

Unit I

1	Introduction to the topic
2	Elements of Life, Explanation about the important elements in any organism. Electronegativity of the element, Importance of carbon.
3	Different types of bonds, Some examples of different types of bonding in the biological systems
4	Water & phospholipid their importance in existence of life
5	Carbohydrates, ATP
6	Proteins and their structures.
7	Enzymes and how enzymes functions with one typical example, Effect of pH
8	Bioenergetics, glycolysis pathway

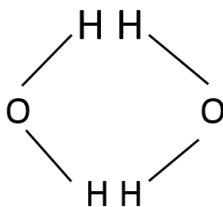
Self assessment

- Silicon is in the same group of the periodic table as Carbon- What makes it less adaptable than carbon as central organizing element?
- Lead also belongs to the same group. Nobody predicted life based on lead. Give reason based on chemistry and physical properties

- The ancient Roman civilization used lead piping to supply water. It is believed that the reason for the downfall of this great civilization was due to lead poisoning. Lead is a neurotoxin. How does the concentration of lead increase in the body?
- Why are the elements C, H, O and N especially suitable to be life's molecules?- Choose the best one
 - a) Because they are abundant in the environment
 - b) They can able to form bonds with each other and themselves
 - c) They are not heavy metals
 - d) All of them
 - e) none of the above

Concept check

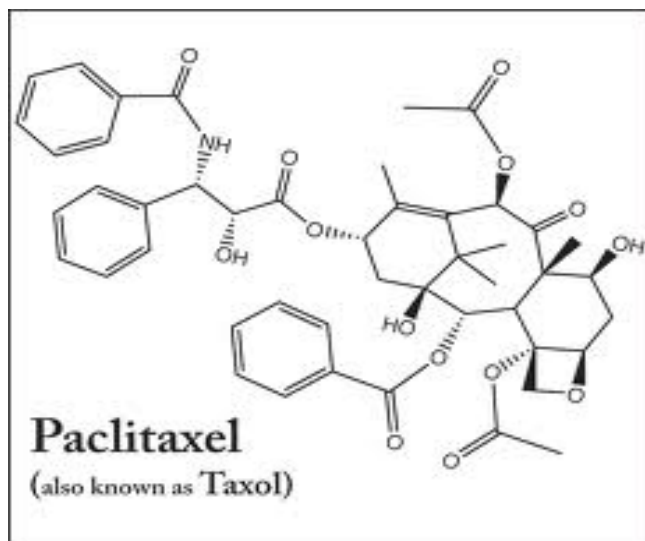
- Why does the structure $\text{H}-\text{C}=\text{C}-\text{H}$ fail to make sense chemically?
- Why is highly unlikely to find two neighbouring water molecules bonded in the mentioned fashion here?



- What would be the effect on the properties of water if oxygen and hydrogen had equal electronegativity?

Concept check

- Paclitaxel is a anticancer drug. The structure of the Paclitaxel is given



- Label in the structure the hydrophobic part of paclitaxel:
- Label in the structure where it can make hydrogen bonds:
- Is this molecule is water soluble ? lipophilic ? both ? explain

Concept check

- Burning of your fingers by touching the side of an iron pot on the stove when water in the pot is still lukewarm....

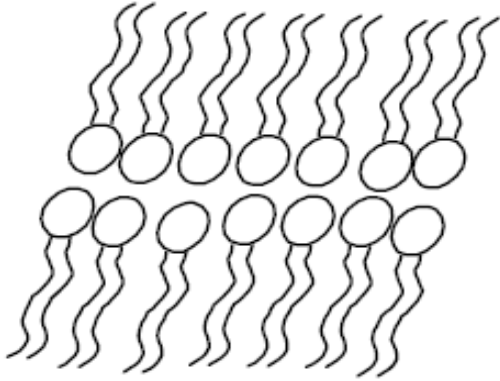
Concept check

1. Many insects are able to walk on the water surface of a pond without breaking the surface. Suggest the explanation.



2. Phospholipid produce in contact with water
 - a. Monolayer
 - b. Bilayer
 - c. Tri-layer
 - d. Membrane
 - e. All of the above
 - f. None of the above

A message was received from a group of researchers, who were looking for the probability of existence of alien life forms on Mars. They found an unusual life form and the cell membrane of that life form is depicted in the figure



Portion of alien membrane

- a. A student requested to send this life form to earth, but the request was rejected stating that this life form is not possible to survive on earth. Why have they told like that?

Concept check

Given below is a list of biological polymers. Indicate which of the properties will apply. Each polymer may have multiple properties and hence a given property may be used more than once

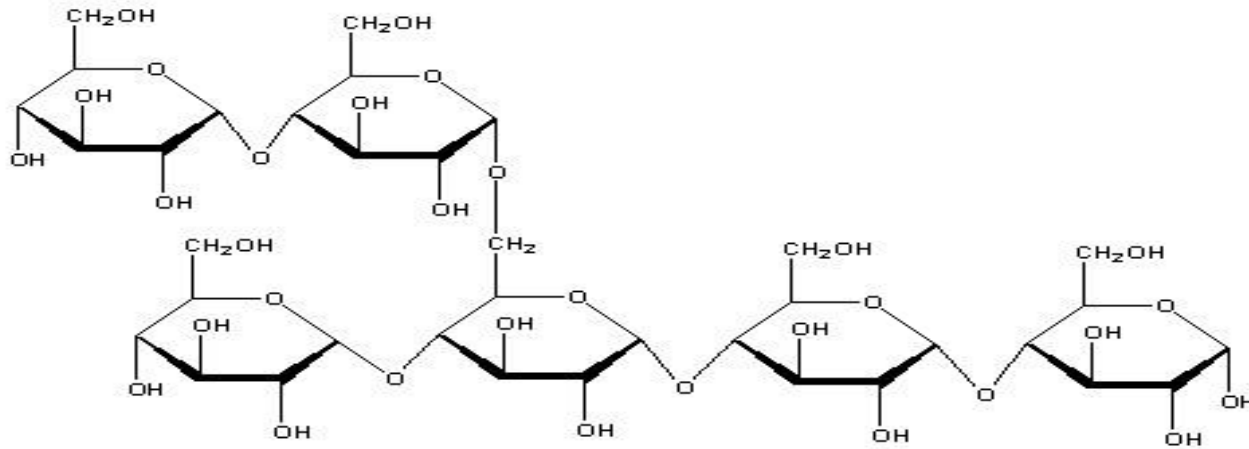
Polymers: (a) Cellulose; (b) Amylose; (c) Amylopectin

Properties: (i) Branched chain polymer (ii) Storage carbohydrate (iii) 1,6 linkage (iv) Glycosidic bond (v) Cable like microfibrils (vi) Polysaccharide

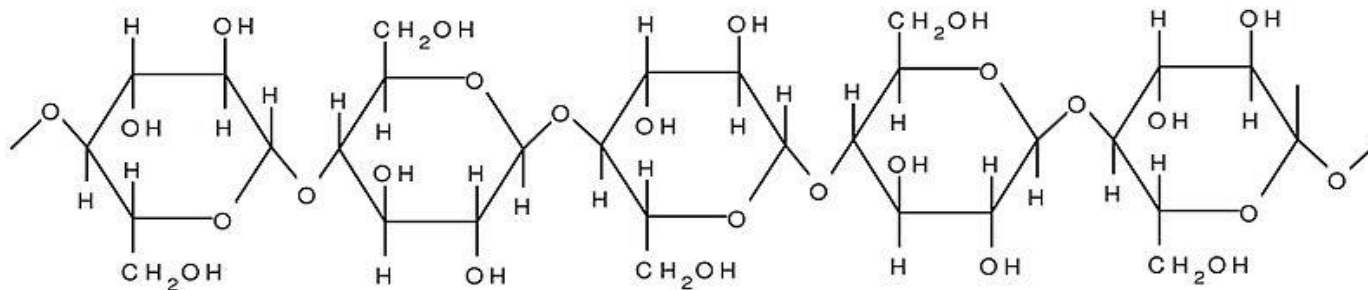
Concept check

- Analyze the following diagram

Amylopectin



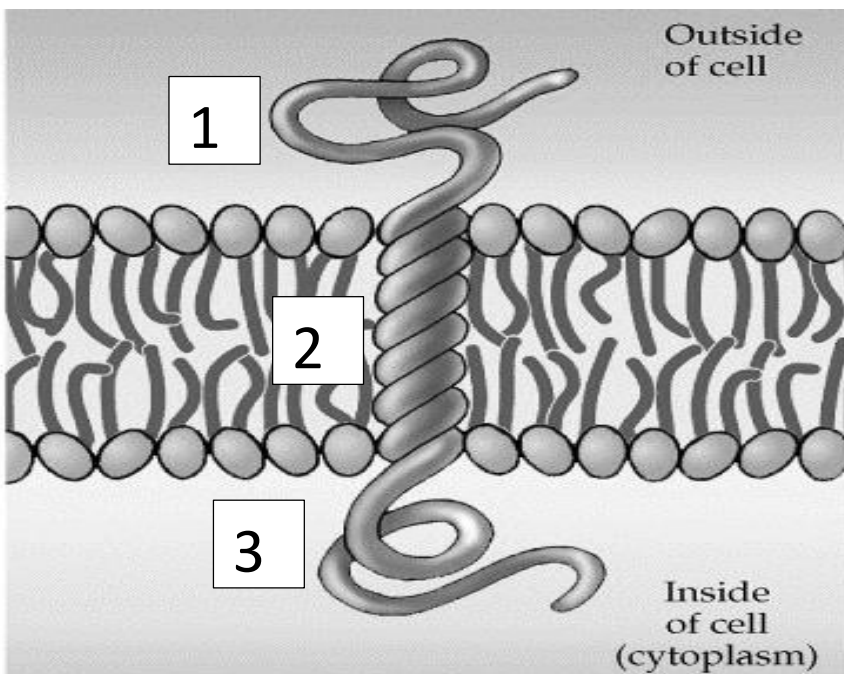
Cellulose



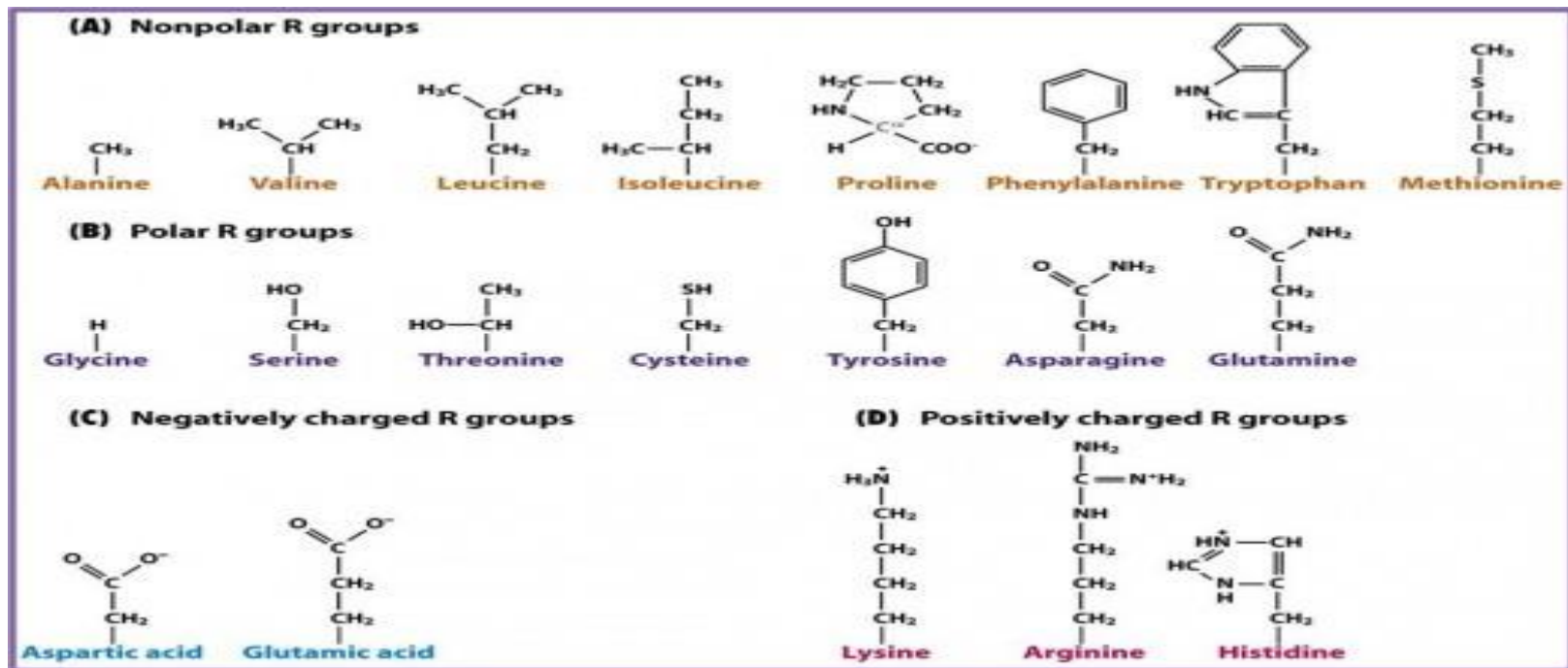
- Are the linkages in the compounds (a) and (b) are same? Explain
- Is the enzyme which can hydrolyze (a) will work for (b)? Explain

Concept check

- Compare the composition, structure and function of starch and cellulose. What role do starch and cellulose play in human body.
- After a cow given antibiotics to treat an infection, a veterinary doctor gives the animal a drink of gut culture containing various prokaryotes. Why is necessary?

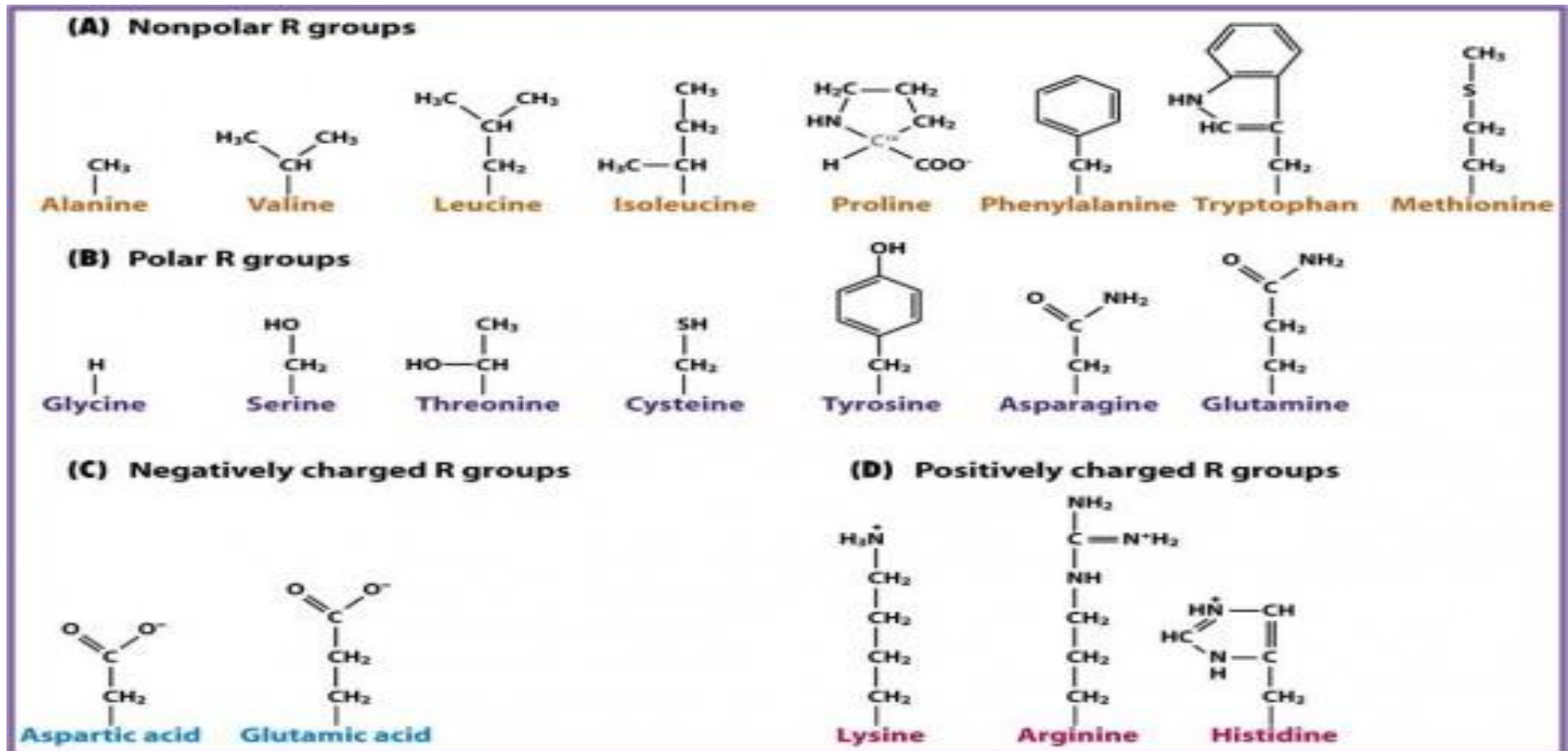


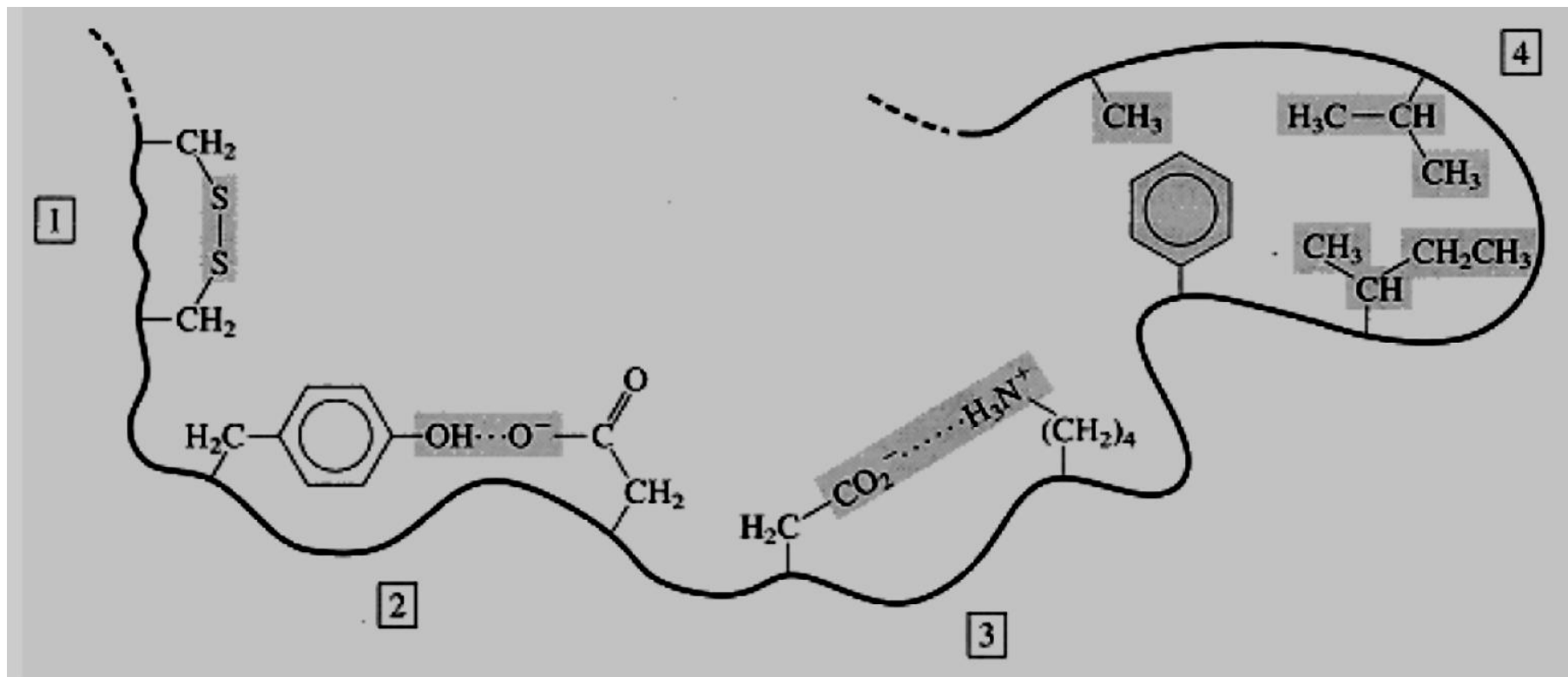
A protein works as a transmembrane protein and a part of the protein traverses the phospholipid bilayer as is illustrated in the figure below. State which amino acids in this protein will be present in area 1, 2 and 3?



Concept check

A 2000 amino acid protein forms a tertiary structure. **Lysine** is at the 38th position and forms ionic bond with the amino acid at 43rd position. Name the suitable amino acid at 43rd position. **Leucine** is present at 112th position and it interacts with the amino acid at 106th position to form vander Waal forces of interaction. Name the suitable amino acid at 106th position.





Analyze the figure and answer the following questions:

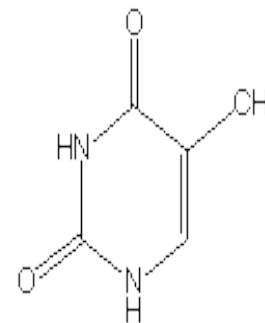
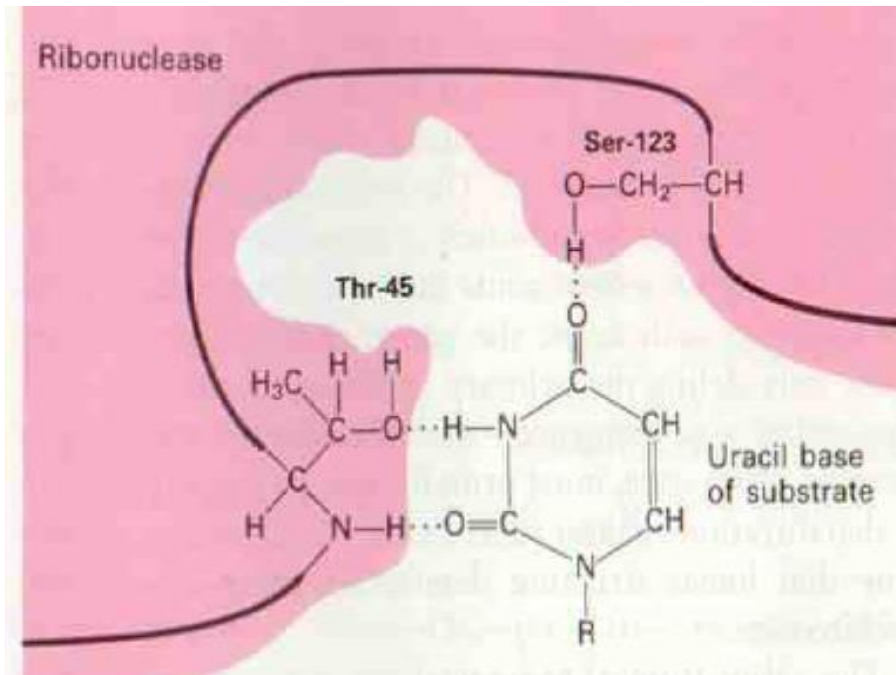
- The figure illustrates _____ structure of protein (Choose from primary, secondary, tertiary or quaternary).
- If hydrophobic amino acids in the part 4 of the protein were modified to serine would the protein folding be affected? Why? Refer to the amino acid structure
- If the protein is heated, which bonds will break first amongst the bonds mentioned in the figure? Why?

Concept check

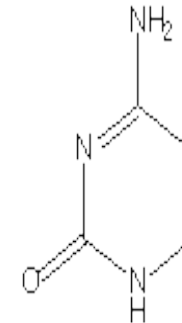
The specific binding of a substrate to an enzyme involves the formation of multiple non-covalent bonds. In the given diagram two amino acid residues of ribonuclease (the enzyme) bind with uracil (the substrate).

How uracil binds with the enzyme? How many bonds are there?

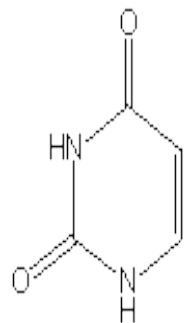
The same enzyme can work for other pyrimidines such as cytosine and thymine? Explain



Thymine (DNA)



Cytosine (DNA/RNA)



Uracil (RNA)

Unit II

9	Mendelian concept of inheritance and Logic of Mendel
10	Monohybrid cross and segregation
11	Terminologies, Back cross and test cross, Dihybrid cross, Law of independent assortment.
12	Chromosomes and cell division, chromosomal theory of inheritance
13	Morgan's experiment, X-linked inheritance
14	Pedigree analysis

Concept check

The physical appearance of a trait is called as:

a) Morphology b) Phenotype c) Genotype d) Homology

What is the alternate form of a gene called?

a) Recessive gene b) Alternate gene c) Allele d)
Chromosome

Concept check

In a plant, purple flower color (P) is dominant over Yellow (p). A homozygous purple flowered plant is crossed with a homozygous yellow flowered plant. The F1 is selfed to get the F2 generation.

Draw a Punnett square for the above mentioned cross and also show the F2 generation

Give the genotype of the parents and F1.

Give the genotype and the phenotype in a test cross for the same trait

Concept check

• In the animal seal, the length of whiskers regulated by two alleles (W- long and w-short). **W** is dominant over w. Find the probability of producing offspring with short whiskers from the cross between a homozygous dominant and heterozygous seal? Show the cross using Punnet square

Concept check

In cattle, hornless (called “polled” represented by P) is dominant over horned (p). A polled bull is bred/mated to three cows, A, B, C. With cow A, which is horned, a polled calf is produced. With cow B, also horned, a horned calf is produced. With cow C, which is polled, a horned calf is produced. What are the genotypes of the four parent (Cows A, B, C)

Concept check

In mice three allele is known to govern the intensity of pigmentation. Thus we find 'D' for dull colour 'd' for dilute colour 'd'' for lethal (progeny dies) and homozygous. The order of dominance is $D > d > d'$. A dull colour mouse carrying a lethal gene is made to breed to a dilute colored mouse carrying lethal gene. What will be the phenotype ratio and genotype ratio.

Concept check

• Pea plants heterozygous for flower position and stem length ($AaTt$) are allowed to self-pollinate, and 400 of the resulting seeds are planted. Draw a Punnett square for this cross. How many offspring would be predicted to have terminal flowers and be dwarf?

- Axial (dominant) and Terminal (recessive)
- Tall (dominant) and dwarf (recessive)

In pea plants, the allele for flower color (purple 'P' and white 'p') and pollen shape (long 'L' and short 'l') are present on the same chromosome. For an experiment to determine the recombination frequency of the genes p and l, the offsprings of the second cross are such that 871 have the genotype Pp ll , 846 are ppLl, 2934 are PpLl and 2768 are pp ll . On the basis of given information, draw an appropriate cross and determine the distance between p and l genes

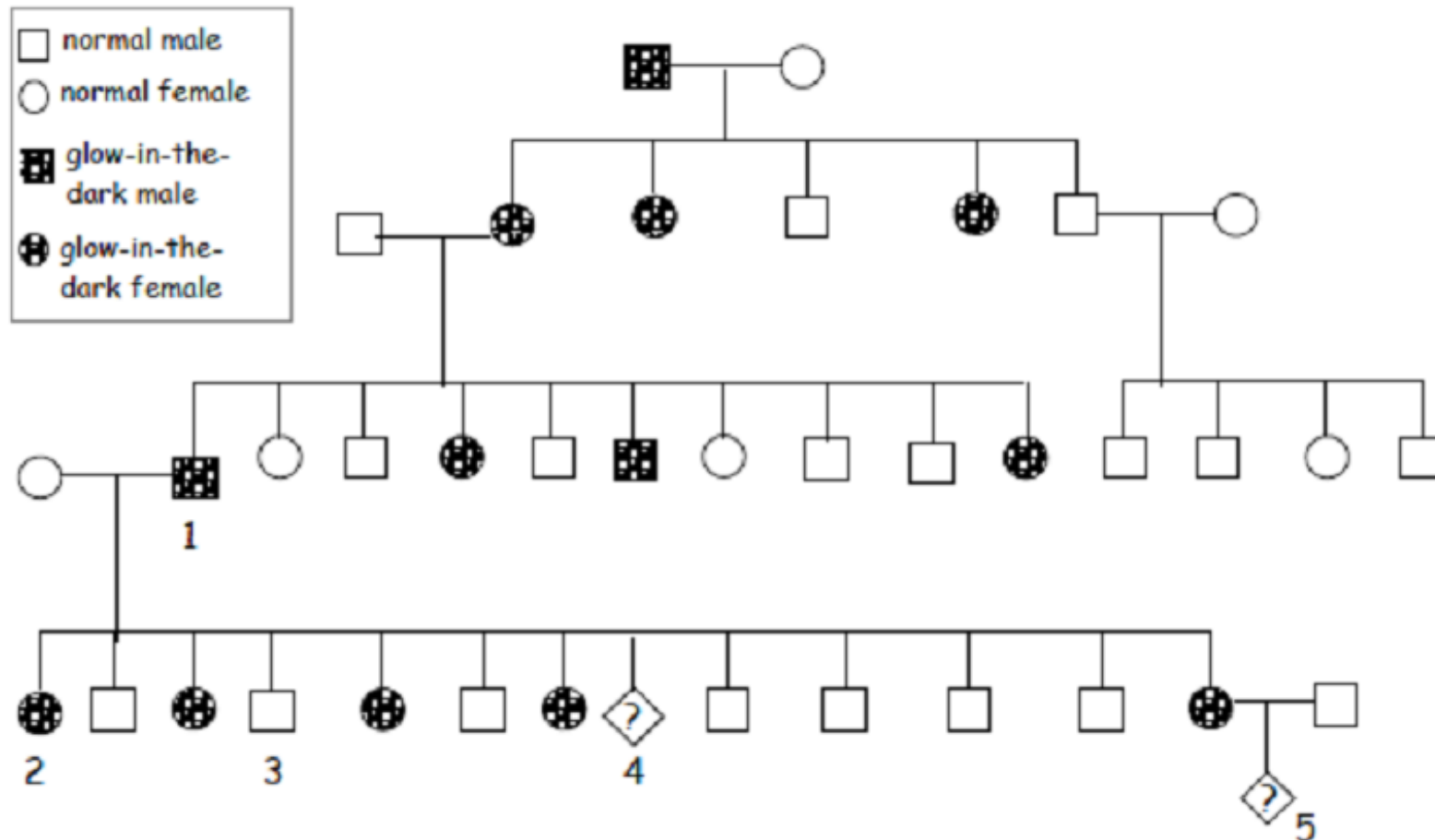
Concept check

(a) Red green color blindness is caused by a X linked recessive allele. A color blind man marries a woman with normal vision whose father was a color blind. What is the probability they will have a color blind daughter? Colour blind son?

(b) The Duchenne Muscular Dystrophy (DMD) is an X-linked recessive trait. If affected male has a child with a carrier woman, what is the probability that the child will be affected daughter? Write the genotype if she is unaffected.

Concept check

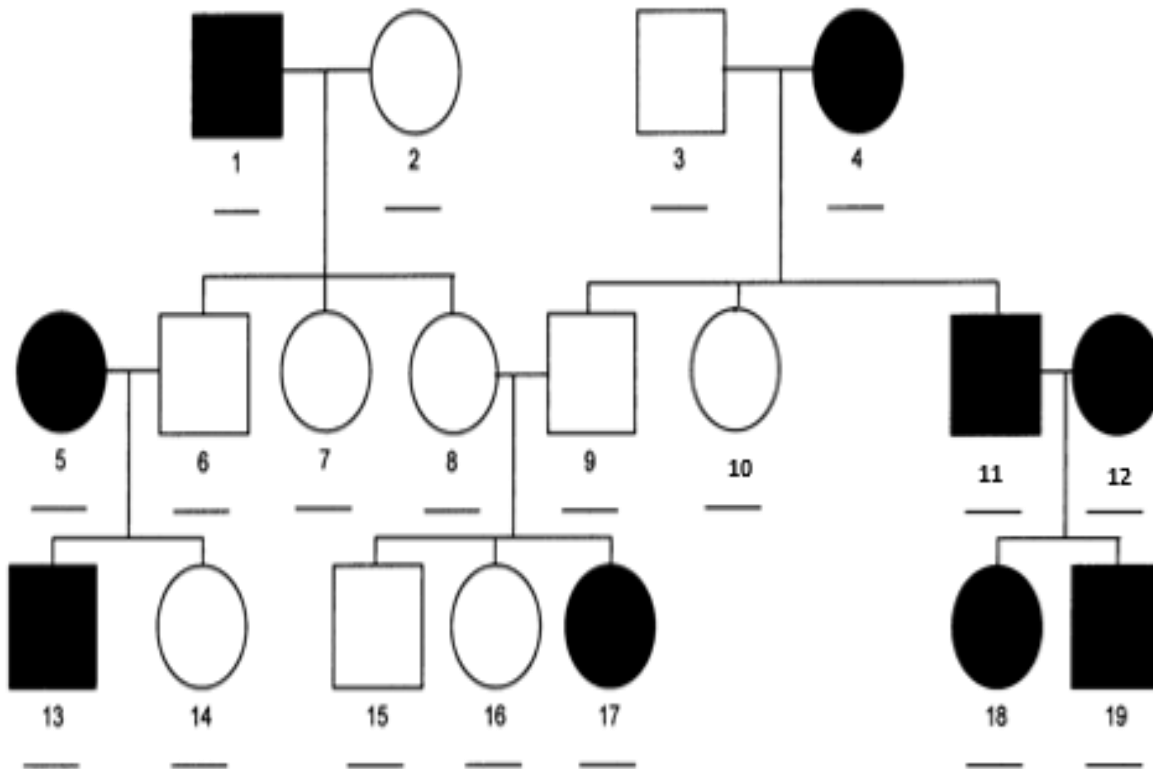
After the Biology for Engineers class, near the staircase of NLH in MIT, students discovered a colony containing amazing never before seen glow-in-the-dark ants. Few students very curious to know how this trait is inherited, they took them to the biotechnology department and observe the progeny descended from one particular glow-in-the-dark ant over several generations. (Assume that these ants follow a XX-XY sex determination mechanism ie all XX are females and all XY are males)



- a) What is the most likely mode of inheritance of the glow-in-the-dark trait? (Choose from: autosomal dominant, autosomal recessive, X-linked dominant, X-linked recessive) . Give reasons

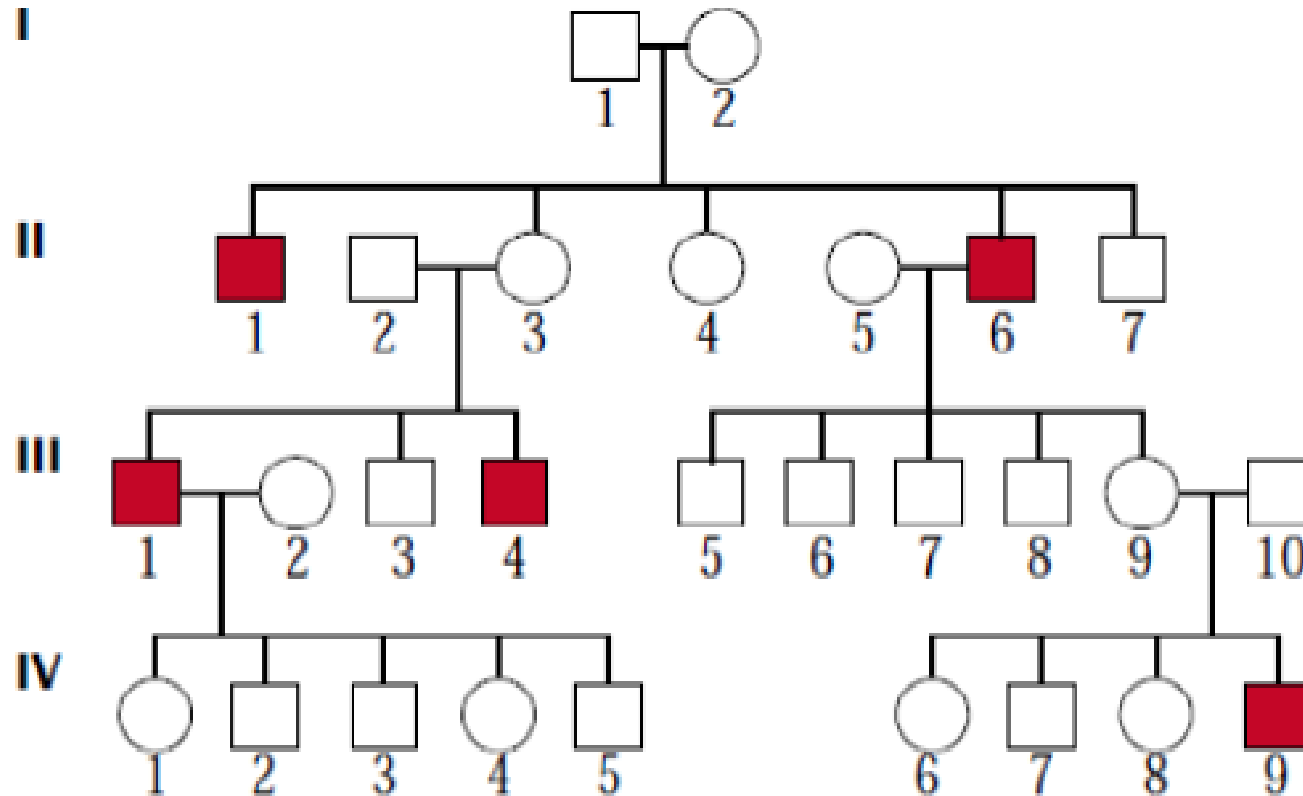
Concept check

The pedigree chart depicts the inheritance of a trait along a family. Explain the possibility of the inheritance pattern for the given chart. Determine the genotype of the individuals 10, 12, 17 and 7. (On the basis of the mode of inheritance you have stated.)



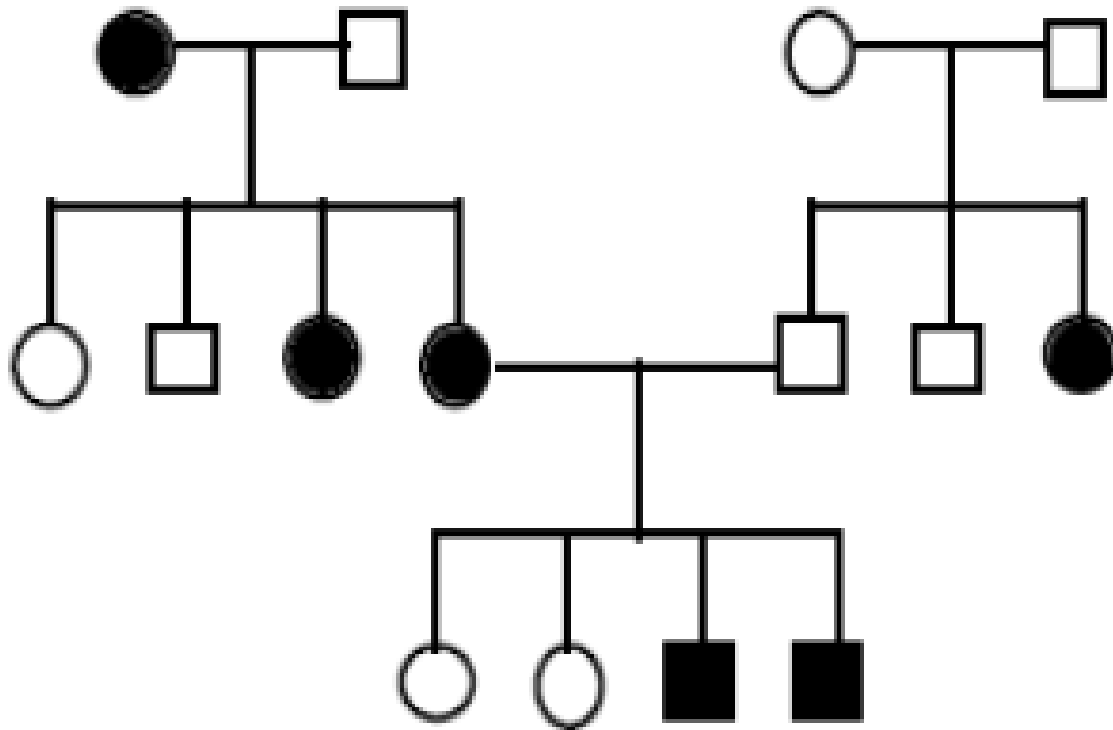
Concept check

The pedigree chart depicts the inheritance of a trait along a family. What is the most probable mode of inheritance. Determine the genotype of the individuals II-2; II-6, III-2



Concept check

The pedigree chart shows the inheritance of the trait of black eye in a family. Based on the information provided what is the most likely mode of inheritance? Give valid justification

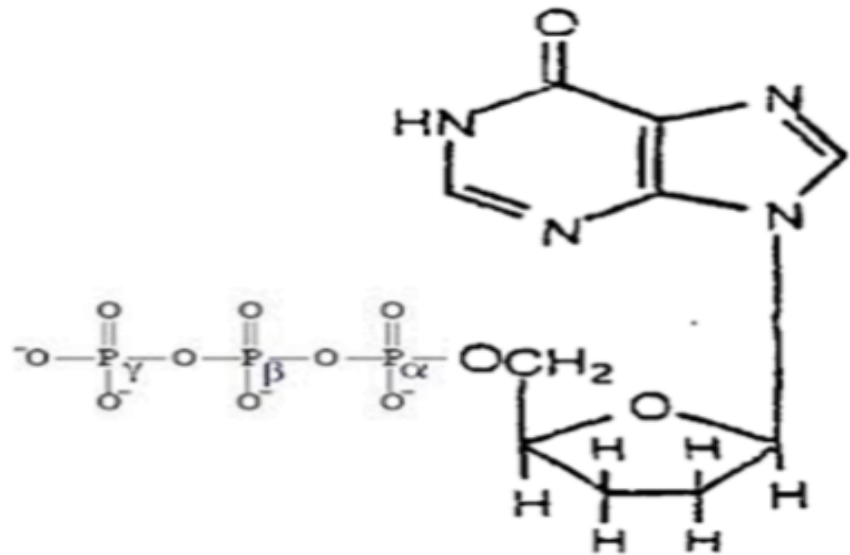


Unit III

15	Discovery of DNA - Griffith transformation experiment
16	Hershey chase experiment, Chargaff's rule
17	Structure of DNA, Meselson and Stahl experiment. Kornberg experiment
18	DNA replication, Mechanism of replication -proof reading and editing.
19	RNA synthesis (Transcription), process of transcription.
20	Post transcriptional modification (RNA processing).
21	General characteristics of genetic code or triplet
22	Translation- initiation, elongation and termination.

Concept check

A nucleotide analog X with the following chemical structure is present in abundance in a cell infected by HIV. This analog X blocks DNA chain elongation when it is incorporated into viral DNA. Why does DNA synthesis stop?



Concept check

DNA isolated from two unidentified species of Bacteria, X and Y, and their sequence is given below. One of the species was isolated from hot spring (thermophilic bacterium survives @ 84°C).

Suggest which species is the thermophilic bacterium among X & Y. What is the basis for your answer?

Species X

5'- A T A A A T T T T G A C T T C G C G C C G T A G -3'
3'- T A T T T A A A A C T G A A G C G C G G C A T C -5'

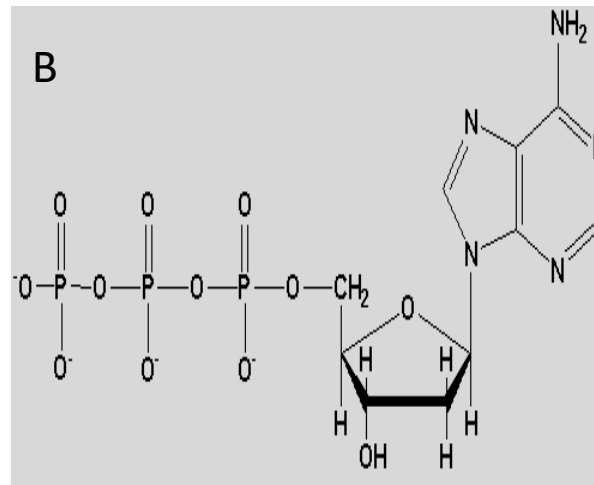
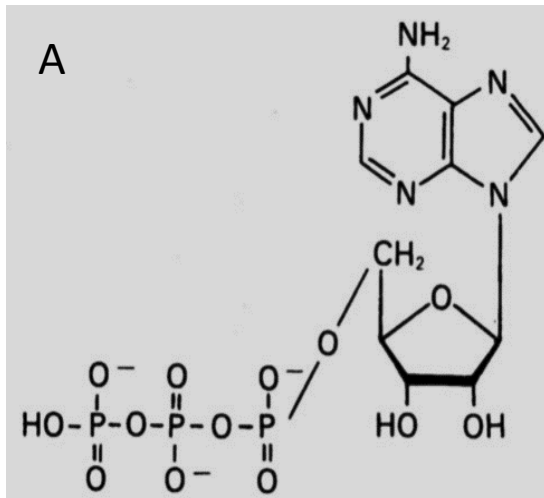
Species Y

5'- A G G G C C C C G G G C G G C G C C G G A G -3'
3'- T C C C G G G G C C C G C C G C G C G G C C T C -5'

Concept check

Given are two nucleotide molecules. Copy the structures in your answer sheets and answer the following questions:

- a) To which type of nucleic acid chain it gets added?
- b) Label where it can form Hydrogen and Phosphodiester bonds.
- c) If any glycosidic bonds are possible, where it can form.



Concept check

1. A bacteriophage and the bacterial host were isolated from the melting glaciers of Antartica. These samples were severely damaged due to the shock of transfer from the cold ice to the atmospheric temperature. The damaged samples were analyzed and the base composition of DNA and RNA samples are given in the in table. Identify the nature of the bacterial and viral genomic material and match the following terms Single stranded RNA, Single stranded DNA, Double stranded DNA and Double stranded RNA with the tubes. Justify your answers with proper reasoning.

	G	A	T	C	U	
TUBE 1	20.9	28.8	29	21	0	
TUBE 2	22.6	22.7	0	39	30	

Concept check

What is the reason behind selecting ^{32}P and ^{35}S for Hershey and Chase experiment? A student wanted to revisit the same experiment by using isotopes of carbon and oxygen. Guide him.

A group of students have isolated a new bacteria from the Udupi area. After carrying out few molecular level investigation of the new bacteria. There were a few findings

- The origin site of DNA replication is rich in AT base pairs. Is this advantageous?
- Loss of SSBP (Single strand binding proteins) proteins and deficient polymerase I is found in few of the DNA replication. How this is affecting DNA replication.

Concept check

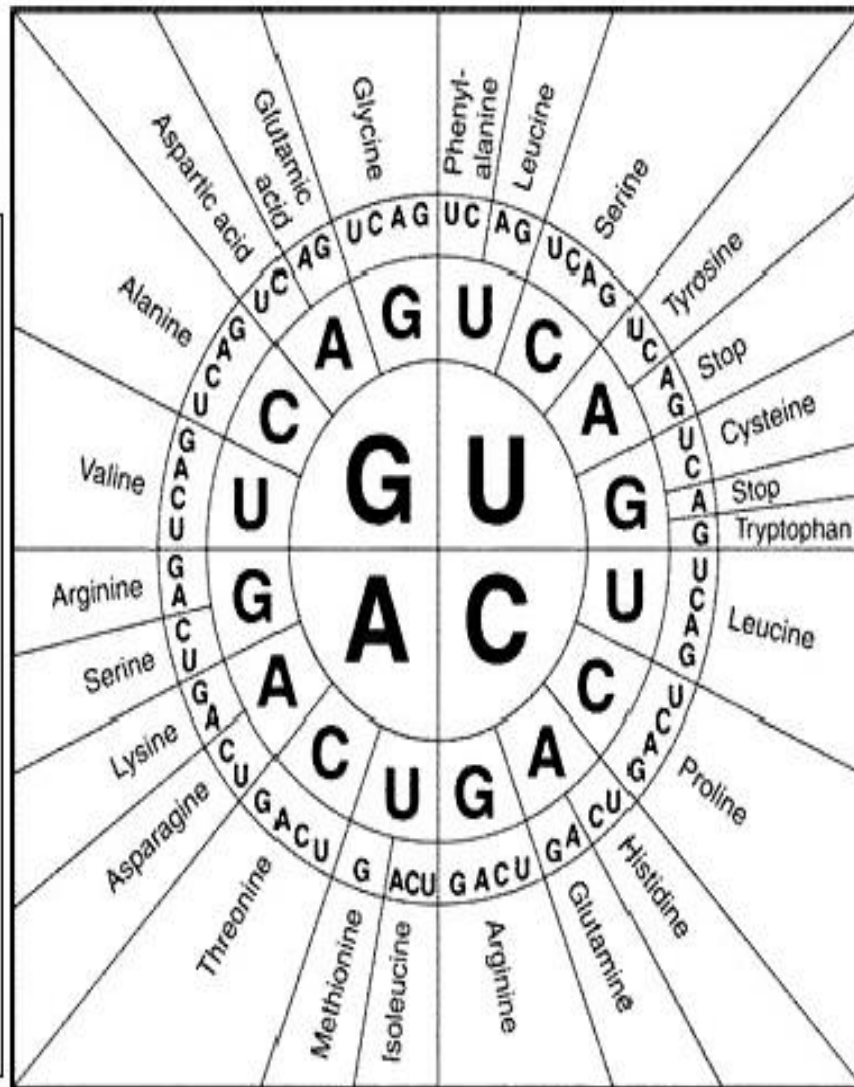
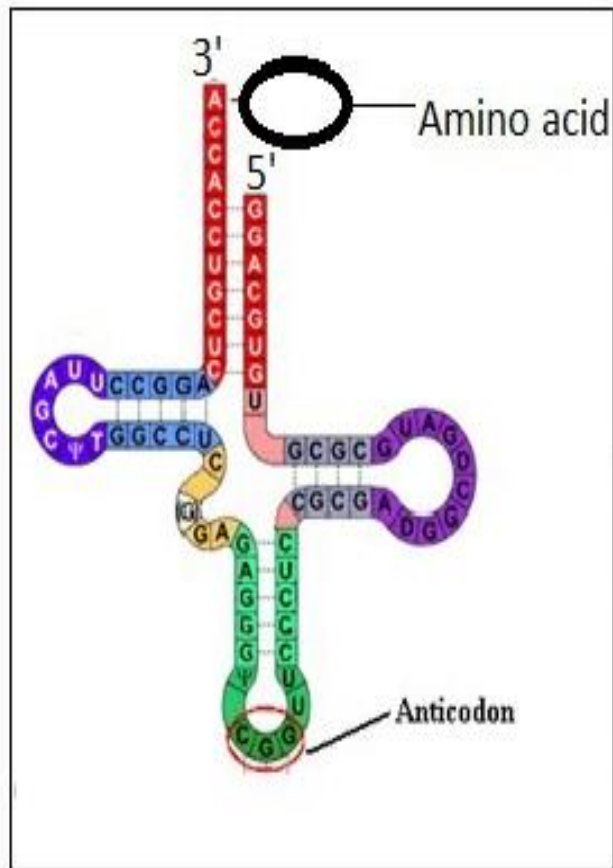
1. The b-globin gene has three exons of 140, 221 and 251 nucleotides and two introns of 130 and 850 nucleotides, using this information/data calculate the amino acids present in the polypeptide that the mature mRNA can encode?

Concept check

1. Indicate whether each of the following statements is true or false. If false, correct the statement or provide a brief explanation for why it is false.

- i) DNA replication is initiated at promoter sequences in the DNA.
- ii) RNA polymerase requires primers to initiate RNA synthesis.
- iii) The 5' to 3' direction of DNA synthesis implies that deoxyribonucleotides are added to the 5' OH group on the growing strand
- iv) Transcription is terminated at stop codons in the mRNA.

Given below is an illustration of a tRNA. Analyze the sequence to find out the codon in mRNA with which it binds and also the amino acid it carries



3'GCC5'; Arginine 5'GCC3', Arginine 3'GCC5', Alanine 5'GCC3'; Alanine

Concept check

Below is the bases sequence of double stranded eukaryotic DNA and underlined bases representing introns. Amino acid sequence produced by this DNA will be

3'GGGCTA CGC CTC CCT CAAGCC ATTGC5'

5'CCC GAT GCG GAGGGAGTTCGGTAACG3'

1. Pro-Asp-Ala-Glu-Phe-Gly-Asn
2. Pro-Asp-Ala-Gln-Gly-Gly-Ser-Val-Thr
3. Met-Arg-Ile-Arg
4. Met-Arg-Arg-Glu-Val-Arg

Concept check

Which mRNA will be translated into a polypeptide chain containing 9 amino acids?

1. 5'AAAUUUAAAAUGUUAAUAGACGAGAUGUAGCGACGAUGU3'
2. 5'CCCAAAAUGAGACGGACUGCAUUCCCAACCAUGUAGUUU3'
3. 5'ACGGGGACGUUUACCAUGCCCAACCGUUAGCCCACGGAG3'
4. 5'CAGAAUCGAUGACAGUCUGGGUUUACAUAUAAACAGGGGG3'

(ii) As part of the "Biology challenge" for MIT students, the following equation was given. How will you analyze this? (1.5 mark)



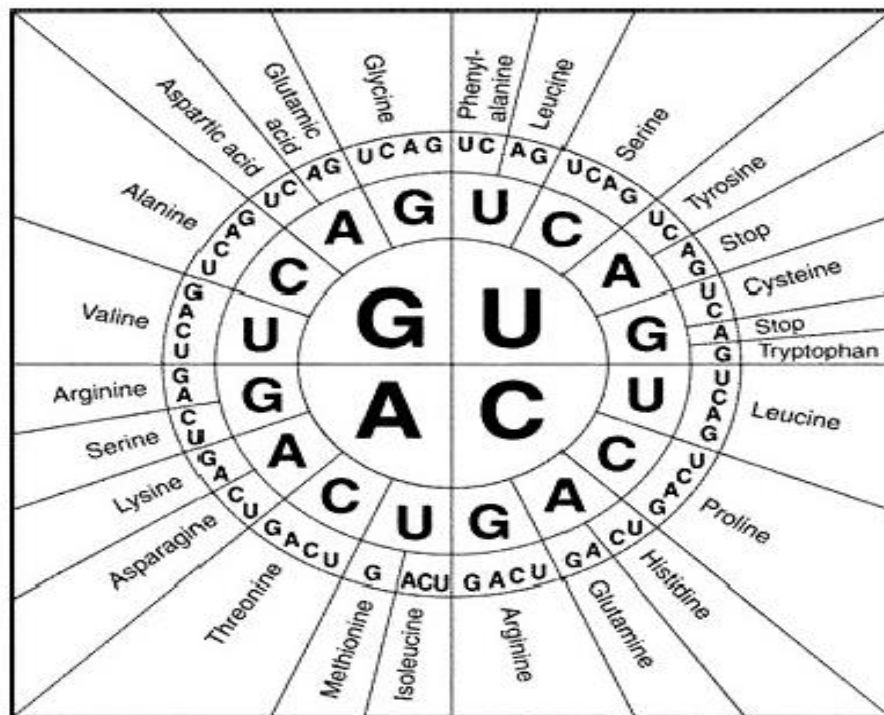
(ii) MIT student interested in learning "Central Dogma of Molecular Biology" was asked to assign the following proteins/enzymes in their respective topic. Can you assist him in identifying the main topic in each of the following cases? (1.5 marks)

t-RNA, DNA polymerase, Single strand Binding proteins

Given below is a nucleic acid sequence which will produce a protein. Assuming all the sequences are coding, answer the following questions

TAC CCC CCC ATG ATT CCC TAC AAA CAT GTA
ATG GGG GGG TAC TAA GGG ATG TTT GTA CAT

- (a) Copy the DNA sequence and label the ends. Which strand can act as the template for transcription?
- (b) Predict the mRNA sequence produced from this DNA and label the ends
- (c) What is the protein sequence produced from this DNA?



For an mRNA to produce a protein, there must be a start and stop. This is only happening when top strand is acting as the template (0.5 Marks)

(a) 5'**AUG** GGG GGG UAC **UAA** GGG AUG UUU GUA CAU AAAAAAAAAAAAAA3' (0.5 Marks)

(b) -Methionine-Glycine-Glycine-Tyrosine-STOP (0.5 marks)

Concept check

A cell contains 165000000 base pairs of DNA. If the speed of the replication machine is 60 base pairs/second and unidirectional; how many days it will take for the cell to complete one round of replication? Show your calculation.

Unit IV & V

23	Prokaryotic gene function: lac operon
24	Lamark and Darwin-Theories of evolution-I
25	Lamark and Darwin- Theories of evolution -II
26	Evidences of evolution-I
27	Evidences of evolution II
28	Mechanism of evolution: Mutation Gene flow, genetic drift and nonrandom mating
29	Constraints on evolution and Relationships in nature, Mutualism, commensalism, parasitism, coevolution, communal benefit,
30	Vaccination
31	Concept of cloning
32	Ascent of sap-plant water relations
33	Principles of Biology, Biological Hierarchies
34	Virus replication
35	Bioinspiration and Biomimetics

Assuming Lactose is only source and it is continuously supplied, choose the best option for each of the given case

No	Condition	Expression of proteins	
		No expression	Always expression
1	No Repressor present		
2	Loss of Promoter sequence		
3	Loss of Operator		
4	Altered RNA polymerase		

Test your understanding

- You have small DNA sequence which is producing a novel protein, which is industrially important. Develop plan and prototype for producing thousands copies of this DNA in a short span of time. Give the protocol.

Test your understanding

- Lichens consists of an algal and fungal component. The fungal component absorbs moisture and nutrients. The alga is able to do the photosynthesis. How will you explain this interaction?

Test your understanding

- What bioinspiration you will get from following to design model and mention its application.
- Snake
- Water strider
- Touch me not plant
- Mosquito bite
- Ants

Test your understanding

A researcher isolates a gene coding for protein X from human cell and using a vector inserts it into a prokaryotic bacterial cell. Assuming that the experiment is carried out under conditions that positively eliminate any possibility of mutation, explain the following observations:

- The resulting amino acid chain from the prokaryotic cell does not function like protein X and is longer in amino acid number than that observed in the protein X. Justify your reasoning

Concept check

A revolutionary new drug is introduced in the market which is capable of arresting the infection of RNA viruses inside the host cell. Determine whether this drug will produce any side effects in the humans. Explain with proper reasoning.

Polio virus is positive single stranded RNA virus and replicates in the host cell. Explain the life cycle of the Polio virus to replicate and produce new virus particles in the host cell?