DAY THIRTY ONE

Evolution

Learning & Revision for the Day

- Origin of Universe
- Origin of Earth
- Origin of Life
- Evidences for Biological or Organic Evolution
- Theories of Evolution
- Mechanism of Evolution
- Adaptive Radiation
- Hardy-Weinberg Law
- Human Evolution

The two important aspects of life are, its origin and evolution and the branch of science which deals with these two aspects is called **evolutionary biology**. The principle of evolution implies the development of a living entity in the due course of time through a gradual sequence of changes, from simple to more complex state. **Biopoiesis** refers to the origin of life forms from non-living substances, while **biogenesis** is the term used to refer to the origin of life from already existing life forms.

Origin of Universe

According to Big Bang Theory of **Abbe Lemaitre** (1931), about 13.3 billion years ago, our solar system was created from a gaseous cloud called **solar nebula** (Kant; 1753) which started to collapse under the force of gravity. It became a group of flattened spinning discs of atoms and particles. Its central region became the 'sun' and dust grains aggregated into clumps and formed into planets.

Origin of Earth

Earth was supposed to have been formed about 4.5 billion years back. It was in molten state, which after cooling resulted in huge emission of carbon dioxide, water vapours, methane and ammonia. The distinction between primitive atmosphere and recent atmospheric conditions of earth are shown in the table below

Distinction between primitive and recent atmospheric conditions of earth

Contents	Primitive atmosphere	Recent atmosphere
Nature	Reducing	Oxidising
Gases (dominant)	Methane (CH_4), ammonia (NH_3), hydrogen (H_2), water (H_2O), etc.	Nitrogen (N_2) oxygen (O_2), carbon dioxide (CO_2), etc.
Free oxygen	Absent	Present
Free hydrogen	Present	Almost absent
Conditions for origin of life	Favourable	Unfavourable
Ultraviolet rays (UV) and cosmic rays	Reaching directly to earth's surface	Absorbed by ozone layer
Temperature	High	Normal
Rainfall and electric storms	High	Normal

Origin of Life

Life on earth appeared 500 million years after its formation. Different theories related to origin of life were given by different thinkers and scientists as discussed below

1. **Theory of Special Creation** This theory was given by Father Suarez and supported by Milton. According to this theory, life is considered to be created by a supernatural power, like god.
2. **Theory of Spontaneous Generation** This theory is also called theory of abiogenesis or autobiogenesis. According to this theory, life has originated from non-living matter automatically.

   It was given by Anaximander, Thales Aristotle, Xenophanes, Plato and van Helmont. The various experiments which discarded this theory are

   - **Francisco Redi's experiment** (1668) He placed well cooked meat in three jars. First jar was uncovered, second was covered by parchment and third by muslin cloth. After some days, he observed that the maggots developed only in uncovered jar.
   - **Lazzaro Spallanzani's experiment** (1767) He took boiled nutritive broth in the vessels and then sealed them. But he always found that, if proper care is taken, no living things appear.
   - **Louis Pasteur's experiment** (1860-1862) He disproved the theory of spontaneous generation by performing a well-designed experiment called swan-necked flask experiment. In his experiment, he kept killed yeast cells in pre-sterilised flask and another flask open into air. The life did not evolved in the former but new living organisms evolved in the later flask.
3. **Theory of Biogenesis** The above experiments discarded the theory of abiogenesis but gave the basics of a new theory, i.e. theory of biogenesis. According to this theory life originates from pre-existing life.
4. **Theory of Cosmozoic Origin** According to this theory, the living objects were formed on earth as a result of the protoplasm which reached on earth, in the form of cosmozoa.
5. **Theory of Panspermia** According to this theory as proposed by Arrhenius (1908) the life on earth has originated as a result of infection from other galaxies.
6. **Theory of Catastrophism** This theory was supported by Cuvier. According to this theory, a catastroph occurred at the end of each age which killed almost all living beings of that age and gave rise to new life.

Modern Theory of Origin of Life

- This theory was given by **AI Oparin** in his book '*Origin of Life*' in 1936 and supported by **JBS Haldane**. According to this theory, life originated on earth after a long period of abiogenic molecular evolution called chemical evolution followed by biological evolution.
- This theory was supported experimentally by Miller and Urey (1953). They designed an apparatus and created an environment very similar to the primitive atmosphere of earth.
- They took hydrogen (H_2), ammonia (NH_3), methane (CH_4) in the ratio $2:1:2$ and supplied energy to the apparatus by heating and giving electric discharge through high electric voltage.
- After continuous heating, cooling, circulation and electrical discharge, an acidic turbid red liquid was obtained which was rich in organic substances. Some products formed under prebiotic conditions are given as follows
  - **Carboxylic acid** Formic acid, acetic acid, propionic acid, fatty acids (C_4 - C_{10}), glycolic acid, succinic acid, lactic acid.
  - **Nucleic acid bases** Adenine, guanine, xanthine, hypoxanthine, cytosine and uracil.
  - **Amino acids** Glycine, alanine, α-amino butyric acid, valine, leucine, isoleucine, proline, aspartic acid, serine and threonine.
- Thus, the origin of life is considered as the result of a long series of physicochemical changes, which brought about first by chemical evolution and which was then followed by biological evolution.

Chemical Evolution

It occurs in following steps

- **Formation of early molecules** Due to gradual fall in temperature free atoms interacted to form lighter compounds.
- **Formation of simple organic molecules** The high concentration of simple molecules made them to react and form hydrocarbons. The further interaction of saturated and unsaturated hydrocarbons produced simple sugars and nitrogenous bases.
- **Formation of large organic molecules** Polymerisation of simple organic molecules lead to the formation of large organic molecules, e.g. Sugar + Sugar + ... $(n) \rightarrow$ Polysaccharide, Amino acid + Amino acid + ... $(n) \rightarrow$ Polypeptide.

- **Formation of complex organic compounds**, e.g. Nucleotide + Nucleotide ..... + $(n) \rightarrow$ Nucleic acid, Adenine + PO_4 + PO_4 + PO_4 $\rightarrow$ Adenosine Triphosphate (ATP).

Biological Evolution

It occurs in following steps

- **Formation of coacervates** The organic macromolecules aggregated into various combinations due to intermolecular attractions and precipitated out in the aqueous medium in the form of large colloidal particles. These colloids were called coacervates by Oparin and microspheres by Sydney Fox.
- **Formation of protocells or Eobionts or protobionts** These are nucleoprotenoid molecules having free living gene which are similar to present day mycoplasma and viruses.
- **Origin of prokaryotes** The protobionts gave rise to prokaryotic organisms. With this origin, two important event took place.
  - **Evolution of modes of nutrition** Perhaps the first living organisms were **chemoheterotrophs**, which obtained energy by fermentation in the sea. As these organisms multiplied rapidly, the nutrients in sea water began to depleted, which leads to the evolution of **chemoautotrophs**. These were the forerunners or photosynthetic cells as they released large amount of carbon dioxide in the atmosphere that paved way for utilisation of carbon dioxide in photosynthesis. The equation is as follows

$$C_6H_{12}O_6 \xrightarrow[\text{Enzymes}]{\text{Fermentation}} C_5H_5OH + 2\ CO_2 + \text{Energy}$$

The first photoautotrophs were anaerobic, which did not use water and did not release oxygen. They performed anoxygenic photosynthesis and released sulphur as waste product.

$$6\ CO_2 + 12H_2S \xrightarrow[\text{Chemical energy}]{\text{Fermentation}} C_6H_{12}O_6 + 6H_2O + 12S$$

Aerobic photoautotroph developed about 3300-3500 million years ago as the result of accumulation of CO_2 in the atmosphere.

- **Oxygen revolution** As the number of photoautotrophs increased, oxygen was liberated. This oxygen led to the conversion of dominant methane and ammonia to carbon dioxide and free nitrogen respectively.

$$CH_4 + 2\ O_2 \longrightarrow CO_2 + 2H_2O$$
$$4NH_4 + 6\ O_2 \longrightarrow 2N_2 + 12H_2O$$

- **Origin of eukaryotes** The increased atmospheric oxygen led to evolution of eukaryotic cells. The most accepted theory for the origin of eukaryotic cell was given by **Lynn Marguilis**.
- **Cognogeny** It is the last step of gradual transformation of inorganic compounds to organic compounds and organic compounds to protocell (life). It involves diversification of Protozoa into Metazoa and Metaphyte and various other characters.

Evidences for Biological or Organic Evolution

The fact that evolution has taken place can be established by taking several kinds of evidences including direct evidences, which are provided by fossil record and indirect evidences, which are available from the study of organisms that are existing today.

1. Evidences from Palaeontology

- **Fossils** are the material remains (bones, teeth and shells) or traces of ancient organisms.
- Palaeontology is the study of fossils of past life.
- **Palaeobotany** deals with the study of plant fossils including study of fossil pollens (i.e. Palynology), whereas, **Palaeozoology** deals with the study of animal fossils.
- Some techniques used in dating of rocks are
  - Radiocarbon dating
  - Potassium-argon (40K/40Ar) and Argon-argon (40Ar/39Ar) dating
  - Uranium series dating
  - Fission track dating
  - Luminescence dating
  - Electron-Spin Resonance (ESR) dating (It is the most accurate method)
- The complete lifespan of earth (i.e. 4600 million years) is known as **geological time**, which have been divided into eras, eras into periods and further periods into epochs.
- The arrangement of eras, periods and epochs on the time scale according to their age is called **geological time scale**.

NOTE
- **Birbal Sahni** is called Father of Indian Palaeobotany. By the initiative of **Prof. Birbal Sahni**, Institute of Palaeobotany was established at Lucknow in 1946.
- An Italian scientist Giovanni Ardulna, developed first geological time scale in 1760.

Geological Time Scale (To be read from below upwards)

Era	Period Age in million years	Epoch Age in million years	**Some Important Fauna** (Animals) **and Flora** (Plants)
Cenozoic (Era of Modern life)	**Quarternary**	Recent (Holocene) 0.01	Modern man dominant, Modern mammals, birds, fishes, insects. Rise of herbaceous plants, decline of woody plants.
		Pleistocene 1.8	Ice ages, humans appear, evolution of human society and culture.
	Tertiary	Pliocene (Age of mammals) 5	Ape-like ancestors of humans appear, adaptive radiation of flowering plants, origin of man.
		Miocene 23	Continued radiation of mammals and angiosperms.
		Oligocene 34	Origin of most modern mammalian orders including apes.
		Eocene 57	Dominance of angiosperm increases, further increase in mammalian diversity, origin of **horse**.
		Palaeocene 65	Major radiation of mammals, birds and pollinating insects. Primitive primates appear.
Mesozoic (Age of Reptiles)	Cretaceous 144		Extinction of dinosaurs and tooth containing birds. Angiosperms (flowering plants) appeared.
	Jurassic 208 (Golden era of Reptiles)		Dinosaurs dominant, origin of tooth containing birds (first birds), gymnosperms were dominant.
	Triassic 245		Origin of dinosaurs and mammals.
Palaeozoic (Era of Ancient life)	Permian 285		Extinction of trilobites. Origin of mammal-like reptile and most modern orders of insects.
	Carboniferous 360 (Age of amphibians)		Origin of reptiles, amphibians were dominant, extensive forests of vascular plants, first seed plants appeared.
	Devonian 408 (Age of fishes)		Origin of amphibians, diversification of bony fishes, origin of gymnosperms.
	Silurian 438		Origin of jawed fishes, colonisation of land by plants and arthropods, origin of vascular plants.
	Ordovician 505 (Age of invertebrates)		Origin of first vertebrates, e.g. Ostracoderms (jawless fishes), Invertebrates and marine algae were abundant. Also called 'age of molluscs'.
	Cambrian 544		Origin of most invertebrate phyla, origin of trilobites.
Precambrian (From 570 to 4600 million years ago)	570		Diversification of algae
	700		Origin of first animals
	1500		Oldest eukaryotic fossils
	2500		Oxygen begins accumulating in atmosphere
	3500		Oldest definite fossils known (prokaryotes)
	4600		Approximate origin of earth.

NOTE • The order of horse is Perissodactyla which includes odd toed mammals, e.g. donkey, one-horned rhinoceros, etc.

2. Evidences from Comparative Anatomy

It includes following evidences

- **Homologous organs** are those, which have the same basic structure, but perform different functions. They show divergent evolution, e.g. forelimbs of vertebrates, legs of insects, phyllode or phylloclade of *Opuntia*, *Ruscus* and cladode of *Asparagus*, haemoglobin of fish and reptiles, etc.
- **Analogous organs** are those that are different in basic structure and origin, but perform similar functions. They show convergent evolution, e.g. insect and bird's wings are different in basic structure and origin because insect wing is formed from integument, while the bird's wing is a modified forelimb, but functionally both are adapted for flight.
- **Vestigial organs** are non-functional organs in an organism, which are functional in related animals and were functional

in the ancestors also. Coccyx (tail bone), nictitating membrane (3rd eyelid), caecum, vermiform appendix, canines, wisdom teeth, body hair, external ear muscles, mammary glands in males, etc., are vestigial organs in human body.

- **Atavism or Reversion** is the sudden reappearance or refunctioning of some ancestral organs, which have either completely disappeared or are present as vestigial organs.

3. Evidences from Embryology

- **von Baer** (1792-1867) proposed Baer's law in 1828, which states that 'during embryonic development, general characters appear before specialised characters, an animal departs progressively from the form of other animals and organisms of different groups resemble with their embryos'.
- **Ernst Haeckel** (1866), an embryologist, proposed **biogenetic law**, which states that 'ontogeny recapitulates phylogeny'. It means evolutionary history (phylogeny) of a species is indicated by the development stages (ontogeny) that it passes through.
  Hence, resemblance of amphibian to fish is seen in most systems of body as both are cold-blooded, respire by gills and lay eggs in water. It shows amphibians have originated from fishes.

4. Evidences from Connecting Links

Organism, which exhibits characteristics of more than one groups are known of connecting link of those groups. For example,

Organism	Connecting link between
Virus	Non-living and living
Euglena	Animals and plants
Peripatus	Annelida and Arthropoda
Neopilina	Annelida and Mollusca
Chimaera	Bony fishes and cartilaginous fishes
Proterospongia	Protozoa and Porifera
Echidna	Reptiles and mammals

5. Molecular Evidences

- Metabolic reactions are present in all living beings from bacteria to man.
- Trypsin and amylase enzymes are same in all animals.
- Cytochrome-*c* is a respiratory pigment found in all eukaryotic cells.
- A, B, AB and O types of blood groups are found in humans while apes has only A and B type and monkeys lack such type of blood groups. This indicates that humans are more closely related to apes than monkeys.

Theories of Evolution

A number of biologist proposed various theories for explaining evolution. The most accepted were theories of Lamarck and Darwin.

1. **Lamarckism** (Theory of inheritance of acquired characters) The first theory of evolution was proposed by **Jean Baptiste de Lamarck** (1744-1829), a French biologist.

   His famous book '***Philosophie Zoologique***' was published in 1809, in which, he discussed his theory in detail.

   - Propositions of Lamarckism are
     - Internal vital force
     - Effect of environment
     - New need
     - Use and disuse of organs
     - Inheritance of acquired character
   - Evidences against Lamarckism include
     - There is no vital force in organisms, which increases their body parts.
     - The environment can affect the animals but it is doubtful that a need forms new structures.
     - The use and disuse of organs is correct only up to some extent.
     - The inheritance of acquired characters is disputed.
   - **Neo-Lamarckism** is a modification of the original theory of Lamarck in order to make it more suitable to modern knowledge.
     - Neo-Lamarckism does not give any importance to the factors of Lamarckism.
     - The theory stresses on the direct effect of changed environment on the organism.
     - Normally only those modifications are transferred to the next generation, which influence germ cells or where somatic cells give rise to germ cells.
2. **Darwinism** (Theory of natural selection) It includes the most impressive study on evolution made by **Charles Darwin**.

   His principal publication, ***The Origin of Species*** by means of natural selection or the preservation of favoured races in the struggle for life appeared in 1859.

Darwin's main idea about evolution includes

- **Overproduction** (rapid multiplication) All organisms possess enormous fertility. They multiply in geometric ratio.

- **Limited food and space** Despite of rapid multiplication, food, space and other resources remain limited.
- **Struggle for existence** The struggle for those basic and limited factors of life can be of following three types; intraspecific, interspecific and environmental struggle.
- **Variations** Except the identical twins, no two individuals are similar and their requirement is different.
- **Inheritance of useful variations** The organisms after getting fitted to the surrounding transmit their useful variations to the next generations, while the non-useful variations are eliminated.
- **Formation of new species** According to Darwin, useful variations are transmitted to the offspring which appear more prominently in succeeding generations resulting in formation of a new species after several generations.
- **Selection by nature** The new species with favourable variations are selected by nature called **natural selection.**

3. **Mutation Theory**
It was proposed by Hugo de Vries in order to explain the mechanism of evolution and was published in his book entitled '*Die Mutation Theorie*' (1901). The mutation theory emphasises on discontinuous variations or saltatory variations which he termed as mutation. Salient features of mutation theory are as follows
   - Mutation is the raw material and a basic requirement of evolution.
   - Sometimes mutations are the cause of new species formation.
   - Mutations are not small changes, but are large and help in changing the organism's physiology comprehensively.
   - Mutation are the changes which are inherited from one generation to next and are the basis of natural selection.
   - Mutation can occur in any direction and may be harmful or useful. Harmful mutations can eliminated, while useful ones are naturally selected.

4. Modern Synthetic Theory of Evolution

The modern theory of origin of species or evolution is known as **Modern Synthetic Theory of Evolution.** It is the combination of Darwinian selection and genetic theory. This concept evolved after a book by **Julian Huxley** (1942) entitled ***Evolution, The Modern Synthesis. Theodosius Dobzhansky*** reviewed the Darwinian concept of evolution by natural selection in **Mendelian populations.**

This theory recognises four basic types of processes

(i) Gene mutations
(ii) Changes in chromosome structure and number
(iii) Genetic recombination
(iv) Natural selection

- Besides these, following three accessory processes affect the working of above four basic processes

  (a) Migration (b) Hybridisation (c) Genetic drift
- **Gene mutations** are the changes in chromosome structure and number and genetic recombination which provide genetic variability.
- **Migration** involves movement of individuals from one population to another and **hybridisation** between races or closely related species, both increase the genetic **variability**.
- The effect of **genetic drift**, acting on small population may alter the way.
- All sexually reproducing organisms contain a large gene pool of genetic variability, which maintains a dynamic equilibrium between inflow and outflow of genes.
- Genes may be added to gene pool by immigration from other gene pool and mutation.
- **Natural selection**, which results from interaction between populations and their environment, may either stabilise gene composition by eliminating most immigrants and mutants or change it in various ways.
- **Reproductive isolation,** which includes all the barriers to gene exchange between populations has a canalising effect.

Ecogeographical Rules-Size, Shapes and Colour

- **Bergman's law** Warm-blooded animals are larger in size in the colder regions as compared to warm region.
- **Allen's law** Extremities like tail, ears become smaller in colder area.
- **Gloger's rule** Warm-blooded animals have more melanin in hot wet areas but develop yellow-red pigment in hot dry areas.
- **Jordan's law** Fishes of colder water have larger size with more vertebrae than the fishes of warmer waters.
- **Cope's law** In the course of evolution, there is tendency in animals to increase in size, e.g. dinosaurs.

Mechanism of Evolution

Evolution is a change in a population, alleles and genotype from generations to generation. There are five basic mechanisms by which evolution takes place. These include mutation, genetic recombination, migration, genetic drift and selection.

1. Mutation

It is sudden and heritable change in an organism. Joshua Lederberg and Esther Lederberg (1952) conducted experiments to demonstrate the genetic basis of drug resistant mutation in *E.coli* by using the replica plating technique. It helps in the accumulation of variations which results in large variations and formation of new species.

2. Genetic Recombination

The alleles of parental linkage groups separate and new associations of alleles are formed due to crossing over in meiosis in the gamete cells. This process is known as genetic recombination.

3. Gene Migration (Gene Flow)

- The movement of individuals from one place to another is called migration. It can be a powerful agent of change because the members of two different populations may exchange genetic material.
- Sometimes gene flow is obvious when an animal moves from one place to another. When a new individual have unique gene combination and is well adapted, it alters the genetic composition of receiving populations.

4. Genetic Drift (Random Drifts)

In small population, frequencies of particular allele may change drastically by chance alone. Such change in allele frequencies occur randomly as if the frequencies were drifting and are thus known as genetic drift. There are two special cases of genetic drift

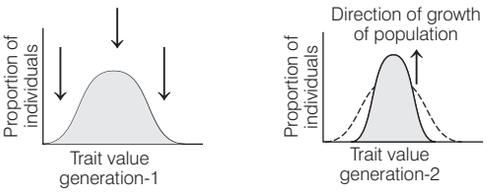
- **Founder effect/Founder principle** It is noted that when a small group of individuals called founders, leave their place of origin and find new settlements, the population in the new settlement may have unique genotypic frequency from that of the parent population. Formation of a different genotype in new settlement is called founder's effect.
- **Bottleneck effect** Due to several natural causes, the population decline even if the organisms do not move from one place to another. A few surviving individuals may constitute a random genetic sample of the original population. The resultant alterations and loss of genetic variability has been termed as bottleneck effect.

5. Selection

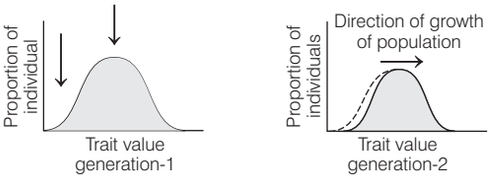
Darwin and **Wallace** explained the differential reproduction as the result of selection. It is of two types as :

- **Artificial selection** In this the breeder select the desired characteristic.
- **Natural selection** Environmental conditions determine that which individual in the population produces the maximum number of offsprings. On the basis of environmental conditions, natural selection can be categorised as follows:

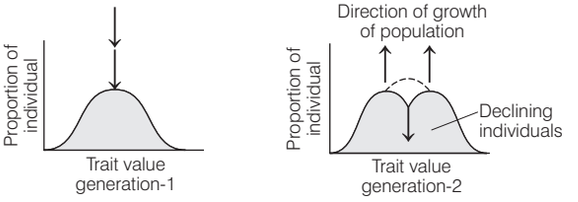
1. **Stabilising or Normalising Selection**
   This occurs when environment does not change and it cause no pressure on well adapted species.



2. **Directional Selection**
   This occurs when environment changes in a particular way and it causes a selective pressure for the species to change in response to environment.



3. **Disruptive or Diverging Selection**
   This occurs when environmental change may produce selection pressure that favours two extreme characteristics.



Modes of natural selection

Industrial Melanism

- It is one of the most classic example of natural selection. Industrial melanism refers to the evolution of dark body colours in animal species that live in habitats blackened by industrial soot.
- This phenomenon has been documented in numerous species that hide from predators by blending in with their backgrounds. Peppered moths (*Biston betularia*) provide one example.
- Before the industrial revolution, peppered moths in the UK were pale grey in colour, but after their habitats became polluted with soot from coal-fired, industrial melanic (black) phenotypes became numerous and spread to other regions. Away from industrial centres, the pale phenotype remained common.
- Following clean air legislation a century later, the atmosphere improved, soot-damaged habitats gradually recovered and the pale phenotype returned as the predominant form. Parallel changes have occurred in America.
- The melanic and pale phenotypes are determined by genes, and the changes in their percentages in populations reflect natural selection.
- Experiments by Kettlewel identify bird predation on the moth phenotypes as the agent of selection. This is because

in non-sooty environment melanic forms could not survive as birds devoured them and *vice-versa*.

Adaptive Radiation

It is an evolutionary process in which an ancestral stock gives rise to new species adapted to new habitats and new ways of life. Examples of adaptive radiation include

- **Darwin's finches** were small black birds, which Darwin observed in Galapagos islands. There were many varieties in the same kind. Darwin reasoned that after originating from a common ancestral seed-eating stock, the finches must have radiated to different geographical areas and undergone adapative changes, especially in the type of beak. Living in isolation for long, the new kinds of finches emerged that could function and survive in the new habitats.
- A number of **Australian marsupials**, each different from the other, evolved from an ancestral stock within Australia.
- When one or more than one adaptive radiation appeared to have occurred in an isolated geographical area with different habitats, it can be called as **convergent evolution**.

Hardy-Weinberg Law

- This law states that the gene and genotypic frequencies in a Mendelian population remain constant generation after generation, if there is no selection, mutation, migration or random drift.
- Hardy-Weinberg used the binomial expression $p^2 + 2pq + q^2$ to calculate the genotypic and allele frequencies of a population.

The original proportions of the genotype in a population will remain constant from generation to generation as long as

(i) The population size is very large.
(ii) Random mating is occurring.
(iii) No mutation takes place.
(iv) No genes input from other sources (i.e. no immigration).
(v) No selection occurs.

Human Evolution

The common ancestor of apes and humans is a primate *Dryopithecus*, that lived 15 million years ago. The next stage in the hominid evolution is *Ramapithecus*. After this, human evolution is as follows

1. ***Australopithecus*** They were first ape man found in African Pliocene era rocks, 5mya (million years ago) They had a brain capacity of 450-600 cc. They were about 4 feet tall and walked nearly upright. They hunted with stone weapons, but ate fruits. They were found in Tanzania and Ethiopia.
2. ***Homo habilis*** They lived in East African grasslands. They had a brain capacity of 650-800 cc. They probably did not eat meat and believed to be present in East Africa 2 mya in Pliocene era.
3. ***Homo erectus*** Their fossils were found in Java. They had a brain capacity of about 900 cc. They probably ate meat. It includes Peking man, Java man and Heidelberg man.
4. ***Homo sapiens*** Their fossils were found in East and Central Asia. The brain capacity was about 1400 cc. They lived between 1,00,000-40,000 years before. They used hides to protect the body and also buried the body after death.

   They became extinct about 25,000 years before. It includes neanderthal man and cro-Magnon man.
5. ***Homo sapiens sapiens*** They arose during the ice age between 75,000-10,000 years ago and learned to cultivate plants and domesticate animals. Agriculture started around 10,000 years back. They started human settlement and civilisation.

NOTE • The most significant trend in evolution of modern man is increased brain capacity.

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 Which of the following was probably not present in large amount in the atmosphere at the time of origin of life?
(a) Water (b) Hydrogen
(c) Oxygen (d) Carbon dioxide

2 Abiogenesis means
(a) spontaneous generation
(b) germplasm theory
(c) origin of panspermia
(d) physicochemical origin of life

3 Theory of spontaneous generation was given by
(a) Redi
(b) Pasteur
(c) Spallanzani
(d) von Helmont

4 Who proved that life on present earth can originate only from pre-existing life?
(a) Louis Pasteur (b) Charles Darwin
(c) Boxmann (d) Weismann

5 Which one of the following experiments suggests that simplest living organisms could not have originated spontaneously from non-living matter?
(a) Larvae could appear in decaying organic matter
(b) Microbes did not appear in stored meat
(c) Microbes appeared from unsterilised organic matter
(d) Meat was not spoiled, when heated and kept sealed in a vessel

6 According to Oparin, which one of the following was not present in the primitive atmosphere of the earth?
(a) Methane (b) Oxygen
(c) Hydrogen (d) Water vapour

7 Which organic compounds have first evolved in the direction of origin of life on the earth?
(a) Urea and amino acids
(b) Urea and nucleic acids
(c) Proteins and nucleic acids
(d) Proteins and amino acids

8 Which of the following has replaced methane of the primitive atmosphere as the major carbon containing compounds of the present day earth's atmosphere?
(a) Coal (b) Carbon dioxide
(c) Carbon monoxide (d) Hydrocarbons

9 During the time of 'origin of life', the water of primitive ocean has been called 'hot dilute soup of organic substances' by
(a) Miller (b) Oparin
(c) Haldane (d) Sydney Fox

10 Which one of the following amino acids was not found to be synthesised in Miller's experiment?
(a) Aspartic acid (b) Glutamic acid
(c) Alanine (d) Glycine

11 The concept of chemical evolution is based on
(a) crystallisation of chemicals
(b) interaction of water, air and clay under intense heat
(c) effect of solar radiation on chemicals
(d) possible origin of life by combination of chemicals under suitable environmental conditions

12 Under certain conditions, the scientists have obtained cell-like structures, but no true organisation of a cell, these are referred as
(a) coacervates (b) microbes
(c) eobionts (d) protists

13 Which one of the following is incorrect about the characteristics of protobionts (coacervates and microspheres) as envisaged in the abiogenic origin of life?
(a) They were able to reproduce
(b) They could separate combinations of molecules from the surroundings
(c) They were partially isolated from the surroundings
(d) They could maintain an internal environment

14 Following are the two statements regarding the origin of life → NEET-I 2016
I. The earliest organisms that appeared on the earth were non-green and presumably anaerobes.
II. The first autotrophic organisms were the chemoautotrophs that never released oxygen.
Of the above statements which one of the following options is correct?
(a) II is correct but I is false (b) Both I and II are correct
(c) Both I and II are false (d) I is correct but II is false

15 Which of the following is the correct sequence of events in the origin of life? → NEET-I 2016
I. Formation of protobionts.
II. Synthesis of organic monomers.
III. Synthesis of organic polymers.
IV. Formation of DNA based genetic systems.
(a) I, II, III, IV (b) I, III, II, IV
(c) II, III, I, IV (d) II, III, IV, I

16 Study of fossils is called
(a) organic evolution (b) Herpetology
(c) Cytology (d) Palaeontology

17 Evolutionary history of an organism is known as
(a) phylogeny (b) ancestry
(c) palaeontology (d) ontogeny

18 Age of fossils in the past was generally determined by radio-carbon method and other methods involving radioactive elements found in the rocks. More precise methods, which were used recently and led to the revision of the evolutionary periods for different groups of organisms, include
(a) study of carbohydrates/proteins in fossils
(b) study of the conditions of fossilisation
(c) Electron Spin Resonance (ESR) and fossil DNA
(d) study of carbohydrates/proteins in rocks

19 Which era could be called the 'age of mammals and birds'?
(a) Mesozoic (b) Cenozoic
(c) Palaeozoic (d) Cretaceous

20 Match the following columns.

	Column I (Era)		Column II (Event)
A.	Proterozoic	1.	Major radiations of flowering plants, insects, birds, mammals, emergence of human forms
B.	Palaeozoic	2.	Major radiations of dinosaurs, origin of flowering plants and mammals
C.	Mesozoic	3.	Rise of early plants on land, origin of amphibians and origin of reptiles
D.	Cenozoic	4.	Origin of protists, fungi and animals

Codes

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	3	4	1	2
(c)	4	3	2	1	(d)	3	2	4	1

21 Which of the following represents order of 'Horse'?
→ NEET 2017

(a) Equidae (b) Perissodactyla
(c) Caballus (d) Ferus

22 The similarity of bone structure in the forelimbs of many vertebrates is an example of → NEET 2018

(a) convergent evolution
(b) analogy
(c) homology
(d) adaptive radiation

23 Among the following sets of examples for divergent evolution, select the incorrect option. → NEEET 2018

(a) Brain of bat, man and cheetah
(b) Heart of bat, man and cheetah
(c) Forelimbs of man, bat and cheetah
(d) Eye of *Octopus*, bat and man

24 Analogous structures are a result of → NEET-I 2016

(a) convergent evolution
(b) shared ancestry
(c) stabilising selection
(d) divergent evolution

25 Which of the following structures is homologous to the wing of a bird? → NEET-I 2016

(a) Wing of a moth
(b) Hindlimb of rabbit
(c) Flipper of whale
(d) Dorsal fin of a shark

26 Forelimbs of cat and lizard are used in walking, forelimbs of whale are used in swimming and forelimbs of bats used in flying are an example of → CBSE-AIPMT 2014

(a) analogous organs (b) adaptive radiation
(c) homologous organs (d) convergent evolution

27 Which one of the following is analogous structures?
→ CBSE-AIPMT 2014

(a) Wings of bat and wings of pigeon
(b) Gills of prawn and lungs of man
(c) Thorns of *Bougainvillea* and tendrils of *Cucurbita*
(d) Flippers of dolphin and legs of horse

28 The eyes of *Octopus* and eyes of cat show different patterns of structure, yet they perform similar function. This is an example of → NEET 2013

(a) homologous organs that have evolved due to convergent evolution
(b) homologous organs that have evolved due to divergent evolution
(c) analogous organs that have evolved due to convergent evolution
(d) analogous organs that have evolved due to divergent evolution

29 The process by which organisms with different evolutionary history evolve similar phenotypic adaptations in response to a common environmental challenge, is called → NEET 2013

(a) natural selection (b) convergent evolution
(c) non-random evolution (d) adaptive radiation

30 Which is not a vestigial part in humans?

(a) Segmental muscles of abdomen
(b) Finger nails
(c) Third molar
(d) Coccyx

31 Being all mammals, whale, dolphin, bat, monkey and horse have some common characters but they also show conspicuous differences. This is due to the phenomenon of

(a) genetic drift (b) convergence
(c) divergence (d) normalisation

32 The reappearance of an ancestral character in the present day organism is called

(a) vestigial organ (b) fossil
(c) atavism (d) Palaeontology

33 Which one of the following options gives one correct example each of convergent evolution and divergent evolution?

	Convergent Evolution	Divergent Evolution
(a)	Eyes of *Octopus* and mammals	Bones of forelimbs of vertebrates
(b)	Thorns of *Bougainvillea* and tendrils of *Cucurbita*	Wings of butterflies and birds
(c)	Bones of forelimbs of vertebrates	Wings of butterfly and birds
(d)	Thorns of *Bougainvillea* and tendrils of *Cucurbita*	Eyes of *Octopus* and mammals

34 The rule of embryonic development is given by

(a) von Baer (b) Haeckel
(c) Mendel (d) Darwin

35 In the developmental history of mammalian heart, it is observed that it passes through a two-chambered fish-like heart, three-chambered frog-like heart and finally four-chambered stage. To which hypothesis can this above cited statement be approximated?

(a) Biogenetic law
(b) Hardy-Weinberg law
(c) Lamarck's principle
(d) Mendelian principle

36 *Peripatus* is a connecting link between

(a) Ctenophora and Platyhelminthes
(b) Mollusca and Echinodermata
(c) Annelida and Arthropoda
(d) Coelenterata and Porifera

37 Cytochrome-*c* was used as an evidence for organic evolution by

(a) Krebs (b) Nuttall (c) Calvin (d) Dickerson

38 What kind of evidence suggested that man is more closely related with chimpanzee than with other hominoid apes?

(a) Evidence from DNA from sex chromosomes only
(b) Comparison of chromosomes morphology only
(c) Evidence from fossil remains and the fossil mitochondrial DNA alone
(d) Evidence from DNA extracted from sex chromosomes, autosomes and mitochondria

39 Which of the following is a true statement about Lamarck?

(a) He was first to realise that earth is billion of year old
(b) He worked out the principles of population genetics
(c) He based his theory on the inheritance of acquired characters
(d) He proposed natural selection as mechanism evolution

40 The objections to Darwin's theory of natural selection is/are

(a) no differentiation between somatic and germinal variation
(b) it fails to explain the role of discontinuous variation
(c) it fails to explain the possible reason behind over speciation
(d) All of the above

41 According to the Neo-Darwinian theory, which of the following is responsible for the origin of new species?

(a) Mutations
(b) Useful variations
(c) Mutations together with natural selection
(d) Hybridisation

42 Which of the following is not a part of Darwin's theory of evolution?

(a) Genetic drift (b) Natural selection
(c) Survival of the fittest (d) Struggle for existence

43 Match the following columns.

	Column I		Column II
A.	Palaeontology	1.	Change in chromosomes
B.	Mutation theory	2.	Genetic drift
C.	Gene mutation	3.	Charles Darwin
D.	Bottle-neck effect	4.	Study of fossils
		5.	Hugo de Vries

Codes

	A	B	C	D
(a)	1	2	3	4
(c)	4	5	1	2

	A	B	C	D
(b)	2	1	3	4
(d)	2	5	4	1

44 The modern synthetic theory of evolution is based on

(a) genetic and chromosomal mutation
(b) genetic recombination and natural selection
(c) reproductive isolation
(d) All of the above

45 Which one of the following sequences was proposed by Darwin and Wallace for organic evolution?

(a) Variations, natural selection, overproduction, constancy of population size
(b) Overproduction, variations, constancy of population size, natural selection
(c) Variations, constancy of population size, overproduction, natural selection
(d) Overproduction, constancy of population size, variations, natural selection

46 Industrial melanism is an example of ➞ CBSE-AIPMT 2015

(a) Neo-Darwinism (b) natural selection
(c) mutation (d) Neo-Lamarckism

47 Industrial melanism as observed in peppered moth proves that

(a) the true black melanic forms arise by a recurring random mutation
(b) the melanic form of the moth has no selective advantage over lighter form in industrial area
(c) the lighter- form moth has no selective advantage either in polluted industrial area or non-polluted area
(d) melanism is a pollution-generated feature

48 Darwin in his natural selection theory did not believe in any role of which one of the following in organic evolution?

(a) Discontinuous variations
(b) Parasites and predators as natural enemies
(c) Survival of the fittest
(d) Struggle for existence

49 Which one of the following phenomena supports Darwin's concept of natural selection in organic evolution?

(a) Development of transgenic animals
(b) Production of 'Dolly' the sheep by cloning
(c) Prevalence of pesticide resistant insects
(d) Development of organs from 'stem cells' for organ transplantation

50 According to Hugo de Vries, the mechanism of evolution is ➞ NEET 2018

(a) phenotypic variations
(b) saltation
(c) multiple step mutations
(d) minor mutations

51 In Lederberg's replica experiment what shall be used to obtain streptomycin resistant strain?

(a) Only minimal medium
(b) Only complete medium
(c) Minimal medium and streptomycin
(d) Complete medium and streptomycin

52 In term of gene frequencies, founder effect results in

(a) polyploidy
(b) hybridisation
(c) large, rapid changes
(d) mechanical incompatibility

53 Genetic drift operates in → NEET-II 2016
(a) small isolated population
(b) large isolated population
(c) non-reproductive population
(d) slow reproductive population

54 Variation in gene frequencies within populations can occur by chance rather than by natural selection. This is referred to as → NEET 2013
(a) genetic flow (b) genetic drift
(c) random mating (d) genetic load

55 Random genetic drift in a population probably results from
(a) large population size
(b) highly genetically variable individuals
(c) interbreeding within this population
(d) constant low mutation rate

56 Darwin's finches are an excellent example of
(a) adaptive radiation (b) seasonal migration
(c) brood parasitism (d) connecting links

57 Evolution of different species in a given area starting from a point and spreading to other geographical areas is known as
(a) adaptive radiation (b) natural selection
(c) migration (d) divergent evolution

58 Adaptive radiation refers to
(a) adaptations due to geographical isolation
(b) evolution of different species from a common ancestor
(c) migration of members of a species to different geographical areas
(d) power of adaptation in an individual to a variety of environments

59 One of the important consequences of geographical isolation is
(a) no change in the isolated fauna
(b) preventing speciation
(c) speciation through reproductive isolation
(d) random creation of new species

60 Select the correct statement from the following given options.
(a) Darwinian variations are small and directionless
(b) Fitness is the end result of the ability to adapt and gets selected by nature
(c) All mammals except whales and camels have seven cervical vertebrae
(d) Mutations are random and directional

61 In which condition the gene ratio remains constant for any species?
(a) Sexual selection (b) Random mating
(c) Mutation (d) Gene flow

62 In Hardy-Weinberg equation, the frequency of heterozygous individual is represented by → NEET-II 2016
(a) p^2 (b) $2pq$ (c) pq (d) q^2

63 *Homo sapiens* evolved during
(a) Pleistocene (b) Oligocene
(c) Pliocene (d) Miocene

64 Among the human ancestors the brain size was, more than 1000 cc in
(a) *Homo neanderthalensis* (b) *Homo erectus*
(c) *Ramapithecus* (d) *Homo habilis*

65 Which one of the following features is closely related with the evolution of humans?
(a) Loss of tail (b) Shortening of jaws
(c) Binocular vision (d) Flat nails

66 What was the most significant trend in the evolution of modern man (*Homo sapiens*) from his ancestors?
(a) Shortening of jaws (b) Binocular vision
(c) Increasing brain capacity (d) Upright posture

67 Which one of the following statements is correct?
(a) Cro-Magnon man's fossil has been found in Ethiopia
(b) *Homo erectus* is the ancestor of man
(c) Neanderthal man is the direct ancestor of *Homo sapiens*
(d) *Australopithecus* is the real ancestor of modern man

68 Which of the following is correct order of evolutionary history of man?
(a) Peking man, *Homo sapiens*, Neanderthal, Cro-Magnon
(b) Peking man, Neanderthal, *Homo sapiens*, Cro-Magnon
(c) Peking man, Heidelberg man, Neanderthal, Cro-Magnon
(d) Peking man, Neanderthal, *Homo sapiens*, Heidelberg man

69 The extinct human who lived 100,000 to 40,000 years ago, in Europe, Asia and parts of Africa, with short stature, heavy eyebrows, retreating foreheads, large jaws with heavy teeth, stocky bodies, a lumbering gait and stooped posture was
(a) *Homo habilis* (b) Neanderthal human
(c) Cro-Magnon human (d) *Ramapithecus*

70 In recent years, DNA sequences (nucleotide sequence) of *mt*DNA and Y-chromosomes were considered for the study of human evolution, because
(a) they can be studied from the samples of fossil remains
(b) they are small and therefore, easy to study
(c) they are uniparental in origin and do not take part in recombination
(d) their structure is known in greater detail

71 Arched palate, uniformed sized teeth were found in which of the following ancestors ?
(a) *Ramapithecus* (b) *Kenyapithecus*
(c) *Dryopithecus* (d) *Shivapithecus*

72 The chronological order of human evolution from early to the recent is
(a) *Australopithecus* → *Ramapithecus* → *Homo habilis* → *Homo erectus*
(b) *Ramapithecus* → *Australopithecus* → *Homo habilis* → *Homo erectus*
(c) *Ramapithecus* → *Homo habilis* → *Australopithecus* → *Homo erectus*
(d) *Australopithecus* → *Homo habilis* → *Ramapithecus* → *Homo erectus*

73 **Assertion** From evolutionary point of view, human gestation period is believed to be shortening.

Reason One major evolutionary trend in humans has been the larger head undergoing relatively faster growth rate in the foetal stage.

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion
(b) If both Assertion and Reason are true, but Reason is not the correct explanation of Assertion
(c) If Assertion is true, but Reason is false
(d) If both Assertion and Reason are false

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 Which one of the following is not a living fossil?
(a) King crab
(b) *Sphenodon*
(c) *Archaeopteryx*
(d) *Peripatus*

2 An imporant evidence in favour of organic evolution is the occurrence of
(a) analogous and vestigial organs
(b) homologous organs only
(c) homologous and analogous organs
(d) homologous and vestigial organs

3 Directional selection
(a) works against adaptive traits
(b) favours intermediate forms of trait
(c) eliminates uncommon forms of an allele
(d) shifts allele frequencies in a steady, consistent direction

4 Genetic drift is the change of
(a) gene frequency in same generation
(b) appearance of recessive genes
(c) gene frequency from one generation to next
(d) None of the above

5 Theory of natural selection dwells on
(a) role of environment in evolution
(b) natural selection acting on favourable variations
(c) changes in gene complex resulting in heritable variations
(d) None of the above

6 Connecting link between annelids and molluscs is
(a) *Limulus* (b) *Peripatus* (c) *Neopilina* (d) *Periplaneta*

7 Which compound had a very important role in prebiotic evolution?
(a) CH_4 (b) NO (c) SO_2 (d) SO_3

8 According to fossils discovered up to present time origin and evolution of man was started from
(a) France (b) Java (c) Africa (d) China

9 Variations during mutations of meiotic recombinations are
(a) random and directionless
(b) random and directional
(c) random and small
(d) random, small and directional

10 Which of the following statements about natural selection is not true?
(a) It can stabilise a gene pool
(b) It can change a gene pool
(c) It can improve the adaptation of species
(d) It can increase mutation rate

11 Which one does not favour Lamarckian concept of inheritance of acquired characters?
(a) Lack of pigment in cave dwellers
(b) Absence of limbs in snakes
(c) Presence of webbed toss in aquatic birds
(d) Melanisation of peppered moth in industrial areas

12 Two populations of a given species will only evolve into two distinct species if they are subjected to
(a) geographical isolation (b) disruptive selection
(c) genetic isolation (d) stabilising selection

13 Darwin's finches provide an excellent evidence in favour of evolution. This evidence comes from the field of
(a) Biogeography (b) Anatomy
(c) Embryology (d) Palaeontology

14 Which one of the following pairs has homologous organs?
(a) Pectoral fins of a fish and forelimbs of an horse
(b) Wings of a bat and wings of cockroach
(c) Air sacs of fish and lungs of frog
(d) Wings of a bird and wings of a butterfly

15 Which one of the following represents a homologous evolutionary feature?
(a) Pentadactyl limb and arthropod claw
(b) Molluscan eye and vertebrate eye
(c) Sperm tail and tadpole tail
(d) Fish haemoglobin and reptile haemoglobin

16 In a random mating population in equilibrium, which of the following brings about a change in gene frequency in a non-directional manner?
(a) Migration
(b) Mutation
(c) Random drift
(d) Selection

17 Jurassic period of the Mesozoic era is characterised by
(a) radiation of reptiles and origin of mammal-like reptiles
(b) dinosaurs became extinct and angiosperms appear
(c) flowering plants and first dinosaurs appear
(d) gymnosperms are dominant plants and first birds appear

18 Modifications in the organisation of the basic pentadactyl limb structure found in vertebrates provide good evidence for the principle of
(a) adaptive radiation
(b) convergent evolution
(c) genetic drift
(d) inheritance of acquired characters

19 The use of Hardy-Weinberg equation for a population shows that
(a) immigration of new mating type can be accounted for
(b) the result of breeding over a number of generation can be predicted
(c) the proportion of phenotype is 3 : 1
(d) there are twice as many phenotypes as recessive phenotype

20 Using imprints from a plate with complete medium and carrying bacterial colonies, you can select streptomycin resistant mutants and prove that such mutations do not originate as adaptation. These imprints need do be used
(a) on plates with and without streptomycin
(b) on plates with minimal medium
(c) only on plates with streptomycin
(d) only on plates without streptomycin

21 In the case of peppered moth (*Biston betularia*), the black-coloured form became dominant over the light-coloured form in England during industrial revolution. This is an example of
(a) natural selection whereby the darker forms were selected
(b) appearance of the darker coloured individuals due to very poor sunlight
(c) protective mimicry
(d) inheritance of darker colour character acquired due to the darker environment

22 The change of the lighter coloured variety of peppered moth, *Biston betularia,* to its darker variety *(Carbonaria)* is due to
(a) deletion of a segment of genes due to industrial pollution
(b) industrial carbon deposited on the wings of the moth resulting in darker variety
(c) mutation of single Mendelian gene for survival in smoke laden industrial environment
(d) translocation of a block of genes in chromosomes in response to heavy carbons

23 Match the following columns.

Column I (Evolution concept)	**Column II** (Proposers)
A. Saltation	1. Darwin
B. Formation of life was preceeded by chemical evolution	2. Louis Pasteur
C. Reproductive fitness	3. de Vries
D. Life comes from pre-existing life	4. Oparin and Haldane

Codes

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	2	1
(c)	4	2	3	1
(d)	2	3	1	4

24 **Assertion** Natural selection is the outcome of difference in survival and reproduction among individuals that show variation in one or more traits.

Reason Adaptive forms of a given trait tend to become more common; less adaptive ones become less common or disappear.

(a) If both Assertion and Reason are true and Reason is the correct explanation of Assertion
(b) If both Assertion and Reason are true, but Reason is not the correct explanation of Assertion
(c) If Assertion is true, but Reason is false
(d) If both Assertion and Reason are false

ANSWERS

SESSION 1

1 (c)	**2** (a)	**3** (d)	**4** (a)	**5** (d)	**6** (b)	**7** (c)	**8** (b)	**9** (c)	**10** (b)
11 (b)	**12** (c)	**13** (d)	**14** (b)	**15** (c)	**16** (d)	**17** (a)	**18** (c)	**19** (b)	**20** (c)
21 (b)	**22** (c)	**23** (c)	**24** (a)	**25** (c)	**26** (c)	**27** (b)	**28** (c)	**29** (b)	**30** (b)
31 (c)	**32** (c)	**33** (a)	**34** (a)	**35** (a)	**36** (c)	**37** (d)	**38** (d)	**39** (c)	**40** (d)
41 (c)	**42** (a)	**43** (c)	**44** (d)	**45** (d)	**46** (b)	**47** (a)	**48** (a)	**49** (c)	**50** (b)
51 (d)	**52** (c)	**53** (a)	**54** (b)	**55** (b)	**56** (a)	**57** (a)	**58** (b)	**59** (c)	**60** (b)
61 (b)	**62** (b)	**63** (a)	**64** (a)	**65** (b)	**66** (c)	**67** (c)	**68** (c)	**69** (b)	**70** (c)
71 (a)	**72** (b)	**73** (a)							

SESSION 2

1 (c)	**2** (d)	**3** (d)	**4** (c)	**5** (b)	**6** (c)	**7** (a)	**8** (c)	**9** (a)	**10** (b)
11 (d)	**12** (c)	**13** (a)	**14** (a)	**15** (d)	**16** (b)	**17** (d)	**18** (a)	**19** (b)	**20** (c)
21 (a)	**22** (c)	**23** (a)	**24** (a)						