BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

First Semester 2009-2010 BIO C111 General Biology

Date: Dec. 10, 2009 | **COMPREHENSIVE EXAMINATION** | Max. Marks: 120

Type: Open-book | Max. Time: 3 hrs

- The question paper has 2 parts – A and B – printed over **4 sides** (2 sheets).
- Start answering each of the 6 questions on a **fresh page**.
- Attempt all parts of a question together; if the order is jumbled, **marks will be deducted**.
- In questions where you have to justify a choice, **no marks will be awarded** if the justification is wrong despite the correct choice.
- If you provide irrelevant information or write more than what is asked for, **you may lose marks**.

PART-A

1. (A) Why does cellulose form dense linear fibrils, whereas amylose (starch) forms open helices? **[2]**

(B) (i) Which microscope will you use to study the orientation of surface proteins in an internal organelle? Explain your answer. **[1]**

(ii) The bottom of an image in a biology textbook reads "EM $5x10^4X$". If the size of this image is 12.5 centimeters, what is the actual size of the object? **[2]**

(iii) Based on the size calculated above, what could be this object? Explain briefly. **[1]**

(C) In human diet, carbohydrates constitute approximately half the total caloric intake, yet on an average, only one percent of tissue weight is carbohydrate. Explain this fact. **[3]**

(D) You are diagnosed with a bacterial infection, but the doctor says the toxin causing the infection was viral in origin. How could this possibly be true? **[2]**

(E) *Write the term for:* **[3]**

(a) The line of evidence for evolution that is the most direct.
(b) The organisms that convert organic matter to inorganic matter by breaking down dead organisms.
(c) The hormone associated with childbirth and stimulation of mammary glands.
(d) The hormone associated with *diabetes insipidus*, a condition in which the body does not reabsorb water and resulting in watery urine, loss of large amounts of ions from the body and extreme thirst.
(e) The specific group of electromagnetic receptors most abundant in humans.
(f) The part of human brain that controls body coordination and balance.

(F) *In each of the following groups, three of the four entities are related by possessing a common feature. Identify the exception in each group and justify your choice suitably:* **[6]**

(i) alveoli, fibrous root, capillary network, plant cuticle

(ii) cork cambium, root apical meristem, mature sclerenchyma, zygote in the embryo sac

(iii) antidiuretic hormone, prolactin, thyroxine, progesterone

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2. (A) What types of plasma membrane-dependent transport and communication are at play during the generation and transmission of a nerve impulse? List all the types along with their contexts of use. **[4]**

(B) Give two points of similarity and two differences between cellular DNA replication and PCR. **[2]**

(C) In humans, a single gene, when mutated, results in severe upper- and lower-respiratory tract infections, and male infertility. It may also contribute to ectopic (tubal) pregnancies in women.

(i) What term in genetics best describes the effect of this gene? **[1]**

(ii)What may be the mechanism by which each of the above three conditions result? **[3]**

(D) How can you produce a human protein (the gene for which has introns) in bacteria using PCR technique as one of the aids? Give answer in a flowchart form. **[3]**

(E) (i) State any three features of the genetic code, illustrating each feature with an example. **[3]**

(ii)Which feature of the genetic code makes it possible for expressing a human gene in bacteria? **[1]**

(F) A DNA sample mixture that contains four types of linear DNA fragments of varying lengths (as given below) was subjected to gel electrophoresis:

(a) A fragment of genomic DNA of *E. coli*
(b) Lactic acid bacterial genomic DNA fragment whose size is same as (a)
(c) A plasmid DNA smaller than (a)
(d) DNA amplified by PCR whose size is lower than that of (b) but higher than (c)

(i) Draw a labeled diagram of the gel indicating the electrodes and the bands you expect to see. **[3]**

(ii) What is the basis of movement, and separation of DNA in a gel? **[1]**

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3. (A) (i) On an average, 125ml of glomerular filtrate are formed collectively through all the glomeruli each minute. Considering the average plasma volume in adult is 2.75 liters, calculate how many times the entire plasma volume is filtered by the kidneys per day. **[2]**

(ii) In the hypothetical case where the reabsorption capacity of the nephrons is zero, using the above information,calculate how long it would take for the total plasma volume to be urinated! **[2]**

(B) Why is it that people with AIDS do not die from the actual HIV infection and yet the disease has a very high mortality rate? **[2]**

(C) Explain (within 2-3 sentences) two mechanisms that operate to maintain homeostasis by regulating the pH of blood. Also mention the organ systems involved. **[3]**

(D) Children with Swyer syndrome are born with female external genitalia and ovaries, but have XY sex chromosomes. What may be the basis for this developmental genetic defect? **[2]**

(E) (i) Why doesn't a woman menstruate while she is pregnant? Explain. **[3]**

(ii) Are the muscles involved during natural childbirth voluntary or involuntary? Justify. **[2]**

(F) (i) Excessive consumption of alcohol causes irreplaceable damage to the liver. How would this affect digestion? **[2]**

(ii) Besides prescribing antibiotics for a peptic ulcer patient, the doctor also prescribed taking vitamin K supplement. Explain the rationale for both the prescriptions. **[2]**

PART-B

4. (A) Researchers have found that pregnant women can pass on cancer cells to their unborn babies, if those cancer cells carry a particular genetic mutation. This study resolves a longstanding puzzle, because in theory any cancer cells that manage to cross the placenta into the baby's bloodstream should be targeted for destruction by the child's immune system. The case, involving a Japanese mother aged 28 and her baby daughter (who developed cancer at the age of 11 months), revealed the following:

(a) Both mother's and the baby's cancer cells were genetically identical

(b) The cancer cells were genetically different from the normal body cells of the baby

(c) The cancer cells of the baby contained, in addition to a translocation mutation that is characteristic of leukemia, deletion of some other genes connected with the immune system.

Based on the given data, answer these questions:

(i) Identify the group of genes mentioned in point (c) above and how their deletion would enable the cancer cells to evade the child's immune system. **[3]**

(ii) What technique may have been used to arrive at conclusions (a) and (b) above? Justify. **[2]**

(iii)Can this be called "inherited cancer" like other forms of inherited cancers? Explain. **[3]**

(iv)Why do you think it is extremely rare for a baby to get cancer in the way described above? **[1]**

(v) In general, what is the major function of the placenta, <u>besides</u> providing a site for materials exchange between the fetus and the mother? Explain briefly. **[2]**

(B) A few hours after a person or animal dies, the joints of the body stiffen and become locked in place. This stiffening is called *rigor mortis*, and is caused due to the contracted skeletal muscles not being able to relax. What is the biochemical basis of rigor mortis? **[3]**

(C) Your friend from Coorg, Karnataka loves coffee. However, lately she has been complaining that she needs to drink more coffee and other caffeinated drinks in order to get the same effect that she used to. Excellent student of biology that you are, you tell her that this is to be expected. Why? **[2]**

(D) On July 31, 2009, in the Rajya Sabha, a member raised an interesting question in the Question Hour regarding human cloning research.

> *"Can Mahatma Gandhi be made to reborn with all his genes?"* he asked. *"Isn't a law worth having if through it research could be done to have Gandhi in a cloned form, with all his qualities -- honesty, dedication and simplicity? This would help all of us who are going astray and need guidance."*

What is the assumption that the member is making about cloned individuals? Using your knowledge of genetics and human physiology, explain if this assumption is correct. Write your answer in a point-wise manner. **[3]**

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5. (A) Mention briefly how a drug that is structurally similar to thymine inhibits the multiplication of a retrovirus in the human body. **[2]**

(B) In humans, a type of blindness called *Aniridia* is caused by a dominant gene, *A*. Another gene for hair color has two alleles showing incomplete dominance: DD = black, dd= blond, and Dd = brown hair. These two genes segregate independently of each other. A man with normal vision and brown hair marries a woman who is blind and has brown hair. Their first child had normal vision and blond hair. The couple would like to know what are the chances that their second child would be born blind and with blond hair. Calculate this probability and briefly show how you arrived at the answer. Also write the genotypes of the parents and the second child. **[4]**

(C) Many biochemical pathways are cyclic in nature. What could be the advantage over linear pathways? Give two examples of cyclic biochemical pathways. **[3]**

(D) Excessive munching of chocolates leads to tooth decay due to acid production in the mouth. How is this phenomenon associated with bacteria that reside in the mouth? **[3]**

(E) What are the conditions necessary for evolution by natural selection? **[3]**

(F) Ectotherms <u>do not</u> utilize a large fraction of ingested food energy to maintain a high and constant body temperature, unlike endotherms.

(i) Consider two different ecological systems - A and B. System A is dominated by ectothermic herbivores and carnivores, while B is dominated by endothermic herbivores and carnivores. What difference might you expect between the food chains in system A vs. food chains in system B? Explain your answer briefly. **[3]**

(ii)Explain precisely how food is used to maintain the internal body temperature. **[2]**

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6. (A) *Define (within one or two sentences) these three often incorrectly used terms*: **[3]**

(i) Heart attack (ii) Cardiac arrest (iii) Stroke

(B) How do plants and animals differ with respect to: (i) growth? (ii) regeneration potential? **[3]**

(C) *Write the term for:* **[3]**

(a) The name by which macrophages and neutrophils are collectively referred to.
(b) A group of blood proteins that can recognize invading bacteria and kill them by forming pores.
(c) Proteins of specific immune system that recognize and mark foreign antigen for phagocytosis.
(d) The branch of immunity that is effective against blood-borne infections.
(e) The interaction between two species in which both species are harmed in some way.
(f) The phenomenon in which tasty viceroy butterfly resembles a bad-tasting monarch butterfly.

(D) Cancer patients undergoing chemotherapy have hair loss and a damaged gut lining. Why do you think hair-root cells and the cells lining the gut are most affected? **[2]**

(E) If you find an unknown plant species, which stage of cell cycle will you opt for counting the chromosome number in that sexually reproducing species? Justify your answer. **[2]**

(F) (i) The rate of photosynthesis is higher when a green plant is illuminated with a light of 680 nm than when light of 700 nm is used. What will be the effect on the rate of photosynthesis when light of both these wavelengths is combined? Explain. **[3]**

(ii) Why is the rate of *dark reaction* slower in night than during daytime? **[2]**

(iii) Explain the mechanisms by which desert plants minimize loss of water. **[2]**

ANSWERS

1. **(i) Those genes that are responsible for self vs. non-self recognition (they are called HLA genes); deletion of these genes entails the cancer cells cannot be recognized as foreign by the baby's immune system.**

   (ii) Genetic fingerprinting was done on the cancer cells of the baby and the mother, as well as the normal body cells of the baby.

   (iii) No, it would not be called "inherited". Usually, when it is said that a cancer is "inherited", it means that the child has acquired a genetic mutation that predisposes the child for getting cancer. In this case, the baby's body cells do not contain any genetic mutation that is present in the cancer cells.

   (iv) The immune system of the child will usually recognize and destroy the cancer cells that crossed the placental barrier and entered the child's circulation (In this particular case, of course, it was not done - possibly due to the gene mutation that rendered the cancer cells invisible to the immune system).

   (v) Placenta is made of the chorion of the fetus, endometrium of the mother and the blood vessels of both the mother and the developing fetus. It's other is function is to secretes hCG, estrogen and progesterone

2. **(i) Pleiotropy (ii) Cilia is affected (more precisely, rendered immotile) – resulting in improper working of the respiratory track cilia (thereby unable to clear debris and mucous), spermatozoa (thereby affecting the mobility) and fallopian tube cila (thereby not being able to push the fertilized zygote to the uterus).**

3. **I would use the bone marrow stem cell, despite the difficulty in obtaining it. In order to clone the animal, a diploid somatic nucleus has to be used. The primary oocyte, having been arrested in meiosis-I, may have undergone crossing over, while the secondary ooctye, having undergone meiosis-I, is haploid.**

4. **(i) A clone does not have to be physically identical to the parent in every instance. Eg. the cloned cat differs from its mother in its coat color. And even among genetically identical twins, the behavioral and emotional differences are very distinct. So, it is very unlikely that a cloned individual would be identical to the parent in terms of all qualities. Lawmakers have to be well aware of these facts before formulating human cloning research policies.**

   (ii) Unless the cells or tissues of the diseased individual were preserved in a proper manner to ensure the intactness of the genetic material, it is not possible to to clone a deceased person.

5. **Most adult plant cells are totipotent, whereas most adult humans cells (except the early stage zygotic cells) are terminally differentiated. Animals have determinate growth, in contrast to the indeterminate plant growth. Plants have a much higher regeneration potential as compared to animals – only some animals can regenerate some of their damaged body parts.**

6. **(i) Plant cuticle - every other entity in the list is an example of maximizing surface area.**

   (ii) Mature sclerenchyma - the only non-dividing type of tissue

   (iii) Nephron - every other functional unit in the group is a single cell

   (iv) hCG - every other hormone is produced in the mother's body also

7. **(i) Total plasma volume = 125 ml /min => 125 x 60 x 24 ml / day = 180 liters / day**
   So, no. of time the filtration happens = 180/2.75 ~ 65 times

   (ii) If there is no reabsorption, then 125 ml of urine is formed per minute; so, for a plasma volume of 2.75 liters to be all converted into urine, it takes 2.75/0.125 = 22 minutes!

8. **When glucose is broken down, besides generating ATPs (useful for cellular work), heat is also generated. This increases the body temperature.**

9. **There is constant material exchange that takes place between the blood plasma and the interstitial fluid.**

10. **So that blood is cleared of the nitrogenous wastes, which if accumulate would disturb the homeostatic balance of the person. Although a fifth of the total cardiac output to 1% of the body weight may seem disproportionate, but kidneys receive this blood not for their own nourishment (only a small portion is used for this), but for clearing them of the accumulated wastes.**

11. **In positive feedback control, the end of the stimulus marks the end of the control, whereas in negative feedback control the mechanism is built-in to check for maintaining the equilibrium state. Eg. the expulsion of the baby out of the uterus would mark the end of the positive feedback.**

12. **(a) vili of the small intestine maximizes nutrient absorption (b) alveolar sacs maximize area for gas exchange (c) several small nephrons, each of which maximizes water and nutrient reabsorption**

13. **Because the movement of food is the digestive tract is one way (in contrast with that of the gastrovascular cavity), different parts of the gut can be specialized to do different functions, thereby increasing the efficiency of the process.**

14. **A balanced diet, besides providing the optimal number of calories, should also provide all the necessary nutrients required for the maintenance of the body, including essential amino acids and fatty acids.**

15. **As the food passes through the pharynx, it could theoretically move toward the front into the trachea rather than toward the back into the esophagus, which is where it should go. The swallowing reflex ensures that food passes into the esophagus. However, talking and eating at the same time interferes with this reflex. Food passing into the trachea stimulates choking and coughing, and could block this air passageway to the lungs.**

16. **Liver produces bile salts in bile, whose major function is to emulsify fats. A person with cirrhosis may have his fat digestion compromised.**

17. **The two atria function mainly as receiving chambers, receiving blood returning to the heart from the lungs and rest of the body. The ventricles are the main pumping chambers. Their thick walls are adapted to pump blood to the lungs and the rest of the body. When ventricle function is impaired and contraction is irregular, the body tissues will be deprived of their blood supply. Therefore, faulty ventricular function is far more serious.**

18. **Cardiac arrest is caused to a temporary stopping of the beating of the heart muscle, resulting in inadequate pumping of blood out of the heart. Heart attack occurs when a part of the cardiac muscle dies due to not receiving sufficient blood via the coronary arteries due to a block. Stroke is the death of brain cells when they do not receive sufficient blood (and oxygen).**

19. **Diaphragm contraction is the main cause for inhalation; when it is relaxed, expiration takes place. Any damage to this organ, or the nervous connection with this organ, would therefore severely impair breathing.**

20. **Maintenance of the level of CO_2 in blood – role of the pH sensors, brain and the respiratory system Regulation of the secretion of protons – distal tubule of nephrons secrete H^+ into the lumen, based on the ion level in body.**

21. **Menstruation is a consequence of drop in levels of progresterone and estradiol (produced by the corpus luteum) – two hormones required for maintaining the vascular endomentrium. Human chorionic gonadotropin (hCG), a hormone secreted by the embryo, maintains the corpus luteum from regression and therefore averts menstruation during the initial stages of pregnancy. Later, after the corpus luteum degrades, but the placenta takes over the production of progesterone and estradiol.**

22. **Estradiol, when present in high amounts, stimulates the anterior pituitary to synthesize FSH and LH in the follicular phase of the ovarian cycle. But during the luteal phase, in the presence of high concentration of progesterone, estradiol inhibits the pituitary from releasing FSH and LH.**

23. **Sexual – to bring forth genetically varied offspring, so that the probability of survival is maximized.**

24. **Both voluntary and involuntary muscles are involved – the uterine contractions are by the involuntary smooth muscles, and the abdominal muscles are voluntary.**

25.

26. **'OMIM' stands for 'Online Mendelian Inheritance in Man'. It is a public database of human genes, genetic phenotypes and mendelian disorders in humans. It is used by physicians, genetics researchers, professional and students as a searchable catalog.**

27. **Since CF is due to a recessive allele, both the parents could be heterozygous, and so not have the disease. But the child suffering from CF would have inherited one recessive allele from each parent.**