**Milestones in DNA history**

1.The Double Helix structure of DNA was first described by :  
Ο Watson and King   
Ο James Watson, Francis Crick and Maurice Wilkins  
Ο Oswald Avery   
Ο Peter Mitchell   
**Answer:** James Watson, Francis Crick and Maurice Wilkins  
The Double Helix structure of DNA is one of the most significant discoveries of all time. James Watson, Francis Crick and Maurice Wilkins received a Nobel Prize for the Double Helix model of DNA in 1962 ! Another important figure, without whom this discovery would not have been possible was Rosalind Elsie Franklin. Unfortunately, Franklin died at the age of 37 from Ovarian Cancer just four years before the Nobel prize was awarded to Watson, Cricks and Wilkins.It is a tremendous shame that Franklin did not receive due credit for her essential role in this discovery, either during her lifetime or after her untimely death...

**2.** The scientist who first showed that genetic material is a heat stable chemical is :  
Ο Franklin Griffith  
Ο Erwin Chargaff   
Ο Friedrich Miescher   
Ο Oswald Avery   
**Answer:** Franklin Griffith  
This famous breakthrough resulted from an experiment carried out by Franklin Griffith in 1928. He discovered that genetic information can be transferred from heat-killed bacteria cells to live ones.  
  
**3.** The scientist who identified the transforming agent in Griffith's famous experiment (1928) as DNA was :  
Ο Erwin Chargaff   
Ο Friedrich Miescher   
Ο Peter Mitchell   
Ο Oswald Avery  
**Answer:** Oswald Avery  
In 1944, Oswald Avery, and his colleagues Maclyn McCarty and Colin MacLeod identified the transforming agent in Griffith's experiment as DNA.  
  
**4.** The scientist who reported that DNA composition is species specific was :  
Ο Erwin Chargaff  
Ο Sidney Brenner   
Ο Herbert Boyer   
Ο Hamilton Smith   
**Answer:** Erwin Chargaff  
In 1949, Erwin Chargaff, a biochemist, reported that the amount of DNA and its nitrogenous bases varies from one species to another. He also found that the amount of adenine equals the amount of thymine, and the amount of guanine equals the amount of cytosine in DNA from every species !  
  
**5.** Proof of the model of DNA replication suggested by Watson and Crick came from the experiments of :  
Ο Stanley Cohen and Herbert Boyer   
Ο Sidney Brenner and Francis Crick   
Ο George Beadle and Edward Tatum   
Ο M. S. Meselson and F. W. Stahl  
**Answer:** M. S. Meselson and F. W. Stahl  
The experiment performed by Meselson and Stahl is sometimes referred to as "The most beautiful experiment in biology." The experiment showed that DNA replication is semi-conservative.   
**Trivia** : Meselson's external advisor for his thesis was Richard Feynman ! !  
  
**6.** The scientist(s) who developed a technique to sequence DNA and later won a Nobel prize for their achievement in 1980 is(are) :  
Ο Walter Gilbert and Frederick Sanger  
Ο Arnold Levine and Gerald Edelman   
Ο Harold Varmus and Rodney Porter   
Ο Clara Bloomfield   
**Answer:** Walter Gilbert and Frederick Sanger  
Dr Walter Gilbert of Harvard University and Frederick Sanger developed a method for decoding DNA. His technique sparked off the biotech revolution because it enabled researchers to begin cloning genes.  
  
**7.** The scientist who created the first recombinant DNA molecules :  
Ο Howard Temin   
Ο James Shapiero   
Ο Ian Wilmut   
Ο Paul Berg  
**Answer:** Paul Berg  
In 1972, Paul Berg combined the DNA of two different organisms, thus creating the first recombinant DNA molecules. He developed a technique for splitting DNA molecules at selected sites, attaching segments of the molecule to the DNA of a virus, and then introducing it into bacterial cells. The foreign DNA was incorporated by the host, which then produced proteins not usually found in the host. This joining of two pieces of DNA from different species is called recombinant DNA. The process is a cornerstone of genetic engineering. He won a Nobel Prize for his work in 1980.  
  
**8.** The first organism ever to be cloned from adult cells was :  
Ο A cow   
Ο Dolly, the sheep  
Ο Northern Leopard frogs   
Ο Tadpoles   
**Answer:** Dolly, the sheep  
On July 5, 1996, Dolly (a sheep), the first organism ever to be cloned from adult cells, was born. Earlier, clones of other organisms such as cows and frogs had been created from early embryo cells and not adult cells.  
  
**9.** One of the surprises uncovered by the Human Genome project was the surprisingly small number of genes that humans possess. This number is approximately :  
Ο 10000   
Ο 35000  
Ο 80000   
Ο 60000   
**Answer:** 35000  
The Human Genome project revealed that humans have approximately 35000 genes which is lower than expected. Even an insect as simple as the fruitfly has as many as 20000 genes.  
  
**10.** Robert Holley, Har Gobind Khorana, and Marshall Nirenberg shared the Nobel prize for medicine in 1968 for their contribution to DNA reasearch, which was :  
Ο the discovery of the structure of DNA.   
Ο the elucidation of protein synthesis.  
Ο the discovery of the lac(tose) operon.   
Ο the discovery of the presence of DNA which could not be expressed.   
**Answer:** the elucidation of protein synthesis.  
In 1968, Robert Holley, Har Gobind Khorana, and Marshall Nirenberg shared the Nobel prize in medicine for the elucidation of the process of protein synthesis. They also discovered which amino acids are designated by each of the three letter codes. They also determined that the translation of the code was universal amongst different organisms.

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| --- | --- |
| Structure and chemical composition of DNA |  |

1.Which base is found in RNA but not DNA ?  
Ο Uracil  
Ο Adenine   
Ο Cytosine   
Ο Thymine   
**Answer:** Uracil  
Adenine, Cytosine and Guanine are found in both RNA and DNA. Thymine is found only in DNA; Uracil takes its (Thymine) place in RNA molecules.  
  
**2.** In the DNA Double Helix, complementary base pairs are held together by :  
Ο hydrogen bonds  
Ο N-glycosidic bonds   
Ο ionic bonds   
Ο peptide bonds   
**Answer:** hydrogen bonds  
The complementary base pairs : A - T and G - C are held together by hydrogen bonds.  
  
**3.** The three pyrimidine bases in DNA are :  
Ο Cytosine,Thymine and Uracil  
Ο Adenine, Thymine and Guanine   
Ο Thymine, Guanine and Cytosine   
Ο Adenine, Uracil and Guanine   
**Answer:** Cytosine,Thymine and Uracil  
In all, there are five nitrogeneous bases : Cytosine, Thymine, Uracil, Adenine and Guanine. The **purine** bases (Adenine and Guanine), have a structure which consists of two rings of atoms. The other three bases are called **pyrimidine** bases.   
The correct answer is : Cytosine, Thymine and Uracil.  
  
**4.** A DNA strand has the sequence A-C-A-G-C-C-G-T-A. What would be its complementary strand ?  
Ο T-G-T-C-G-G-C-A-T  
Ο A-C-A-G-C-C-G-T-A   
Ο U-G-U-C-G-G-C-A-U   
Ο G-T-G-A-T-T-A-C-G   
**Answer:** T-G-T-C-G-G-C-A-T  
Note that complementary base pairs are : A - T and G - C. So, to find the complementary strand, replace A by T, G by C and vice versa.   
U replaces T in an RNA strand and is absent in DNA. Here, the letters A, T, G, C and U represent the base pairs that form both DNA and RNA molcules.   
The correct answer is T-G-T-C-G-G-C-A-T.  
  
**5.** The DNA molecules of different species differ in their :  
Ο phosphate backbone   
Ο sequence of bases  
Ο type of nucleotides   
Ο All of the above   
**Answer:** sequence of bases  
The DNA molecules of different species have different sequences of base-pairs.  
  
**6.** The difference between DNA and RNA is :  
Ο The RNA sugar phosphate backbone contains ribose rather than deoxyribose.   
Ο DNA molecules are double stranded while RNA molecules are single stranded for the most part.   
Ο Thymine in DNA is replaced by Uracil in RNA.   
Ο All of the above.  
**Answer:** All of the above.  
The three options provided accurately list the differences between DNA and RNA molecules. Note that RNA molecules are single stranded with a few double stranded regions of complementary base-pairing. These regions are called hairpin loops. Also, the 5-carbon sugar in RNA has more oxygen than the corresponding sugar in DNA.   
The correct answer is : All of the above.  
  
**7.** Where would you expect to find genetic information describing the characteristics of a Dodo ?  
Ο In virtually every cell in its body.  
Ο In the ribosomes.   
Ο In the primary spermatocytes.   
Ο In its feathers !   
**Answer:** In virtually every cell in its body.  
Genetic information would be present in almost all cells in its body.  
  
**8.** The number of hydrogen bonds that hold the Adenine - Thymine base pair together is :  
Ο 2  
Ο 3   
Ο 4   
Ο 5   
**Answer:** 2  
The Adenine - Thymine base pair is held together by 2 hydrogen bonds while the Guanine - Cytosine base pair is held together by 3 hydrogen bonds. That is also the reason why the two strands of a DNA molecule can be separated in more easily at sections that are densely populated by A - T base pairs.  
  
**9.** The DNA molecule is a polymer. Its monomer units are :  
Ο nucleotides  
Ο nucleic acids   
Ο amino acids   
Ο nucleosides   
**Answer:** nucleotides  
The DNA molecule is a polymer whose monomer units are nucleotides and the polymer is known as a "polynucleotide". Each nucleotide consists of a 5-carbon sugar (deoxyribose), a nitrogen containing base attached to the sugar, and a phosphate group. There are four different types of nucleotides found in DNA. They are : Adenine, Guanine, Cytosine and Thymine.  
  
**10.** The total length of a DNA molecule in the human genome when fully outstretched is approximately :  
Ο 1.8 meters.  
Ο 1.8 centimeters.   
Ο 1.8 millimeters.   
Ο Varies from person to person.   
**Answer:** 1.8 meters.  
The correct answer is 1.8 meters. The coiled molecule is contained within the cell nucleus which has a diameter of about 6 micrometers !!!  
  
**11.** Because one original strand of the double stranded DNA helix is found in each daughter cell (after cell division), the DNA replication process is :  
Ο semiconservative  
Ο conservative   
Ο derivative   
Ο dispersive   
**Answer:** semiconservative  
The DNA replication process is semiconservative because one original strand of the double stranded DNA helix is found in each daughter cell after replication.  
  
**12.** The technique Rosalind Franklin used to determine the structure of DNA was :  
Ο centrifuge analysis   
Ο X-Ray crystallography  
Ο bacteriophages   
Ο None of the above   
**Answer:** X-Ray crystallography  
Rosalind Franklin used X-Ray crystallography to determine the structure of DNA. She was in fact the first to state that the the sugar-phosphate backbone of DNA lies on the outside of the molecule. She also elucidated the basic helical structure of the molecule.  
  
**13.** Each nucleotide in a DNA molecule consists of :  
Ο a phosphate group,a pentose sugar and a nitrogeneous heterocyclic base.  
Ο a phosphate group, a pentose sugar, and a oxygen base.   
Ο a phosphate group, a hexose sugar and a nitrogeneous heterocyclic base.   
Ο a sulfonyl group, a pentose sugar, and a nitrogeneous heterocyclic base.   
**Answer:** a phosphate group,a pentose sugar and a nitrogeneous heterocyclic base.  
A nucleotide consists of a nitrogenous heterocyclic base (a purine or a pyrimidine), a pentose sugar (deoxyribose in DNA or ribose in RNA), and a phosphate or polyphosphate group. A DNA molecule (a polynucleotide) is made up of a large number of these nucleotide (monomer) units.   
**Note : A polynucleotide is a nucleic acid.**  
  
**14.** A nucleoside consists of :  
Ο a pentose sugar and a nitrogeneous heterocyclic base.  
Ο a pentose sugar and a oxygen base.   
Ο a hexose sugar and a nitrogeneous heterocyclic base.   
Ο a phosphate group, a pentose sugar and a nitrogeneous heterocyclic base.   
**Answer:** a pentose sugar and a nitrogeneous heterocyclic base.  
A nucleoside is similar to a nucleotide, except that it contains only the sugar and base, without the phosphate group. Examples include guanosine, thymidine and inosine.  
  
**15.** How does the sequence of a strand of DNA correspond to the amino acid sequence of a protein ? This concept is explained by the central dogma of molecular biology which states that :  
Ο DNA is replicated and sections of the replica are used to make protein.   
Ο DNA is used to make RNA which is used to make protein.  
Ο protein is manufactured directly from DNA without any intermediate.   
Ο None of the above.   
**Answer:** DNA is used to make RNA which is used to make protein.  
The correct answer is : DNA is used to make RNA which is used to make protein.   
The RNA molecule is an intermediate between the DNA molecule and the protein. This lets the DNA stay pristine and protected, away from the caustic chemistry of the cytoplasm outside the nucleus. Also, many copies of an RNA molecule can be made which enables the amplification of genetic information.  
  
**16.** The single stranded molecule that is **transcribed** from a DNA template (i.e a photocopy of a specific section of the DNA molecule) and is subsequently used to manufacture proteins is :  
Ο mRNA  
Ο tRNA   
Ο rRNA   
Ο snRNA   
**Answer:** mRNA  
mRNA is a photocopy of a gene with a sequence complementary to one section of the DNA strand (gene) and identical to the other. The mRNA carries this genetic information from the cell nucleus to the ribosomes in the cytoplasm where proteins are manufactured.   
**Note** : mRNA - messenger RNA ; tRNA - transfer RNA ; rRNA - ribosomal RNA ; snRNA - small nuclear RNA  
  
**17.** The process of protein manufacture within ribosomes using mRNA is called :  
Ο transcription   
Ο protein derivation   
Ο translation  
Ο None of the above   
**Answer:** translation  
The correct answer is translation. In short, a gene is transcribed to give mRNA which is then used to manufacture proteins in ribosomes.  
  
**18.** A significant difference between prokaryotes and eukaryotes is :  
Ο The DNA of prokaryotes floats freely around the cell while the DNA of eukaryotes is held within its nucleus.  
Ο Prokaryotes do not have DNA as their genetic material while eukaryotes do.   
Ο Prokaryotes do not have ribosomes while eukaryotes do.   
Ο Prokaryote cells are not membrane-bound while eukaryote cells are.   
**Answer:** The DNA of prokaryotes floats freely around the cell while the DNA of eukaryotes is held within its nucleus.  
The DNA of prokaryotes floats freely around the cell while the DNA of eukaryotes is held within its nucleus. Also, the DNA of eukaryotes is much more complex and therefore much more extnsive than the DNA of prokaryotes.  
  
**19.** Melting of DNA is a standard method for preparing "single stranded DNA". A 4000 kb (kilobase- pair) DNA molecule melts at 79oC. What percent of the base pairs are GC pairs?  
Ο 24.4 %  
Ο 2.44 %   
Ο 30.4 %   
Ο 42.4 %   
**Answer:** 24.4 %  
The two strands of a DNA molecule can be melted into single strands by heat, which breaks the hydrogen bonds between complementary bases. Since G - C pairs consist of three hydrogen bonds, while A - T pairs only have two hydrogen bonds, the temperature at which different DNA molecules "melt" varies depending on their basepair sequences. A DNA molecule consisting of only A - T pairs will melt at approximately 69oC, while a DNA molecule consisting of only GC pairs will melt at approximately 110oC. The relationship between GC content in the molecule and the melting temperature (Tm) of the molecule is as follows :   
%(G - C content) = 2.44(Tm - 69)   
Substitute Tm = 79oC   
=> %(G - C content) = 24.4   
The correct answer is 24.4 %.  
  
**20.** The unit within the nucleus that contains a protein complex (located at the center of the unit) of two H2A, H2B, H3 and H4 histone proteins with DNA wrapped around the complex in two turns, each turn consisting of about 80 base pairs is called a :  
Ο nucleosome  
Ο ribosome   
Ο centrosome   
Ο histosome   
**Answer:** nucleosome  
The unit described above is called a **nucleosome**. The main purpose of nucleosomes is the organization and packing of DNA. Under an electron microscope, the DNA looks like a bead on a string. The beads are nucleosomes, and the string is the DNA.

## DNA Replication

1.The enzyme responsible for initiating the unwinding of double-stranded DNA (eliminating supercoiling) by nicking a single strand of the DNA molecule is :  
Ο Topoisomerase  
Ο Gyrase   
Ο Ligase   
Ο Helicase   
**Answer:** Topoisomerase  
DNA Topoisomerase nicks a single strand of the DNA molecule and this releases the tension holding the two strands together in a supercoiled structure. The enzyme is also known as **DNA Gyrase**.  
  
**2.** The enzyme that accomplishes the unwinding of the original double stranded DNA molecule, once supercoiling has been eliminated, by breaking the hydrogen bonds that hold the two strands together is :  
Ο Helicase  
Ο Topoisomerase   
Ο DNA Polymerase II   
Ο Primase   
**Answer:** Helicase  
Helicase seperates the two strands by disrupting the hydrogen bonds that hold the two strands of the DNA molecule together. The resulting unwound and partially opened up helix is called a **"replication fork"**.  
  
**3.** The enzyme that (during replication) proceeds along one of the strands of a DNA molecule adding deoxy-nucleotide-triphosphates to hydrogen bond with their appropriate complementary dNTP on the other single strand and to form a covalent phosphodiester bond with the previous nucleotide of the same strand is called :  
Ο DNA Polymerase III  
Ο DNA Polymerase II   
Ο DNA Polymerase I   
Ο Primase   
**Answer:** DNA Polymerase III  
As DNA helicase moves down the DNA molecule and separates the two strands by breaking the bonds between the nitrogenous bases, **DNA Polymerase III** adds the appropriate complementary bases to the now exposed bases on the single strands.  
  
**4.** Because DNA polymerase III can only act from 5' to 3', continuous strand growth can be achieved only along one of the template strands (Leading strand) and strand growth along the other strand must occur discontinuously resulting in the production of a series of short sections of new DNA called :  
Ο Replicon fragments   
Ο Okazaki fragments  
Ο Klenow fragments   
Ο None of the above   
**Answer:** Okazaki fragments  
DNA polymerase III synthesizes new DNA fragments in the 5' to 3' direction along the **Lagging strand**. These fragments are called Okazaki fragments.  
  
**5.** The enzyme that stitches Okazaki fragments together (along the lagging strand) is called :  
Ο DNA Ligase  
Ο DNA Polymerase II   
Ο Topoisomerase   
Ο Holoenzyme   
**Answer:** DNA Ligase  
To ensure that the Okazaki fragments are made into a continuous strand, they are joined by DNA Ligase which ligates the fragments together by forming the missing phosphodiester bonds.  
  
**6.** DNA Polymerase III is actually an aggregate of several different protein subunits. So it is often called a :  
Ο Holoenzyme  
Ο Primeosome   
Ο replisome   
Ο None of the above   
**Answer:** Holoenzyme  
Holoenzyme consists of ten protein subunits and it is a dimeric enzyme with one half that copies the leading strand and another half that copies the lagging strand. The two halves of the enzyme communicate with one another such that both strands are replicated more or less simultaneously.  
  
**7.** The enzyme that creates a short RNA oligonucleotide at initiation sites where replication is to be carried out is called :  
Ο Primase  
Ο DNA Ligase   
Ο DNA Gyrase   
Ο Exonuclease   
**Answer:** Primase  
The correct answer is Primase. Primase is actually part of an aggregate of proteins called the Primeosome which attaches a small RNA primer to the single-stranded DNA to act as a substitute 3'OH (on the Lagging strand) for DNA polymerase to begin synthesizing from.  
  
**8.** The enzyme X removes RNA primers attached by Primase and this gap is then filled in by DNA Polymerase I. The enzyme X is :  
Ο RNase H  
Ο DNA amylase   
Ο DNA ligase   
Ο Reverse Transcriptase   
**Answer:** RNase H  
The correct answer is RNase H.  
  
**9.** A major difference between DNA replication in prokaryotes and eukaryotes is :  
Ο there is only one replication origin in prokaryotes.  
Ο DNA amylase performs the function of DNA helicase in prokaryotes   
Ο replication is conservative in prokaryotes   
Ο prokaryotes do not use Topoisomerase in the replication process   
**Answer:** there is only one replication origin in prokaryotes.  
The main difference between DNA replication in prokaryotes and eukaryotes is that there is only one replication origin in the replication of DNA in prokaryotes, whereas eukaryotes may have up to 1000 replication origins.  
  
**10.** A repeating DNA sequence at the end of chromosomes that prevents them from losing base pair sequences at their ends and from fusing together is called :  
Ο A Telomere  
Ο A Telomerase   
Ο A replicon   
Ο None of the above.   
**Answer:** A Telomere  
The correct answer is 'A Telomere'. A Telomere can reach a length of 15,000 base pairs. Each time a cell divides, some of the Telomere is lost and when it becomes too short, the chromosome reaches a "critical length" and can no longer replicate. So, a cell becomes "old" and dies because of the shortening of chromosomal telomeres.  
  
**11.** The enzyme (made of proteins and RNA) that elongates chromosomes by adding TTAGGG sequences to the end of existing chromosomes is :  
Ο Telomerase  
Ο Exonuclease   
Ο Endonuclease   
Ο Amylase   
**Answer:** Telomerase  
The correct answer is Telomerase. Telomerase, also called Telomere terminal transferase, lengthens the 5' end of DNA strands before replication, to compensate for Telomere shortening during DNA replication.  
  
**12.** An enzyme (used by all retroviruses) that transcribes genetic information of the virus from RNA into DNA, is :  
Ο Reverse transcriptase  
Ο RNA polymerase   
Ο Restriction nuclease   
Ο Methylase   
**Answer:** Reverse transcriptase  
The correct answer is Reverse transcriptase. Retroviruses are viruses whose genome consists of RNA and not DNA. HIV-1 and HIV-2, the agents that cause AIDS, are retroviruses. Reverse transcriptase is a DNA polymerase that uses RNA as its template. Thus it is able to make genetic information flow in the opposite direction (RNA => DNA) instead of (DNA => RNA).  
  
**13.** An enzyme that recognizes and cuts DNA only at a particular sequence of nucleotides is often called :  
Ο Restriction endonuclease  
Ο RNA polymerase   
Ο Photolyase   
Ο DNA glycosylase   
**Answer:** Restriction endonuclease  
The correct answer is Restriction endonuclease. DNA restriction enzymes recognize short, specific pallindromic sequences of DNA bases and make breaks in the sugar-phosphate backbone of the DNA in the region of the recognized sequence.  
  
**14.** What does transformation involve in Bacteria ?  
Ο assimilation of external DNA into a cell  
Ο the creation of a strand of DNA from RNA   
Ο the creation of a strand of RNA from DNA   
Ο the infection of cells by a phage DNA molecule   
**Answer:** assimilation of external DNA into a cell  
Transformation is the genetic alteration of a cell resulting from the introduction, uptake and expression of foreign DNA. It is a common technique in molecular biology.   
The correct answer is option 2.  
  
**15.** A mamalian cell typically has 1.2 meters (when completely outstretched) of double stranded DNA.The total time to duplicate the DNA is 5 hours. How many origins of replication are there if the rate of duplication is 16µmeters/min ?  
Ο 250  
Ο 15000   
Ο 1   
Ο 500   
**Answer:** 250  
The correct answer is 250 origins of replication. If there was only one origin of replication, the rate of DNA duplication would be given by :   
Rate = Length of DNA / duplication time   
=> Rate = 1.2 / (5 x 60) = 400µm/min which is not consistent with the data provided. Clearly, there exists more than one origin of replication !   
Let the number of origins of replication be n. The rate of duplication from each origin will be 16µmeters/min. Hence, n x 16µmeters/min x 5 x 60 min = 1.2 x 106meters   
=> n = 250.  
  
**16.** The enzyme that replaces the nucleotides of the RNA primer with the appropriate DNA nucleotides is :  
Ο DNA Polymerase II  
Ο RNA Polymerase   
Ο DNA Ligase   
Ο DNA Gyrase   
**Answer:** DNA Polymerase II  
The correct answer is DNA Polymerase II. DNA polymerase II digests away the RNA primer (on the Lagging strand) and replaces the RNA nucleotides of the primer with the proper DNA nucleotides to fill the gap before DNA Ligase links the strands together.  
  
**17.** The end of a DNA strand that has a phosphate group attached to the number 5 carbon of its terminal deoxyribonucleotide is called :  
Ο The 5 prime end (5')  
Ο The 3 prime end (3')   
Ο N-Terminus   
Ο C-Terminus   
**Answer:** The 5 prime end (5')  
The correct answer is the 5 prime end (5'). The 5 prime end of a DNA strand will aways have a phosphate group attached to the number 5 carbon of its terminal deoxyribonucleotide. The other end of that strand, called the 3 prime end, will always have a hydroxyl (OH) on the number 3 carbon of its terminal deoxyribonucleotide.   
Note : DNA can only be synthesized in the 5' to 3' direction.  
  
**18.** In DNA, mutations at G-C sequences occur quite frequently since 5-methyl cytosine easily deaminates to form :  
Ο Thymine  
Ο Adenine   
Ο Guanine   
Ο Cytosine   
**Answer:** Thymine  
The correct answer is Thymine. Cytosine can be methylated into 5-methylcytosine (by an enzyme called DNA methyltransferase) which can undergo spontaneous deamination to form Thymine.  
  
**19.** Which of the following agents is not a mutagen ?  
Ο Ultraviolet radiation   
Ο A retrovirus   
Ο A transposon or jumping gene   
Ο None of the above  
**Answer:** None of the above  
A mutagen increases the number of mutations that occur during DNA replication above the natural background level. Mutagens can be chemical compounds or radiation. Ultraviolet radiation, retroviruses and transposons are mutagens.  
  
**20.** In 1940, Nobel Laureate Barbara McClintock discovered sequences of DNA that can move around to different positions within the genome of a single cell and cause mutations. These sequences (first observed in maize) are called :  
Ο Transposons  
Ο inverted repeats   
Ο direct repeats   
Ο sticky ends   
**Answer:** Transposons  
The correct answer is Transposons (also known as "jumping genes").

## Transcription (RNA Synthesis)

1.The process by which messenger RNA is synthesized by complementary base pairing of ribonucleotides with deoxyribonucleotides to match a section of DNA (a gene) is called :  
Ο Translation   
Ο Replication   
Ο Transcription  
Ο I have no idea ! !   
**Answer:** Transcription  
The correct answer is Transcription. Transcription is the process of copying DNA to mRNA and is the first step of protein biosynthesis.  
  
**2.** The sequence of bases located prior to the gene (along the DNA strand), to which a complex of RNA polymerase and sigma factors attaches itself to initiate transcription is called :  
Ο promotor  
Ο terminator   
Ο exon   
Ο telomere   
**Answer:** promotor  
A promotor may be described as a sequence of bases at which RNA polymerase begins transcription. Once the RNA polymerase - sigma factor complex recognizes the promoter sequence, the sigma factor dissociates from RNA polymerase which unwinds the DNA helix thus exposing a template for transcription.  
  
**3.** A segment of DNA that includes regions preceding and following the coding DNA ( introns as well as exons ) is called :  
Ο cistron  
Ο retroposon   
Ο operon   
Ο transposon   
**Answer:** cistron  
The correct answer is cistron. Note that the terms cistron and gene are approximately the same. A gene could have several cistrons but this is unusual.  
  
**4.** Genes that are expressed at all times and under all conditions of growth are called :  
Ο constitutive genes  
Ο regulatable genes   
Ο antibody genes   
Ο chimeric genes   
**Answer:** constitutive genes  
Constitutive genes are expressed under all circumstances by a cell or organism, regardless of environmental influences.  
  
**5.** Proteins that bind between the promotor region and the section of the gene which is transcribed thus blocking transcription (preventing gene expression) are called :  
Ο Repressors  
Ο Activators   
Ο inducer   
Ο Operator   
**Answer:** Repressors  
Repressor proteins bind to DNA in such a way that they interfere with RNA Polymerase action and prevent gene expression. This is a form of negative control on protein synthesis. Hence, the activity of specific proteins within cells is regulated through either blocks or enhancement of RNA polymerase action at the level of transcription. Also, genes whose expression can be controlled by external factors are called regulatable genes.  
  
**6.** A G-C-rich stretch of nucleotides, followed by an A-T-rich stretch of nucleotides is the signal for :  
Ο Rho dependent termination  
Ο Rho independent termination   
Ο Initiation   
Ο transcription   
**Answer:** Rho dependent termination  
For rho-independent termination, there is a G-C-rich stretch of nucleotides, followed by an A-T-rich stretch of nucleotides. When this stretch is transcribed into RNA, the sequence of the nucleotides is such that the RNA molecule forms a short double-stranded region called a hairpin which significantly slows down RNA polymerase causing it to pause in the A-T-rich region. Because the A-T rich region is relatively unstable, the transcription complex falls apart, ending transcription.  
  
**7.** The bacterial promotor sequence usually found at the -10 position (ten base pairs upstream of the transcription start site) is :  
Ο TATAAT  
Ο TTGACA   
Ο TAGACA   
Ο TATTAT   
**Answer:** TATAAT  
Bacterial promoters usually contain two important DNA sequences that are involved in the regulation of transcription :   
1) TATAAT at the -10 position.   
2) TTGACA at the -35 position.   
Both sequences are upstream of the actual gene...The 10 sequence is also known as the Pribnow box, in honor of its discoverer.  
  
**8.** Sections of DNA within a gene that do not encode part of the protein that the gene produces are called :  
Ο Introns  
Ο Exons   
Ο Transposons   
Ο intein   
**Answer:** Introns  
Introns are sections of DNA within a gene that do not encode part of the protein that the gene produces. They are spliced out of the mRNA that is transcribed from the gene before it is exported from the cell nucleus. The regions of a gene that remain in the spliced mRNA are called Exons. Introns allow for alternative splicing of a gene, so that several different proteins that share some common DNA sections can be produced from a single gene.  
  
**9.** An RNA molecule that can catalyze either its own cleavage (self-splicing) or the cleavage of other RNA molecules is :  
Ο A ribozyme  
Ο A spliceosome   
Ο A chaperone enzyme.   
Ο An inducer   
**Answer:** A ribozyme  
RNA with enzymatic activity, (for example - self-splicing RNA) are called ribozymes. Note that the functional part of the ribosome (the protein translator), is a ribozyme.  
  
**10.** Due to the presence of Introns and Exons, in Eukaryotes the splicing process of pre-mRNA can lead to different ripe mRNA molecules and therefore to different proteins. This phenomenon is called :  
Ο alternative splicing  
Ο exonic splicing   
Ο intronic splicing   
Ο gene splicing   
**Answer:** alternative splicing  
The transcribed mRNA includes several introns and exons. But what is an intron and what is an exon is not decided yet. This decision is made during the splicing process. The result of alternative splicing is that information can be stored much more economically. Several proteins can be encoded in a DNA sequence whose length would only be enough for two proteins. The regulation of the splicing process is still widely unknown...  
  
**11.** A base sequence that is part of the DNA of an organism and appears to have once coded a gene product, such as a protein or transcription factor but no longer does so is called :  
Ο A pseudogene  
Ο A selfish gene   
Ο A jumping gene   
Ο An Oncogene   
**Answer:** A pseudogene  
Pseudogenes are inactive sequences of genomic DNA which have a similar sequence to known functional genes and are considered to be evolutionary relatives to normally functioning genes.  
  
**12.** A guanine triphosphate nucleotide that binds to the 5' end of the mRNA thus increasing the stability of the synthesized RNA and enhancing translation efficiency is called a :  
Ο Cap  
Ο poly-A-tail   
Ο leader   
Ο trailer   
**Answer:** Cap  
Most mRNAs have their starting end blocked by the addition of a cap (7-methylguanosine) which has no free phosphates. As a result it is protected from attack by phosphatases, or nucleases. It also helps ribosomes attach for translation.  
  
**13.** The series of three consecutive mRNA bases coding for one specific amino acid in a protein is called a :  
Ο codon  
Ο intron   
Ο exon   
Ο transposon   
**Answer:** codon  
A codon is a three nucleotide sequence which codes for the insertion of a unique amino acid during translation. As an example, UCU specifies the amino acid serine.  
  
**14.** A series of 20 to 200 Adenine ribonucleotides that is added to the 3' end of the transcribed RNA molecule (pre-mRNA) that helps in the transportation of mRNA out of the nucleus is called :  
Ο the poly-A-tail  
Ο trailer   
Ο cap   
Ο a Shine-Dalgarno sequence   
**Answer:** the poly-A-tail  
The poly A tail which is usually 20 to 200 nucleotides is not encoded by the gene but is added post-transcriptionally. It is is thought to confer stability to the mRNA. The addition of the poly-A-tail is called RNA polyadenylation.  
  
**15.** A collection of genes including one which acts as a switch that governs the expression of the structural genes in the collection is called :  
Ο An Operon  
Ο lac operon   
Ο A regulon   
Ο Does everything have to have a name ? ? ! !   
**Answer:** An Operon  
An Operon is a collection of multiple structural genes so that they are transcribed as a single mRNA. Operons found primarily in prokaryotes and nematodes were first described by Francois Jacob and Jacques Monod in 1961. They allow cells to respond to their environment.  
  
**16.** The switch of an operon is turned on if specific substance is not bound to the operator. This substance is called :  
Ο a repressor  
Ο a promoter   
Ο an operon   
Ο an activator   
**Answer:** a repressor  
A DNA-binding protein in prokaryotes that prevents the transcription of a gene by binding to the operator region is called a Repressor. For example : The lac repressor protein prevents the expression of the lac Operon which governs the production of enzymes for metabolizing lactose.  
  
**17.** The lac repressor protein binds to the operator region...  
Ο in the absence of lactose  
Ο in the presence of lactose   
Ο in the presence of cAMP   
Ο in the absence of glucose   
**Answer:** in the absence of lactose  
The lac repressor stops the metabolism of lactose in bacteria as long as glucose is available. However, when lactose is plentiful and glucose is scarce, the lac repressor becomes inactive. This allows the conversion of lactose to glucose.  
  
**18.** A RNA transcript (whose base sequence is complementary to that of the mRNA of a gene) that can inhibit the expression of a gene by forming a duplex with the mRNA strand is called :  
Ο antisense RNA  
Ο tRNA   
Ο dsRNA   
Ο rRNA   
**Answer:** antisense RNA  
A RNA sequence that is complementary to the mRNA of a particular gene will prevent the translation of that gene into a protein by binding to the mRNA of that gene. This may be a defense mechanism against viruses which can use double-stranded mRNA as an intermediate.  
  
**19.** A gene that encodes RNA that functions without being translated into a protein is called :  
Ο An RNA gene  
Ο AN Oncogene   
Ο A quiet gene   
Ο A pseudogene   
**Answer:** An RNA gene  
A Gene that is transcribed into RNA which in turn is not translated into a protein is called an RNA gene or non-coding RNA (ncRNA) or functional RNA (fRNA). Examples are : Transfer RNA (tRNA) and Ribosomal RNA (rRNA), both of which are involved in the process of translation.  
  
**20.** The base sequence of the RNA strand transcribed from a DNA strand of the sequence T-G-C-A-G-C-A-C-A is :  
Ο A-C-G-U-C-G-U-G-U  
Ο A-C-G-U-C-G-U-G-U   
Ο U-G-C-A-G-C-A-C-A   
Ο G-U-A-C-U-A-C-A-C   
**Answer:** A-C-G-U-C-G-U-G-U  
For the transcribed RNA sequence, base pairs are : A - U and G - C.

## Translation

**1.** The process of translating mRNA into protein occurs...  
Ο at the ribosomes  
Ο within the nucleus   
Ο inside the Lysosomes   
Ο inside the Peroxisomes   
**Answer:** at the ribosomes  
A ribosome is an organelle found in the cytosol of all cells. It is composed of RNA and ribosomal proteins which translate mRNA into protein (i.e a polypeptide chain).  
  
**2.** Prokaryotes use 70S ribosomes which consist of :  
Ο a (small) 30S and a (large) 50S subunit  
Ο a (small) 40S and a (large) 60S subunit   
Ο a (small) 40S and a (large) 30S subunit   
Ο a (small) 10S and a (large) 60S subunit   
**Answer:** a (small) 30S and a (large) 50S subunit  
Ribosomes consist of two subunits that fit together and work as one to translate the mRNA into a protein. The size of the ribosome and its subunits are expressed in terms of Svedberg units (S) which is a measure of the rate of sedimentation of a particle in a centrifuge, where the sedimentation rate is associated with the size of the particle and its 3D shape. **Note : Svedberg units are not additive ! !**   
  
**3.** The triplet base sequence of tRNA nucleotides that is complementary to an mRNA codon (for a particular amino acid) is called :  
Ο an anticodon  
Ο a transposon   
Ο a retroposon   
Ο a cistron   
**Answer:** an anticodon  
The three-nucleotide sequence at the end of a transfer RNA molecule that is complementary to, an amino acid specifying codon in messenger RNA is called an anticodon.  
  
**4.** Every polypeptide chain formed in translation starts with the amino acid :  
Ο methionine  
Ο lysine   
Ο serine   
Ο alanine   
**Answer:** methionine  
The leading codon of the messenger RNA molecule is the sequence AUG which encodes the amino acid, methionine. The initial methionine unit is usually split off the finished polypeptide. In bacteria, the first aminoacyl-tRNA to initiate translation is always a formyl derivative of methionine called FMet-tRNA.  
  
**5.** tRNA molecules are linked to their respective amino acids by enzymes called :  
Ο aminoacyl-tRNA synthetases  
Ο phenylalanine hydroxylases   
Ο beta-galactosidases   
Ο Ornithine decarboxylases   
**Answer:** aminoacyl-tRNA synthetases  
  
**6.** Some tRNAs can recognize more than one codon because there is a relaxation of the complementation rule of base pairing between the anticodon and codon in the third position (of the codon sequence). This relaxation is called :  
Ο the Wobble Hypothesis  
Ο Sutton-Boveri Hypothesis   
Ο the Levene's Hypothesis   
Ο the Monkey-Man Hypothesis   
**Answer:** the Wobble Hypothesis  
The Wobble Hypothesis says that a single tRNA can decode more than one codon because there is a relaxation of the complementation rule of base pairing between the anticodon and codon in the third position (of the codon sequence).  
  
**7.** Which of the following is not a stop codon ?  
Ο GUA  
Ο UAA   
Ο UAG   
Ο UGA   
**Answer:** GUA  
AUG is a start codon and encodes the protein methionine. In some organisms, GUG is also used as a start codon for some proteins.  
  
**8.** Most amino acids are encoded by more than one codon except tryptophan and :  
Ο methionine  
Ο glycine   
Ο lysine   
Ο leucine   
**Answer:** methionine  
Codons are triplets of four possible bases (A, U, G and C). Basic math tells us that we can have 43 or 64 triplets in all. Since there are only 20 amino acids, each of them is encoded by more than one codon except tryptophan and methionine.  
  
**9.** In prokaryotic mRNA, a particular base sequence (AGGAGGU) exists near the AUG start codon. This sequence which is sometimes referred to as the ribosome binding site is known as :  
Ο a Shine Dalgarno sequence  
Ο a promoter sequence   
Ο a Kozak's consensus sequence   
Ο a trailer sequence   
**Answer:** a Shine Dalgarno sequence  
The Shine Dalgarno sequence is a section of nucleotides on a prokaryotic mRNA molecule upstream of the translational start site, that serves to bind to ribosomal RNA and thereby bring the ribosome to the start codon on the mRNA. It is complementary to the 3' end of 16S rRNA.  
  
**10.** If the mammalian genetic code were a four letter code, then it would have the potential to encode...  
Ο 256 amino acids  
Ο 128 amino acids   
Ο 64 amino acids   
Ο 216 amino acids   
**Answer:** 256 amino acids  
If the genetic code were a four letter code, then the number of amino acids that could be encoded would be equal to 44 = 256.  
  
**11.** A sequence of about 5 to 20 bases seperating one stop codon from the next start codon in a polycistronic prokaryotic mRNA molecule is called :  
Ο a spacer  
Ο a Shine Dalgarno sequence   
Ο a poly-A-tail   
Ο a transposon   
**Answer:** a spacer  
A polycistronic prokaryotic mRNA molecule must possess a series of start and stop codons since it encodes more than one protein. A spacer simply seperates two successive cistrons (genes).  
  
**12.** The movement of peptidyl tRNA from the A site to the P site (of the larger ribosomal subunit) and the movement of mRNA in relation to the ribosome is called :  
Ο translocation  
Ο RNA processing   
Ο dislocation   
Ο elongation   
**Answer:** translocation  
A tRNA molecule enters the large ribosomal subunit through the A site. Follwing this, a peptide bond forms between its amino acid and the one being held in the P site and the tRNA molecule in the P site releases its hold on its amino acid, while the tRNA molecule in the A site moves to the P site. At the same time, the mRNA molecule moves a distance of three bases in order to position the next codon at the A site. This whole process is called translocation.  
  
**13.** Which of the following statements is correct ?  
Ο Methionine is found at the N-terminus of nearly all newly synthesised eukaryotic proteins.   
Ο Each mRNA molecule is usually translated into, hundreds of copies of a single polypeptide chain.   
Ο In prokaryotes, both transcription and translation take place in the same part of the nucleus.   
Ο All of the above.  
**Answer:** All of the above.  
In prokaryotes, both transcription and translation take place in the cytoplasm.  
  
**14.** The enzyme that forms a peptide bond between adjacent amino acids in the ribosome during translation is called :  
Ο peptidyl transferase  
Ο Deiodinase   
Ο Diastase   
Ο Phospholipase   
**Answer:** peptidyl transferase  
Peptidyl transferase catalyses peptide bond formation between adjacent amino acids in the ribosome during translation.  
  
**15.** Synthesis of proteins can take place quickly by multiple ribosomes being able to attach themselves to one mRNA chain. An mRNA chain with multiple ribosomes is called :  
Ο a polysome  
Ο a peroxisome   
Ο a lysosome   
Ο a centrosome   
**Answer:** a polysome  
A cluster of several ribosomes simultaneously translating the same mRNA is called a polysome (short form for polyribosome !).  
  
**16.** The difference in the products translated from a tricistronic mRNA molecule by the ribosomes of prokaryotes and eukaryotes is that :  
Ο the prokaryotic ribosome translates only one cistron while the eukaryotic ribosome translates all cistrons.   
Ο the eukaryotic ribosome will produce one polyprotein instead of three smaller proteins.   
Ο None of the above.   
**Answer:** the eukaryotic ribosome translates only one cistron while the prokaryotic ribosome translates all cistrons.  
In eukaryotes, reinitiation of polypeptide synthesis following an encounter of a ribosome with a stop codon does not occur. Eukaryotic mRNA is always polycistronic.  
  
**17.** The base inosine is usually found in :  
Ο tRNA  
Ο mRNA   
Ο rRNA   
Ο hnRNA   
**Answer:** tRNA  
The base inosine is found in the anticodons of several tRNA molecules.  
  
**18.** Which of the following pairs of codons encode the same protein ?  
Ο GUA and GUG  
Ο AUG and AUC   
Ο UAA and UAC   
Ο UAG and UAC   
**Answer:** GUA and GUG  
UAA, UAG are stop codons and do not encode any proteins. AUG is the only codon that encodes methionine. This eliminates all options except GUA and GUG.  
  
**19.** The triplet base sequence in DNA that is translated into a stop codon, whose corresponding tRNA anticodon, is AUU is given by :  
Ο ATT  
Ο TAA   
Ο CGG   
Ο GCC   
**Answer:** ATT  
The tRNA anticodon corresponding to the codon in question is AUU. Hence, the base sequence of the corresponding codon is UAA (a stop codon). The DNA sequence that corresponds to the RNA sequence UAA, is ATT.  
  
**20.** How many amino acids are encoded by the following mRNA sequence : UAUCAUCCACUUGGUUGA ?  
Ο 5  
Ο 6   
Ο 4   
Ο 7   
**Answer:** 5  
The last codon UGA is a stop codon. All the other codons in the sequence encode specific amino acids. Since there are five codons other than the stop codon, the correct answer is 5.