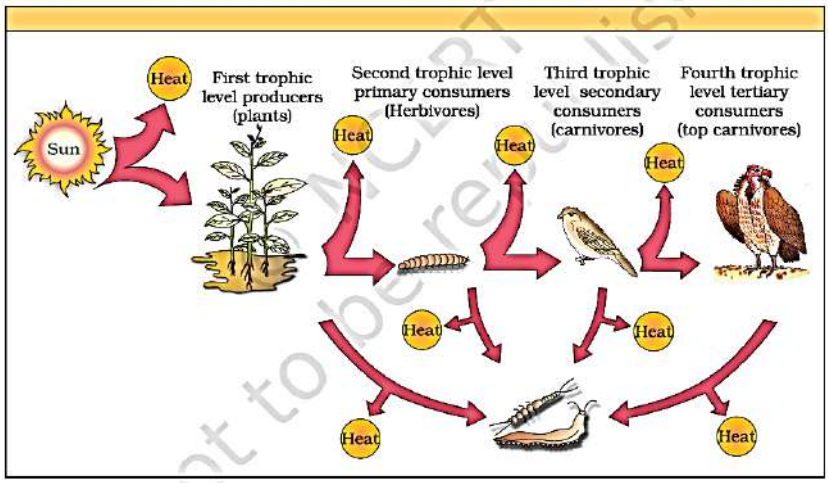
Q.1 What would happen to the successive trophic levels in the pyramid of energy, if the rate of reproduction of phytoplankton was slowed down? Suggest two factors which could cause such a reduction in phytoplankton reproduction.

Q.2 During an ecological study, students observed that green plants capture solar energy, herbivores feed on plants, and carnivores feed on herbivores. They also noticed that only a small amount of energy is available at higher trophic levels, while a significant amount is lost as heat during energy transfer.Based on the above observation, answer the following:

a. Explain how energy flows through an ecosystem.

b. How does the First Law of Thermodynamics apply to energy flow in an ecosystem?

c. How does the Second Law of Thermodynamics explain the loss of energy at each trophic level?



Food Chain

It is a sequence of living organisms which involves transfer of food energy from producers, through a series of organisms with repeated eating and being eaten is called food chain. Each level or step in a food chain where transfer of energy takes place is called **trophic level**.

Types of Food Chain:

1. **Grazing Food Chain (GFC)** or Predator food chain
2. **Detritus Food Chain (DFC)** or Saprophytic food chain
3. **Parasitic Food Chain (PFC)** or Auxiliary food chain

(i) Grazing Food Chain (GFC):

Consists of producers, consumers and decomposers. Source of energy for such food chain is sun.

(a) Primary Producers (PP):

They are autotrophic organisms which fix up the solar energy and manufacture their own food from inorganic raw material. So, they form the base of food chain constituting first trophic level (**T_1**).

(b) Primary Consumers (PC) or Herbivores:

These are animals which feed on green plants or plant products, so they constitute second trophic level (**T_2**).

(c) Secondary Consumers (SC) or Primary Carnivores:

These are animals which feed on herbivores and form third trophic level (**T_3**).

(d) Tertiary Consumers (TC) or Secondary Carnivores:

These are animals which feed on secondary consumers and constitute the fourth trophic level (**T_4**) and so on.

Q.**What are the major differences between the grazing food chain (GFC) and the detritus food chain (DFC)?**

Basis	Grazing Food Chain (GFC)	Detritus Food Chain (DFC)
Starting point	**Begins with green plants (producers)**	**Begins with dead and decaying organic matter (detritus)**
First trophic level	**Producers (plants)**	**Decomposers/detritivores (bacteria, fungi, earthworms)**
Energy source	**Solar energy captured by photosynthesis**	**Energy from dead organic matter**
Flow of energy	**Sun → plants → herbivores → carnivores**	**Detritus → decomposers → predators**
Dependency on living plants	**Directly depends on living green plants**	**Does not depend directly on living plants**
Example	**Grass → deer → tiger**	**Dead leaves → earthworm → bird**

(ii) **Detritus Food Chain (DFC)** : Begins with detritus or dead organic matter. It is made up of decomposers which are heterotrophic organisms mainly fungi and bacteria. Detrivores act over it. Therefore food energy present in detritus passed into them. Detrivores and decomposers are consumed by smaller carnivores which in turn become food for larger carnivores and so on.
A common detritus food chain with earthworm as detrivore is given below.
Detritus → Earthworm → Sparrow → Falcon.
(iii) **Parasitic food chain/Auxillary food chain** : Size of the organisms finally reduces at higher trophic level (parasite).
e.g., Tree → herbivore birds → lices and bugs.

NOTE-.

- **In terrestrial ecosystems, a much larger fraction of energy flows through DFC than through GFC.**
- **In an aquatic ecosystem, GFC is the major conduit for energy flow.**

Food Web :
DFC may be connected with GFC chains at some levels. Some of the organisms of DFC are prey to the GFC animals.
In ecosystem, linear food chains as shown above seldom exists, because every organism has alternate source of food. An animal may have preference for a particular prey, but if the latter has a small population, it may feed upon some other prey.
Single animal may be eaten by different animals and thus, different food chains get interconnected and one animal may be a link in more than one food chain. The network of interconnected food chains at different trophic levels in a biotic community is termed food web.
Occurrence of food webs provides stability to ecosystem. Food webs operate because of taste preference for particular food and unavailability of food. One animal may feed upon organism of even different trophic level like, snakes may feed upon mice (herbivore) and frogs (carnivore), jackals are both carnivores and scavengers. Sparrow is a primary consumer when it eats seeds, fruits etc. and a secondary consumer when it eats insects and worms.

Standing crop: Each trophic level has a certain mass of living material at a particular time called as the standing crop. The standing crop is measured as the mass of living organisms (biomass) or the number in a unit area. The biomass of a species is expressed in terms of fresh or dry weight.

Q.3 Explain the structure and function of an ecosystem using a forest as an example.

Q.4 Describe the steps involved in decomposition and discuss the factors affecting the rate of decomposition.

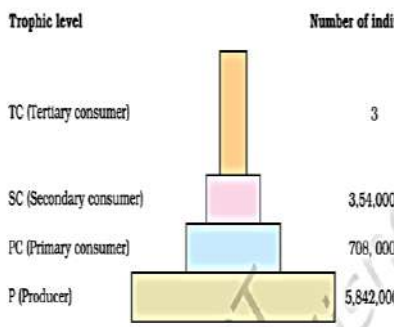
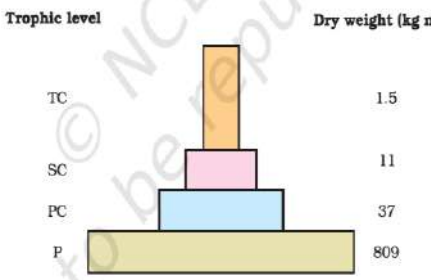
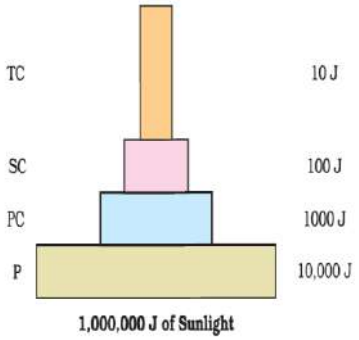
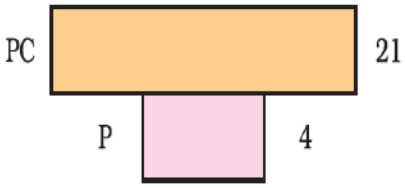
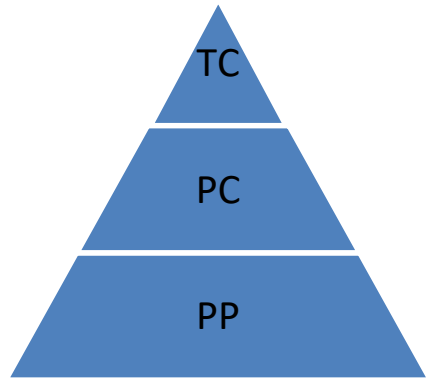
Ecological pyramids:

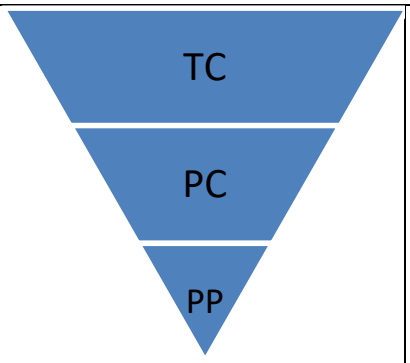
Ecological pyramids are the shapes that represent the food or energy relationship between organismsat different trophic levels. This, relationship is expressed in terms of number, biomass or energy.
The base of each pyramid represents the producers or the first trophic level while the apex represents tertiary or top level consumer.

The three types of ecological pyramids that are usually studied are -----
(a) Pyramid of number
(b) Pyramid of biomass
(c) Pyramid of energy.

Pyramid of energy **<u>can never be inverted</u>**, because when energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step. Each bar in the energy pyramid indicates the amount of energy present at each trophic level in a given time or annually per unit area.

<u>Limitationsof ecological pyramids</u>:
1. It does not take into account the same species belonging to two or more trophic levels.
2. It assumes a simple food chain, something that almost never exists in nature
3. It does not accommodate a food web.
4. Saprophytes are not given any place even though they play a vital role in the ecosystem.

Pyramid of Number	**Pyramid of Biomass**	**Pyramid of Energy**
Generally upright	Generally upright	Always upright
Producers are more in number than the herbivores, and herbivores are more in number than the carnivores. 	Producers are more in biomass than the herbivores, and herbivores are more in biomass than the carnivores. 	Producers are more in energy than the herbivores, and herbivores are more in energy than the carnivores. 
Exception : A big tree on which a number of insects feed, small birds feeding on insects as also the number of larger birds eating the smaller.	**Exception :**The pyramid of biomass in sea is generally inverted because the biomass of fishes far exceeds that of phytoplankton. 	**No exception:** Energy at a lower trophic level is <u>always more than at a higher level.</u> 

Chapter 13: BIODIVERSITY AND ITS CONSERVATION

Note - For answers of intext questions, scan the QR code of the Question bank of the chapter

Syllabus (2026-27): (Marks4- 6) Biodiversity-Concept, patterns, importance; loss of biodiversity; biodiversity conservation; hotspots, endangered organisms, extinction, Red Data Book, Sacred Groves, biosphere reserves, national parks, wildlife, sanctuaries and Ramsar sites.

Main Points:

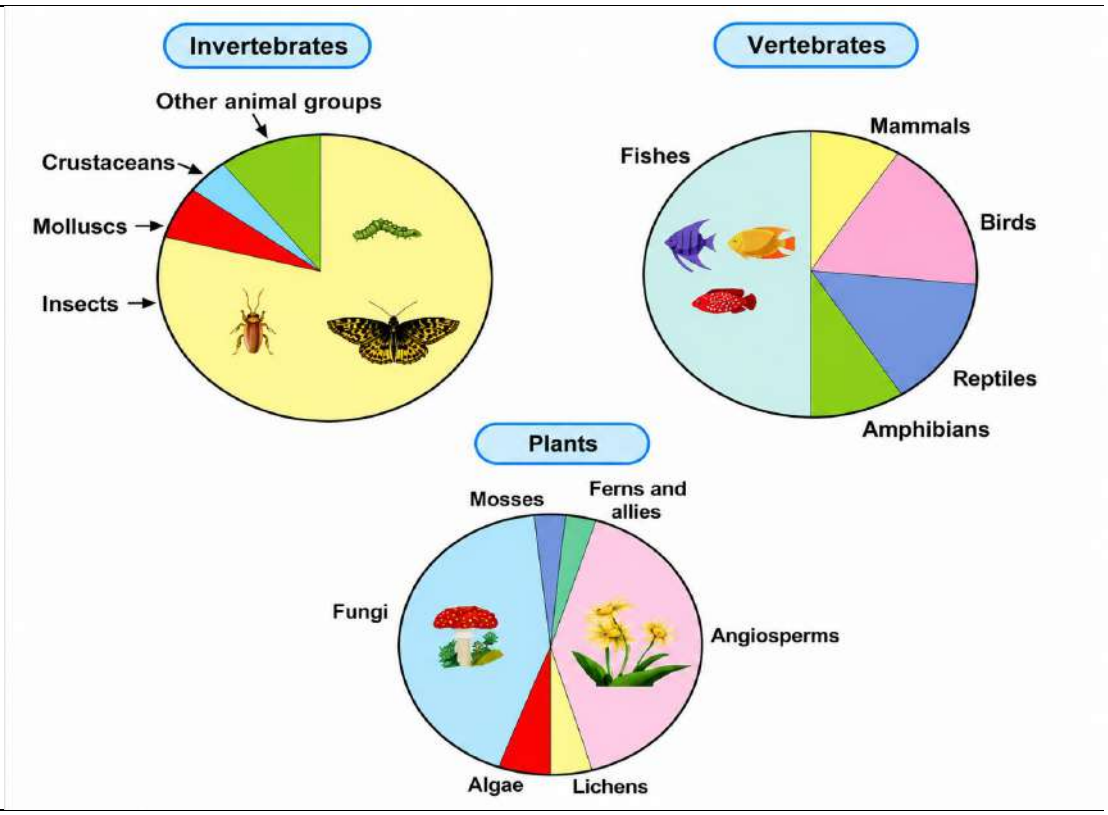
Biodiversity (Biological Diversity) refers to the totality of genes, species, and ecosystems of a region. The term was popularized by sociobiologist Edward Wilson to describe the combined diversity at all levels of biological organization.

Types or level of biodiversity:

Genetic Diversity: Diversity within a single species is called genetic diversity. Example: 50000 of rice and 1,000 of mango strains/varieties in India. The genetic variation shown by the medicinal plant Rauwolfia vomitoria growing in different Himalayan ranges might be in terms of the potency and concentration of the active chemical (reserpine) that the plant produces.

Species Diversity: The variety of species within a region. Example: There are more species of Amphibians in Western Ghat than in Eastern Ghat.

Ecological Diversity: The variety of ecosystems in a given area. Example: India, with its deserts, rainforests, mangroves, coral reefs, wetlands, estuaries, and alpine meadows, has a greater ecosystem diversity than a Scandinavian country like Norway.

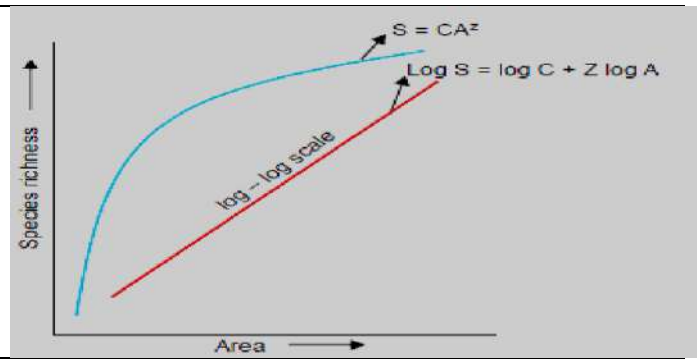
How many species are on earth? As per Robert May Total Global species diversity is 7 million. Out of these slightly more than 1.5 million species are described till date as per IUCN (International Union for Nature & Natural Resources) 2004.	

INVERTEBRATES	VERTEBRATES	PLANTS & FUNGI
• Insects: ~70% (The most species-rich taxonomic group) • Other Animal Groups: ~15% • Molluscs: ~7.5% • Crustaceans: ~7.5%	• Fishes: ~50% (Nearly half of all vertebrate species) • Reptiles: ~15% • Birds: ~14% • Amphibians: ~12% • Mammals: ~9%	• Fungi: ~42% • Angiosperms (Flowering Plants): ~42% • Algae: ~8% • Ferns and Allies: ~4% • Mosses: ~2% • Lichens: ~2%

Patterns of Biodiversity:

<u>Latitudinal Gradient:</u> Species diversity generally decreases as we move away from the equator towards the poles. Reason: Tropical environments are less seasonal and more predictable, and there is more solar energy available which contributes to higher productivity allowing more time for speciation. **Example:** Near equator Colombia 1400 species of birds>New York 41◦ N 105 species of birds>Green Land 71◦ 56 species of birds.	**<u>Species Area Relationship:</u>** As per **Alexander Van Humboldt** Within a region the species richness increases with increasing explored area up to a limit. There after it does not increase. When it is shown in graph rectangular hyperbola is obtained.

Graph showing relationship between species richness & area--

The equation showing species area relationship is- **log S=log C+Z log A** Where- S=Species Richness, A=Area, Z=Slope of the line (regression coefficient) C=Y intercept Generally, value of Z is 0.1to 0.2 but for very large area say continent Z is 0.6 to 1.2 irrespective of taxonomic group of the area.	

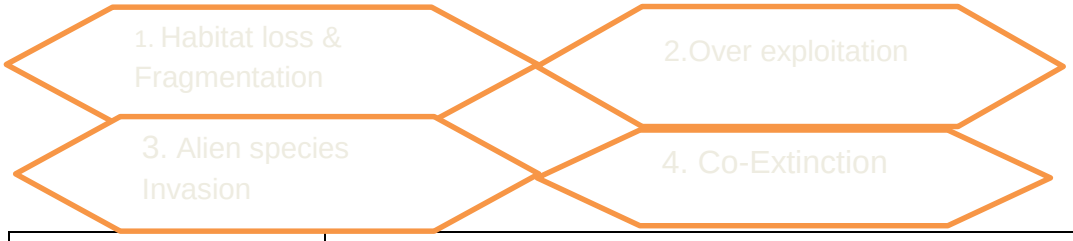
Value (slope of the species-area relationship) for frugivorous birds and mammals in tropical forests across different continents is characteristically high, typically measured at 1.15. This steep slope indicates a rapid increase in species richness with increased area, reflecting high diversity and niche specialization within tropical frugivore communities

Q.1 Colombia (near equator), New York (41° N), and Greenland (71° N) have different bird species richness. Choose the correct sequence of bird species for these locations respectively:

Importance of Species Diversity to the Ecosystem:

- **David Tilman** found that plots with more species showed less year-to-year variation in total bio mass. This gives stability to community.
- **Rivet Popper Hypothesis** by **Paul Ehrlich:**
- Paul Ehrlich Hypothesized that if we consider Airplane as Ecosystem & thousands of Rivets as Species joining the parts of plane.
- If rivets are taken away by every passenger (species extinct) then in starting it will not affect the flight safety (proper functioning of Ecosystem) but if it is more & more than plane becomes weak & flight safety becomes very dangerous & plane may crash.
- Also, if very critical rivet is removed (Key Species is lost) viz. rivet of wings then more serious threat to flight safety will occur & plane will collapse (Ecosystem may collapse).

Causes of Biodiversity Loss (Evil Quartet):



Cause	Description & Example
1. Habitat Loss & Fragmentation	The most important cause. Example: Amazon rainforests are being cleared for soya bean cultivation and cattle ranching.
2. Over-exploitation	Humans over-harvesting resources. Example: Extinction of Steller's sea cow and passenger pigeons in the last 500 years.

Cause	Description & Example
3. Alien Species Invasion	Non-native species outcompeting local ones. Example: Nile Perch introduced into Lake Victoria (East Africa) led to the extinction of 200+ species of Cichlid fish.
4. Co-extinction	When a species becomes extinct, the plant and animal species associated with it in an obligatory way also become extinct. Example: Host fish and its unique parasites.

Biodiversity Conservation:

It has taken millions of years of evolution, to accumulate this rich diversity in nature, but we could lose all that wealth in less than two centuries if the present rates of species losses continue. Biodiversity and its conservation are now vital environmental issues of international concern as more and more people around the world begin to realise the critical importance of biodiversity for our survival and well- being on this planet.

Narrowly utilitarian View–	Broadly utilitarian View-	Ethical Reason:
Biodiversity conservation due to direct economic benefits from nature like food, fiber, medicine, fire wood, industrial products etc.	Biodiversity conservation due to indirect benefits through ecosystem services. **Example**-Production of Oxygen by plants viz. Amazon rain forest contributes 20% of total Oxygen in atmosphere. Pollination done by pollinators & aesthetic pleasures obtained from watching flowers, natural scenery etc.	We need to realize that every species in the word has importance in nature. So, if it is not of any economic importance even that it is our moral duty to conserve them so that they can be passed to future generations in good order.

Q.Match the animals given in column I with their location in column II.

Column-I	Column-II
A. Dodo	**(i) Africa**
B. Quagga	**(ii) Russia**
C. Thylacine	**(iii) Mauritius**
D. Stellar's sea cow	**(iv) Australia**

How Do We Conserve Biodiversity?

***In situ* conservation**	***Ex situ* Conservation**
When we conserve and protect the whole ecosystem, its biodiversity at all levels is protected This approach is called *in situ* (on site) conservation. **Example**: we save the entire forest to save the tiger. (14 biospheric reserve,90 national parks,448 wild life sanctuaries, Hot spots, Sacred grooves.)	When threatened animals and plants are taken out from their natural habitat and placed in special setting where they can be protected and given special care. Then it is called ***Ex-situ (off site)* Conservation.** **Example:** Zoological Parks, Botanical Gardens, Wild life safari parks, advance method-tissue culture cryopreservation of gametes etc.

- **Biodiversity Hot Spots:** Biodiversity hotspots are the regions with very high levels of species richness and high degree of endemism.
- Total 34 biodiversity hot spots are in world.

- 03 of these hotspots in India– **Western Ghats and Sri Lanka, Indo-Burma** and **Himalaya.** Although all the biodiversity hotspots put together cover less than2 % of the earth's land area, the number of species they collectively bear is very high.
- **Sacred grooves:** Patches of pristine or near-natural forests protected by local communities due to deep religious, spiritual, and cultural beliefs are called sacred groves.

Example: Khasi and Jaintia Hills in Meghalaya, Aravalli Hills of Rajasthan, Western Ghat regions of Karnataka and Maharashtra and the Sarguja, Chanda and Bastar areas of Madhya Pradesh.

Q.3 A species that is confined to a particular region and not found anywhere else is termed as:

Q.4 The IUCN Red Data Book (2004) primarily maintains a record of:

Q.5 Assertion: Biodiversity is declining at an accelerated rate worldwide.

Reason: Introduction of exotic species often causes the extinction of endemic species.

Earth summit:

- The Earth Summit' held in Rio de Janeiro in 1992,
- Aim was to take appropriate measures for conservation of biodiversity and sustainable utilization of its benefits.
- Later on, the World Summit on Sustainable Development held in 2002 in Johannesburg, South Africa, 190 countries pledged their commitment to achieve goal by 2010.

Most recently Earth Summit was held in Stockholm in SWEDEN IN JUNE 2022.

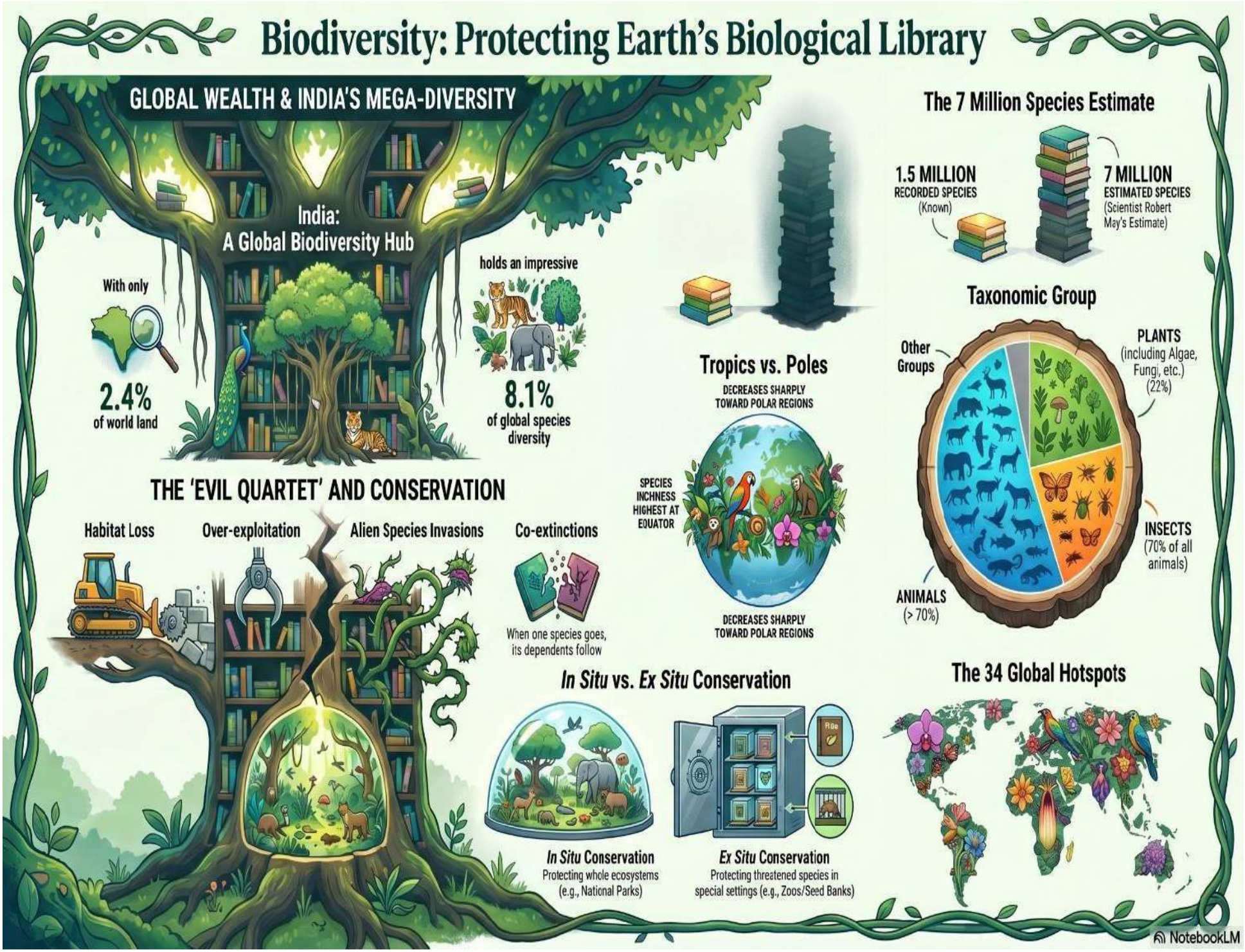
Ramsar Site:

- A Ramsar site is a wetland site designated to be of international importance under the Ramsar Convention
- It is also known as "The Convention on Wetlands", an international environmental treaty signed on 2 February 1971 in Ramsar, Iran, under the auspices of UNESCO.
- Ramsar sites are home of many plant & animal species. So that these are conserved.

Q.6 Mention the two main criteria used to identify a region as a "Biodiversity Hotspot."

Q.7 Justify with an example how the invasion of an exotic species can lead to the extinction of indigenous species.

Q.8 Explain the "Rivet Popper Hypothesis." Who proposed it, and what do the "rivets" and the "airplane" represent?


Biodiversity: Protecting Earth's Biological Library
GLOBAL WEALTH & INDIA'S MEGA-DIVERSITY
India:
A Global Biodiversity Hub
With only
2.4%
of world land
holds an impressive
8.1%
of global species diversity
THE 'EVIL QUARTET' AND CONSERVATION
Habitat Loss
Over-exploitation
Alien Species Invasions
Co-extinctions
When one species goes, its dependents follow
Tropics vs. Poles
DECREASES SHARPLY TOWARD POLAR REGIONS
SPECIES INCHNESS HIGHEST AT EQUATOR
DECREASES SHARPLY TOWARD POLAR REGIONS
The 7 Million Species Estimate
1.5 MILLION
RECORDED SPECIES
(Known)
7 MILLION
ESTIMATED SPECIES
(Scientist Robert May's Estimate)
Taxonomic Group
Other Groups
PLANTS
(including Algae, Fungi, etc.)
(22%)
INSECTS
(70% of all animals)
ANIMALS
(> 70%)
In Situ vs. Ex Situ Conservation
In Situ Conservation
Protecting whole ecosystems
(e.g., National Parks)
Ex Situ Conservation
Protecting threatened species in special settings (e.g., Zoos/Seed Banks)
The 34 Global Hotspots
NotebookLM

Test Your Knowledge

Quiz		Question Bank	
Chapter 1: Sexual Reproduction in Flowering Plants	Chapter 8: Microbes in Human Welfare	Chapter 1: Sexual Reproduction in Flowering Plants	Chapter 8: Microbes in Human Welfare
Chapter 2: Human Reproduction	Chapter 9: Biotechnology: Principles and Processes	Chapter 2: Human Reproduction	Chapter 9: Biotechnology: Principles and Processes
Chapter 3: Reproductive Health	Chapter 10: Biotechnology and its Applications	Chapter 3: Reproductive Health	Chapter 10: Biotechnology and its Applications
Chapter 4: Principles of Inheritance and Variation	Chapter 11: Organisms and Populations	Chapter 4: Principles of Inheritance and Variation	Chapter 11: Organisms and Populations
Chapter 5: Molecular Basis of Inheritance	Chapter 12: Ecosystem	Chapter 5: Molecular Basis of Inheritance	Chapter 12: Ecosystem

Chapter 6: Evolution	Chapter 13: Biodiversity and Conservation	Chapter 6: Evolution	Chapter 13: Biodiversity and Conservation
Chapter 7: Human Health and Disease		Chapter 7: Human Health and Disease	

CBSE CLASS 12 BIOLOGY - SET 1 (57/1/1)-2026

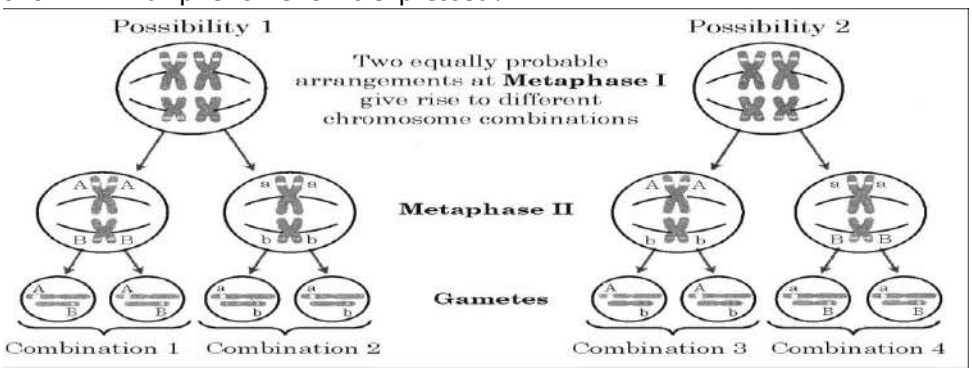
Question Paper & Answer Scheme

General Instructions:

Read the following instructions carefully and follow them:

1. Question paper is divided into FIVE sections – Section A, B, C, D and E.
2. Section A – questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.
3. Section B – questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.
4. Section C – questions number 22 to 28 are short answer type questions. Each question carries 3 marks.
5. Section D – questions number 29 and 30 are case-based questions. Each question carries 4 marks. Each question has subparts with internal choice in one of the subparts.
6. Section E – questions number 31 to 33 are long answer type questions. Each question carries 5 marks.
7. There is no overall choice. However, internal choices have been provided in some questions. A candidate has to write answer for only one of the alternatives in such questions.
8. Kindly note that there is a separate question paper for Visually Impaired candidates.
9. Wherever necessary, neat and properly labelled diagrams should be drawn.

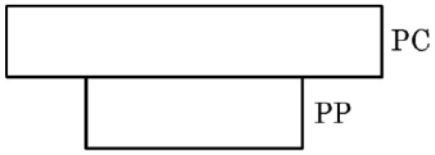
Q.N.	**QUESTION**	Marks	Total Marks
	SECTION – A		
1	Identify the plant in which emasculation is not required for artificial hybridization. a. Rice b. Wheat c. Pea d. Papaya **Answer: d. Papaya.**	1	1
2	Which of the following is not a component of the immune system? a. Lymphocytes b. Plasma Proteins c. Red Blood Cells d. Bone Marrow **Answer: c. Red Blood Cells.**	1	1
3	3. Select the option that shows correct statements: (i) Corpus luteum secretes progesterone. (ii) Only FSH attains a peak level in the middle of the cycle. (iii) LH surge induces rupture of Graafian follicle. (iv) Luteal phase of the menstrual cycle is also called the proliferative phase. **Answer: b. (i) and (iii) are correct.**	1	1
4	4. Select the mismatched pair: a. Mega diversity countries in the world - 12 b. Genetically different strains of rice in India - Less than 1000 c. Robert May's estimation on global species diversity - 7 million d. Zoological parks - Ex-situ conservation **Answer: b. Genetically different strains of rice in India -**	1	1
5	5. Pomato was produced by fusing protoplasts of: a. Tomato and Potato b. Pomegranate and Tomato c. Pomegranate and Potato d. Pomegranate, Potato and Tomato **Answer: a. Tomato and Potato.**	1	1
6	6. In an ecosystem, different species occupy different levels and vertical distribution of species is found. This is called: a. Stratification b. Layering c. Fragmentation d. Population **Answer: a. Stratification.**	1	1

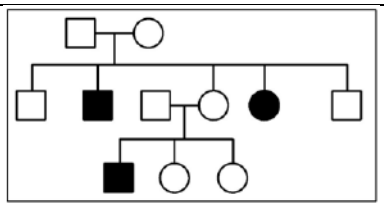
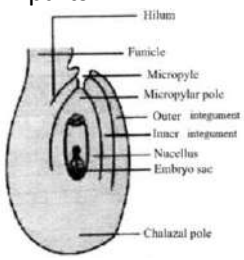
7	7. Which of the following sacred groves is found in Meghalaya? a. Jaintia hills b. Chanda c. Bastar d. Sarguja **Answer: a. Jaintia hills.**	1	1
8	8. In the following figure, two ways of pairing of two homologous pairs of chromosomes are shown. Which phenomenon is expressed?  a. Linkage of genes b. Independent assortment of genes c. Multiple alleles d. Incomplete dominance **Answer: b. Independent assortment of genes.**	1	1
9	Match Column-I with Column-II: a. Biolistic gun - (v) Plant cell b. Chitinase - (iv) Fungal cell c. Ti - (ii) Tumour inducing d. Ca++ - (i) Bacterial cell **Answer: c. a-v, b-iv, c-ii, d-i. Explanation:**	1	1
10	The idea of use and disuse of organs for evolution of organism was proposed by: a. Charles Darwin b. Thomas Malthus c. Hugo De Vries d. Lamarck **Answer: d. Lamarck**	1	1
11	Which of the following statements about plasmids is incorrect? a. Plasmids have the ability to replicate within the bacterial cell. b. Their replication is controlled by chromosomal DNA. c. They are autonomously replicating circular extra-chromosomal DNA. d. They often carry antibiotic-resistant genes. **Answer: b. Their replication is controlled by chromosomal DNA.**	1	1
12	Which connective tissue connects the ovary to the pelvic wall and uterus? a. Tendons b. Ligaments c. Cartilage d. Bone **Answer: b. Ligaments.**	1	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) b. Both Assertion a. and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A) c. Assertion (A) is true but Reason (R) is false. d. Assertion (A) is false but Reason (R) is true.		
13	Assertion (A) : The population of melanized moths increased in industrial areas after the Industrial Revolution. Reason (R): In Industrial environments, lichen-covered trees were replaced by soot-covered trees, offering better camouflage to dark-colored moths. **Answer: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation.**	1	1

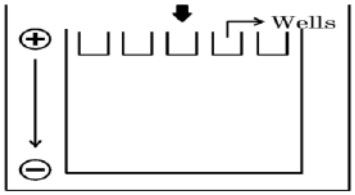
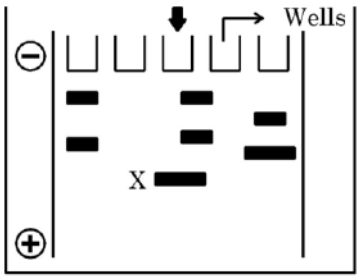
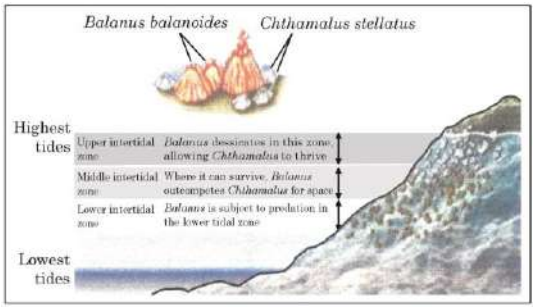
14	Assertion (A): The milk produced by the transgenic cow 'Rosie' was a nutritionally more balanced product for human babies than natural cow milk. Reason (R): It was human protein-enriched milk containing human alpha-lactalbumin. **Answer: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation.**	1	1
15	Assertion (A): Flocs are masses of bacteria associated with fungal filaments in the secondary treatment of sewage. Reason (R): Flocs help in the digestion of solid waste by anaerobic respiration. **Answer: c. Assertion (A) is true, but Reason (R) is false.**	1	1
16	Assertion (A): In terrestrial ecosystems, a much larger fraction of energy flows through the grazing food chain. Reason (R): The grazing food chain may be connected to the Detritus food chain at some levels. **Answer: d. Assertion (A) is false, but Reason (R) is true.**	1	1
	SECTION – B		
17	a. Define Humoral immune response. b. Name any two types of antibodies found to give humoral immune response in humans. **Answer: a.An immune response where the B-lymphocytes produce an army of proteins in response to pathogens into our blood to fight with them.** **b. Antibodies – IgA, IgE, IgM, IgG** **(**Any two)	1 ½+ ½	2
18	**(a)** (i) How does a farmer use dormancy of seed to his advantage? (ii) Differentiate between pea seed and castor seed. **1** **Answer:(i) Dormancy is crucial for storage (dehydration) of seeds to be used to raise the crops in next season / Seeds are used as source of food / for commercial purpose** **(ii)**	1 1 1 ½+ ½	2

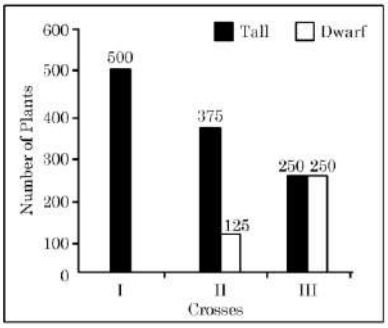
Pea seed	Casto r seed
Non endospermic seed	Endospermi c seed
Non-albuminous seed	Albuminou s seed
No endosperm is left in the seed as it is fully consumed	It contains some amount of endosperm as it is not consumed completely

	during embryo development. | during embryo development. **(**Any one difference**)** **OR** (b) Identify the stage of follicle where primary oocyte undergoes first meiotic division. Also mention the products of this division. **Answer:** • Tertiary follicle in the ovary • Secondary oocyte and 1st polar body.		
19	Study the sequence of bases in a DNA molecule that is shown below and answer the questions. 5' – GAATTC – 3' 3' – CTTAAG – 5' a. What are such sequences called? Name the enzyme used that recognizes such nucleotide sequences. b. How do these enzymes' function? Answer: a. • Palindromic sequences • Restriction endonuclease / EcoRI. b.Restriction endonucleases cut the strands of DNA a little away from the centre of the palindrome sites to form sticky end on each strand / Restriction endonucleases cut at specific recognition site between two same bases in opposite strands to produce sticky ends / EcoRI cuts the DNA between bases G and A in both the strand in the sequence 5'-GAATTC-3' 3'-CTTAAG-5	½+ ½ 1	2
20	a. Analyse the following two cases of sex determination in different organisms: Case I : Males have (XO) sex chromosomes and females have two copies of same sex chromosome (XX). Case II : Females have two different sex chromosomes (ZW) and males have two copies of same sex chromosome (ZZ). Identify the type of heterogamety in each case, giving one example of each. OR b. (i) Differentiate between a DNA and RNA nucleotide. (ii) Name the two types of bonds present within a single nucleotide **Answer: a.**Case 1 –Male heterogamety Organism – Many insects / grasshopper / any correct example. Case II–Female heterogamety Organism – Birds / hen / any correct example. **OR** **Answer:** b. (i) DNA nucleotide RNA nucleotide | DNA nucleotide RNA nucleotide Has deoxyribose sugar Has Ribose sugar | Has deoxyribose sugar Has Ribose sugar Types of nitrogen bases are | Types of nitrogen bases are **(**Any one difference**)** **(ii) Bonds in a nucleotide N – Glycosidic linkage (between Sugar and Base)** **Phosphoester linkage – (Between Sugar and Phosphate)**	½+ ½ ½+ ½ 1 ½+ ½	2

21	a. Given below is a pyramid found in an ecosystem, where each bar represents the standing crop available in the trophic level.  (i) Identify the kind of pyramid and with the help of an example explain the conditions where this kind of pyramid is possible in nature. (ii) Write any two limitations of ecological pyramids. OR b. In an ecosystem there was loss of biodiversity due to some project in that area. (i) How will biodiversity be affected? (2 points) (ii) List two major causes of loss of biodiversity. Answer: a. (i) • Inverted Pyramid of Biomass • Such pyramids are seen in Aquatic Conditions where a small standing crop of phytoplankton's supports a large standing crop of zooplankton or fish /In terrestrial ecosystem – when a large number of insects are feeding on a single tree / or any other correct example (ii) -Ecological pyramids does not take into account the same species belonging to two or more trophic levels. -It does not accommodate a food web. -Saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem. (Any two) OR Answer: b. (i) -Decline in plant production. -Lowered resistance to environmental perturbations as drought. -Increased variability in certain ecosystem processes such as water use and pest and disease cycles - Any other correct point (Any two points) (ii) -Habitat loss and fragmentation. -Alien species invasion. -Over exploitation -Co-extinction (Any two)	½+ ½ ½+ ½ ½+ ½ ½+ ½	2
	SECTION – B		
22	a. Do all pollen grains remain viable for the same length of time? Support your answer with two suitable examples. b. How are pollen grains stored in pollen banks? Answer: a. • No • -In cereals or rice or wheat pollen grains loose viability within 30 minutes of their release, -In some members of Rosaceae or Leguminosae or Solanaceae –they maintain viability for months, - or any other correct example b. They are stored using Cryo-preservation techniques / In liquid nitrogen at – 196oC	½ 1 1 ½	3
23	a. What is pedigree analysis? Mention its importance in human genetics. (2 pts.) b. Analyze the following pedigree and write the (i) Pattern of inheritance. (ii) Give one example of disease showing such an inheritance pattern.		3

	 Answer: a. • Pedigree analysis –It is analysis of traits or inheritance of traits in several generations of a family. • Importance: To trace the inheritance of a trait, abnormality or a disease. b. (i) Autosomal- Recessive (ii) Sickle Cell Anaemia / Thalassemia / Phenylketonuria /Any other correct example.	1 ½+ ½ ½+ ½	
24	a. How is Hardy-Weinberg expression (p2 + 2pq + q2) = 1 derived? b. List any two factors that disturb the genetic equilibrium. Answer: a. According to Hardy Weinberg principle – Sum total of all the Allelic frequencies in a population = 1. Let there be two alleles A and a in the population. Let their frequencies be 'p' and 'q' respectively. p + q = 1 The frequency of AA will be p2 because - the probability that an allele A with frequency 'p' would appear on both the chromosomes of a diploid individual will be product of probabilities i.e. p2. Similarly, frequency of 'a' will be q2, and Aa is 2pq Hence $p^2 + 2pq + q^2 = 1$ b. Gene migration or Gene flow, Genetic drift, Mutation, Genetic Recombination, Natural selection (Any two factors)	½ ½ ½ ½ ½+ ½	3
25	Draw a neat diagram of megasporangium of an angiosperm and label any six parts.  (Label any six parts)	½x6	3
26	a. Mention the scientific name of the source plant and the part from which opioids are extracted. b. How are morphine and heroin related? Mention the effect each one of them has on human body. Answer: a. Source plant - Papaver somniferum Part - latex of the plant b.• Heroin is formed by acetylation of morphine. • Morphine →It is effective sedative/ used as pain killer/ useful in patient who has undergone surgery Heroin is a depressant / slows down body function	**½** **½** 1 **½** **½**	3
27	A farmer grew two varieties of corn crop in field A and B. He grew normal corn crops in field A and GM corn crops in field B. He observed that corn borers attacked only in field A. To control it, spores of Bt were sprayed on field A. a. Name the gene in the spores responsible for control of pest. b. What effect will the spores of Bt have on insect pest?		3

	c. How has corn plants of field B developed resistance against this pest? Explain. Answer: a. Cry I Ab b.The spores of Bt were mixed with water and sprayed in field A where these are eaten by the insect larvae, in the gut of the insect toxins are released, and insect get killed. c. The genetically modified plants (GM) express Bt gene /produce Bt toxin which when ingested will kill the pest.	½ ½x3 1	
28	Observe the given picture carefully. A mixture of DNA with fragments ranging from 100 base pairs to 1800 base pairs were separated by electrophoresis on agarose gel with the following arrangement:  a. What result will be obtained in staining with ethidium bromide? Explain with reasons. b. The above setup was modified as shown below and a band with 100 base pairs was obtained at X.  What changes were made to the previous design to get a band at 'X'. Why did the band appear at 'X'? Answer: a. • No bands will be seen in agarose gel. • DNA fragments being negatively charged will not move towards negative end or cathode / DNA being negatively charged will remain positioned at anode or positive end. b. • Position of positive terminal or anode and negative terminal or cathode has been interchanged. • Band at X being the smallest fragment of DNA move farthest towards the anode.	½ ½ 1 1	3
	SECTION – D Question Nos. 29 and 30 are case-based questions. Each question has subsections with internal choice in one sub-section.		
29	The diagram below shows the distribution of two barnacle species, Chthamalus and Balanus on a rocky sea shore. When Balanus is experimentally removed, Chthamalus expands its range in lower intertidal zone. a. Identify and define the ecological phenomenon demonstrated by this observation.  OR	½	4

	a. State the principle that explains the elimination of one species. b. Two different species can compete for the same resource. Give another example of it. c. How do species avoid competition in nature ? Explain with an example. Answer: a. -Competitive release. -A species whose distribution is restricted to small geographical area due to the presence of competitively superior species expands its distributional range when competing superior species is removed. OR a. Gause's competitive exclusion principle, states that two closely related species cannot co-exist indefinitely and the competitively inferior one will be eliminated eventually. b. In shallow south American lakes visiting flamingos and resident fishes compete for common food Zooplankton / any other correct example c.• By "Resource partitioning" • They choose different times for feeding or different foraging patterns e.g. Five closely related species of warblers avoid competition and coexist due to behavioral differences in their foraging activities / any other correct example.	½ ½+½ 1 1 1	
30	A student performed some crosses in plants and represented the result in the form of bar graphs as shown below. Each graph displays the phenotypic proportion of the progeny. Study the graphs and answer the questions:  a. What can you infer about the genotype of parents in crosses I and II? OR a. Which genetic cross is represented by these crosses? b. Looking at bar graph of cross III, identify the type of cross performed and its importance in genetics. c. What conclusion can you draw from the results of bar graphs of crosses I and II? Name the genetic principle illustrated. Answer: a. Cross I – Genotypes TT and tt / TT and Tt / TT and TT Cross II – Genotypes Tt and Tt. OR a.Monohybrid Cross b.• Test Cross. • It is done to find the genotype of an organism showing dominant phenotype. c.• It shows that tall trait is dominant over dwarf. • Genetic principle – Law of Dominance.	½ ½ 1 1 1 ½ ½	4
	SECTION – E		
31	a. Trace the events from fertilization till implantation of blastocyst in human female. Also mention the site where fertilization takes place. OR b. (i) Case studies of some couples are given below. They were not able to have kids even though the parents were not taking any precautions. They also do not wish to adopt a child or take the help of donors. Study these cases and suggest an appropriate Assisted Reproductive Technology that could help them.		5

	Case I – Female – Normal Reports Male – Normal sperms but no connection between epididymis and vas deferens. Case II – Female – Normal eggs but Fallopian tube blocked. Male – Normal sperms. Male reports are normal. Case III – Female – Normal Reports. Male – Low sperm count with less motility. (ii) Copper releasing intrauterine devices are very effective and popular contraceptive devices. Name any two-copper releasing IUDs. Write two reasons that make them effective contraceptives. Answer: a.• After the entry of sperm into female gamete, it undergoes meiotic division II, to produce haploid ovum i.e. ootid, then the nucleus of sperm and ootid fuse together to form zygote, zygote moves through the isthmus of oviduct towards uterus and it undergoes mitotic division or cleavage to form blastomeres, the embryo with 8 to 16 blastomere is called morula and it further divides and transforms into Blastocyst, blastocyst have outer layer trophoblast and inner cell mass and the trophoblast layer of blastocyst gets attached to endometrium, Uterine wall divides rapidly and covers blastocyst and this it gets embedded in the endometrium of uterus this is called implantation. • The site of fertilization is ampullary region of fallopian tube /isthmus ampullary junction of fallopian tube. OR b. (i) Case I In vitro fertilization followed by zygote intra fallopian transfer or ZIFT / In vitro fertilization followed by Intra uterine transfer or IUT / Intra Uterine insemination or IUI / Artificial insemination or AI. Case II - Invitro fertilization followed by IUT Case III - Intra Cytoplasmic Sperm Injection or ICSI / Artificial insemination or AI / Intra Uterine insemination or IUI. (ii)• The copper releasing IUDs are CUT, Cu7, Multiload 375 (Any two) •-Copper releasing IUD's increases phagocytosis of sperms within the uterus, -Cu ions released suppress sperm motility and the fertilizing capacity of sperms.	½x8 1 1 1 1 ½+½ ½+½	
32	a. (i) Watson and Crick's discovery of double helical structure was based on which two findings. Also mention the name of the scientists associated with these findings. (ii) Write down the salient features of double helix structure of DNA (any three points). OR b. Given below is a stretch of DNA showing the coding strand of structural gene of transcription unit. 5' - ATG ACC GTA TTT TCT GTA GTG CCC GTA CTT CAG GCA TTA 3' (i) Write the corresponding template strand and m-RNA strand that will be transcribed along with its polarity. (ii) If GUA of transcribed mRNA is an intron, then depict the sequence involved in formation of mRNA / mature / processed hn RNA strand: (1) In a bacterium (2) In humans (iii) How many amino acids the resulting polypeptide will have after the process of translation in humans? Answer: a. (i)-Maurice Wilkins and Rosalind franklin, – X- ray diffraction studies of DNA.	½+½	5

	-Erwin Chargaff, – For a double stranded DNA the ratios between Adenine and Thymine and Guanine and Cytosine are constant and equal to one. (ii) The salient features of double helix structure of DNA are as follows: -It is made of two polynucleotide chains, in which backbone is constituted by sugar phosphate and the bases project inside. -The two chains have antiparallel polarity. -The bases in two stands are paired through hydrogen bonds forming base pairs(bp). Adenine form double hydrogen bond with thymine and Guanine form triple hydrogen bond with cytosine. -The two chains are coiled in a right-handed fashion. The pitch of helix is 3.4 nm and 10b.p in each turn. Distance between base pair in a helix is approximately 0.34 nm. -The plane of one base pair stack over the other in double helix. (Any three points) OR b.(i) Template strand 3' – TAC TGG CAT AAA AGA CAT CAC GGG CAT GAA GTC CGT AAT – 5' m – RNA 5' – AUG ACC GUA UUU UCU GUA GUG CCC GUA CUU CAG GCA UUA – 3' (ii) (1) In a bacterium 5' – AUG ACC GUA UUU UCU GUA GUG CCC GUA CUU CAG GCA UUA – 3' (2) In humans 5' – mGppp AUG ACC UUU UCU GUG CCC CUU CAG GCA UUA – poly A tail 3' (iii) It will have 10 amino acids.	½+½ 1x3 1 1 1 1 1	
33	a. (i) Name the protozoan species that is responsible for causing the most serious and even fatal malarial disease. (ii) Name the host in which the parasite completes its sexual stages and explain the changes taking place. (iii) How does the parasite damage the human body after entering the blood stream (iv) Suggest two effective preventive measures to control the spread of this disease in endemic regions. OR b. (i) What are bio-fertilizers? (ii) Name the different types of microorganisms used as biofertilizers in organic farming and explain how each contributes to soil fertility. (i) Write two advantages of using bio-fertilizers over chemical fertilizers. Answer: a.(i) Plasmodium falciparum (ii)• Female Anopheles Mosquito •-Mosquito picks up gametocytes from the infected person. -Fertilization and development take place in mosquito gut. -Sporozoites from gut migrate to salivary glands of mosquito. (iii) After entering the blood stream, they enter liver, and then into red blood cells and reproduce asexually, RBCs rupture and a toxic substance hemozoin is released causing chills and high fever. (iv) -Avoiding stagnation of water in and around residential areas. -Regular cleaning of household coolers. -Use of mosquito nets. -Introduce fishes like Gambusia in ponds – they feed on mosquito larval. -Spraying insecticides in ditches of doors and windows to have wire mesh. -Any other appropriate preventive measures. OR	**½** **½** **½x3** **½x3** **½+½**	5

	b.(i) Bio fertilizers – Organisms that enrich the nutrient quality of soil. e.g. bacteria fungi and cyanobacteria (ii)-Bacteria / Rhizobium / Azotobacter / Azospirillum Rhizobium forms symbiotic association with roots of leguminous plants and fix atmospheric nitrogen into organic forms to be used by the plant, Azotobacter or Azospirillum fix atmospheric nitrogen while free living in the soil. (Award one mark for any one organism with its correct contribution) -Fungi /genus Glomus. Fungi breakdown organic matter to release nutrients, Glomus form mycorrhiza with roots of the plants.This association helps to absorb phosphorous from soil and pass to the plant, plants show resistance to root-borne pathogens, plants show tolerance to salinity and drought, There is increase in plant growth. (Any one) -Cyanobacteria / Anabaena / Nostoc / Oscillatoria Fix atmospheric Nitrogen, serve as important biofertilizers in paddy fields (Any one) (iii)-Bio fertilizers do not pollute our environment (soil, ground water). -They conserve the beneficial soil microbes. -Do not cause contamination and harm human health.	1 ½ ½ ½ ½ ½+½ ½+½	

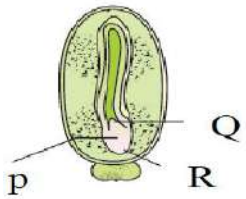
BIOLOGY-044
SAMPLE PAPER-1

Maximum Marks: 70 **Time: 3 hours**

General Instructions:

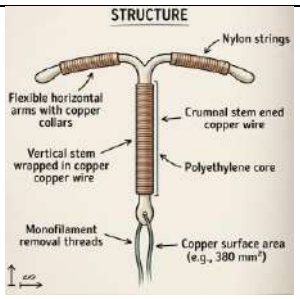
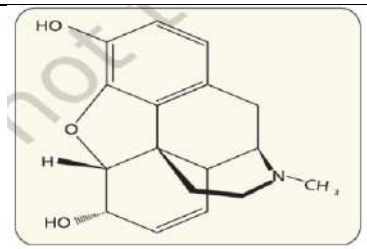
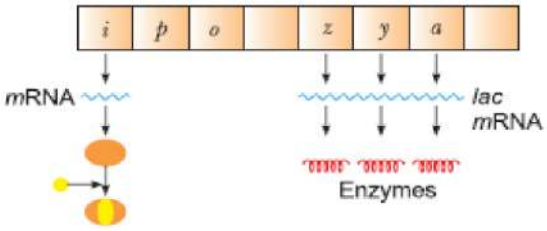
(i) All questions are compulsory.
(ii) The question paper has five sections and 33 questions.
(iii) Section–A has 16 questions of 1 mark each; Section–B has 5 questions of 2 marks each; Section– C has 7 questions of 3 marks each; Section– D has 2 case-based questions of 4 marks each; and Section–E has 3 questions of 5 marks each.
(iv) There is no overall choice. Answer all 33 questions. However, internal choices have been provided in some questions. A student has to attempt only one of the alternatives in such questions.
(v) Wherever necessary, neat and properly labeled diagrams should be drawn.

	Section – A		
Q. No	**Question**	**Marks**	**Total Marks**
1	Identify the parts P, Q R, in the figure given below and select the option in the correct order	1	1

<table>
<tr><td></td><td>


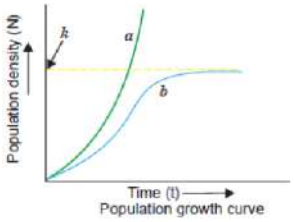
<table>
<tr><td></td><td>P</td><td>Q</td><td>R</td></tr>
<tr><td>a</td><td>Endosperm</td><td>Seed Coat</td><td>Hypocotyl root axis</td></tr>
<tr><td>b</td><td>Hypocotyl root axis</td><td>Root tip</td><td>Cotyledon</td></tr>
<tr><td>c</td><td>Shoot Apical meristem</td><td>Hypocotyl root axis</td><td>Root tip</td></tr>
<tr><td>d</td><td>Hypocotyl root axis</td><td>Shoot Apical meristem</td><td>Root tip</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td>2</td><td>During childbirth, stretching of the uterus sends signals to the mother's brain, leading to strong uterine contractions. The foetal ejection reflex triggers the release of which hormone and from where?
a. Oxytocin from foetal pituitary b. Oxytocin from maternal pituitary
c. hCG from placenta d. Progesterone from corpus luteum</td><td>1</td><td>1</td></tr>
<tr><td>3</td><td>A sample of double-stranded DNA contains 28% Cytosine bases. What is the calculated percentage of Adenine bases present in this DNA molecule?
a. 22% b. 28% c. 44% d. 56%</td><td>1</td><td>1</td></tr>
<tr><td>4</td><td>In a classic Mendelian dihybrid cross between a plant with round yellow seeds (RRYY) and wrinkled green seeds (rryy), the F_2 generation exhibits recombinant phenotypes. What is the precise combined proportion of these recombinant plants?
a.1\16 b. 3\16 c. 6\16 d. 9\16</td><td>1</td><td>1</td></tr>
<tr><td>5</td><td>Which of the following layers of an ovum prevents polyspermy in humans?
a. Corona radiata B. Zona pellucida C. Perivitelline space D. Plasma membrane</td><td>1</td><td>1</td></tr>
<tr><td>6</td><td>Fossils discovered in Java in 1891 revealed a hominid stage with a cranial capacity of about 900cc. This stage is known as:
a. Homo habilis b. Homo erectus c. Australopithecus d. Neanderthal man</td><td>1</td><td>1</td></tr>
<tr><td>7</td><td>A patient undergoing an organ transplant is prescribed an immunosuppressive agent produced by the fungus Trichoderma polysporum. Identify this bioactive molecule:
a. Statin b. Streptokinase c. Cyclosporin A d. Citric Acid</td><td>1</td><td>1</td></tr>
<tr><td>8</td><td>While preparing competent bacterial cells, the role of divalent cations like Ca^{2+} is to:
a. Break down the cell wall of bacteria
b. Increase the efficiency with which DNA enters the bacterium through cell wall pores
c. Protect the alien DNA from host exonucleases
d. Act as a selectable marker</td><td>1</td><td>1</td></tr>
<tr><td>9</td><td>If a population of mice has an average natality of 500, mortality of 480, immigration of 40, and emigration of 60, what is the net change in population size?
a. Increase of 20 b. Decrease of 20 c. Net change of 0 d. Increase of 10</td><td>1</td><td>1</td></tr>
<tr><td>10</td><td>Why is the introduction of genetically engineered lymphocytes into an ADA-deficient patient not a permanent cure?
a. Genetically engineered cells are rejected by the host immune system.
b. Lymphocytes are not immortal and require periodic infusion.</td><td>1</td><td>1</td></tr>
</table>

	c. Retroviral vectors cannot safely integrate cDNA into human genomes. d. The enzyme produced by these cells is structurally non-functional.		
11	**The process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography is called:** a. Convergent evolution b. Adaptive radiation c. Genetic drift d. Saltation	1	1
12	Sacred groves are especially useful in which of the following activities? a. Generating environmental awarenessb. Preventing soil erosion c. Conserving rare and threatened species d. Year-round water supply	1	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) b. Both Assertion a. and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A) c. Assertion (A) is true but Reason (R) is false. d. Assertion (A) is false but Reason (R) is true.		
13	**Assertion** (A)**: Proximal end of fallopian tube (infundibulum) possess fimbriae (finger like projection).** **Reason: Fimbriae help in catching of ovum after ovulation.**		
14	**Assertion** (A)**:** DNA fingerprinting is highly reliable for paternity testing. **Reason (R):** VNTRs (Variable Number of Tandem Repeats) are highly specific and inherited from parents to offspring.	1	1
15	**Assertion (A):** Secondary treatment of sewage water is primarily a mechanical filtration process. **Reason (R):** Primary sludge is components like grit and pebbles settled down through sedimentation	1	1
16	**Assertion** (A)**:** EcoRI cleaves a recombinant DNA molecule at any random site containing a high concentration of Adenine and Thymine. **Reason (R):** Every restriction endonuclease recognizes a specific palindromic nucleotide sequence in the target DNA molecule.	1	1
	SECTION – B		
17	Draw a neat, simplified diagram of a mature anatropous ovule of an angiosperm. Label any four structural parts clearly. OR a. List any two characteristic features of wheat flowers that make it a good example of wind pollination. b. It is observed that plant breeders carrying out wheat hybridisation often take pollen grains from the 'pollen banks'. Do you agree? Give one reason in support of your answer.	½ x 4 1 + ½½	2
18	Given below is the diagram of CuT, a commonly used contraceptive method. Based on the information answer the following questions:	1 1	2

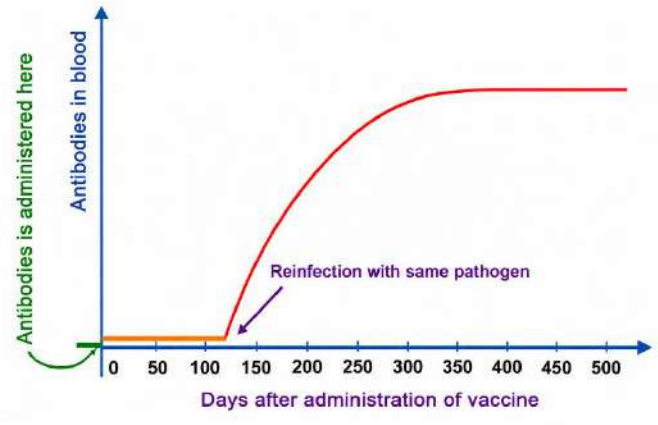
	 (i) A mother of one year old daughter wanted to space her second child. Her doctor suggested CuT. Explain its contraceptive actions. (ii) Bring out one main difference between CuT and LNG-20.		
19	a.  Name the category of drugs represented by the chemical structure given above. b. Name the natural source of these compounds. c. If the methyl group is substituted by acetyl group we get a bitter crystalline compound. Name the compound.	1 1	2
20	cryIAb is introduced in a plant to control infestation by corn borer. a. Name the resultant plant after successful insertion of the gene desired. b. Summarise the action of the gene introduced. OR a. Mention the cause and the body system affected by ADA deficiency in humans. b. Name the vector used for transferring ADA-DNA into the recipient cells in humans. Name the recipient cells.	1 + 1 1 + 1	2
21	The pyramid of biomass in a terrestrial forest ecosystem is upright, whereas the pyramid of biomass in an open ocean ecosystem is inverted. Analyze and provide a scientific justification for this structural difference. OR Describe the process of decomposition of detritus under the following heads: Fragmentation; leaching; catabolism; humification and mineralisation.	1 + 1	2
	SECTION – B		
22	Flowering plants have evolved complex genetic and morphological mechanisms to prevent self-pollination and promote cross-pollination. Explain any three such outbreeding devices.	1+1 +1	3
23	Study the figure given below and answer the questions:  (*i*) How does the repressor molecule get inactivated? (*ii*) When does the transcription of *lac* *m*RNA stop? (*iii*) Name the enzyme transcribed by the gene 'z'	1 + 1 + 1	3
24	In a certain population, the frequency of three genotypes is as follows. Genotypes: BB Bb bb Frequency: 22% 62% 16% What is the likely frequency of B and b alleles?	1+ ½ 1 + ½	3

25	Identify a,b,c,d.e and f in table given below.	½	3

Organism	Bioactive molecule	Use	½½
Monascus perpureus(yeast)	A	B	½
C	D	Antibiotic	½
E	Cyclosporine A	F	½

26	a. Tobacco plants are damaged severely when infested with Meloidogyne incognita. Name and explain the strategy that is adopted to stop this infestation. b. Name the vector used for introducing the nematode specific gene in tobacco plant.	1 + 1 + 1	3
27	Due to heavy pesticide use in an agricultural zone, the population of native bees, bats, and butterflies declines by 80%. The farmers notice a severe drop in fruit yield despite maintaining optimal soil nutrients and watering schedules. 1. Identify the specific ecosystem service that has been compromised. 2. Classify this service under the appropriate utilitarian argument category. 3. Propose the economic consequences if farmers try to substitute this natural service manually.	1+1 +1	3
28	**given**  **Identify the curves '*a*' and '*b*' shown in the graph below. List the conditions responsible for growth patterns '*a*' and '*b*'.**	½+ ½ 1 1	3
	SECTION-D		
29	In a genetic engineering experiment, scientists artificially synthesized a piece of eukaryotic hnRNA inside a test tube. Before exporting it into the cytoplasm for translation, they divided the sample into two batches. In **Batch 1**, they added an enzyme that prevents the addition of **methyl guanosine triphosphate**. In **Batch 2**, they treated the RNA with a chemical that completely blocks the template-independent addition of **adenylate residues**. a. Name the two post-transcriptional processes that were targeted in Batch 1 and Batch 2, respectively. b. Specify the exact locations (ends of the RNA strand. where the modifications in Batch 1 and Batch 2 normally occur. OR (c) Predict the fate of the RNA in Batch 1 if it is introduced into the cytoplasm without its corresponding modification. (d) Why do prokaryotes skip post-transcriptional mRNA modifications.	1+1 1 1 1	4
30	For any cloning vector to replicate inside a host organism, it must possess an **Origin of Replication (ori)**. This is a specific DNA sequence where replication initiates. The *ori* sequence also plays a critical role in controlling the **copy number** of the linked foreign DNA. If a researcher wants to harvest a high yield of a target protein, they must choose a vector whose *ori* supports a high copy number. Additionally, pBR322 features several unique recognition sites for restriction endonucleases, such as *EcoRI*, *ClaI*, *HindIII*, *PvuI*, *PstI*, *BamHI*, *SalI*, and *PvuII*. The presence of unique, single restriction sites is preferred because multiple restriction		4

	sites within a vector would cut it into several fragments, complicating the gene cloning process. The vector also contains a **rop gene**, which codes for proteins involved in regulating the replication and copy number of the plasmid. a. If a target gene is cloned at the BamHI site of pBR322, which specific antibiotic resistance gene is disrupted? b. Predict the consequence on plasmid replication if the ***rop*** gene is deleted or mutated in a pBR322 vector. OR c. A student clones a gene of interest into pBR322 but accidentally uses a restriction enzyme that has three recognition sites within the plasmid map. What difficulties will this cause in the experiment? d. Which region of the pBR322 plasmid should a scientist modify if they want to significantly increase the yield of the cloned foreign gene product per cell?	1 1 1 1+1	
	SECTION – E		
31	**a.** Explain the process of spermatogenesis in human males with the help of a schematic flowchart. **b.** Differentiate between spermatogenesis and oogenesis with respect to: • Age of onset • Number of gametes produced from one primary cell. • Continuity of the process. • Polar body formation. OR he menstrual cycle is a complex orchestrated process regulated by pituitary and ovarian hormones. **a.** Describe the phases of the menstrual cycle in human females. **b.** Correlate the changes in the levels of pituitary hormones (LH and FSH) and ovarian hormones (estrogen and progesterone) during the follicular and luteal phases. What triggers ovulation?	1+1 + 1 ½ ½ ½ ½ +1 1+1 +1	5
32	Morgan performed experiments on Drosophila and proposed the concept of linkage. (i) Explain the term linkage. (ii) Differentiate between complete linkage and incomplete linkage. (iii) Why are linked genes inherited together? (iv) Explain the role of crossing over in producing variations. OR In snapdragon plants, red flowered plants were crossed with white flowered plants and pink flowers were obtained in F_1 generation. (i) Name the type of inheritance shown. (ii) Write the genotypes of parents and F_1 generation. (iii) Show the F_2 phenotypic and genotypic ratio. (iv) Differentiate between incomplete dominance and complete dominance.	1+1 1 1 1 1 1 1 1+1	5
33	A time-bound vaccination programme is followed for the children in our country from their birth up to ten years of age. A graph plotted below shows the effect of the		5

	vaccination followed by infection by the same pathogen, and the antibody concentration in the blood of the child. (i) Explain why the administration of a vaccine causes an increase in the antibody concentration. (ii) If the child is infected with the same pathogen almost four months later, the antibody concentration in blood increases very fast. Explain why.  OR **a.** Normal genes called **cellular oncogenes (c-onc.** or **proto-oncogenes** are present in all healthy human cells. Explain how these normal genes can cause cancer. **b.** Differentiate between a **Benign tumor** and a **Malignant tumor** based on their growth rate, movement, and threat to life. **c.** Name the property that allows malignant tumor cells to invade and destroy neighboring healthy tissues.	1+1 1+1 +1 1+1 1 1 1	

BIOLOGY-044

SAMPLE PAPER-2

Maximum Marks: 70 Time: 3 hours

General Instructions:

(i) All questions are compulsory.

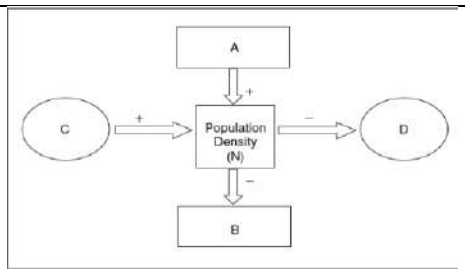
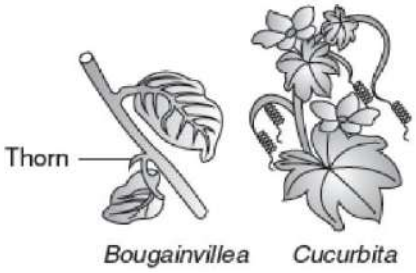
(ii) The question paper has five sections and 33 questions.

(iii) Section–A has 16 questions of 1 mark each; Section–B has 5 questions of 2 marks each; Section– C has 7 questions of 3 marks each; Section– D has 2 case-based questions of 4 marks each; and Section–E has 3 questions of 5 marks each.

(iv) There is no overall choice. Answer all 33 questions. However, internal choices have been provided in some questions. A student has to attempt only one of the alternatives in such questions.

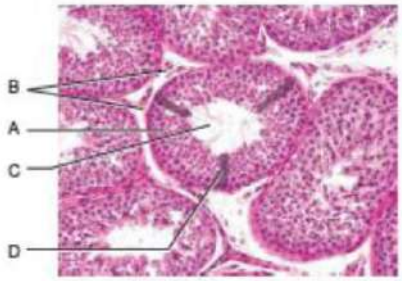
(v) Wherever necessary, neat and properly labeled diagrams should be drawn.

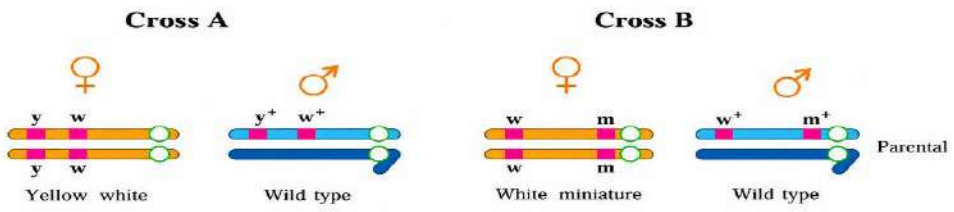
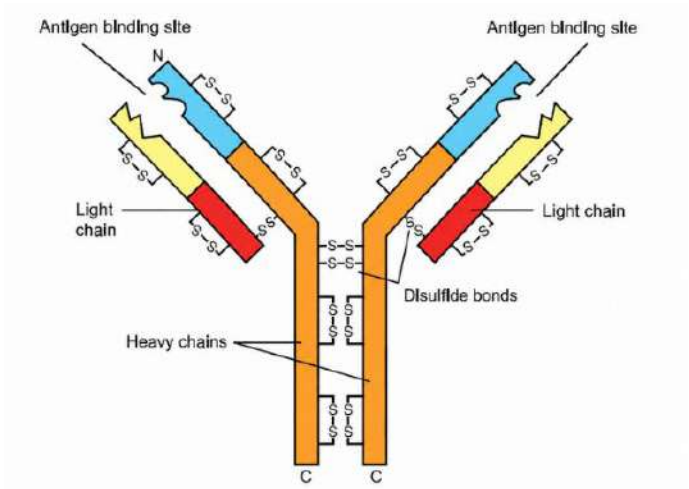
	Section – A		
Q.No	Question	Marks	Total Marks
1	What indicates 'A' in the above figure? a. Root tip b. Shoot apical meristem c. Cotyledon d. Endosperm	1	1
2	A hormone secreted by the placenta helps maintain the corpus luteum during pregnancy. Identify the hormone. a. LH b. FSH c. hCG d. Oxytocin	1	1
3	In a 200 base pair sharp segment of double-stranded DNA, there are 40 Adenine bases. What is the total number of Guanine bases present in this segment? a. 40 b. 80 c. 160 d. 320	1	1
4	A scientist crosses a pure-breeding pea plant with violet flowers and a pure-breeding pea plant with white flowers. The F1 generation is self-pollinated. Out of 800 plants produced in the F2 generation, approximately how many are expected to have white flowers? a. 200 b. 400 c. 600 d. 800	1	1
5	Which hormone acts as the primary biomarker to maintain the endometrium during the secretory phase? a. Estrogen b. LH c. Progesterone d. FSH	1	1
6	Which of the following is considered the common ancestor of all vascular plants? a. Chlorophyte ancestors b. Rhynia-type plantsc. Psilophyton d. Tracheophyte ancestors	1	1
7	The large holes in Swiss cheese are due to the production of a large amount of CO_2 by which bacterium? a. *Propionibacterium sharmanii* b. *Saccharomyces cerevisiae* c. *Penicillium roqueforti* d. *Leuconostoc mesenteroides*	1	1
8	The sequence recognized by EcoRI is a. 5'-GAATTC-3' 3'-CTTAAG-5' b. 5'-CCAATG-3' 3'-GAATCC-5' c. 5'-GATACC-3' 3'-CCTAAG-5' d. 5'-CATTAG-3' 3'-GATAAC-5'	1	1
9	Identify A, B, C and D in this figure.	1	1

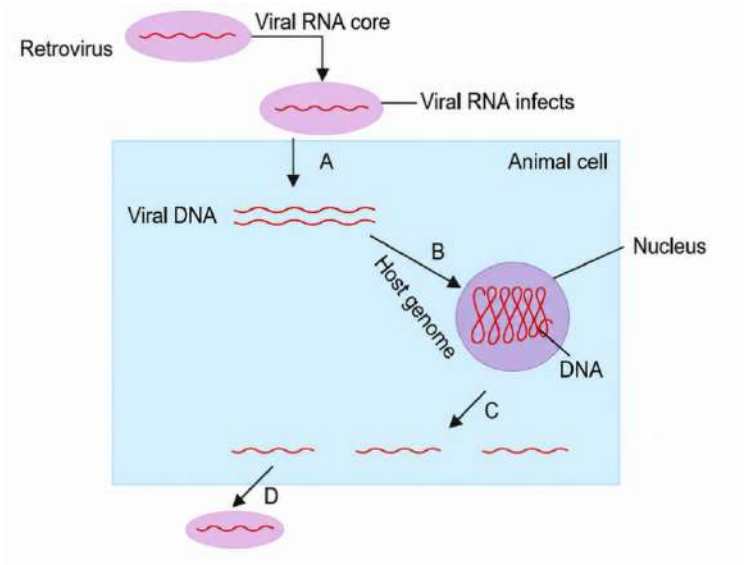
	 a. A: Immigration (I), B: Emigration (E), C: Natality b., D: Mortality d. b. A: Natality b., B: immigration (I), C: Mortality d., D: Emigration (E) c. A: Mortality d., B: Emigration (E), C: Natality b., D: Immigration (I) d. A: Mortality d., B: Natality b., C: Emigration (E), D: Immigration (I)		
10	The applications of Biotechnology include a. Therapeutics b. Diagnostics c. GM crops for agriculture d. Processed food (E) Bioremediation (F) Waste treatment (G) Energy production a. A, B, C, E only b. C only c. B, C, D, E only d. All of these	1	1
11	What does this diagram show?  a. Convergent evolution b. Divergent evolution c. Homologous organ d. Both b. and c.	1	1
12	Find the incorrect statement from the following. a. Introduction of Nile perch in Lake Victoria in east Africa lead to the extinction of more than 200 species of cichlid fish in the lake. b. Fast dwindling Amazon forest is estimated to produce, through photosynthesis, 20 per cent of the total oxygen in the earth's atmosphere. c. More than 25 per cent of drugs currently sold worldwide are derived from plants. d. Illegal introduction of American catfish Clarias gariepinus for aquaculture purpose is posing threat to indigenous cat fishes in our rivers.	1	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) b. Both Assertion a. and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A) c. Assertion (A) is true but Reason (R) is false. d. Assertion (A) is false but Reason (R) is true.		
13	Assertion (A): LH surge induces the rupture of the Graafian follicle and thereby the release of an ovum. Reason (R): Both LH and FSH attain a peak level in the middle of the menstrual cycle.		
14	Assertion (A): Less than 2 per cent of the human genome codes for proteins.	1	1

	Reason (R): A very large portion of the human genome is made up of repeated sequences.		
15	Assertion (A): The organic farmer works to create a system where the insects that are sometimes called pests are not completely eradicated. Reason (R): Without these pests, the beneficial predatory and parasitic insects which depend on them for food or as a life cycle host would not be able to survive.	1	1
16	Assertion (A): RNA interference (RNAi) takes place in all eukaryotic organisms as a method of cellular defence. Reason (R): RNAi involves the silencing of a specific mRNA due to a complementary double-stranded RNA (dsRNA. molecule	1	1
	SECTION – B		
17	a. Differentiate between chasmogamous and cleistogamous flowers. b. Why is geitonogamy genetically similar to autogamy? Or How are pollen grains stored for artificial plant breeding programs over long periods? State the exact conditions required.	1 1 1 1	2
18	How can amniocentesis help an expectant mother with a known family history of genetic disorders? Give two examples of disorders it can detect.	1 1	2
19	An experimental drug administered to mice blocks the interaction between the cellular surfaces of helper T-lymphocytes and B-lymphocytes. Predict the effect of this drug on Humoral Immunity versus Cell-Mediated Immunity.	1 1	2
20	a. Name the specific enzyme utilized to dissolve the cell wall of a fungal cell during the isolation of its genomic DNA. b. Why is chilled ethanol added to the purified, cell-free mixture at the end of the DNA isolation process? Or Can you suggest a method to remove oil (hydrocarbon) from seeds based on your understanding of *r*DNA technology and chemistry of oil?	1 1 1 1	2
21	a. Differentiate between Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) in an ecosystem. b. Why is the primary productivity of a tropical rainforest significantly higher than that of a desert ecosystem? Or a. Name the process by which water-soluble inorganic nutrients go down into the soil horizon and get precipitated as unavailable salts during decomposition. b. How does a high concentration of lignin and chitin in detritus affect the overall rate of its decomposition?	1 1 1 1	2
	SECTION-C		
22	The functional megaspore in an angiosperm ovule undergoes free-nuclear mitotic divisions to form a mature embryo sac. a. Explain what is meant by "free-nuclear" divisions during this process.	1+1+ 1	3

	b. Describe the cellular reorganization that takes place immediately after the 8-nucleate stage is reached. c. State the final cellular and nuclear composition of this mature embryo sac.		
23	A molecular biologist creates a mutant strain of *E. coli* that lacks a functional DNA Helicase enzyme. a. Predict the immediate structural effect of this mutation on the parental double-stranded DNA molecule during cell division. b. Why cannot the entire length of a long genomic DNA molecule be separated completely all at once to act as a template? c. What is a "replication fork"? Name the small chemical sequence that must be laid down first before any DNA polymerisation can begin.	1 + 1 + 1	3
24	In a randomly mating population of organisms at genetic equilibrium, the frequency of the homozygous recessive phenotype (aa. is found to be 16% (0.16). a. Calculate the individual frequencies of the dominant allele a. and the recessive allele a. in this gene pool. b. Determine the total percentage of individuals in the population that are expected to be heterozygous (A(A)	1+ ½ 1 + ½	3
25	A sewage treatment plant releases treated water into a nearby river only after secondary treatment. During the process, activated sludge is formed. (i) What is activated sludge? (ii) Why is aeration important during secondary treatment? (iii) What happens if untreated sewage is released into rivers?	1 1 1	3
26	State the role of transposons in silencing of *m*RNA in eukaryotic cells.	1+1 + 1	3
27	**a.** How do co-existing species avoid competitive exclusion in nature? Explain with an example. **b.** Differentiate between Competitive Release and Resource Partitioning.	1+1 ½½	3
28	Ecologists have observed that tropical regions possess significantly greater biodiversity than temperate regions. Explain any three biological reasons proposed to justify this latitudinal gradient.	1+1+1	3
	SECTION-D		
29	In eukaryotes, transcription occurs in the nucleus and produces a non-functional primary transcript called heterogeneous nuclear RNA (hnRN(A) This molecule contains both coding regions (exons) and non-coding regions (introns). To form a mature, functional messenger RNA (mRNA. capable of translation, the hnRNA must undergo extensive post-transcriptional modifications, including splicing, capping, and tailing. In contrast, prokaryotic transcription takes place in the cytoplasm and requires no structural processing before translation can begin. a. Name the specific enzyme responsible for transcribing hnRNA in eukaryotic cells. b. Identify the biochemical nature of the 'cap' added to the 5'-end of the hnRNA transcript. OR c. State the structural feature of prokaryotic structural genes that explains why their mRNA does not require splicing.	1 1 1 2	4

	d. c. What is the biological significance of adding a poly-A tail to the 3'-end of the mRNA molecule?		
30	A biotechnology firm aims to scale up the production of a therapeutic protein by cloning its gene into *E. coli*. They employ the standard cloning vector pBR322. The gene of interest is restriction-digested and ligated specifically at the PstI restriction site, which is located inside the ampicillin resistance (amp^R) gene. The plasmid also contains an intact tetracycline resistance (tet^R) gene, an origin of replication (ori), and a (rop) gene. The reaction mixture is then transformed into host bacterial cells that lack any natural resistance to antibiotics. The lab technician must now perform screening to isolate the correct recombinant colonies. a. What will be the impact of inserting the therapeutic gene at the PstI site on the ampicillin resistance of the recombinant plasmid? Name the underlying genetic principle. b. How can a researcher differentiate between transformants and non-transformants using the antibiotic properties of this experimental setup? Or c. Predict the growth outcome when the recombinant transformants are replica-plated onto a medium containing tetracycline, and explain the reason behind this observation. d. c.If a mutation occurs in the (rop) gene of pBR322 during this experiment, what specific quantitative property of the plasmid will be altered within the *E. coli* host? Explain your answer.	1 1 1 1+1	4
	SECTION-E		
31	a. When and how does placenta develop in human female? b. How is the placenta connected to the embryo? c. Placenta acts as an endocrine gland. Explain. Or Study the figures given below and answer the questions that follow. (*i*)  During reproduction, the chromosome number (2n) reduces to half (n) in the gametes and again resume the number (2n) in the offspring, original what which are the processes through these events take place? (*ii*) Write the functions of A and D. (*iii*) Mention the function of mitochondria in sperm.	1 1 1+ 1 +1 1+1 ½½½ ½1	5

32	a. When a cross is made between tall plant with yellow seed (TtYy) and tall plant with green seed (Ttyy), what proportions of phenotype in the offspring could be expected to be a. tall and green b. dwarf and green? b. Two heterozygous parents are crossed. If the two loci are linked what would be the distribution of phenotypic features in F1 generation for a dihybrid cross? Or c. Study the figures given below and answer the questions that follow.  *a.* (*i*) In a dihybrid cross, when would the proportion of parental gene combinations be much higher than non-parental types, as experimentally shown by Morgan and his group? (*ii*) If two genes are located far apart from each other on a chromosome, how the frequency of recombination will get affected? (*iii*) What are 'true breeding lines' that are used to study inheritance pattern of traits in plants? b. The map distance in certain organisms between gene A and B is 4 units, B and C is 2 units and between C and D is 8 units which one of these gene pairs will show more linkage? Give reasons in support of your answer.	1+1 1 1 1 1 1 1 1+1	5
33	(a) Given below is the structure of an antibody.  (i) A boy of ten years had chicken pox. He is not expected to have the same disease for the rest of his life. Mention how it is possible.	1+1+1	5

	(*ii*) Why is secondary immune response more intense than the primary immune response in humans? (*iii*) Some allergens trigger sneezing and wheezing in human beings. What causes this type of response by the body? (b) What is an autoimmune disease? Give an example. Or (a) Identify A, B, C and D in the replication of HIV (retrovirus).  (b) Name the type of cells the AIDS virus first enters into after getting inside the human body. Explain the sequence of events that the virus undergoes within these cells to increase their progeny.	1+1 ½½½ ½ 1 1 1	

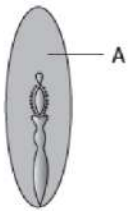
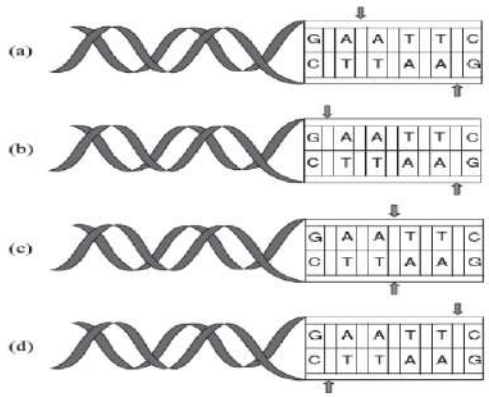
BIOLOGY-044
SAMPLE PAPER-3

Maximum Marks: 70 Time: 3 hours

General Instructions:

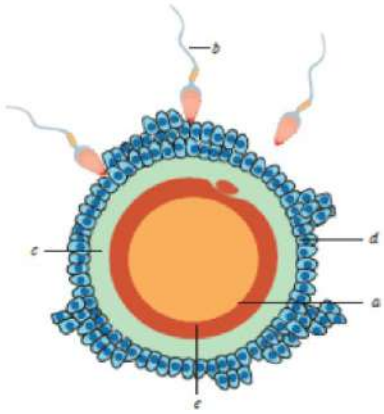
(i) All questions are compulsory.
(ii) The question paper has five sections and 33 questions.
(iii) Section–A has 16 questions of 1 mark each; Section–B has 5 questions of 2 marks each; Section– C has 7 questions of 3 marks each; Section– D has 2 case-based questions of 4 marks each; and Section–E has 3 questions of 5 marks each.
(iv) There is no overall choice. Answer all 33 questions. However, internal choices have been provided in some questions. A student has to attempt only one of the alternatives in such questions.
(v) Wherever necessary, neat and properly labeled diagrams should be drawn.

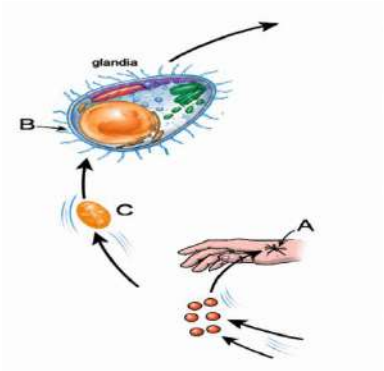
	Section – A		
Q. No	Question	Marks	Total Marks
1	What indicates 'A' in the following figure?	1	1

	 a. Micropyle b. Cotyledon c. Endosperm d. Scutellum		
2	A pregnant woman has low secretion of progesterone during early pregnancy. Which effect is most likely observed? a. Increased milk production b. Failure to maintain pregnancy c. Increased ovulation d. Rapid follicle growth	1	1
3	A sample of DNA is analyzed and found to have a Guanine content of 34%. What is the expected percentage of Thymine? a. 34% b. 68% c. 16% d. 32%	1	1
4	In a plant nursery, a gardener crosses a true-breeding yellow-seeded pea plant with a true-breeding green-seeded pea plant. The F1 plants are then test-crossed. What percentage of the test-cross offspring will have green seeds? a. 25% b. 50% c. 75% d. 100%	1	1
5	What triggers the breakdown of the endometrial lining leading to menstruation? a. Surge in LH levels b. Withdrawal of progesterone support c. Peak levels of estrogen d. Increase in FSH secretion	1	1
6	Seed ferns (Pteridosperms) originated during which geological period? a. Devonian b. Carboniferous c. Silurian d. Permian	1	1
7	Statins, used as blood-cholesterol lowering agents, are commercially produced by the yeast: a. *Saccharomyces cerevisiae* b. *Monascus purpureus* c. *Candida lipolytica* d. *Torulopsis utilis*	1	1
8	Which diagram correctly represents the cutting of both strands of DNA by EcoRI? 	1	1
9	A biologist studied the population of eats in a barn. He found that the average natality was 250, average mortality is 240, immigration is 20 and emigration to be 30. The net increase in population is a. 10 b. 15 c. 05 d. Zero	1	1
10	Critical research areas of biotechnology are a. Providing the best catalyst in the form of improved organism usually a microbe or pure enzyme. b. Creating optimal condition through engineering for a catalyst to act. c. Downstream processing technologies to purify the protein organic compound. d. All the above	1	1
11	Arrange the ascending order of extinction (reptiles): a. Pelycosaurs, Thecodonts, Therapsids, Dinosaurs b. Thecodonts, Dinosaurs, Pelycosaurs, Therapsids	1	1

	c. Dinosaurs, Therapsids, Thecodonts, Pelycosaurs d. Therapsids, Thecodonts, Pelycosaurs, Dinosaurs		
12	Biodiversity of a geographical region represents a. Endangered species found in the region. b. The diversity in the organism living in the region. c. Genetic diversity in the dominant species of the region. d. Species endemic to the region.	1	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) b. Both Assertion a. and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A) c. Assertion (A) is true but Reason (R) is false. d. Assertion (A) is false but Reason (R) is true.		
13	Assertion (A): GnRH levels rise significantly at the age of puberty in human males. Reason (R): GnRH acts on the posterior pituitary gland and stimulates the secretion of LH and FSH.	1	
14	Assertion(A): Expressed Sequence Tags (ESTs) and Sequence Annotation were the two major approaches used in HGP. Reason (R): ESTs focused on identifying all the genes that are expressed as RNA, whereas Sequence Annotation blindly sequenced the whole genome.	1	1
15	Assertion (A): Ladybird and Dragonflies are used to get rid of aphids and mosquitoes respectively. Reason (R): These insects act as predatory biocontrol agents by feeding on specific pest populations.	1	1
16	Assertion(A): Tobacco plants transgenic for RNAi can survive in fields heavily infested with the nematode *Meloidogyne incognita*. Reason (R): The specific mRNA of the nematode is silenced inside the parasite body, preventing it from producing essential survival proteins.	1	1
	SECTION – B		
17	a. Write the name of the outer and inner layer of ovule. b. What is the functional difference between the integument and the nucellus of a developing ovule. Or Explain the concept of 'monosporic development' of an embryo sac.	1+1 1+1	2
18	How does a lactational amenorrhea method act as a natural contraceptive mechanism? State its maximum effective period.	1 1	2
19	A patient undergoes a surgical removal of the spleen due to physical trauma. Analyze how this condition impacts their body's capability to filter blood-borne pathogens versus tissue-fluid pathogens.	1 1	2
20	a. Why are genes encoding resistance to antibiotics considered valuable tools in genetic cloning protocols? b. Give an example of a natural organism that acts as a "natural genetic engineer" to deliver genes into plant cells, and name the vector derived from it. Or a. How is a disarmed pathogen vector made safe for delivering a gene of interest into an animal or plant host cell? b. Name the specific tumor-inducing plasmid that is modified and disarmed to transform dicotyledonous plant tissues safely.	1 + 1 1 + 1	2

21	a. Explain the functional role of detritivores in an ecosystem, providing a suitable example. b. Why is the rate of decomposition exceptionally slow under anaerobic (oxygen-poor) climatic conditions? Or a. Distinguish between a Grazing Food Chain (GFC. and a Detritus Food Chain (DFC. based on their primary source of energy. b. In a terrestrial ecosystem, which of these two food chains is responsible for transferring a major fraction of energy?	1 + 1 1+1	2
	SECTION – B		
22	Pollen grains exhibit a highly specialized wall structure that protects them from environmental extremes. a. Identify the two distinct layers of the pollen wall and name the chemical components that make up each layer. b. What are germ pores, and what is their functional significance during pollen germination? c. Why can pollen grains be preserved perfectly for thousands of years as fossils?	1+1+1	3
23	During DNA replication, deoxyribonucleoside triphosphates (dNTPs) play a crucial role in supporting the polymerisation process. a. State the primary catalytic function of dNTPs in the synthesis of a new DNA strand. b. Explain the energetic advantage that dNTPs provide to the replication machinery.	 1 1 +1	3
24	A researcher studies a stable population of 500 individuals that follows Hardy-Weinberg equilibrium. A specific gene has two alleles, where the frequency of the dominant allele (p) is 0.7. a. Calculate the expected frequency of the homozygous dominant genotype (p^2) and the homozygous recessive genotype (p^2). b. Out of the total 500 individuals, calculate the exact number of individuals that will possess the heterozygous (Aa. genotype.	 1+ ½ 1 + ½	3
25	A doctor advised a patient to complete the full course of antibiotics even after recovery from fever. a. Why should antibiotics not be stopped midway? b. Name one antibiotic produced by fungi. c. Why are antibiotics ineffective against viral diseases?	½ ½½ ½ ½ ½	3
26	What is gene therapy? Illustrate using the example of adenosine deaminase (ADA. deficiency.	1 + 1+1	3
27	a. Why is predation considered a necessary evil in an ecosystem? (Give two reasons) b. Differentiate between Ectoparasites and Endoparasites with examples.	1+1 1	3
28	Human activities have accelerated the rate of species extinction. Explain any three attributes of 'The Evil Quartet' that drive this loss of biodiversity.	1+1 1	3
	SECTION-D		
29	The conversion of genetic information from a nucleic acid polymer into a protein polymer requires a molecular dictionary known as the genetic code. The code consists of 64 triplet codons, where 61 code for specific amino acids and 3 serve as termination signals. Translation relies heavily on adapter molecules (tRNAs) that read the mRNA codons and carry the appropriate amino acids to the active site of a ribosome. The overall process moves systematically through initiation, elongation, and termination phases. a. Why is the genetic code described as degenerate? Provide a brief definition.	 1 1 1	4

	b. Name the unique amino acid that is always incorporated as the first residue in any freshly synthesized eukaryotic polypeptide chain. Or c. Write the specific structural codons that act as stop codons (termination codons) during translation. d. If an mRNA codon reads 5'- UUC -3', state the exact sequence of the anticodon loop on its cognate tRNA, specifying its polarity (ends).	2	
30	In recombinant DNA technology, identifying transformants that carry the desired foreign gene is a critical step. Traditionally, scientists used selectable markers like antibiotic resistance genes (amp^R) and (tet^R) on cloning vectors like pBR322. This required a cumbersome process of replica plating on two different antibiotic media. To simplify this, an alternative method called insertional inactivation was developed. This technique involves inserting the foreign DNA within the coding sequence of an enzyme, such as β-galactosidase (encoded by the *lacZ* gene) or an antibiotic resistance gene. When the foreign gene is successfully inserted, it disrupts the sequence, rendering the gene non-functional. For instance, in the blue-white screening method, recombinants lose the ability to produce the enzyme and form white colonies, while non-recombinants form blue colonies in the presence of a chromogenic substrate. a. State the dual function of a selectable marker in a cloning vector during transformation. b. In blue-white screening, what biochemical reaction causes the non-recombinant colonies to develop a blue colour? Or c. Why is screening recombinants via the *lacZ* gene considered less cumbersome than using the (amp^R) and (tet^R)genes of pBR322? d. d. A recombinant plasmid is formed by inserting a gene into the *PstI* site of the ampicillin resistance (\(amp^{R}\)) gene of pBR322. Explain how this insertion affects the bacterium's growth on ampicillin-containing medium.	1 1 1 1+1	4
	SECTION – E		
31	Study the illustration given and answer the questions that follow:  (*i*) Identify '*a*' and '*e*'. (*ii*) Name and state the function of '*c*'. (*iii*) Identify '*d*'. (*iv*) Explain the role of hormones in the formation and release of '*a*'. (*v*) Draw a diagram of '*b*' separately and label the parts: — that help its entry into 'a'; — that carry genetic material; Or a. When and how does placenta develop in human female? b. How is the placenta connected to the embryo? c. Placenta acts as an endocrine gland. Explain.	1+1+1 ½ ½ ½½ ½ ½ 1+1+1 1 1+1 1+1	5

32	a. Both haemophilia and thalassemia are blood related disorders in humans. Write their causes and the difference between the two. Name the category of genetic disorder they both come under. b. A colour-blind man marries a woman with normal vision whose father was colour-blind. Work out a cross to show the genotype of the couple and their respective sons. Or a. A cross was carried out between a pea plant heterozygous for round and yellow seeds with a pea plant having wrinkled and green seeds. a. Show the cross in a Punnett square. b. Write the phenotype of the progeny of this cross. c. What is this cross known as? State the purpose of conducting such a cross. b. Explain the following terms with example (*i*) Co-dominance (*ii*) Incomplete dominance	1+1 1 1 1 1 1 1 1+1	5
33	a. Study a part of the life cycle of malarial parasite given alongside.  Answer the questions that follow: (*i*) Mention the roles of 'A' in the life cycle of the malarial parasite. (ii) Name the event 'C' and the organ where this event occurs. (iii) Identify the organ 'B' and name the cells being released from it. b. (i) How does the human body respond when vaccine is introduced into it ? (ii) It is said that vaccinations are a must for a healthy society. Justify Or a. Cancer is one of the most dreaded diseases of humans. Explain 'Contact inhibition' and 'Metastasis' with respect to the disease. b. Name the group of genes which have been identified in normal cells that could lead to cancer and how they do so? c. Name any two techniques which are useful to detect cancers of internal organs. d. Why are cancer patients often given α-interferon as part of the treatment?	1 1 1 1+1	5

BIOLOGY-044
SAMPLE PAPER-4

Maximum Marks: 70 Time: 3 hours

General Instructions:

(i) All questions are compulsory.

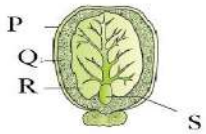
(ii) The question paper has five sections and 33 questions.

(iii) Section–A has 16 questions of 1 mark each; Section–B has 5 questions of 2 marks each; Section– C has 7 questions of 3 marks each; Section– D has 2 case-based questions of 4 marks each; and Section–E has 3 questions of 5 marks each.

(iv) There is no overall choice. Answer all 33 questions. However, internal choices have been provided in some questions. A student has to attempt only one of the alternatives in such questions.

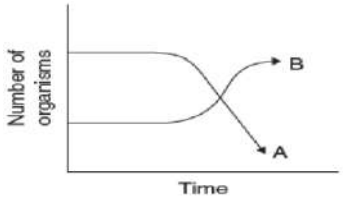
Wherever necessary, neat and properly labeled diagrams should be drawn.

(v)

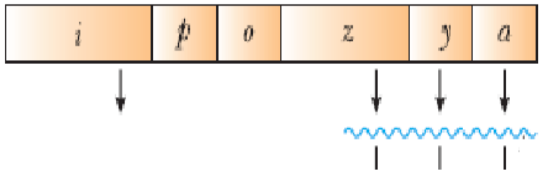
	Section – A		
Q. No	Question	Marks	Total Marks
1	Identify the parts P, PQ R, S in the figure given below and select the option in the correct order  	1	1

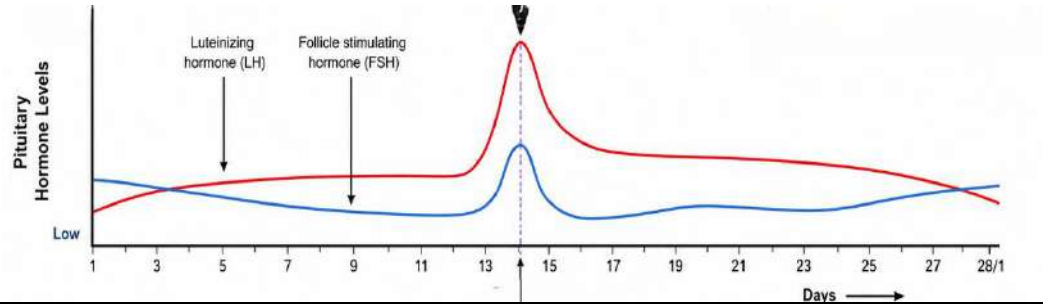
	P	Q	R	S
a	Endosperm	Seed Coat	Cotyledon	Hypocotyl root axis
b	Seed Coat	Endosperm	Cotyledon	Hypocotyl root axis
c	Cotyledon	Hypocotyl root axis	Seed Coat	Endosperm
d	Cotyledon	Hypocotyl root axis	Endosperm	Seed Coat

2	After childbirth, a mother is unable to eject milk though milk is being produced normally. Deficiency of which hormone is responsible? a. Prolactin b. Oxytocin c. Estrogen d. Progesterone	1	1
3	If the sum of Adenine and Thymine in a double-stranded DNA molecule is 56%, what is the percentage of Guanine? a. 56% b. 44% c. 22% d. 28%	1	1
4	A researcher crosses a pea plant having inflated green pods with another plant having constricted yellow pods. The F1 generation shows all inflated green pods. If the F1 plants are self-pollinated, which of the following represents a recombinant phenotype in the F2 generation? a. Inflated green pods b. Constricted yellow pods c. Inflated yellow pods d. Both a. and b.	1	1
5	Which of the following correctly traces the chronological phases of a standard menstrual cycle? a. Menstrual →Secretory →Follicular →Ovulatory b. Menstrual →Follicular →Ovulatory →Luteal c. Luteal →Ovulatory →Follicular →Menstrual d. Follicular →Menstrual →Ovulatory →Luteal	1	1
6	Choose the correct chronological sequence of geological eras from oldest to youngest. a. Mesozoic → Coenozoic → Palaeozoic	1	1

	b. Palaeozoic → Mesozoic → Coenozoic c. Coenozoic → Mesozoic → Palaeozoic d. Palaeozoic → Coenozoic → Mesozoic		
7	During sewage treatment, biogas is produced in which of the following tanks? a. Primary settling tank b. Aeration tank c. Anaerobic sludge digester d. Secondary settling tank	1	1
8	EcoRI cuts palindrome sequence which produces overhanging stretches called sticky ends on each strand. These are named sticky because a. They can combine with any DNA. b. They form hydrogen bonds with their complementary cut counterpart. c. They facilitate the action of the enzyme DNA ligase. d. Both b. and c.	1	1
9	The following graph depicts changes in two populations (A and B. of herbivore in a grassy field. A possible reason for these changes is that  a. Both plant populations in this habitat is decreased. b. Population B compound is more successful for food than population A. c. Population A produces more offspring than population B. d. Population A consumed the members of population B.	1	1
10	During the process of prohormone 'proinsulin' into mature insulin synthesis a. C-peptide is added to proinsulin b. C-peptide is removed from proinsulin c. β-peptide is added to proinsulin d. β-peptide is removed from proinsulin	1	1
11	Hugo de Vries, based on his work on _____ , brought forth the idea of mutations. a. *Pisum sativum* b. *Lathyrus odoratus* c. Evening primrose d. *Lathyrus sativus*	1	1
12	Select the correct statement about biodiversity. a. Large scale planting of Bt cotton has no adverse effect on biodiversity. b. Western Ghats have a very high degree of species richness and endemism. c. Conservation of biodiversity is just a fad pursued by the developed countries. d. The desert areas of Rajasthan and Gujarat have a very high level of desert animal species as well as numerous rare animals.	1	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R). Answer these questions selecting the appropriate option given below: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) b. Both Assertion a. and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A) c. Assertion (A) is true but Reason (R) is false. d. Assertion (A) is false but Reason (R) is true.		
13	Assertion (A): In humans, the sex of the baby is determined by the genetic makeup of the father.		

	Reason (R): Human males produce two types of gametes, 50% carrying the X chromosome and 50% carrying the Y chromosome.		
14	Assertion (A): BAC and YAC were used as vectors for cloning large fragments of human DNA. Reason (R): BAC stands for Bacterial Artificial Chromosome and YAC stands for Yeast Artificial Chromosome.	1	1
15	Assertion (A): Baculoviruses belonging to the genus *Nucleopolyhedrovirus* are excellent candidates for species-specific, narrow-spectrum insecticidal applications. Reason (R): They have been shown to have negative impacts on plants, mammals, birds, fish, or even on non-target insects.	1	1
16	Assertion (A): The complementary double-stranded RNA (dsRNA. required to initiate RNAi can originate from mobile genetic elements called transposons. Reason (R): Transposons replicate via an RNA intermediate that can form double-stranded loops within the host cell.	1	1
	SECTION – B		
17	Why is self-pollination completely prevented in dioecious plant species? Give two examples of dioecious plants. Or If one can induce parthenocarpy through the application of growth substances, which fruits would you select to induce parthenocarpy and why?	1+1 1+1	2
18	Why are surgical sterilization methods considered terminal birth control options? Mention one major drawback of these methods.	1 1	2
19	During a severe respiratory tract infection, a patient experiences temporary swelling in the neck region. Biologically evaluate this scenario by answering: a. What causes the localized swelling in the neck region? b. Which structural category of the lymphoid tissue lining the respiratory tract serves as the first line of defense here? State its short-form acronym.	1 1	2
20	a. When using chromogenic substrates for screening, what color change indicates that a bacterial colony contains a non-recombinant plasmid? b. Explain the economic and structural advantage of using chromogenic selection over traditional replica plating with antibiotics. Or a. Why is a hydrophilic molecule like a naked DNA plasmid unable to pass directly through the plasma membrane of a living host cell? b. State the functional purpose of utilizing ice-cold temperatures before and after the brief thermal shock during chemical transformation.	1 + 1 1 + 1	2
21	a. State the percentage of incident solar radiation that constitutes Photosynthetically Active Radiation (PAR). b. What percentage of this PAR is actually captured by photosynthetic green plants to sustain the entire living world? Or a. State Lindeman's 10% law of energy transfer across consecutive trophic levels. b. If the net primary productivity of the producer level in an ecosystem is 20,000 J of energy, calculate the amount of energy available to the tertiary consumer.	1 + 1 1 1	2
	SECTION – B		
22	In an anther, the microsporangium is surrounded by four distinct wall layers.	1+1+	3

	a. List the four wall layers of a microsporangium in order from the outermost to the innermost. b. State the common function performed by the outer three layers. c. Explain how the innermost layer differs structurally (in terms of cytoplasm/nuclei) and functionally from the rest.	1	
23	A variety of enzymes cooperate to ensure that DNA unzips and replicates without breaking. a. Name the specific enzyme responsible for unwinding the double helix by breaking hydrogen bonds. b. What is the function of the enzyme DNA ligase on the lagging strand?	1 + 1 + 1	3
24	A specific population of beetles is in genetic equilibrium. Out of 1000 beetles collected from the field, 900 beetles show the dominant dark shell colour, while the remaining beetles show the recessive light shell colour (a(A) a. Identify the total number of beetles showing the recessive phenotype and use it to find the frequency of the recessive allele (q) [1]. b. Calculate the frequency of the dominant allele (p) in this beetle population [1]. c. Find the exact number of beetles among the 900 dark-colored ones that are carrying the recessive allele silently as heterozygotes (A(A)	1 1 1	3
25	A village installed a biogas plant using cattle dung and agricultural waste. a. Which group of microorganisms is mainly involved in biogas production? b. Name the major combustible gas present in biogas. c. Mention one environmental advantage of biogas plants.	1 1 1	3
26	Can you suggest a method to remove oil (hydrocarbon) from seeds based on your understanding of *r*DNA technology and chemistry of oil?	1 + 1 + 1	3
27	a. Explain the J-shaped population growth curve mathematically and graphically. b. Why is this growth model considered unrealistic in a natural habitat? c. Define "Intrinsic Rate of Natural Increase (r)".	1+1+1	3
28	b. Graphically represent the Species-Area relationship as described by Alexander von Humboldt. Write its corresponding linear equation and identify what (Z) stands for.	1+1+1	3
	SECTION-D		
29	Gene expression in prokaryotes is highly regulated to conserve cellular energy. The *Lac Operon* in *E. coli* is a classic example of an inducible system that controls the breakdown of lactose. The operon consists of a regulatory gene (i) gene), a promoter (P), an operator (O), and three structural genes (z), (y), and (A) In the absence of an inducer, a repressor protein binds tightly to the operator, preventing transcription. When lactose is introduced, it interacts with the repressor, altering its shape so it can no longer block the transcription machiner  		4

	a. Identify the structural gene (z), (y), or a.) that codes for the enzyme Permease, and state this enzyme's primary function. b. Name the specific chemical compound that acts as the natural inducer in the Lac Operon system. OR c. Why is the regulation of the Lac Operon characterized as a negative regulation system? d. Predict what would happen to the operon's expression if a mutation permanently inactivates the regulatory (i) gene.	1 1 1 2	
30	A biotechnology student was studying the first artificially constructed plasmid used extensively in recombinant DNA technology. The plasmid, named **pBR322**, was derived from naturally occurring plasmids of *Escherichia coli*. The letter 'p' stands for plasmid, 'B' and 'R' refer to **Bolivar** and **Rodriguez**, the scientists who constructed it, and '322' is its serial number. pBR322 has a size of **4361 base pairs** and carries two antibiotic resistance genes — one for **ampicillin (amp^R)** and another for **tetracycline (tet^R)**. It also has an **origin of replication (ori)** that allows it to replicate autonomously within the host cell, and multiple unique restriction sites where foreign DNA can be inserted. One such site — *Bam*HI — lies within the *tet^R* gene, while *Pst*I lies within the *amp^R* gene. These restriction sites make pBR322 a highly efficient cloning vector. a. Name any **two essential features** of pBR322 that make it a suitable cloning vector. State the role of the 'ori' sequence present in it. b. What are **selectable markers**? Identify the two selectable markers present in pBR322 and explain how they help in selecting transformed host cells from non-transformed ones. a. Or c. A researcher inserts a foreign gene into the *Bam*HI site of pBR322. Which antibiotic resistance gene gets disrupted? What is the **phenomenon** called, and how will the researcher identify recombinant colonies ? d. After inserting foreign DNA at the *Bam*HI site of pBR322, the bacteria are plated on a medium containing **ampicillin** and then replica-plated on **tetracycline**. Predict the growth pattern of (i) non-transformed cells, (ii) transformed non-recombinants, and (iii) transformed recombinants on each medium. Tabulate your answer.	1 1 1 1+1	4
	SECTION – E		
31	Study the graph given below and answer the questions that follow:  		5

	a. What is the importance of LH surge? b. Identify the ovarian phases during the menstrual cycle. i. 5th day to 12th day of the cycle. ii. 14th day of the cycle. c.Which hormones regulate menstrual cycle? d.Menstrual cycles are absent during pregnancy. Why? Or Give the term/reason: a. Mechanism responsible for parturition. b. Role of oxytocin during expulsion of the baby out of uterus c. Why does zona pellucida layer block the entry of additional sperms? d. Sperm cannot reach ovum without seminal plasma. (e) All copulations do not lead to fertilisation and pregnancy.	1 1 ½ ½ 1 1 1 1 1 1 1	
32	a. A relevant portion of β-chain of haemoglobin of a normal human is given below: The codon for the sixth amino acid is GAG. The sixth codon GAG mutates to GAA as a result of mutation 'A' and into GUG as a result of mutation 'B'. Haemoglobin structure did not change as a result of mutation 'A' whereas haemoglobin structure changed because of mutation 'B' leading to sickle shaped RBCs. (*i*) Explain giving reasons how could mutation 'B' change the haemoglobin structure and not mutation 'A'. (*ii*) Write the genotype of (*i*) an individual who is carrier of sickle cell anaemia gene but apparently unaffected, and (*ii*) an individual affected with the disease. b. Give an example of a gene responsible for multiple phenotypic expressions. What are such genes called? State the cause that is responsible for such an effect. or a. Identify '*a*', '*b*', '*c*', '*d*', '*e*' and '*f*' in the table given below: S. No. | Syndrome | Cause | Characteristics of affected individuals | Sex Male/Female/Both 1. | Down's | Trisomy of 21 | '*a*' (*i*) (*ii*) | '*b*' 2. | '*c*' | XXY | Overall masculine development | '*d*' 3. | Turner's | 45 with XO | '*e*' (*i*) (*ii*) | '*f*' b. Explain pleiotropy with the help of an example.	1 1 1+1+ 1 ½ x 8 1	5
33	a. Name the types of lymphoid organs, lymph nodes and thymus are. Explain the role playedby them in causing immune response. b. Differentiate between innate immunity and acquired immunity. Or A group of youth were having a 'rave party' in an isolated area and was raided by	1+11 1+1	5

	police. Packets of ‘smack’ and syringes with needles were found littered around. a. Why is taking ‘smack’ considered an abuse? b. Write the chemical name of ‘smack’ and the name of its source plant. c. Syringes and needles used by the youth for taking the drug could prove to be very fatal. Why?	 1 1+1 1+1	

BIOLOGY-044
SAMPLE PAPER-5

Maximum Marks: 70 Time: 3 hours

General Instructions:

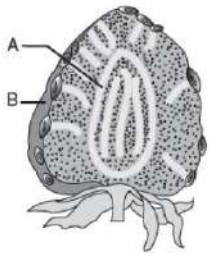
(vi) All questions are compulsory.

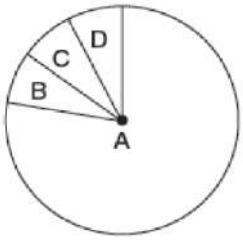
(vii) The question paper has five sections and 33 questions.

(viii) Section–A has 16 questions of 1 mark each; Section–B has 5 questions of 2 marks each; Section– C has 7 questions of 3 marks each; Section– D has 2 case-based questions of 4 marks each; and Section–E has 3 questions of 5 marks each.

(ix) There is no overall choice. Answer all 33 questions. However, internal choices have been provided in some questions. A student has to attempt only one of the alternatives in such questions.

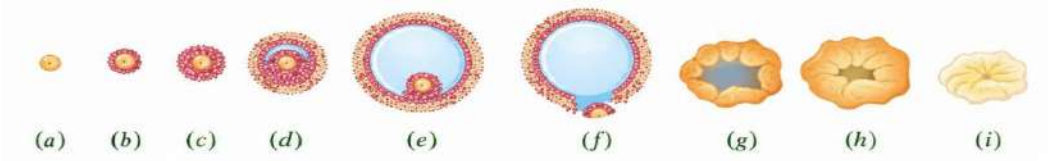
(x) Wherever necessary, neat and properly labeled diagrams should be drawn.

	Section – A		
Q. No	Question	Marks	Total Marks
1	Identify A and B in this figure.  a. A: Thalamus, B: Endocarp b. A: Thalamus, B: Achene c. A: Endocarp, B: Mesocarp d. A: Mesocarp, B: Endocarp	1	1
2	The foetal ejection reflex in human triggers the release of _____ hormone from _____. Fill in the blanks by choosing right option. a. oxytocin, foetal pituitary b. oxytocin, maternal pituitary c. human chorionic gonadotropin, placenta d. progesterone, corpus luteum	1	1
3	A single strand of DNA has the base composition: A = 22%, T = 28%, G = 30%, and C = 20%. What will be the percentage of Adenine in its complementary strand? a. 22% b. 28% c. 30% d. 20%	1	1
4	A student in a botanical lab performs a genetic cross between two true-breeding pea plants. Parent 1 produces Round and Yellow seeds (RRYY), and Parent 2 produces Wrinkled and Green seeds (rryy). The resulting F1 offspring are all allowed to self-pollinate to yield the F2 generation. The student collects a total of 800 seeds from the F2 generation. Out of the 800 F2 seeds collected, statistically how many seeds are expected to show the parental phenotype of Wrinkled and Green? a. 50 b. 150 c. 450 d. 200	1	1
5	Which of the following statements about the menstrual cycle is incorrect? a. Lack of menstruation always indicates pregnancy. b. LH surge induces the rupture of the Graafian follicle. c. The cycle is absent during lactation. d. Gonadotropins increase gradually during the follicular phase.	1	1

6	From which evolutionary lineage did the modern-day Horsetails (Sphenopsids) directly emerge? a. Psilophyton b. Rhynia-type plants c. Zosterophyllum d. Chlorophyte ancestors	1	1
7	Which microbe is widely used to control butterfly caterpillars in agricultural fields? a. *Bacillus thuringiensis* b. *Trichoderma harzianum* c. *Nosema locustae* d. *Agrobacterium tumefaciens*	1	1
8	Arrange the following process in the sequence used in rDNA technology. (1) Isolation of DNA (2) Fragmentation of DNA by RE (3) Isolation of desired DNA fragment (4) Ligation of DNA fragment into vector (5) Transferring rDNA into host (6) Culturing host cells in a medium at large scale (7) Extraction of the desired product a. 1, 2, 3, 4, 5, 6, 7 b. 1, 2, 3, 4, 6, 5, 7 c. 2, 1, 3, 4, 5, 6, 7 d. 1, 2, 3, 5, 4, 6, 7	1	1
9	What parameters are used for tiger census in our country's national parks and sanctuaries? a. Pug marks only b. Pug marks and faecal pellets c. Faecal pellets only d. Actual head counts	1	1
10	Select the true statements from the following. (1) Insulin from animal source, may develop allergy in some patients. (2) C-peptide is not present in mature insulin. (3) Recombinant therapeutics do not induce unwanted immunological response. (4) Insulin can be administered orally to diabetic patients a. 1 and 3 only b. 1 and 2 only c. 3 and 4 only d. 1, 2 and 3 only	1	1
11	Arrange the following in the order of their evolution. a. Homo habilis → Ramapithecus → Homo erectus → Dryopithecus → Homo sapiens → Australopithecines → Neanderthal man b. Dryopithecus → Ramapithecus → Australopithecus → Homo habilis → Homo erectus → Neanderthal man → Homo sapiens c. Australopithecines →Homo sapiens → Ramapithecus → Dryopithecus → Homo habilis→ Homo erectus → Neanderthal man d. Neanderthal man → Australopithecines → Homo sapiens → Homo erectus →Homo habilis → Ramapithecus → Dryopithecus	1	1
12	Given below is the representation of the extent of global diversity of invertebrates. What groups the four portions (A to D. represent respectively?  a. A: Insects, B: Crustaceans, C: Other animal groups, D: Molluscs b. A: Crustaceans, B: Insects, C: Molluscs, D: Other animal groups c. A: Molluscs, B: Other animal groups, C: Crustaceans, D: Insects d. A: Insects, B: Molluscs, C: Crustaceans, D: Other animal groups	1	1
	Question No. 13 to 16 consist of two statements – Assertion (A) and Reason (R).		

	Answer these questions selecting the appropriate option given below: a. Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of Assertion (A) b. Both Assertion a. and Reason (R) are true but Reason (R) is not the correct explanation of Assertion (A) c. Assertion (A) is true but Reason (R) is false. d. Assertion (A) is false but Reason (R) is true.		
13	Assertion(A).: Seminal plasma is rich in fructose, calcium, and certain enzymes. Reason (R): Secretions of Bulbourethral glands help in the lubrication of the penis.		
14	Assertion (A)Chromosome 1 was the first human chromosome to be completely sequenced in the Human Genome Project. Reason (R): Chromosome 1 has the maximum number of genes (2968) among all human chromosomes.	1	1
15	Assertion (A).: *Trichoderma* species are free-living fungi present in the root ecosystems that act as effective biocontrol agents. Reason (R): *Trichoderma* attacks and kills beneficial nitrogen-fixing bacteria like *Rhizobium* in the soil.	1	1
16	Assertion (A).: *Agrobacterium tumefaciens* is widely used to engineer nematode resistance in host tobacco roots. Reason (R): *Agrobacterium* naturally transfers a specific piece of DNA (T-DNA. into the host plant genome, which can be modified to express both sense and anti-sense RNA.	1	1
	SECTION – B		
17	Differentiate between: a. hypocotyl and epicotyl b. coleoptile and coleorhiza Or Differentiate between: a. integument and testa b. perisperm and pericarp	1+1 1+1	2
18	Why are surgical sterilization methods considered terminal birth control options? Mention one major drawback of these methods.	1 1	2
19	Describe the functional cooperation between Bone Marrow and Secondary Lymphoid Organs (like lymph nodes) in maintaining the body's immune surveillance.	1 1	2
20	a. For which specific cell type (plant or animal) is the micro-injection method most suitable for delivering foreign genes? Justify your answer. b. What heavy metal micro-particles are commonly utilized to coat DNA in the biolistics or gene gun method? Or a. Identify the specific step of a PCR cycle where synthetic oligonucleotide primers bind to single-stranded target DNA templates. b. State the approximate temperature range required for the optimal binding of these primers during amplification.	1 + 1 1 + 1	2
21	a. Why is the pyramid of biomass in a sea or deep aquatic ecosystem generally inverted? b. Draw a simple, well-labeled schematic representation of this inverted aquatic pyramid of biomass Or Describe the process of decomposition of detritus under the following heads:	1 + 1	2

	Fragmentation; leaching; catabolism; humification and mineralisation.		
	SECTION – B		
22	A breeder wants to cross two true-breeding varieties of a bisexual flower to create a superior hybrid. a. Detail the two sequential manual steps the breeder must perform on the female parent flower to prevent unwanted pollination. b. Why is the step of "emasculation" completely unnecessary if the female parent plant happens to be dioecious? c. What is the purpose of "bagging" the flower after dust-pollination has been completed?	1+1+1	3
23	Before DNA polymerase can begin adding deoxynucleotides, a crucial initiation step must occur. a. Identify the short chemical sequence that must be laid down on the template strand first, and name the enzyme that synthesizes it. b. State the specific end (3' or 5') of this sequence to which DNA polymerase adds the incoming nucleotides.	1+ 1 1	3
24	In a population of mice at genetic equilibrium, the dark coat color is completely dominant over the white coat colour. If 9% of the population displays the white coat phenotype: a. Calculate the frequency of the dominant allele in the gene pool. b. Find the proportion of dark-coloured mice that are carriers (heterozygous) for the white coat trait.	1+ ½ 1 + ½	3
25	Three water samples namely river water, untreated sewage and secondary effluent discharge from a sewage treatment plant were subjected to BOD test. The samples were labelled A, B and C but the laboratory attendant did not note which was which. The BOD values of the three samples A, B and C were recorded as 20 mg/L, 8 mg/L: and 400 mg/L respectively. Which sample of the water is most polluted? Can you assign the correct label to each assuming the river water is relatively clean?	1+1+1	3
26	Suggest any two possible treatments that can be given to a patient exhibiting adenosine deaminase deficiency	1 + 1 + 1	3
27	Predators are often described as "prudent" in nature. Justify this statement and explain what would happen if a predator were not prudent.	1+1+1	3
28	a. Differentiate between *In-situ* and *Ex-situ* conservation strategies with two examples of each. b. What are 'Biodiversity Hotspots'?	1+1 1	3
	SECTION-D		
29	The human genome contains massive stretches of DNA that do not code for proteins. A significant portion consists of repetitive DNA sequences where a small stretch of bases is repeated many times. These sequences can be separated from bulk genomic DNA during density gradient centrifugation, appearing as small peaks called satellite DNA. Depending on base composition, length of the segment, and number of tandem repeats, they are categorized into micro-satellites and mini-satellites. These repeats show high degrees of polymorphism, forming the bedrock of modern forensic DNA fingerprinting. a. Expand the abbreviation VNTR, and identify which class of satellite DNA it belongs to.	1 1	4

	b. What is the primary analytical method used to separate satellite DNA from bulk genomic DNA based on molecular weight? Or c. Why are VNTRs from a single individual identical across blood, hair follicles, skin, and saliva samples? d. Except for one specific biological exception, no two humans share the exact same DNA fingerprint profile. Name this exception.	1 1 2	
30	In a school biotechnology laboratory, students performed a genetic engineering experiment. They used the restriction enzyme *Pst*I to cut the pBR322 plasmid and insert a gene of interest. The plasmid was then introduced into competent *E. coli* cells by the process of transformation. The cells were plated on nutrient agar plates containing both ampicillin and tetracycline. The teacher explained that when foreign DNA is inserted into the *Pst*I site within the amp^R gene, the gene is disrupted and the bacterium loses its ability to survive on ampicillin. However, the tet^R gene remains intact. This method of identifying recombinants — based on disruption of an antibiotic resistance gene by inserted DNA — is called insertional inactivation. The teacher further noted that modern vectors now use a more convenient marker called *lacZ*, where recombinant colonies appear white while non-recombinant colonies appear blue in the presence of the substrate X-gal. This is known as blue-white colony screening. a. Define insertional inactivation. When a foreign DNA fragment is inserted at the *Pst*I site of pBR322, which antibiotic resistance gene gets inactivated, and why does the recombinant bacterium fail to grow on ampicillin medium? b. What is meant by a competent cell? Name the chemical treatment most commonly used in the laboratory to make *E. coli* cells competent for uptake of recombinant plasmid DNA. Or c. Explain the principle of blue-white colony screening using the *lacZ* gene. d. A scientist claims: *"All transformed cells are recombinant cells."* Do you agree or disagree with this statement? Justify your answer with reference to pBR322 transformation experiments. Also suggest one advantage of blue-white screening over antibiotic-resistance-based screening.	1 1 1 1+1	4
	SECTION – E		
31	The following is the illustration of the sequence of ovarian events (*a* – *i*) in a human female.  		5

	a. Identify the figure that illustrates mature follicle, ovulation and corpus luteum and mention the stage of oogenesis it represents. b. Name the ovarian hormone and the pituitary hormone that have caused the above mentioned event. c. Explain the changes that occur in the uterus simultaneously in anticipation. d. What is the fate of 'I'? Or (a) Study the figure given below and answer the questions that follow: (*i*) Name the stage of human embryo the figure represents. (*ii*) Mention the fate of the inner cell mass after implantation in the uterus. (*iii*) Where are the stem cells located in this embryo? (b) Draw the labelled diagram of sperm. (any four labelling)	1+1+ 1+1 ½½ 1+1+ 1 ½ x 4	
32	a. Haemophilia is a sex-linked recessive disorder of humans. The pedigree chart given below shows the inheritance of haemophilia in one family. Study the pattern of inheritance and answer the questions given. (*i*) Give all the possible genotypes of the members 4, 5 and 6 in the pedigree chart. (ii) A blood test shows that the individual 14 is a carrier of haemophilia. The member numbered 15 has recently married the member numbered 14. What is the probability that their first child will be a haemophilic male? b. Name a disorder, give the karyotype and write the symptoms where a human male suffers as a result of an additional X-chromosome. Or a. List the three different allelic forms of gene 'I' in humans. Explain the different phenotypic expressions, controlled by these three forms. b. A woman with blood group 'A' marries a man with blood group 'O'. Discuss the possibilities of the inheritance of the blood groups in the following starting with 'yes' or'no' for each: (i) They produce children with blood group 'A' only. (ii) They produce children some with 'O' blood group and some with 'A' blood group..	½x 3 ½ 1 x 3	5
33	a. Cancer is one of the most dreaded diseases of humans. Explain 'Contact inhibition' and 'Metastasis' with respect to the disease. b. Name the group of genes which have been identified in normal cells that could	1+1 1	5

	lead to cancer and how they do so?	1	
	c. Name any two techniques which are useful to detect cancers of internal organs.	1	
	d. Why are cancer patients often given α-interferon as part of the treatment?		
	Or		
	a. Name and explain giving reasons, the type of immunity provided to the newborn by the colostrum and vaccinations.		
	b. Name the type of antibody	1	
	(*i*) present in colostrum	1	
	(*ii*) produced in response to allergens in human body.	1	
	c. Name a drug used (i) as an effective sedative and pain killer (ii) for helping	1	
	patients to cope with mental illnesses like depression, but often misused.	1	
	d. How does the moderate and high dosage of cocaine affect the human body		