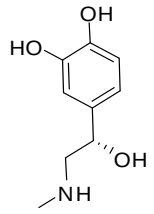
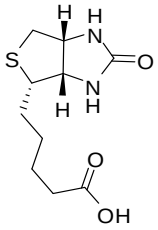
NATIONAL SCIENCE OLYMPIAD 2012: LIFE SCIENCES

These questions were compiled from a variety of sources and the detailed answers are mainly from WIKIPEDIA as well as Encyclopedia Britannica and some textbooks.

The following structures are naturally occurring compounds which perform various functions in animal/mammalian biology. Look at them carefully and answer questions (1), (2), (3), (4), (5), (6), (7), (8), (9) and (10).



(1)



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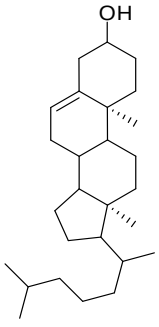
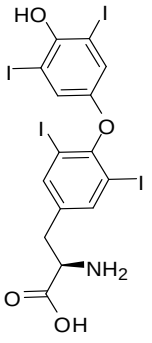


(3)



(4)

(1) Which of the structures is known as vitamin B_7?

(A) (1)
(B) (2)
(C) (3)
(D) (4)

ANSWER: B

Biotin (vitamin B_7) is a water-soluble B-complex vitamin. It is composed of a tetrahydroimidazalone ring fused with a tetrahydrothiophene ring. A valeric acid substituent is attached to one of the carbon atoms of the tetrahydrothiophene ring. Biotin is a coenzyme in the metabolism and plays a role in cell growth, the production of fatty acids, and the metabolism of fats and amino acids. It plays a role in the Krebs' cycle, which is the process by which biochemical energy is generated during aerobic respiration.

(2) Which structure is necessary for cell growth, the production of fatty acids, and the metabolism of fats and amino acids?

A) (1)
(B) (2)
(C) (3)
(D) (4)

ANSWER: B

Please read the explanation in the answer to question (1)

(3) Which structure is the precursor for the hormones testosterone and oestrogen?

(A) (1)
(B) (2)
(C) (4)
(D) None of the options (A) to (C)

ANSWER: (D)

Cholesterol [structure no **(3)**] is a waxy steroid produced in the liver or intestines. It is an essential structural component of mammalian cell membranes and is required to establish proper membrane permeability and fluidity. In addition, cholesterol is an important component for the production of bile acids, steroid hormones (e.g., testosterone and oestrogen), and vitamin D.

(4) Which of the structures is involved in controlling the rate of metabolic processes in the body and influencing physical development?

(A) (1)
(B) (2)
(C) (4)
(D) None of the options (A) to (C)

ANSWER: (C)

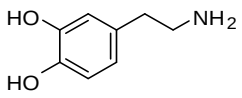
Thyroxine, or 3,5,3',5'-tetraiodothyronine (often abbreviated as T_4), is the major hormone secreted by the follicular cells of the thyroid gland. Thyroxine is synthesized via the iodination and covalent bonding of the phenyl portions of tyrosine residues found in an initial peptide, thyroglobulin, which is secreted into thyroid granules. These iodinated diphenyl compounds are cleaved from their peptide backbone upon being stimulated by thyroid stimulating hormone. T_4 is involved in controlling the rate of metabolic processes in the body and influencing physical development.

(5) Which of the structures is called dopamine, a neurotransmitter in the brain involved in cognition, mood, motivation and voluntary movement control?

(A) (1)
(B) (2)
(C) (3)
(D) None of the above

ANSWER: (D)

Dopamine, which has the IUPAC name 4-(2-aminoethyl)benzene-1,2-diol, has the following structure:



(6) Which of the structures is adrenaline, the fight/flight hormone?

(A) (1)
(B) (2)
(C) (3)
(D) (4)

ANSWER: (A)

Adrenaline, also called epinephrine is a hormone and neurotransmitter that increases heart rate, constricts blood vessels, dilates air passages and

participates in the fight of flight response of the sympathetic nervous system. Chemically, epinephrine is a catechol-derived monoamine, produced only by the adrenal glands from the amino acids phenylalanine and tyrosine.

(7) Which of the structures is known as triidothyronine, a hormone produced by the thyroid gland?

(A) (2)
(B) (3)
(C) (4)
(D) None of the above

ANSWER: D

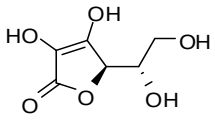
The prefix triiodo means 3 iodine atoms in a structure, whereas the depicted structure **(4)** has 4 iodine atoms and is called tetraiodothyronine. See the Answer to Question 4.

(8) Which of the structures is called ascorbic acid, also known as vitamin C?

(A) (1)
(B) (3)
(C) (4)
(D) None of the above

ANSWER: (D)

Vitamin C has the following structure:



Vitamin C, also known as ascorbic acid, functions as a water-soluble antioxidant and as a cofactor in various enzyme systems, such as those involved in the synthesis of connective tissue components and neurotransmitters. A deficiency in vitamin c leads to scurvy, a disease whose symptoms include pinpoint hemorrhages (petechiae) under the skin, bleeding gums, joint pain, and impaired wound healing.

(9) Which of the structures is Follicle Stimulating Hormone, a peptide hormone which regulates the development, growth, pubertal maturation, and reproductive processes of the body?

(A) (1)
(B) (2)
(C) (4)
(D) None of the above

ANSWER: D

Follicle-stimulating hormone (FSH) is a glycoprotein hormone secreted by the pituitary gland. The hormone regulates the development, growth, pubertal maturation, and reproductive processes of the body. It is a dimeric structure containing two sub-units called alpha and beta, both of which have a sugar unit attached to them. The alpha subunit of FSH contains 92 amino acids and

is similar to that of three other hormones secreted by the pituitary gland: Luteinizing Hormone (LH), Thyroid Stimulating Hormone (TSH) and human chorionic gonadotrophin (hCG). The beta subunit of FSH has 118 amino acids and confers its specific biologic action and is responsible for interaction with the FSH receptor. The sugar part of the hormone is composed of fucose, galactose, mannose, galactosamine, glucosamine and sialic acid.

(10) Which of the structures are derivatives of the amino acid tyrosine?

(A) (1) and (2)
(B) (2) and (3)
(C) (1) and (4)
(D) (1) and (3)

ANSWER: C

Please read the answers to questions (4) and (6).

The following statement was apparently uttered by Mohammad Ali, the legendary heavyweight boxing champion, as advice to a young man.

"Go to college and get an education and stay there until you finish. If they can make penicillin out of mouldy bread, they sure can make something out of you!"

On the basis of this statement, please answer questions (11), (12), (13) (14) and (15).

(11) Which mould was penicillin isolated from?

(A) *Penicillium camemberti*
(B) *Penicillium roqueforti*
(C) *Penicillium chrysogenum*
(D) *Penicillium marneffei*

ANSWER: C

Penicillium chrysogenum is a fungus (mould) common in temperate and subtropical regions and can be found on salted food products, but it is mostly found in indoor environments, especially in damp buildings. It was previously known as *Penicillium notatum*. It is the source of several beta-lactam antibiotics, most notably penicillin.

Penicillium camemberti is a species of fungus used in the production of Camembert and Brie cheeses, on which colonies of *P. camemberti* form a hard, white crust. It is responsible for giving these cheeses their distinctive taste.

Penicillium roqueforti is a fungus widespread in nature- it can be isolated from soil, decaying organic matter, and plants. The major industrial use of this fungus is the production of blue cheeses such as Roquefort, Stilton and Danish Blue.

Penicillium marneffei, discovered in 1956, is the only known thermally dimorphic species of *Penicillium* and it can cause a lethal systemic infection (penicillosis) with fever and anaemia. Discovered in bamboo rats in Vietnam, it is associated with these rats and the tropical South-East Asia area. It infects

mainly immuno-compromised (HIV infected) people in that part of the world. However, an increase in global travel and migration means it is increasingly becoming important/noticeable as an infection in AIDS sufferers worldwide.

(12) As an antibiotic, penicillin acts by

(A) inhibiting the formation of peptidoglycan cross-links in the bacterial cell wall.
(B) inhibiting DNA polymerases and leading to cell death
(C) Blocking all bacterial transcription factors and inhibiting protein synthesis.
(D) None of the above.

ANSWER: A

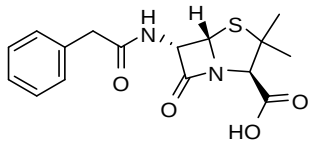
Penicillin refers to a group of beta-lactam antibiotics used in the treatment of bacterial infections caused by susceptible, usually Gram-positive, organisms. The serendipitous discovery of penicillin is usually attributed to Scottish scientist Alexander Fleming in 1928, though others had earlier noted the anti-bacterial effects of Penicillin. The chemical structure of penicillin was determined by Dorothy Crowfoot Hodgkin in the early 1940s, enabling synthetic production. A team of Oxford research scientists led by Australian Howard Walter Florey and including Ernst Boris Chain and Norman Heatley discovered a method of mass producing the drug. Florey and Chain shared the 1945 Nobel Prize in Medicine or Physiology with Fleming for this work. Penicillin has since become the most widely used antibiotic to date and is still used for many Gram positive bacterial infections. It works by inhibiting the formation of peptidoglycan cross-links in the bacterial cell wall.

(13) Which two amino acids are precursors to the bicyclic core of penicillin?

(A) valine and cysteine
(B) isoleucine and methionine
(C) proline and cycteine
(D) proline and methionine

ANSWER: A

Depicted below is the structure of penicillin G.



The first step in the biosynthesis of penicillin G is the condensation of three amino acids L-α-aminoadipic acid, L-cysteine, L-valine into a tripeptide. This condensation is catalyzed by an enzyme called δ-(L-α-aminoadipyl)-L-cysteine-D-valine synthetase. Before condensing into a tripeptide, the amino acid L-valine will undergo epimerization and become D-valine. The second step is transformation of the tripeptide by oxidation followed by ring closure to form the bicyclic structure. These

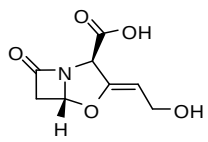
steps are catalyzed by the enzyme isopenicillin *N* synthase. The last step in the biosynthesis of penicillin G is the exchange of the side-chain group so that isopenicillin N will become penicillin G. Through the catalytic coenzyme isopenicillin *N* acyltransferase (IAT), the alpha-aminoadipyl side-chain of isopenicillin N is removed and exchanged for a phenylacetyl side-chain.

(14) Some bacteria are resistant to penicillin because they produce an enzyme called beta-lactamase. How does this enzyme render penicillin ineffective?

(A) By opening the 4-memebered ring in penicillin
(B) By opening the 5-memebered ring in penicillin
(C) By oxidising the sulfur in the penicillin core structure
(D) None of the above.

ANSWER: A

Bacteria often develop resistance to β-lactam antibiotics by synthesizing beta-lactamase, an enzyme that attacks the β-lactam ring (the four membered cyclic amide ring). To overcome this resistance, β-lactam antibiotics are often given with beta-lactamase inhibitors such as clavulanic acid.



clavulanic acid

Clavulanic acid is a natural product that contains a β-lactam group, similar to that found in penicillins. When potassium clavulanate is present penicillin, the bacterial β-lactamase reacts with the clavulanate and makes a stable enzyme complex (irreversible reaction) and this prevents the β-lactamases from being able to inactivate the penicillin, making sure that it maintains its effectiveness as an antibiotic.

(15) For his discovery of penicillin in 1928, Alexander Fleming was awarded

(A) The Nobel Prize in Medicine or Physiology in 1945.
(B) The Nobel Prize in Medicine or Physiology in 1934.
(C) The Nobel Prize in Chemistry in 1945.
(D) The Nobel Prize in Chemistry in 1934.

ANSWER: A

Please read the answer to question 12.

Use the following statement to answer questions (16), (17), 18), (19), (20), 21 and (22).

HIV a retrovirus that causes acquired immunodeficiency syndrome (AIDS), a condition in humans in which progressive failure of the immune system allows life-threatening opportunistic infections and

cancers to thrive. This leads to eventual death of the infected person.

(16) Which of the following are the three layers of the immune system?

(A) surface barriers, innate and adaptive
(B) acute, chronic and indeterminate
(C) non-specific, specific and indeterminate
(D) None of the above

ANSWER: A

The immune system protects organisms from infection with layered defenses of increasing specificity. In simple terms, physical and chemical barriers prevent pathogens such as bacteria and viruses from entering the organism. Examples of these barriers are the skin, acid in the stomach, coughing, sneezing, tears in the eyes and enzymes in the saliva.

If a pathogen breaches these barriers, the innate immune system provides an immediate, but non-specific response. This is characterized by cell- mediated inflammation and phagocytosis where the invading particle is isolated and enzymatically destroyed.

If pathogens successfully evade the innate response, vertebrates possess a third layer of protection, the adaptive immune system, which is activated by the innate response. Here, the immune system adapts its response during an infection to improve its recognition of the pathogen. This improved response is then retained after the pathogen has been eliminated, in the form of an immunological memory, and allows the adaptive immune system to mount faster and stronger attacks each time this pathogen is encountered.

The cells of the adaptive immune system are special types of leukocytes, called lymphocytes. There are two kinds of these; B- cells and T cells lymphocytes and are derived from hematopoietic stem cells in the bone marrow. Both B cells and T cells carry receptor molecules that recognize specific targets. B cells secrete antibodies. Each antibody recognizes a specific antigen unique to its target. By binding their specific antigens, antibodies can cause agglutination and precipitation of antibody-antigen products, prime for phagocytosis by macrophages and other cells, block viral receptors, and stimulate other immune responses, such as the complement pathway.

There are two major subtypes of T cells: the killer T cell and helper T cell. Killer T cells kill cells that are infected with viruses (and other pathogens), or are otherwise damaged or dysfunctional. T helper cells regulate both the innate and adaptive immune responses and help determine which types of immune responses the body will make to a particular pathogen. These cells have no cytotoxic activity and do not kill infected cells or clear pathogens directly. They instead control the

immune response by directing other cells to perform these tasks.

(17) Which cells of the immune system are killed by HIV?

(A) T-helper cells, hepatocytes and reticulocytes
(B) T-helper cells, macrophages and dendritic cells.
(C) T-helper cells, platelets and white blood cells.
(D) T-helper cells, adipocytes and osteoblasts.

ANSWER: B

HIV infects vital cells in the human immune system such as T- helper cells, (specifically $CD4^+$ T cells), macrophages and dendritic cells.

(18) HIV infection leads to low levels of CD4 cells through several mechanisms. Which of the following ARE NOT SUCH MECHANISMS?

(i) *direct viral killing of infected cells,* ***(ii)*** *increased rates of apoptosis in infected cells* ***(iii)*** *killing of infected CD4 cells by CD8 cytotoxic lymphocytes that recognize infected cells,* ***(iv)*** *inhibition of bone marrow by HIV leading to fewer immune cells,* ***(v)*** *inducing cancer in the blood cells (leukaemia), leading to rapid cell death*

(A) *(ii)* and *(iii)*
(B) *(iii)* and *(v)*
(C) *(iv)* and *(v)*
(D) *(ii)* and *(iv)*

ANSWER: C

HIV infection leads to low levels of $CD4^+$ T cells through three main mechanisms: First, direct viral killing of infected cells; second, increased rates of apoptosis (programmed cell death) in infected cells; and third, killing of infected $CD4^+$ T cells by CD8 cytotoxic lymphocytes that recognize infected cells. When $CD4^+$ T cell numbers decline below a critical level, cell-mediated immunity is lost, and the body becomes progressively more susceptible to opportunistic infections.

(19) Which of the following best represents the estimated per-act risk for acquisition of HIV by exposure route?

(A) blood transfusion > childbirth > needle sharing during drug use > sexual intercourse.
(B) blood transfusion > sexual intercourse > needle sharing during drug use > childbirth.
(C) blood transfusion > needle sharing during drug use > childbirth > sexual intercourse.
(D) childbirth > sexual intercourse > needle sharing during drug use > blood transfusion.

ANSWER: A

In general, if infected blood comes into contact with any open wound, HIV may be

transmitted. This transmission route carries the highest risk and can account for infections in recipients of blood transfusions, although most transfusions are checked for HIV. The transmission of the virus from the mother to the child can occur during pregnancy, at child birth or via breast feeding. In the absence of treatment, the transmission rate up to birth between the mother and child is high. However, where combination antiretroviral therapy and Caesarean section are available, this risk can be greatly reduced. Postnatal mother-to-child transmission may be largely prevented by complete avoidance of breast feeding; however, this has significant associated morbidity.

Like blood transfusion, needle sharing during drug use also carries a high risk if the needles are not sanitized before use.

The majority of HIV infections are acquired through unprotected sexual acts. Although the risk per act is much lower, complacency about HIV leads to this mode of transmission being responsible for the majority of HIV cases. Sexual transmission occurs when infected sexual secretions of one partner come into contact with the genital, oral or rectal mucous membranes of another. Practising safe sex, staying faithful to one partner or abstinence greatly reduces/eliminates this risk.

(20) The following is the sequence of events in the HIV life cycle once inside the human host:

(i) *adsorption of the virus onto receptors on the cell membrane* ***(ii)*** *fusion of the viral envelope with the cell membrane* ***(iii)*** *release of the HIV capsid into the cell* ***(iv)*** *reverse transcription* ***(v)*** *transportation of the double-stranded viral DNA to the nucleus* ***(vi)*** *insertion into the host cell's genome* ***(vii)*** *transcription the translation by the host's mechanisms* ***(viii)*** *cleavage and packaging by HIV protease* ***(ix)*** *budding and maturation*

Which of the steps can be prevented by the use of a condom?

(A) *(i) only*
(B) (i) and *(ii)*
(C) all steps (i) to *(ix)*
(D) None of the above

ANSWER: C

Once inside the human host (i.e., once a person is infected, a condom will not prevent HIV from multiplying in his/her body. Only antiretroviral drugs can. But such an individual must practise safe sex to avoid infecting others or getting infected with other HIV strains.

(21) Which of the steps in the HIV life cycle stated in question (20) above, can be inhibited by the drugs nevirapine and AZT?

(A) *(i)*
(B) (iv)
(C) *(ix)*
(D) ALL of the above

ANSWER: B

Azidothymidine (AZT) is a nucleoside analog reverse transcriptase inhibitor (NRTI). During reverse transcription (synthesis of DNA from RNA) the virus' reverse transcriptase enzyme mistakenly inserts AZT into the growing DNA strand. However, unlike natural nucleotides, AZT has an azide group and not the requisite OH on its deoxyribose sugar fragment and thus the chain cannot grow further, blocking transcription. Unlike bacterial and eukaryotic DNA polymerases, reverse transcriptase does not have proof-reading capability and thus cannot remove the wrongfully inserted AZT and replace it with the correct nucleotide.

Nevirapine falls in the non-nucleoside reverse transcriptase inhibitor (NNRTI) class of antiretrovirals. Both nucleoside and non-nucleoside RTIs inhibit the same target, the reverse transcriptase enzyme, which transcribes viral RNA into DNA. Unlike nucleoside RTIs, which bind at the enzyme's active site, NNRTIs bind allosterically at a distinct site away from the active site termed the NNRTI pocket.

(22) Which of the steps in the HIV life cycle stated in question (20) above, can be inhibited by the drugs maraviroc and enfurvitide?

(A) *(i) and (ix)*

(B) (i), (ii) and (iii)

(C) (vii) and *(ix)*

(D) ALL of the above

ANSWER: B

Maraviroc is an HIV entry inhibitor. Specifically, maraviroc is a negative allosteric modulator of the CCR5 receptor, which is found on the surface of certain human cells. The chemokine receptor CCR5 is an essential co-receptor for most HIV strains and necessary for the entry of the virus into the host cell. The drug binds to CCR5, thereby blocking the HIV protein gp120 from associating with the receptor. HIV is then unable to enter human macrophages and T-cells. Because HIV can also use other co-receptors, such as CXCR4, an HIV tropism test must be performed to determine if the drug will be effective.

Enfuvirtide works by disrupting the HIV molecular machinery at the final stage of fusion with the target cell, preventing uninfected cells from becoming infected. It is a peptide drug that mimics components of the HIV fusion machinery and displace them, preventing normal fusion. HIV binds to the host CD4+ cell receptor via the viral protein gp120; gp41, a viral transmembrane protein, then undergoes a conformational change that assists in the fusion of the viral membrane to the host cell membrane. Enfuvirtide binds to gp41 preventing the creation of an entry pore for the capsid of the virus, keeping it out of the cell.

Diabetes mellitus, often simply referred to as diabetes, is a group of metabolic diseases in

which a person has high blood sugar, either because the body does not produce enough insulin (type 1), or because cells do not respond to the insulin that is produced (type 2).

Use this information to answer questions (23), (24), (25), (26), (27), (28), (29), (30) and (31).

(23) What is insulin?

(A) a peptide hormone of 51 amino acids produced by the pancreas.
(B) a peptide hormone of 61 amino acids produced by the islets of Langerhans.
(C) a peptide hormone of 3 different subunits produced by the islets of Langerhans.
(D) a peptide hormone showing all four levels of protein structure.

ANSWER: A

Insulin is a peptide hormone composed of 51 amino acids and has a molecular weight of 5808 Daltons. It is produced in the islets of Langerhans in the pancreas. Insulin causes cells in the liver, muscle and fat tissue to take up glucose from the blood, storing it as glycogen in the liver and muscle, and stopping use of fat as an energy source. When insulin is absent (or low), glucose is not taken up by body cells, and the body begins to use fat as an energy source, for example, by transfer of lipids from adipose tissue to the liver for mobilization as an energy source. When control of insulin levels fails, it results in the disease diabetes mellitus.

(24) Which of the following are the long term effects of untreated diabetes?

(A) cardiovascular disease, chronic renal failure and retinal damage
(B) liver damage, loss of motor coordination and blindness
(C) renal failure, auto-immune disorders and frequent comas
(D) None of the above.

ANSWER: A

Diabetes without proper treatments can cause many complications. Acute complications include hypoglycaemia (low blood sugar), diabetic ketoacidosis, or nonketonic hyperosmolar coma. Serious long-term complications include cardiovascular disease, chronic renal failure and damage to the retinas of the eyes.

(25) Which of the following are the most common symptoms of diabetes?

A) increased thirst, frequent urination, glucose in the urine.
(B) enlarged spleen, swollen liver and kidneys due to the need for frequent glomerular filtration
(C) increased thirst, blurred vision, and incontinence
(D) ALL of the above

ANSWER: A

The classical symptoms of diabetes are polyuria (frequent urination), polydipsia (increased thirst) and polyphagia (increased hunger). Symptoms may develop rapidly (weeks or months) in type 1 diabetes while in type 2 diabetes they usually develop much more slowly and may be subtle or absent.

(26) Another symptom of diabetes is the smell of acetone in the untreated sufferer's breath. This is as a result of

(A) the body burning fat to produce energy, and producing ketones as by-products.
(B) excess/unabsorbed sugar in the blood being metabolised non-specifically by blood enzymes.
(C) excess sugar in the blood being oxidised to acetone by oxygen in red-blood cells
(D) None of the above

ANSWER: A

This symptom is called diabetic ketoacidosis (DKA) and is more common in type-1 diabetes. Due to a shortage of insulin, the body switches to burning fatty acids and producing acidic ketone bodies (β-hydroxybutyrate and acetoacetate) that cause most of the symptoms and complications. β-Hydroxybutyrate can serve as an energy source in absence of insulin-mediated glucose delivery, and is a protective mechanism in case of starvation. The ketone bodies, however, have a low pH and therefore turn the blood acidic. The body initially buffers the change with the bicarbonate buffering system, but this system is quickly overwhelmed and other mechanisms must work to compensate for the acidosis. One such mechanism is hyperventilation to lower the blood carbon dioxide levels.

(27) For insulin dependent diabetes, treatment entails regular injections of insulin. The clinical effects of such injections are, mainly,

(A) increased glycogen and lipid synthesis.
(B) increased gluconeogenesis and proteolysis
(C) inhibition of the Krebs' cycle
(D) ALL of the above

ANSWER: A

Please see the detailed answer to Question 23 above.

(28) For type 2 diabetes, treatment entails administration of drugs called insulin sensitizers, such as metformin. The mode of action of metformin is by

(A) reduction of gluconeogenesis in the liver and making the cells of the body more willing to absorb glucose.
(B) increasing gluconeogenesis and glycolysis

(C) inhibition of the Krebs' cycle

(D) inhibition of fatty acid synthesis

ANSWER: A

Metformin improves hyperglycemia primarily by suppressing glucose production by the liver (hepatic gluconeogenesis The "average" person with type 2 diabetes has three times the normal rate of gluconeogenesis; metformin treatment reduces this by over one third. Metformin also increases insulin sensitivity, enhances peripheral glucose uptake (by phosphorylating GLUT-4 enhancer factor), increases fatty acid oxidation and decreases absorption of glucose from the gastrointestinal tract.

(29) Insulin isolated from many other animal species can be used in treating human diabetes because

(A) there is very little variation in the insulin sequence of diverse species.

(B) as a peptide hormone, insulin is never recognised as foreign by the body's immune system.

(C) insulin isolated from other animals is the inactive form that a human body can easily process into the active form.

(D) ALL of the above

ANSWER: A

Within vertebrates, the amino acid sequence of insulin is extremely well-preserved. Bovine insulin differs from human in only three amino acid residues, and porcine insulin in one. Even insulin from some species of fish is similar enough to human to be clinically effective in humans. Insulin in some invertebrates is quite similar in sequence to human insulin, and has similar physiological effects. The strong homology seen in the insulin sequence of diverse species suggests that it has been conserved across much of animal evolutionary history.

(30) Regulation of blood glucose levels is an example of which homeostatic control mechanism that the body uses to ensure survival?

(A) positive feedback

(B) negative feedback

(C) hormonal control

(D) genetic fat down-regulation

ANSWER: B

Negative feedback occurs when the output of a system acts to oppose changes to the input of the system, with the result that the changes are attenuated.

Glucose is the primary source of energy for the body's cells, and blood lipids (in the form of fats and oils) are primarily a compact energy store. Glucose is transported from the intestines (after food intake and digestion) or liver to body cells via the bloodstream. When this happens, the blood glucose levels rise and the pancreas secretes insulin, which stimulates body cells to absorb this glucose, the excess of which is stored as glycogen then fat in adipose

tissue. When blood glucose levels drop, the pancreas releases the hormone glucagon which stimulates conversion of glycogen back to glucose.

(31) Several scientists have been awarded the Nobel Prize in recognition of their work with insulin. These include

(A) Frederick Banting and J.J.R. McLeod (Medicine or Physiology, 1923) for the discovery of insulin, and Frederick Sanger (Chemistry, 1958) for determining the amino acid sequence of insulin.

(B) Dorothy Hodgkin (Chemistry, 1964) for the crystal structure of insulin, and Sydney Brenner, (Medicine or Physiology, 2002) for his discovery of the anti-diabetes drug metformin.

(C) Hans Krebs (Medicine or Physiology, 1953) for deciphering the role insulin plays in the citric acid cycle, and Frederick Sanger (Chemistry, 1958) for determining the amino acid sequence of insulin.

(D) ALL of the above

ANSWER: A (www.nobelprize.org)

The Nobel Prize in Physiology or Medicine 1953 was divided equally between Hans Adolf Krebs *"for his discovery of the citric acid cycle"* and Fritz Albert Lipmann *"for his discovery of co-enzyme A and its importance for intermediary metabolism"*.

The Nobel Prize in Chemistry 1964 was awarded to Dorothy Crowfoot Hodgkin *"for her determinations by X-ray techniques of the structures of important biochemical substances"*.

The Nobel Prize in Physiology or Medicine 2002 was awarded jointly to Sydney Brenner, H. Robert Horvitz and John E. Sulston *"for their discoveries concerning 'genetic regulation of organ development and programmed cell death'"*.

People who deprive themselves of food while trying to lose weight find it easy to shed weight initially and much harder to lose more after. With this information in mind, please answer questions (32), (33), (34), (35) and (36).

(32) The reason why initial weight loss is easy is because

(A) when starved, metabolism slows down and the body burns all stored starch then slowly, fats and dispensable muscle.

(B) when starved, the body secretes more thyroxine and lethargy sets in, prompting the person to eat.

(C) when starved, the body releases all stored fat and replaces it with water, leading to no apparent weight loss

(D) None of the above.

ANSWER: A

When food intake ceases, the body enters the starvation response. Ordinarily, the body

responds to reduced caloric intake by burning fat reserves first, and only consumes muscle and other tissues when those reserves are exhausted. Specifically, the body burns fat after first exhausting the contents of the digestive tract along with glycogen reserves stored in muscle and liver cells. This is a slow process, fats have very high energy content and the body's daily energy needs can be met by only releasing a small amount of fat at a time. After prolonged periods of starvation, the body will utilize the proteins within muscle tissue as a fuel source.

(33) The American psychologist William Herbert Sheldon proposed that the human physique be classed according to what are called somatotypes, named after the three germ layers of embryonic development. Which of the following correctly matches the somatotype and its characteristic(s)?

(A) Ectomorph: characterized by long and thin muscles/limbs and low fat storage; usually referred to as slim. Ectomorphs are not predisposed to store fat or build muscle.

(B) Mesomorph: characterized by medium bones, solid torso, low fat levels, and wide shoulders with a narrow waist; usually referred to as muscular. Mesomorphs are predisposed to build muscle but not store fat.

(C) Endomorph: characterized by increased fat storage, a wide waist and a large bone structure, usually referred to as fat. Endomorphs are predisposed to storing fat.

(D) ALL of the above.

ANSWER: D

All of the above statements are correctly matched. William Herbert Sheldon developed what is called constitutional psychology in an attempt to associate body types with human temperament types.

(34) An old and since abandoned way to help obese people lose weight was by administration of drugs called metabolic uncouplers. These drugs worked by

(A) inhibiting transportation of fatty acids to adipose tissue, thus ensuring that people never stored fat.

(B) accelerating release of fats from adipose tissue and burning, instead of glucose, for ATP generation.

(C) carrying protons across the mitochondrial membrane, leading to a rapid consumption of energy without generation of ATP.

(D) None of the above

ANSWER: C

As the name suggests, uncouplers separate oxidative phosphorylation from ATP generation by carrying protons across the

mitochondrial membrane, leading to a rapid consumption of energy and production of heat without generation of ATP. One example of such agents is the compound 2,4-dinitrophenol which was used extensively in diet pills in the 1930s.

(35) The reason why these drugs were discontinued in weight control was because

(A) by inhibiting transportation of fatty acids to adipose tissue, this caused a large build-up of fats in the arteries causing deaths from heart attacks
(B) by accelerating release of fats from adipose tissue and burning them instead of glucose, it gave people symptoms suggestive of diabetes.
(C) by leading to a rapid consumption of energy without generation of ATP, people died from excessive heat thus generated in the body.
(D) None of the above

ANSWER: C

Uncouplers allow protons to leak across the inner mitochondrial membrane and thus bypass ATP synthase. This makes ATP energy production less efficient. In effect, part of the energy that is normally produced from cellular respiration is wasted as heat. The inefficiency is proportional to the dose of the uncoupler that's taken. As the dose increases and energy production is made more inefficient, metabolic rate increases (and more fat is burned) in order to compensate for the inefficiency and meet energy demands. Thus, uncontrolled/large doses of uncouplers cause excessive rise in body temperature (hyperthermia) due to the heat produced during uncoupling.

(36) Which of the following is/are the most sensible way to treat/prevent obesity?

(i) eating less and exercising regularly for life
(ii) taking over the counter diet pills
(iii) undergoing gastric bypass surgery
(iv) taking prescription diet pills such as orlistat
(v) undergoing liposuction

(A) (i) only
(B) (i) and (ii)
(C) (iv) only
(D) (iii) and (v)

ANSWER: A

Having a healthy/balanced diet is a way to prevent health problems, and will provide your body with the right balance of vitamins, minerals, and other nutrients. The amount of food consumed should be commensurate with the physical activity (exercise), of the person.

Biochemically (photosynthetically), there are three types of plants; C_3 plants, C_4 plants and CAM plants. With this statement in

mind, please answer questions (37), (38), (39), (40), (41) and (42).

(37) What are C_3 plants?

(A) Plants that convert CO_2, taken directly from the air, and ribulose bisphosphate (a 5-carbon sugar), into 3-phosphoglycerate.

(B) Plants that convert CO_2, taken indirectly via malate, and ribulose bisphosphate (a 5-carbon sugar), into 3-phosphoglycerate.

(C) Plants that are particularly resistant to drought and thrive in desert areas.

(D) Gymnosperms

ANSWER: B

C_3 carbon fixation is a metabolic pathway for carbon fixation in photosynthesis where carbon dioxide is reacted with ribulose bisphosphate (RuBP, a 5-carbon sugar) into 3-phosphoglycerate by the enzyme RuBisCO (Ribulose-1,5-bisphosphate carboxylase oxygenase). This reaction occurs in all plants as the first step of the Calvin-Benson cycle. In C_4 plants, carbon dioxide is drawn out of malate and into this reaction rather than directly from the air. C_3 plants tend to thrive in areas where sunlight intensity is moderate, temperatures are moderate, carbon dioxide concentrations are around 200 ppm or higher, and ground water is plentiful. Examples include rice and barley. C_3 plants cannot grow in hot areas because RuBisCO incorporates more oxygen into RuBP as temperatures increase. This leads to phottorespiration, which leads to a net loss of carbon and nitrogen from the plant and can, therefore, limit growth.

(38) Which of the following environmental conditions favour C_4 plants?

(A) Drought, high temperatures, and nitrogen or CO_2 limitation.

(B) Moderate sunlight intensity, moderate temperatures, CO_2 concentrations around 200 ppm or higher, and plentiful ground water.

(C) Plentiful water supply, near freezing conditions and plentiful sunlight.

(D) Dry conditions, hot and windy, with at least 4 hours of intense light on any given day.

ANSWER: D

C_4 fixation is an elaboration of the more common C_3 carbon fixation. C_4 and CAM overcome the tendency of the enzyme RuBisCO to wastefully fix oxygen rather than carbon dioxide in what is called photorespiration. This is achieved by using a more efficient enzyme to fix CO_2 in mesophyll cells and shuttling this fixed carbon via malate or asparate to bundle sheath cells. In these bundle-sheath cells, RuBisCO is isolated from atmospheric oxygen and saturated with the CO_2 released by decarboxylation of the malate or oxaloacetate. These additional steps, however, require more energy in the form of

ATP. Because of this extra energy requirement, C_4 plants are able to more efficiently fix carbon in only certain conditions, with the more common C_3 pathway being more efficient in other conditions. C_4 metabolism originated when grasses migrated from the shady forest undercanopy to more open environments, where the high sunlight gave it an advantage over the C_3 pathway. Drought was not necessary for its innovation; rather, the increased resistance to water stress was a by-product of the pathway and allowed C_4 plants to more readily colonise arid environments.

(39) What is the main difference between a C_4 plant and a CAM plant?

(A) CAM plants concentrate CO_2 as malate at night, then floods it around RuBisCO during the day, whereas C_4 plants concentrate CO_2 spatially, with a RuBisCO reaction centre in a bundle sheath cell being inundated with CO_2.

(B) C_4 plants concentrate CO_2 as malate at night, then floods it around RuBisCO during the day, whereas CAM plants concentrate CO_2 spatially, with a RuBisCO reaction centre in a bundle sheath cell being inundated with CO_2 ,

(C) Since every CO_2 molecule has to be fixed twice, first by 4-carbon organic acid and second by RuBisCO, the C_4 pathway uses more energy than the CAM pathway.

(D) In CAM plants RuBisCO sequesters CO_2 directly from the air whereas in C_4 it is done indirectly via malate.

ANSWER: A

CAM plants are adapted to life in arid conditions by conserving water. During the night, the CAM plant's stomata are open, allowing CO_2 to enter and be fixated as organic acids that are stored in vacuoles. During the day the stomata are closed (thus preventing water loss), and the carbon is released to the Calvin cycle so that photosynthesis may take place.

(40) Which of the following shows the correct match of plant with photosynthetic type?

(A) Pineapple (CAM), Rice (C_3) and Maize (C_4)

(B) Cabbage (C_4), Rice (CAM) and Cactus (C_3)

(C) Pineapple (C_4, Rice (C_3) and Maize (C_4)

(D) Cabbage (CAM), Rice (C_4) and Cactus (C_3)

ANSWER: A

C_4 carbon fixation is less common in dicots than in monocots. However, only three families of monocots utilise C_4 carbon fixation compared to 15 dicot families. Nearly half of grasses are C_4 and together account for 61% of C_4 species. These

include the food crops maize, sugar cane, millet and sorghum. Cabbages (dicots) and other members of the family Brassicaceae are C_4 plants, Pineapples, like cacti, are CAM plants, whilst rice is a C_3 plant.

(41) The C_3 plants represent approximately 95% of Earth's plant biomass. The reason for this is because

(A) C_4 plants lose 97% of the water taken up through their roots to transpiration.
(B) The C_3 plants, originating during Mesozoic and Paleozoic eras, predate the C_4 plants
(C) The C_4 plants, originating during Mesozoic and Paleozoic eras, predate the C_3 plants and most off them died during the last ice age.
(D) C_3 plants can best sequester CO_2 than the other two classes, hence their dominance of the Earth.

ANSWER: B

The C_3 plants, originating during Mesozoic and Paleozoic eras, predate the C_4 plants and still represent approximately 95% of Earth's plant biomass. C_3 plants lose 97% of the water taken up through their roots to transpiration. Examples include rice and barley.

(42) It is argued that increasing the proportion of C_4 plants on earth could help drastically reduce the effects of global warming. This is because

(A) C_4 plants, once fossilised, give much cleaner burning fuels that C_3 plants.
(B) C_3 plants retain more water in their plant bodies, leading to more rapid evaporation from oceans to maintain the atmosphere's water vapor levels constant.
(C) C_4 plants, although they need lots of water, grow rapidly and can be cheap biofuel substitutes.
(D) None of the above.

ANSWER: D

Today, C_4 plants represent about 5% of Earth's plant biomass and 1% of its known plant species. Despite this scarcity, they account for about 30% of terrestrial carbon fixation. Increasing the proportion of C_4 plants on earth could assist biosequestration of CO_2 and represent an important climate change avoidance strategy. Present-day C_4 plants are concentrated in the tropics (below latitudes of 45°) where the high air temperature contributes to higher possible levels of oxygenase activity by RuBisCO, which increases rates of photorespiration in C_3 plants.

Human cells have 23 pairs of large linear nuclear chromosomes (22 pairs of autosomes and one pair of sex chromosomes), giving a total of 46 per cell. Mutations and the gain or loss of DNA from

chromosomes can lead to a variety of genetic disorders. Given this information, answer questions (43), (44), (45), (46), (47), (48) and (49).

(43) Down's syndrome is an example of a genetic disorder, characterised by decreased muscle tone, stockier build, asymmetrical skull, slanting eyes and mild to moderate developmental disability. The cause of this disorder is

(A) deletion of one copy of chromosome 21, hence this poor development.
(B) an extra copy of chromosome 21
(C) a trisomy of chromosome 18
(D) None of the above

ANSWER: B

Down syndrome is a chromosomal condition characterized by the presence of an extra copy of genetic material on the chromosome 21 either in whole (trisomy 21) or part (such as due to translocations). The effects and extent of the extra copy vary greatly among people, depending on genetic history, and pure chance. The incidence of Down syndrome is estimated at 1 per 733 births, although it is statistically more common with older parents due to increased mutagenic exposures upon some older parents' reproductive cells.

(44) Sickle–cell disease is an autosomal recessive genetic blood disorder with incomplete dominance, characterized by red blood cells that assume an abnormal, rigid, sickle shape. The cause of this abnormality is

(A) a point mutation in the β-globin chain of haemoglobin, whose gene is found on the short arm of chromosome 11.
(B) A deletion of the β-globin gene found on the short arm of chromosome 11.
(C) deffects in the genes encoding bone marrow leading to its inability to make healthy red blood cells.
(D) None of the above

ANSWER: A

Sickle-cell anaemia is caused by a point mutation in the β-globin chain of hemoglobin, causing the hydrophilic amino acid glutamic acid to be replaced with the hydrophobic amino acid valine at the sixth position. The β-globin gene is found on the short arm of chromosome 11. The association of two wild-type α-globin subunits with two mutant β-globin subunits forms haemoglobin S (HbS). Under low-oxygen conditions (being at high altitude, for example), the absence of a polar amino acid at position six of the β-globin chain promotes the non-covalent polymerisation (aggregation) of haemoglobin, which distorts red blood cells into a sickle shape and decreases their elasticity.

(45) Cystic fibrosis is a common recessive genetic disorder which affects the entire body, causing progressive disability. It is caused by

(A) a mutation in the gene CFTR found on chromosome 7.
(B) a mutation in the gene CFTR found on chromosome X
(C) a mutation in the gene CFTR found on chromosome Y
(D) a mutation in the gene CFTR found on chromosome 18

ANSWER: A

CF is caused by a mutation in the gene cystic fibrosis transmembrane conductance regulator (CFTR). The CFTR gene, found at the q31.2 locus of chromosome 7, is 230,000 base pairs long, and creates a protein that is 1,480 amino acids long. The most common mutation, is a deletion (Δ) of three nucleotides that results in a loss of the amino acid phenylalanine (F) at the 508th (508) position on the protein. Although most people have two working copies (alleles) of the CFTR gene, only one is needed to prevent cystic fibrosis. CF develops when neither allele can produce a functional CFTR protein. Thus, CF is considered an autosomal recessive disease

(46) Duchenne muscular dystrophy is a recessive X-linked form of muscular dystrophy, which results in muscle degeneration, difficulty walking, breathing, and death. This means

(A) females and males are affected, but males more so than females
(B) females and males are equally affected.
(C) only females are affected because the Y chromosome in males can take over the functions of the X chromosome.
(D) a male with such a disorder can only pass it on to his sons.

ANSWER: A

Duchenne muscular dystrophy results in muscle degeneration, difficulty walking, breathing, and death. Females and males are affected, though females are rarely affected and are more often carriers. The disorder is caused by a mutation in the dystrophin gene, located in humans on the X-chromosome (Xp21). The dystrophin gene codes for the protein dystrophin, an important structural component within muscle tissue. Dystrophin provides structural stability to the dystroglycan complex (DGC), located on the cell membrane.

(47) Infantile Tay–Sachs disease is an autosomal recessive genetic disorder which causes a relentless deterioration of mental and physical abilities that commences around six months of age and usually results in

death by the age of four. This means

(A) when both parents are carriers, there is a 50% risk of giving birth to an affected child.
(B) a heterozygous individual expresses at least 75% of the normal level of enzyme activity.
(C) the disease does not follow simple Mendelian ratios of inheritance.
(D) it occurs when a child has two defective copies of the gene, when neither copy can be transcribed as a functional enzyme product.

ANSWER: D

An autosomal recessive genetic disorder means that when both parents are carriers, there is a 25% risk of giving birth to an affected child. Autosomal genes are chromosomal genes that are not located on one of the sex chromosomes. Every individual carries two copies of each autosomal gene, one copy from each parent. When both parents carry a mutation, the classic 25% Mendelian ratio determines the likelihood of disease. As with all genetic disease, Tay-Sachs Disease may arise in any generation from a novel mutation, although such mutations are rare.

(48) Haemophilia is a group of hereditary genetic disorders that impair the body's ability to control blood clotting which is used to stop bleeding when a blood vessel is broken. It is a

(A) dominant, sex-linked, X-chromosome disorder.
(B) recessive, sex-linked, X-chromosome disorder.
(C) dominant, sex-linked, Y-chromosome disorder.
(D) recessive, sex-linked, Y-chromosome disorder.

ANSWER: B

Hemophilia is a recessive sex-linked X chromosome disorders, meaning that it is more likely to occur in males than females. This is because females have two X chromosomes while males have only one, so the defective gene is guaranteed to manifest in any male who carries it. Because females have two X chromosomes and haemophilia is rare, the chance of a female having two defective copies of the gene is very low, so females are almost exclusively asymptomatic carriers of the disorder. Female carriers can inherit the defective gene from either their mother or father, or it may be a new mutation. Only under rare circumstances do females actually have haemophilia.

(49) Albinism is a recessive autosomal genetic disorder characterized by the complete or partial absence of pigment in the skin, hair and eyes due to absence or defects in enzyme involved in the production of

melanin. Is it possible then, for two albinos to have a normal child?

(A) No, both parents have two defective copies of the gene, thus it's a hopeless situation.
(B) No, albinism follows classical Mendelian inheritance ratios.
(C) Yes, provided that the parents do not have identical defective genes.
(D) Yes, nature, through transposons, always mitigates against genetic defects and one gene will automatically mutate to the wild type to ensure that the parents have at least one normal child.

ANSWER: C

Skin pigmentation is due to a compound called melanin. This compound is produced in human bodies through a series of enzyme-catalysed steps, starting from the amino acid tyrosine. If both parents have exactly the same defective gene/enzyme, they cannot have normal children. However, if they have different mutations, the overall combination will result in normal (pigmented) children.

(50) Which of the following is NOT a primate?

(A) Human being
(B) Gorrilla
(C) Lemur
(D) None of the above.

ANSWER: D

The Order Primates has traditionally been divided into two main groupings: prosimians and anthropoids (simians). Prosimians have characteristics more like those of the earliest primates, and include the lemurs, lorisiforms and tarsiers. Simians include the monkeys, apes and humans.

(51) Which of the following is NOT a characteristic of primates?

(A) relatively large brain
(B) increased reliance on stereoscopic vision
(C) opposable thumb and in some, a prehensile tail.
(D) None of the above.

ANSWER: D

Primates have forward-facing eyes on the front of the skull; binocular vision allows accurate distance perception. They also have large brains in comparison to body size, especially in simians, five digits on the fore and hind limbs with opposable thumbs and big toes and two pectoral mammary glands.

(52) Reptiles are animals in the class Reptilia. They are characterized by breathing air, laying shelled eggs (except for some vipers and constrictor snakes that give live birth), and having skin covered in scales and/or scutes. Which of the

following is NOT an Order of reptiles?

(A) Squamata
(B) Testudines
(C) Sphenodontia
(D) Strigiformes

ANSWER: D

Strigiformes is an Order of Birds comprising 200 birds of prey, with the owls being the most common members.

(53) Which of the following is NOT true about reptiles?

(A) All reptiles breathe using lungs.
(B) Like in all animals, reptilian muscle action produces heat.
(C) Reptile kidneys are unable to produce liquid urine more concentrated than their body fluid.
(D) Their poikilotherm metabolism has very high energy requirements.

ANSWER: D

A poikilotherm is an organism whose internal temperature varies considerably. It is the opposite of a homeotherm, an organism which maintains a near constant internal body temperature.. Usually the variation is a consequence of variation in the environment's temperature. Because their metabolism is variable and generally below that of homeothermic animals, sustained high-energy activities like powered flight in large animals or maintaining a large brain is generally beyond poikilotherm animals. Thus, for larger poikilotherms, their hunting strategy is sit-and-wait hunting rather than chasing prey, which requires a lot of energy. As they do not use their metabolism to heat or cool themselves, total energy requirement over time is low

(54) Birds (class Aves) are feathered, winged, bipedal, endothermic, egg-laying vertebrate animals. Which of the following is NOT true about birds?

(A) Modern birds have a beak with no teeth, a high metabolic rate, a four-chambered heart, and a lightweight but strong skeleton.
(B) Many species undertake long distance annual migrations.
(C) Birds are social and breed and hunt cooperatively, and mob predators in self defence.
(D) None of the above.

ANSWER: D

All of the above statements about birds are true.

(55) Which of the following is NOT true about the anatomy/physiology of birds?

(A) Their kidneys extract nitrogenous wastes from their bloodstream and excrete it as uric acid via the ureters into the intestine

(B) The digestive system of birds is unique, with a crop for storage and a gizzard that contains swallowed stones for grinding food.

(C) Birds have two openings called cloacae, one for excretion and one for sexual reproduction.

(D) A bird's lungs receive a constant supply of fresh air during both inhalation and exhalation

ANSWER: C

A cloaca is the posterior opening that serves as the only such opening for the intestinal, reproductive, and urinary tracts of certain animal species. All birds, reptiles and amphibians possess this orifice. The cloaca is a multi-purpose opening: waste is expelled through it, birds mate by joining cloaca, and females lay eggs from it. In contrast, placental mammals possess two (or three) separate orifices for defecation, excretion and sexual reproduction.

(56) Amphibians are a class of vertebrates characterized as non-amniote, cold-blooded tetrapods. Being non-amniotic means

(A) the embryo is not protected by several membranes and there is a larval stage.

(B) embryos are protected and aided by several extensive membranes.

(C) internal fertilization obviates the need for eggshells

(D) None of the above.

ANSWER: A

The amniotes are a group of tetrapods (four-limbed animals with backbones or spinal columns) that have a terrestrially adapted egg. They include mammals, reptiles and birds. Amniote embryos, whether laid as eggs or carried by the female, are protected and aided by several extensive membranes. In mammals such as humans, these membranes include the amniotic sac that surrounds the fetus. These embryonic membranes, and the lack of a larval stage, distinguish amniotes from tetrapod amphibians.

(57) How many orders of amphibians are there currently, and what are they?

(A) **4:** Anura, Caudata, Squamata and Gymnophiona

(B) **3:** Anura, Caudata and Gymnophiona.

(C) **3:** Frogs, Toads and Salamanders

(D) **4:** Anura, Frogs, Toads and Salamanders

ANSWER: B

There are three orders of amphibians: Anura (frogs and toads), Caudata (salamanders and newts), and Gymnophiona (caecilians, limbless amphibians that resemble snakes). In total, they number approximately 6,500 species.

(58) A fungus is a member of the Kingdom Fungi, which comprises a large group of eukaryotic organisms

that includes microorganisms such as yeasts and moulds, as well as the more familiar mushrooms.

Which of the following is NOT true about fungi?

(A) Fungal cells have cell walls that contain chitin, unlike the cell walls of plants, which contain cellulose.
(B) Fungi perform an essential role in the decomposition of organic matter
(C) The fungus kingdom encompasses a small diversity of taxa, but with varied ecologies.
(D) Most fungi lack an efficient system for long-distance transport of water and nutrients, such as the xylem and phloem.

ANSWER: D

Fungi lack an efficient system for long-distance transport of water and nutrients, such as the xylem and phloem in many plants. To overcome these limitations, some fungi form rhizomorphs, that resemble and perform functions similar to the roots of plants. Rhizomorphs, also called mycelial cords, are linear aggregations of parallel-oriented hyphae. The mature cords are composed of wide, empty vessel hyphae surrounded by narrower sheathing hyphae. Mycelial cords are capable of conducting nutrients over long distances. For instance, they can transfer nutrients to a developing fruiting body, or enable wood-rotting fungi to grow through soil from an established food base in search of new food sources. For parasitic fungi, they can help spread infection by growing from established clusters to uninfected parts.

(59) Many fungi are parasites on plants, animals (including humans), and other fungi. Which of the following is NOT a fungal disease?

(A) *Pneumocystis* pneumonia
(B) Blast disease in rice, wheat and rye.
(C) Rust in wheat, barley and rye.
(D) Kaposi's sarcoma in AIDS sufferers.

ANSWER: D

Pneumocystis pneumonia is caused by *Pneumocystis jirovecii,* a yeast-like fungus of the genus *Pneumocystis*. This fungus is an important human pathogen, particularly among immuno-compromised people. Prior to its discovery as a human-specific pathogen, *P. jirovecii* was known as *P. carinii*.

Blast disease is caused by *Magnaporthe grisea* a plant-pathogenic fungus. Members of the *Magnaporthe grisea* complex can also infect other agriculturally important cereals including wheat, rye, barley and pearl millet.

Wheat leaf rust is fungal disease that affects wheat, barley and rye stems, leaves and grains. The pathogen is Puccinia rust fungus. *Puccinia triticina* causes 'black rust', *P.recondita* causes 'brown rust' and *P.sriiformis* causes 'Yellow rust'. It is the most prevalent of all the wheat rust

diseases, occurring in most wheat growing regions.

Kaposi's sarcoma (KS) is a tumor caused by human herpesvirus 8 (HHV8), also known as Kaposi's sarcoma-associated herpesvirus (KSHV). It was originally described by Moritz Kaposi, a Hungarian dermatologist practicing at the University of Vienna in 1872. It became more widely known as one of the AIDS defining illnesses in the 1980s. The viral cause for this cancer was discovered in 1994.

(60) Since the discovery of penicillin, fungi have been used as a source of many clinically useful drugs. Which of the following drugs is not of fungal origin?

(A) Cyclosporin, an immunosuppressant drug used to avoid rejection in organ transplantation.
(B) Mycophenolate, an immunosuppressant drug used to prevent rejection in organ transplantation.
(C) Paclitaxel, a mitotic inhibitor used in cancer chemotherapy.
(D) None of the above.

ANSWER: C

Cyclosporin was initially isolated from the fungus *Tolypocladium inflatum*. It is ciclosporin is a cyclic non-ribosomal peptide of 11 amino acids and contains a single D-amino acid, which are rarely encountered in nature.

Mycophenolate is derived from the fungus *Penicillium stoloniferum*.

Paclitaxel (taxol) was isolated from the bark of the Pacific yew tree, *Taxus brevifolia.*

Bacteria are a large domain of single-celled, prokaryotic microorganisms, found ubiquitously in every habitat on earth. The grow in soil, acidic hot springs, radioactive waste, water and deep in the earth's crust, as well as in organic matter and the live bodies of plants and animals. Use this information to answer Questions (61), (62), (63), (64), (65), (66), (67), (68), (69) and (70)

(61) Some bacteria are termed facultative anaerobes. This means

(A) they make ATP by aerobic respiration if oxygen is present but are also capable of switching to fermentation.
(B) they die in the presence of oxygen.
(C) oxygen is not the final electron acceptor in their oxidative phosphorylation.
(D) they maintain the natural hydrogen-oxygen balance by reducing water to its elemental components.

ANSWER: A

A facultative anaerobic organism is an organism that makes ATP by aerobic respiration if oxygen is present but is also capable of switching to fermentation. In contrast, obligate anaerobes die in the presence of oxygen.

(62) Bacterial metabolism is classified into three nutritional groups. These are

(A) Phototrophs, Lithotrophs and Organotrophs
(B) Heterotrophs, Autotrophs and Lithotrophs
(C) Heterotrophs, Autotrophs and Phototrophs
(D) Heterotrophs, Autotrophs and Organotrophs.

ANSWER: A

Bacterial metabolism is classified into nutritional groups on the basis of three major criteria: the kind of energy used for growth, the source of carbon, and the electron donors used for growth.

1: Phototrophs derive their energy from sunlight; if the source of carbon is organic compounds, they are called photoheterotrophs and photoautotrophs if they use carbon dioxide

2: Lithotrophs derive their energy from inorganic compounds; those that use organic compounds as the source of carbon are called lithoheterotrophs and those capable of carbon fixation are called lithoautotrophs.

3: Organotrophs derive their energy from Organic compounds and if they also derive their carbon from organic compounds, they are called chemoheterotrophs. Those who are cable of carbon fixation are called chemoautotrophs.

(63) Bacteria are vital in recycling nutrients, with many steps in nutrient cycles depending on these organisms. Which of the following bacteria is involved in the nitrogen cycle?

(A) *Eschericia coli*
(B) *Nitrosomonas europaea*
(C) *Acetobacter aceti*
(D) *Pseudomonas aeruginosa*

ANSWER: B

Nitrosomonas europaea is a Gram-negative obligate chemolithoautotroph that can derive all its energy and reductant for growth from the oxidation of ammonia to nitrite. It lives in several places such as soil, sewage, freshwater, the walls of buildings and on the surface of monuments especially in polluted areas where the air contains high levels of nitrogen compounds. *Nitrosomonas europaea* are important in the treatment of industrial and sewage waste.

(64) Which of the following is not a common morphology in bacteria?

(A) Cocci
(B) Spirilla
(C) Spirochaetes
(D) Fimbriae

ANSWER: D

Bacteria display a wide diversity of shapes and sizes, called morphologies. Most

bacterial species are either spherical, called cocci, or rod-shaped, called bacilli. Elongation is associated with swimming. Some rod-shaped bacteria, called vibrio, are slightly curved or comma-shaped; others, can be spiral-shaped, called spirilla, or tightly coiled, called spirochaetes. A small number of species even have tetrahedral or cuboidal shapes.

In bacteriology, a fimbria is an appendage made of proteins and found in many Gram-negative and some Gram-positive bacteria. It is thinner and shorter than a flagellum. This appendage ranges from 3-10 nanometers in diameter and can be up to several micrometers long. Fimbriae are used by bacteria to adhere to one another and to adhere to animal cells and some inanimate objects.

(65) Who is the first person to observe (see and reveal the existence of) bacteria?

(A) Louis Pasteur
(B) Antonie van Leeuwenhoek
(C) Robert Koch
(D) Edward Jenner

ANSWER: B

Antonie Philips van Leeuwenhoek (October 24, 1632 – August 26, 1723) was a Dutch tradesman and scientist. He considered to be the first microbiologist and is best known for his work on the improvement of the microscope and for his contributions towards the establishment of microbiology. Using his handcrafted microscopes, he was the first to observe and describe single celled organisms (including bacteria), which he originally referred to as *animalcules*, and which we now refer to as micro-organisms.

(66) Some bacteria are parasites and cause a variety of diseases. Which of the following is not a bacterial disease?

(A) Tetanus
(B) Legionnaires' disease
(C) Crohn's disease
(D) None of the above

ANSWER: C

Tetanus is a medical condition characterized by a prolonged contraction of skeletal muscle fibers. The primary symptoms are caused by tetanospasmin, a neurotoxin produced by the bacterium *Clostridium tetani*.

Legionnaires' disease is a potentially fatal infectious disease caused by the Gram-negative aerobic bacterium *Legionella pneumophila*. It is characterized by high fever and pneumonia.

Crohn's disease is an inflammatory disease of the intestines that may affect any part of the gastrointestinal tract, from the mouth to the anus, causing a wide variety of symptoms. Crohn's disease is thought to be an autoimmune disorder, in which the body's immune system attacks the gastrointestinal tract, causing inflammation.

(67) Bacteria do not only cause diseases, but produce medicines that are beneficial to mankind. Which of the following is not a medical drug of bacterial origin?

(A) Streptomycin, used in the treatment of tuberculosis
(B) Rifampicin, used in the treatment of tuberculosis
(C) Bleomycin, used in the treatment of cancer
(D) Gleevec, used in the treatment of cancer

ANSWER: D

Streptomycin is a broad spectrum antibiotic drug, the first of a class of drugs called aminoglycosides to be discovered, and was the first antibiotic remedy for tuberculosis. It is derived from the actinobacterium *Streptomyces griseus*. Streptomycin is a protein synthesis inhibitor. It binds to the small 16S rRNA of the 30S subunit of the bacterial ribosome, interfering with the binding of formyl-methionyl-tRNA to the 30S subunit. This leads to codon misreading and eventual inhibition of protein synthesis and ultimately death of microbial cells.

Rifampicin is a bactericidal antibiotic of the rifamycin group. It is a semisynthetic compound derived from the bacterium *Amycolatopsis rifamycinica.* Rifampicin inhibits DNA-dependent RNA polymerase in bacterial cells by binding its beta-subunit, thus preventing transcription to RNA and subsequent translation to proteins.

Bleomycin is a glycopeptides antibiotic produced by the bacterium *Streptomyces verticillus*. Bleomycin refers to a family of structurally related compounds. When used as an anticancer agent, the chemotherapeutical forms are primarily bleomycin A_2 and B_2. It works by causing breaks in DNA and thereby kills all fast dividing cells.

Gleevec (Imatinib) is the first member of a new class of agents that act by specifically inhibiting a certain enzyme that is characteristic of a particular cancer cell, rather than non-specifically inhibiting and killing all rapidly dividing cells. It is a completely artificial compound invented through rational drug design and served as a model for other targeted therapy modalities through tyrosine kinase inhibition.

(68) Some bacteria are useful in food processing, such as in the production of yoghurt, cheese and wine. Which of the following bacterial species is not useful in food production?

(A) *Lactobacillus casei*
(B) *Oenococcus oeni*
(C) *Vibrio alginolyticus*
(D) None of the above.

ANSWER: C

Lactobacillus casei is a bacterium found in the human intestine and mouth. It is part of the lactic acid bacteria group, named as such because most of its members convert

lactose and other sugars to lactic acid. The most common application of *L. casei* is industrial, specifically for dairy production.

Oenococcus oeni is a Gram-positive bacteria species and it is the primary bacteria involved in completing the malolactic fermentation. In wine production, it is added to produce diacetyl. The compound, diacetyl, in low levels, can impart positive *nutty* or *caramel* characters. However at higher levels it creates an intense *buttery* flavour.

Vibrio alginolyticus is a Gram-negative marine bacterium. It is medically important since it causes otitis and wound infection. It is also present in the bodies of animals such as Puffer fish, where it is responsible for the production of the potent neurotoxin, tetrodotoxin.

(69) Certain genera of Gram-positive bacteria can form highly resistant, dormant structures called endospores. Which of the following bacteria does not form endospores?

(A) *Bacillus anthracis*
(B) *Clostridium tetani*
(C) *Bacillus subtilis*
(D) None of the above.

ANSWER: D

An endospore is a dormant, tough, and temporarily non-reproductive structure produced by certain bacteria. It is a stripped-down, dormant form to which the bacterium can reduce itself. Endospore formation is usually triggered by a lack of nutrients, and usually occurs in Gram-positive bacteria, especially *Bacillus* and *Clostridium* genera. In endospore formation, the bacterium divides within its cell wall. One side then engulfs the other. Endospores enable bacteria to lay dormant for extended periods, even centuries. They can survive without nutrients. They are resistant to ultraviolet radiation, desiccation, high temperature, extreme freezing and chemical disinfectants.

(70) Antibacterial agents (antibiotics) are commonly classified based on their mechanism of action, chemical structure, or spectrum of activity. Which of the following is not a mode of action of known antibacterial drugs?

(A) Inhibition of peptidoglycan synthesis.
(B) Inhibition of protein synthesis.
(C) Inhibition of lipid biosynthesis.
(D) Inhibition of microtubule depolymerization

ANSWER: D

Bacteria are prokaryotes and do not have microtubules. Microtubules are a component of the cytoskeleton. These rope-like polymers of tubulin can grow as long as 25 micrometers and are highly dynamic. Microtubules are important for maintaining cell structure, providing platforms for intracellular transport, forming the spindle

during mitosis, as well as other cellular processes.

(71) Plants are very important in human lives as sources of food, structural material and medicines. Which of the following medicines is not derived from plants?

(A) Vincristine, used in the treatment of cancer.
(B) Morphine, used in severe pain alleviation.
(C) Bleomycin, used in the treatment of cancer.
(D) Tubocurarine used adjunctively in anesthesia during surgery.

ANSWER: C

Vincristine is a nitrogen-containing organic compound (alkaloid) from Madagascar periwinkle, *Catharanthus roseus*. The species is an evergreen shrub and has long been cultivated for herbal medicine and as an ornamental plant for its white to dark pink flowers.

Morphine is the most abundant alkaloid found in opium, the dried sap (latex) derived from shallowly slicing the unripe seedpods of the opium, or common and/or edible, poppy, *Papaver somniferum*. Morphine was the first active principle purified from a plant source and is one of at least 50 alkaloids of several different types present in opium.

Tubocurarine is a naturally occurring *mono*-quaternary alkaloid obtained from the bark of the South American plant *Chondodendron tomentosum*, a climbing vine known to the European world since the Spanish conquest of South America. Curare had been used as a source of arrow poison by South American Natives to hunt animals, and they were able to eat the animals' contaminated flesh subsequently without any untoward effects because tubocurarine cannot easily cross mucous membranes.

(72) Which of the following food crops is not considered a grass?

(A) Cucumber
(B) Sorghum
(C) Sugar cane
(D) Emmer

ANSWER: A

Poaceae are a family in the Class Liliopsida (the monocots) of the flowering plants. Poaceae are often considered to be the most important of all plant families to human economies. It includes the staple food grains and cereal crops grown around the world, such as maize, rice, wheat (bread wheat, durum wheat, emmer wheat and einkorn), oats, rye, barley and sorghum.

Sugarcane is also a grass and is the major source of table sugar (sucrose). Many other grasses are grown for forage and fodder for animal feed, particularly for sheep and cattle, thereby indirectly providing more human calories.

Grasses are also cultivated for their aesthetic features as lawns and bamboo, another grass, is widely used for

construction in Asia. Civilization was founded largely on the ability to domesticate cereal grass crops around the world.

Cucumber (*Cucumis sativus*) is a widely cultivated plant in the pumpkin family Curcubitaceae. The plant is a creeping vine which bears cylindrical edible fruit when ripe. Curcubitaceae are dicots with several leaf morphologies and the flowers are unisexual, with male and female flowers on different plants (dioecious) or on the same plant (monoecious).

(73) Which of the following is a fruit?

(A) Pumpkin
(B) Hazelnut
(C) Peanut
(D) All of the above

ANSWER: D

In its strict botanical sense, a fruit is the fleshy or dry ripened ovary of a plant, enclosing the seed or seeds. Thus, apricots, bananas, and grapes, as well as bean pods, corn grains, tomatoes, cucumbers, and (in their shells) acorns and almonds, are all technically fruits. Popularly, however, the term is restricted to the ripened ovaries that are sweet and either succulent or pulpy.

The peanut, or groundnut (*Arachis hypogaea*), is a species in the legume or "bean" family (Fabaceae). The flowers are a typical pea flower in shape, 2 to 4 cm (¾ to 1½ in) across, yellow with reddish veining. *Hypogaea* means "under the earth", after pollination, the flower stalk elongates causing it to bend until the ovary touches the ground. Continued stalk growth then pushes the ovary underground where the mature fruit develops into a legume pod, the peanut – a classical example of geocarpy.

(74) Huge quantities of fertilizer are produced annually in the world. This is applied to the soil by farmers in order to increase the amount of plant nutrients in the soil. The most important nutrient element(s) required by plants is/are:

(A) Nitrogen, Phosphorus and Potassium
(B) Nitrogen, Phosphorus and Calcium
(C) Nitrogen and Phosphorus only
(D) Nitrogen only

ANSWER: A

Plants, as autotrophic organisms, use light energy to photosynthesize sugars from CO_2 and water. They also synthesize amino acids and vitamins from carbon fixed in photosynthesis and from inorganic elements garnered from the environment. Certain key elements are required, or essential, for the complex processes of metabolism to take place in plants. The required concentrations of each essential and beneficial element vary over a wide range. The essential elements required in relatively large quantities for adequate growth are called macroelements. Nine minerals make up this group: carbon (C), hydrogen (H), oxygen (O), nitrogen (N), potassium (K), calcium

(Ca), magnesium (Mg), phosphorus (P), and sulfur (S).

Seven other essential mineral elements are required in smaller amounts (0.01 percent or less) and are called microelements. These are iron (Fe), chlorine (Cl), manganese (Mn), boron (B), copper (Cu), molybdenum (Mo), and zinc (Zn). The specific required percentages may vary considerably with species, genotype (or variety), age of the plant, and environmental conditions of growth. A macronutrient is the actual chemical form or compound in which the macroelement enters the root system of a plant. The macronutrient source of the macroelement nitrogen, for example, is the nitrate ion (NO_3^-). Carbon dioxide from the atmosphere provides the carbon atoms and two-thirds of the oxygen required by plants. Water taken from the soil provides about one-third of the oxygen and much of the hydrogen. Soil provides macroelements and microelements from mineral complexes, parent rock, and decaying organisms.

Modern chemical fertilizers include one or more of the three elements that are most important in plant nutrition: nitrogen, phosphorus, and potassium. Of secondary importance are the elements sulfur, magnesium, and calcium. Nitrogen is an essential component of all proteins. Nitrogen deficiency most often results in stunted growth. Phosphorus is important in plant bioenergetics. As a component of ATP, phosphorus is needed for the conversion of light energy to chemical energy (ATP) during photosynthesis. Phosphorus can also be used to modify the activity of various enzymes by phosphorylation, and can be used for cell signalling. Since ATP can be used for the biosynthesis of many plant biomolecules, phosphorus is important for plant growth and flower/seed formation. Potassium regulates the opening and closing of the stoma by a potassium ion pump. Since stomata are important in water regulation, potassium reduces water loss from the leaves and increases drought tolerance. Potassium deficiency may cause necrosis or interveinal chlorosis.

(75) Fatty acids and proteins (including enzymes) are all organic macromolecules with important functions in living organisms. Which of the following statements is/are true of the structure of these macromolecules?

I. A fatty acid contains a long hydrophobic carbon chain attached to a hydrophilic carboxylic acid group at one end

II. A protein consists of two amino acids linked by a peptide bond which is formed from the reaction of the $–COO^-$ group of one amino acid with the $–NH_3^+$ group of the other amino acid

III. Nearly all enzymes are globular proteins

(A) **II** only
(B) **I** and **II** only
(C) **I**, **II** and **III**
(D) **I** and **III** only

ANSWER: D

II is not accurate because it actually describes a dipeptide; a protein is a polypeptide containing more than 50 amino acids in a chain.

(76) The reactions responsible for the color and flavor of toasted bread and roasted meat are collectively known as:

(A) Aldol reactions
(B) Maillard reactions
(C) Einstein reactions
(D) Esterification reactions

ANSWER: B

The Maillard reaction is a chemical reaction between an amino acid and a reducing sugar in food, usually requiring heat. Vitally important in the preparation or presentation of many types of food, it is named after chemist Louis-Camille Maillard, who first described it in the 1910s. The reactive carbonyl group of the sugar reacts with the nucleophilic amino group of the amino acid, and forms a complex mixture of poorly-characterized molecules responsible for a range of odors and flavors. The type of the amino acid determines the resulting flavor. In the process, hundreds of different flavor compounds are created. These compounds, in turn, break down to form yet more new flavor compounds, and so on. Each type of food has a very distinctive set of flavor compounds that are formed during the Maillard reaction.

(77) Antacids are substances (bases) taken by mouth to relieve heartburn, the major symptom of acid indigestion. Which of the following correctly matches the brand name and active ingredient (base)?

(A) Gaviscon: $Al(OH)_3$
(B) Milk of Magnesia: $Mg(OH)_2$
(C) Maalox (liquid): $Al(OH)_3$ and $Mg(OH)_2$
(D) All of the above

ANSWER: D

Gaviscon is based on a mixture of calcium, magnesium and sodium carbonates and the gelling agents alginic acid and aluminium hydroxide. When taken by mouth the combination of the alginic acid and bicarbonate creates a barrier which prevents stomach acid from refluxing back up into the oesophagus.

Magnesium hydroxide has a low solubility in water and its suspension in water is often called milk of magnesia because of its milk-like appearance. Milk of Magnesia is used as an antacid to neutralize stomach acid, and as a laxative.

Maalox is a brand name antacid containing aluminium hydroxide and magnesium hydroxide to neutralize or reduce stomach acid. Liquid Maalox Regular Strength contains magnesium hydroxide and aluminium hydroxide.

(78) Which important technique used by Rosalind Franklin and Maurice Wilkins contributed significantly to the determination of the structure of DNA?

(A) Nuclear Magnetic Resonance Imaging (MRI)
(B) DNA Fingerprinting
(C) X-ray Diffraction
(D) Polymerase Chain Reaction (PCR)

ANSWER: C

X-rays were discovered by Wilhelm Conrad Roentgen in 1895 and their use in the study of materials (crystals) is known as X-ray crystallography. When a beam of X-rays strikes a crystal, atoms in this crystal cause the beam of light to spread into many specific directions. From the angles and intensities of these diffracted beams, a crystallographer can produce a three-dimensional picture of the density of electrons within the crystal. From this electron density, the mean positions of the atoms in the crystal can be determined, as well as their chemical bonds, their disorder and various other information.

Single crystal X-ray diffraction is used to solve the complete structure of crystalline materials, ranging from simple inorganic solids to complex macromolecules, such as proteins and nucleic acids. Powder diffraction (XRD) is used to characterise the crystallographic structure, crystal size (grain size), and preferred orientation in polycrystalline or powdered solid samples. Powder diffraction is commonly used to identify unknown substances, by comparing diffraction data against a database maintained by the International Center for Diffraction Data.

(79) Baking powder is added as one of the ingredients in baking to make cakes rise. How does it work?

(A) Baking powder is magnesium carbonate and it gives off carbonic acid when heated, causing rising.
(B) Baking powder is a mixture of sodium bicarbonate and tartaric acid and these two react together giving off CO_2 when water is added to cause rising.
(C) Baking powder contains yeast, which releases CO_2 on heating, causing rising.
(D) None of the above

ANSWER: B

Sodium bicarbonate ($NaHCO_3$), referred to as "baking soda" is primarily used in cooking/baking, as a leavening agent. It reacts with acidic components in batters, releasing carbon dioxide, which causes expansion of the batter and forms the characteristic texture and grain in pancakes, cakes, quick breads, and other baked and fried foods. Thermal decomposition causes sodium bicarbonate alone to act as a raising agent by releasing carbon dioxide at baking

temperatures. The carbon dioxide production starts at temperatures above 80 °C. The mixture for cakes using this method can be allowed to stand before baking without any premature release of carbon dioxide.

(80) Though at times devastating, veld fires are an important natural phenomenon. Which of the following are NOT some of the roles of forest fires?

I. Clearing of dead biomass to make way for new growth.
II. Helping some plants to germinate by burning tough seed shells.
III. Burning larvae of pest insects to keep their populations in control.
IV. Killing small rodents, reptiles and amphibians to keep their populations in control.

(A) **I** and **II**
(B) **II** and **IV**
(C) **III** and **IV**
(D) **II** and **IV**

ANSWER: C

All animals have an important ecological role to play, though it may not be obvious and nature does not deliberately kill some species through fires. Animals that die during forest fires do so accidentally as they may not be able to escape fast enough, depending on the size and intensity of the fire.

These days, global warming is of utmost concern and requires mankind to minimise energy consumption and recycle as much as possible. On the basis of this statement, answer Questions (81), (82), (83), and (84).

(81) What causes global warming?

(A) Trapping of sunlight by greenhouse gases, especially water vapor, methane and carbon dioxide.
(B) Trapping of sunlight by greenhouse gases, especially carbon dioxide, sulfur dioxide and hydrogen.
(C) Trapping of sunlight by carbon dioxide and ozone
(D) Excess heat from the sun as it grows bigger every year, like other stars.

ANSWER: A

The greenhouse effect is a process by which thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. Since part of this re-radiation is back towards the surface, energy is transferred to the surface and the lower atmosphere. As a result, the temperature there is higher than it would be if direct heating by solar radiation were the only warming mechanism. Naturally occurring amounts of greenhouse gases have a mean warming effect of about 33 °C. The major greenhouse gases are water vapor, which causes about 36–70 percent of the greenhouse effect; carbon

dioxide (CO_2), which causes 9–26 percent; methane (CH_4), which causes 4–9 percent; and ozone (O_3), which causes 3–7 percent.

(82) Which of the following fossil fuels pollutes more per ton of fuel burned for energy production?

(A) Coal
(B) Natural gas
(C) Petroleum
(D) Uranium

ANSWER: A

Coal is a solid comprising complex compounds composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, with smaller quantities of sulfur, oxygen and nitrogen. Coal is primarily used as a solid fuel to produce electricity and heat through combustion. It is usually pulverized and then burned in a furnace with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. There are a number of adverse health and environmental effects of coal burning especially in power stations and of coal mining. During combustion, the reaction between coal and the air produces oxides of carbon, including carbon dioxide (CO_2 - an important greenhouse gas), oxides of sulfur, and various oxides of nitrogen (NO_x). Oxides of sulfur react further in the atmosphere to produce acid rain. Coal and coal waste products, including ash and slag contain many heavy metals including arsenic, mercury and cadmium, which are dangerous if released into the environment. Coal also contains low levels of uranium and thorium whose release into the environment may lead to radioactive contamination. Coal mining also produces significant amounts of methane, an explosive gas responsible for many human deaths in coal mines, as well as a powerful greenhouse gas.

(83) Which of the following has the greatest potential to provide all of the world's electricity needs without any damage to the environment?

(A) Nuclear energy
(B) Solar energy
(C) Wind power
(D) Hydroelectricity

ANSWER: B (Encyclopaedia Britannica & Wikipedia)

Harnessing solar energy and its uses are limited only by human ingenuity. The Sun is an extremely powerful energy source, and sunlight is by far the largest source of energy received by the Earth, but its intensity at the Earth's surface is actually quite low. The Earth receives 174 petawatts (PW = 10^{15} Watts) of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately

3,850,000 exajoules (EJ = 10^{18} Joules) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.

Hydroelectricity is electrical power produced through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy. Once a hydroelectric complex is constructed, the project produces no direct waste, and has a considerably lower output level of CO_2 than fossil fuel powered energy plants. Worldwide, an installed capacity of 777 gigawatts supplied 2998 terawatts of hydroelectricity in 2006. This was approximately 20% of the world's electricity, and accounted for about 88% of electricity from renewable sources. Whilst hydroelectricity has great potential, unlike solar energy, it is not limitless because there are only so many perennial rivers in the world that can sustain large dams for significant power generation. In addition, dam construction requires a large amount of material (steel for reinforcement and cement) as well as moving large masses of earth and in some cases, relocation of animals and human settlements (please read about the construction of China's Three Gorges Dam or Brazil's Itaipu Dam to better understand this).

(84) Which of the following requires more electrical power for production, making recycling a must wherever possible?

(A) Aluminium
(B) Steel
(C) Paper
(D) Plastics

ANSWER: A

Aluminium forms strong chemical bonds with oxygen. Compared to most other metals, it is difficult to extract from its ore, bauxite, due to the energy required to reduce aluminium oxide (Al_2O_3). The Hall–Héroult process is the major industrial process for the production of aluminium. It involves dissolving alumina in molten cryolite, and electrolysing the molten salt bath to obtain pure aluminium metal. The electrolysis process produces exhaust which escapes into the fume hood and is evacuated. The exhaust is primarily CO_2 produced from the anode consumption and hydrogen fluoride (HF) from the cryolite and flux. HF is a highly corrosive and toxic gas, even etching glass surfaces. The gases are either treated or vented into the atmosphere; with HF being neutralized to its sodium salt, sodium fluoride. Because of their high electricity requirement, aluminium smelters are usually sited where inexpensive hydroelectric power is available. A significant proportion of the

metal (from beverage cans, automobiles, etc) is recovered and recycled. Recycling involves melting the scrap, a process that requires only 5% of the energy used to produce aluminium from ore, which is a huge step in environmental conservation.

(85) Depending on the temperature in the room you are writing this exam in, you might be shivering because it is cold, or sweating because it is too warm (or just having cold sweats because of nervousness). The part of your brain responsible for this is

(A) the medulla oblongata
(B) the pituitary gland
(C) the pons
(D) None of the above

ANSWER: D

The part of the brain that performs this function is the cerebral cortex. This is a sheet of neural tissue outermost to the cerebrum of the mammalian brain. It plays a key role in memory, attention, perceptual awareness, thought, language and consciousness.

The medulla oblongata is the lower half of the brainstem. It contains the cardiac, respiratory, vomiting and vasomotor centers and deals with autonomic, involuntary functions, such as breathing, heart rate and blood pressure.

The pons contains nuclei that relay signals from the forebrain to the cerebellum, along with nuclei that deal primarily with sleep, respiration, swallowing, bladder control, hearing, equilibrium, taste, eye movement, facial expressions, facial sensation and posture.

The pituitary gland, or hypophysis, is an endocrine gland at the bottom of the hypothalamus at the base of the brain. It secretes nine hormones that regulate homeostasis.