BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **BME 401** (Molecular Biology for Engineers)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

Symbols have their usual meanings

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) What would you observe if you omitted adaptins, clathrin, dynamin, Rab proteins, SNAREs, and tethering proteins from the vesicles or plasma membrane? **(10)**

   (b) "Many of the key intracellular signaling proteins behave as molecular switches": Explain with suitable schematic illustration. **(15)**

   (c) Describe the different mechanisms of solute transport across cell membrane. **(10)**

2. (a) In the disease myasthenia gravis, the human body makes – by mistake – antibodies to its own acetylcholine receptor molecules. These antibodies bind to and inactivate acetylcholine receptors on the plasma membrane of muscle cells. The disease leads to a devastating progressive weakening of the people affected. Early on, they may have difficulty opening their eyelids, for example, and, in an animal model of the disease, rabbits have difficulty holding their ears up. As the disease progresses, most muscles weaken, and people with myasthenia gravis have difficulty speaking and swallowing. Eventually, impaired breathing can cause death. Explain which step of muscle function is affected. **(10)**

   (b) How do you clone a particular/single fragment of DNA. **(15)**

   (c) Describe the different ways of cellular communication using extracellular signal molecules. **(10)**

3. (a) You have developed a single-stranded DNA probe that is complementary to the nucleotide sequence of interest. Describe a sensitive way to examine whether the probe can determine the specific nucleotide sequence efficiently. **(15)**

   (b) How does an action potential propagate along the length of an axon? **(10)**

   (c) Eukaryotic cell surface are coated with a carbohydrate layer. Mention different components of the carbohydrate layer and describe their functions. **(10)**

Contd P/2

BME 401

4. (a) You have isolated a single-stranded DNA fragment (3′-CGTATACAGT-5′) and you want to determine the complete sequence of that fragment. Show the steps only, with appropriate illustrations. **(15)**

   (b) Some organelles are surrounded by inner and outer membranes. Describe the mechanism of protein transport through these organelles with necessary diagrams. **(10)**

   (c) To fully understand an individual protein, it must be separated from all the other cell proteins. How do you separate the membrane protein? Explain. **(10)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) The complement system consist of several plasma proteins that are activated by microbes and promote destruction of the microbes and inflammation. Describe the classical pathways of microbial destruction by the complement system. **(15)**

   (b) What is cytokines? What are the properties of cytokines? **(10)**

   (c) How do phagocytes destroy foreign cells? **(10)**

6. (a) Briefly describe the functions of different components of innate immune system. **(10)**

   (b) What are the effector functions of antibodies? **(10)**

   (c) Naive $CD4^+$T cells differentiate into distinct subsets, such as T_H1 and T_H2 cells, in response to antigen, costimulators, and cytokines. Describe the development of T_H1 and T_H2 cells. **(15)**

7. (a) Describe the function of different gamma globulin proteins that react specifically with antigen that stimulated their production. **(20)**

   (b) What are the different types of adaptive immunity? Compare and contrast between them. **(15)**

8. (a) Cells of the immune system are almost all derived from hematopoietic stem cells (HSCs) in the bone marrow, which differentiate along branching lineages. Describe the functions of different immune system cells who are differentiated from Myeloid progenitor. **(20)**

   (b) How does cytokine help during T cell differentiation in both innate and adaptive immunity? **(15)**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **BME 403** (Medical Imaging)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

All the symbols used in the question paper have their usual meanings.

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) Consider a beam of mono-energetic X-ray photons incident upon a thin slab of non-homogenous material. Derive an expression of X-ray intensity at the detector as a function of the attenuation coefficient, slab thickness and intensity of the incident been. Extend your intensity expression to accommodate for poly-energetic X-ray photons. **(20)**

(b) An X-ray imaging system shown below is used to image a bar phantom. The detector is placed on the $z = 0$ plane. The bar phantom with two dark bars in placed on the $z = z_0$ plane, and the X-ray source is placed on the $z = 3z_0$ plane. The two dark bars on the phantom have width w and are separated by a distance w. The X-ray source fires monochromatic X-ray beams that are uniformly shed upon the phantom. Suppose the dark bars on the phantom absorb 75% of the photons passing through the phantom, and the white bars let all photons go through. Assume an ideal point source and ignore the thickness of the phantom. Also, ignore scattering, the inverse square law, obliquity, and image noise. **(15)**

(i) Sketch the intensity profile on the detector as a function of the position x for $y = 0$. Assume the intensity is 1 at $x = 0$, $y = 0$. Carefully label the axes

(ii) What is the contrast of the image on the detector? Assume the dark bars are the targets.

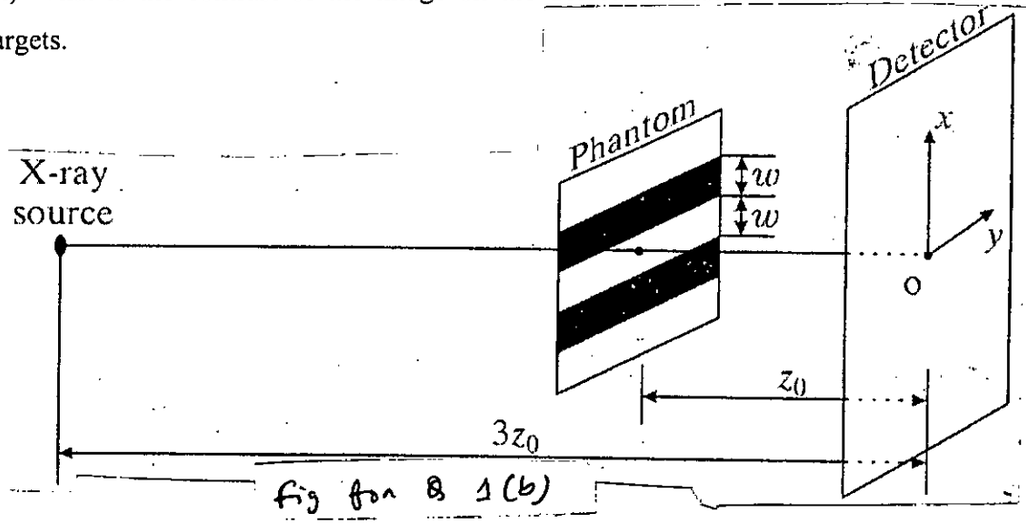

fig for Q 1 (b)

2. (a) State the projection slice theorem and derive its formation. **(12)**

(b) Write down the equations for each step of the convolution back-projection CT image reconstruction algorithm. You may use a filter approximation of your choice. **(13)**

Contd P/2

BME 403

Contd ... Q. No. 2

(c) A unit square indicator function $f(x, y)$ is given by: **(10)**

$$f(x,y)=\begin{cases}1 & ; \quad -\frac{1}{2}\le x,\ y\le\frac{1}{2}\\ 0 & ; \quad \text{otherwise}\end{cases}$$

For some value of θ where $0 \le \theta \le \pi/4$, sketch the 2-D radon transform $g_\theta(l)$ for the function $f(x, y)$. You are not required to find the mathematical expression of $g_\theta(l)$.

3. (a) Consider a parallel-beam CT system with one source, D detectors and M angles where D = M = 256. Assume that the width of each detector is d = 0.25 cm, detectors are separated by 0.05 cm and the ramp filter uses a rectangular window with cutoff $\rho_0 = 1/d$. The scanner is used to image a lesion with contrast C = 0.005 embedded in water (μ = 0.15 cm^{-1}). We require the image to have an SNR of at least 20 dB. What is the minimum number of photons per projection at the detectors that is required in order to meet this SNR constraint? **(15)**

(b) Considering a parallel hole collimator, show that there is a trade-off between collimator resolution and efficiency in nuclear medicine imaging. Explain the reason for this trade-off. **(12)**

(c) What are the ideal properties of a radiotracer to be used for nuclear medicine imaging? Mention a commonly used radiotracer. **(8)**

4. (a) With appropriate diagrams, describe these geometric effects in planar radiography: (i) inverse square-law, (ii) obliquity, and (iii) path length. Write an expression of intensity at the detector that combines these effects. Assume that the detector is flat and the imaging object is a rectangular slab having a constant linear attenuation coefficient. **(15)**

(b) What is a pulse higher analyzer as used in Nuclear Medicine imaging systems? Why is it important? **(12)**

(c) Write the major differences between SPECT and PET nuclear imaging techniques. **(8)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Figure below shows the magnitude spectra obtained from the 2D Fourier transform of two MR images (Image A and Image B). Explain which image will be more suitable for radiologists provide a diagnosis. **(5)**

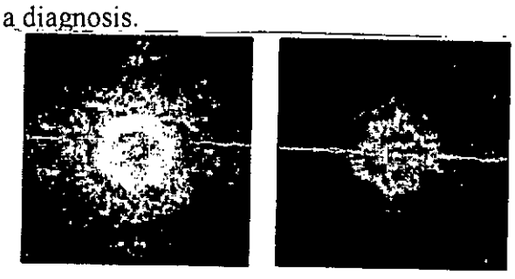

Image A Image B

Figure for Q. 5(a)

Contd P/3

BME 403

Contd ... Q. No. 5

(b) The ultrasound imaging equation is given by:

$p_s(r,t) = \frac{Re^{-\mu_a r}}{r} A_0 e^{-\mu_a d} f\left(t - c^{-1}d - c^{-1}r\right)$. Explain, with suitable illustrations, the different components of the equation. Also, using this equation, explain the underlying physics that leads to the formation of the backscattered signal. **(10+5)**

(c) For a LSI medical imaging system, the system PSF is given by $H(u,v) = 2e^{-\pi\left(u^2+4v^2\right)}$ **(3+3+3+3+3)**

(i) Explain why the system is isotropic. (hint: $h(x, y) = e^{\frac{-\left(x^2+y^2\right)}{4}}$)

(ii) Calculate the modulation transfer function of the system.

(iii) If a sinusoidal object $f(x,y) = 2 + sin(2\pi x)$ is imaged through the system, what is the recorded image, $g(x,y)$? What is the percentage change in modulation?

(iv) What is the full width at half maximum (FWHM) of the system?

(v) Another medical imaging system has the MTF shown below. Which system has the better resolution? Explain quantitatively.

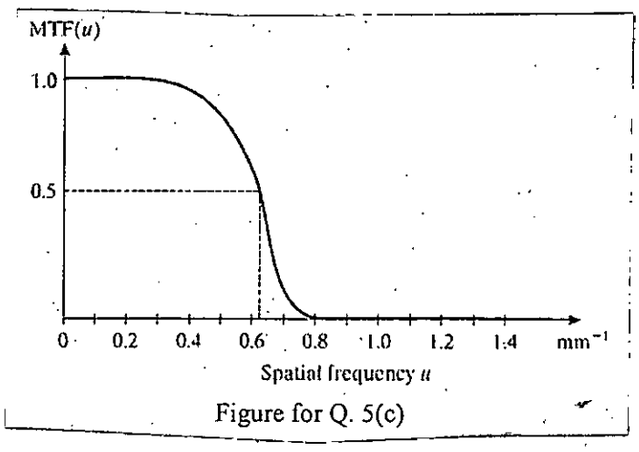

Figure for Q. 5(c)

6. (a) Consider an origin with a tumor is imaged. In the resulting image, the organ has intensity I_0 and the tumor has intensity $I_t > I_0$. Explain the impacts of the following on the local contrast if the organ is treated as a background: **(5+5)**

(i) Multiplying the image by a constant α.

(ii) Subtracting a constant $0 < I_s < I_0$ from the image.

(b) Consider a flat 1-cm transducer operating at 2 MHz in water. Find the approximate beamwidth at a (i) 5 cm range, and (ii) a 20 cm range. It is known that the speed of ultrasound waves in water is approximately 1485 m/s. **(5+5)**

(c) With suitable illustrations, explain the T_1 and T_2 time constants in MRI. **(15)**

Contd P/4

BME 403

7. (a) Compare artifacts, noise, and distortion in medical imaging and state the differences among them. **(5)**

(b) Explain the A-mode, M-mode, and B-mode in ultrasound imaging. **(5)**

(c) An ultrasound imaging is operating in B-mode and requires 256 pulses to generate an image. Assume that the transducer is sensitive to at most 80 dB loss. If the material being imaged has a speed of sound c=1540 m/s and α=1 dB cm^{-1} MHz^{-1}, what should the working frequency be to achieve a frame rate of 15 frames/second? **(10)**

(d) With suitable illustrations, explain the purpose of the slice-selection gradient in MRI. **(15)**

8. (a) Suppose a 3.5 MHz acoustic pulse travels through 2 cm of fat, and then encounters an interface with the liver at normal incidence, Calculate **(5+10)**

(i) the time interval after which the echo arrives back at the transducer.

(ii) amplitude loss in decibels taking both attenuation and reflection losses into account.

You may use the information in Table 1 for Q. 8(a) attached with the question paper.

Table 1 for Q. 8 (a)

Acoustic Properties of Various Materials

Material	Density, ρ [kg m^{-3}]	Speed, c [m s^{-1}]	Characteristic Impedance, Z [kg m^{-2} s^{-1}] ($\times 10^6$)	Absorption Coefficient, α [dB cm^{-1}] (at 1 MHz)	Approximate Frequency Dependence of α
Air at STP	1.2	330	0.0004	12	f^2
Aluminum	2,700	6,400	17	0.018	f
Brass	8,500	4,490	38	0.020	f
Castor oil	950	1,500	1.4	0.95	f^2
Mercury	13,600	1,450	20	0.00048	f^2
Polyethylene	920	2,000	1.8	4.7	$f^{1.1}$
Polymethyl-methacrylate	1,190	2,680	3.2	2.0	f
Water	1,000	1,480	1.5	0.0022	f^2
Blood	1,060	1,570	1.62	[0.15]	
Bone	1,380–1,810	4,080	3.75–7.38	[14.2–25.2]	
Brain	1,030		1.55–1.66	[0.75]	
Fat	920	1,450	1.35	[0.63]	
Kidney	1,040	1,560	1.62	—	
Liver	1,060	1,570	1.64–1.68	[1.2]	
Lung	400		0.26	[40]	

(b) With suitable illustrations, explain the concepts of frequency and phase encoding in MRI **(15)**

(c) From the 2x2 contingency table given below, calculate the sensitivity, specificity, DA, PPV, and NPV. **(5)**

		Disease	
		+	–
Text	+	54	6
	–	5	85

L-4/T-1/BME Date : 29/10/2019

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA
L-4/T-1 B.Sc. Engineering Examinations 2018-2019

Sub : **BME 409** (Tissue Engineering)

Full Marks : 210 Time : 3 Hours

The figures in the margin indicate full marks.

USE SEPARATE SCRIPTS FOR EACH SECTION

SECTION – A

There are **FOUR** questions in this Section. Answer any **THREE**.

1. (a) What are clinical needs for tissue engineering? How tissue engineering approach can be useful for new drug development? **(10)**

   (b) Tissue engineering applications typically involve the combination of three pillars, which represent the "triad of tissue engineering". With schematic briefly mention those. **(12)**

   (c) Compare the advantages and disadvantages between the 2D monolayer culture and 3D culture with biomaterial. **(13)**

2. (a) Write down the composition of ECM. With schematic compare the alignment of collagen between normal and scar tissue. **(12)**

   (b) What is the use of decellularization in tissue engineering? Mention the details steps involved in the process of preparing transplantable recelllarized liver graft. **(15)**

   (c) What are the properties of biomaterials? **(8)**

3. (a) Which natural polymer can be obtained from brown algae? What are the advantages and disadvantages of using it in tissue engineering and drug delivery? **(11)**

   (b) When you are working with a degradable implement, why you should know the degradation kinetic of the implants/scaffolds. How the degradation of polymer can be controlled? **(12)**

   (c) With schematic, write short note on photolithography. Give example of how it is being used in the field of tissue engineering. **(12)**

4. (a) What is the motivation of organ-on-a-chip technology? **(8)**

   (b) With schematic show how microfluide devices can be used for the study of liquid plug rupture effect in lung. Also mention the limitations and directions of current lung-on-a-chip devices. **(22)**

   (c) Mention the advantages of soft lithography. **(5)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) What are the properties of stem cells? "Stem cells divide to self renew and to produce terminally differentiated cell types" – with schematic draw the steps involved in these processes. **(12)**

   (b) Can a stem cell become all the types of cells it wants to be? Explain. **(12)**

   (c) How human embryonic stem cells (hESCs) can be derived? **(11)**

Contd P/2

BME 409

6. (a) Shinya Yamanaka was awarded Nobel Prize in 2012 for the discovery that mature cells can be reprogrammed to become pluripotent. What was the application of his invention? **(7)**

   (b) There are many methods for making induced pluripotent stem cells (iPSCs). Briefly describe the effects of donor cell types and culture conditions on reprogramming. **(14)**

   (c) What controls the fate of stem cells in its differentiation pathways? How mesenchymal stem cells (MSCs) can be directed towards smooth muscle cells? **(14)**

7. (a) What are the tests you should conduct to confirm whether any biomedical product is biocompatible? **(10)**

   (b) Write down the steps involved in the pre-clinical and clinical development phase of a biomedical product. **(15)**

   (c) What are the challenges in regard to translating tissue engineering technologies to the clinic? **(10)**

8. (a) How can you incorporate mechanical cues and electrical signals to cells? For what types of cells, mechanical and electrical stimulation can be useful? **(10)**

   (b) Write short note on hollow fiber bioreactors. Also mention the advantages and disadvantages of such bioreactors. **(13)**

   (c) What are the limitations of current bioreactors? **(6)**

   (d) What are the fundamental criteria for engineering functional tissues? **(6)**

L-4/T-1/BME **Date: 06/11/2019**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **HUM 415** (Professional Ethics)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

SECTION – A

There are **FOUR** questions in this section. Answer any **THREE**.

1. (a) What are the stages of moral development according to Kohlberg? Describe the stages and criticize his theory. **(15)**

   (b) Discuss the similarities and differences between Kohlberg and Gilligan's theory of moral development. **(20)**

2. (a) What is whistle blowing? **(5)**

   (b) Write about the necessary precautions before whistle blowing. **(15)**

   (c) Write about the situations to give protections to the whistle blower. **(15)**

3. (a) What is ethics? What are the branches of ethics? **(10)**

   (b) Give a short description of utilitarianism and write the limitations of utilitarianism. **(25)**

4. (a) Discuss the arguments for and against discrimination in job. **(15)**

   (b) Give your opinion on whether environment is anthropocentric or non-anthropocentric. **(20)**

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

5. (a) Give your opinion about physician assisted suicide. **(10)**

   (b) Discuss the ethical issues and policies of organ denotation. **(25)**

6. (a) Discuss different scenarios invading ethical issues of prosthetic limbs. **(20)**

   (b) Do you think that in vitro fertilization and embryo transfer is ethical? Justify your answer. **(15)**

7. (a) What are the types of euthariasia? **(10)**

   (b) Discuss the prolife and pro choice arguments of abortion debate. **(25)**

8. (a) Should genetic testing be allowed? Justify your answer. **(25)**

   (b) Write about the principles of medical ethics. **(10)**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA

L-4/T-1 B. Sc. Engineering Examinations 2018-2019

Sub : **CSE 495** (Industrial Metal Working Processes)

Full Marks : 210 Time : 3 Hours

USE SEPARATE SCRIPTS FOR EACH SECTION

The figures in the margin indicate full marks.

SECTION – A

There are **NINE** questions in this section. Answer any **SEVEN**.

1. (a) If the sequencing reads obtained from a genome are CGGTA, GCTCA, ACTGA, AGCTC, TAACT, ACGGT, construct the string graph (for minimum overlap = 2) and the de Bruijn graph (for k=4) Provide a possible assembly of the reads? **(15)**

2. Explain the difficulties caused by the following during genome assembly and strategies used to deal with these. **(15)**

   (i) Sequencing errors

   (ii) Double strandedness of DNA

   (iii) Reports in genomes

3. The Burrows Wheeler transform (BWT) of a sequence is GC$GATTCC. What is the original sequence? Show the process. **(15)**

4. Suppose you are given two sequences GCGGTASTTATCCCG and ACGGTATCATCCCG. We want to find the k-mers that are present more times in the first sequence compared to the second sequence (for k=3). For example, TAT appears twice in the first sequence and once in the second sequence and GCG appears once in the first sequence and zero times in the second. Explain how you can do this using hash tables. **(15)**

5. (a) Show that if a permutation contains a decreasing strip, then there exists a reversal that decreases the number of breakpoints. **(8+7)**

   (b) Provide a 4-approximation algorithm for the sorting by reversals problem using the above observation.

6. Briefly describe the working principle of the following: **(15)**

   (i) Sanger sequencing

   (ii) RNA-seq assay

   (iii) Microarray

Contd P/2

CSE 495

7. (a) The experimental spectrum of cyclic peptide is given below (assume there are no false/missing masses and ion loss): **(10+5)**

0 71 99 101 103 170 174 200 204 271 273 275 303 374

Determine the amino acid sequence in this peptide using a branch and bound algorithm (you can avoid showing branches that will be pruned). The masses of amino acids are given in the following table:

Amino acid	Mass	Amino acid	Mass
G	57	D	115
A	71	K/Q	118
S	87	E	129
P	97	M	131
V	99	H	137
T	101	F	147
C	103	R	156
L/I	113	Y	163
N	114	W	186

(b) Briefly explain how you can extend the branch and bound algorithm to cases where there may be false/missing masses and ion losses.

8. Describe an algorithm for the k-means clustering problem. What are some approaches to choose the 'k' for the algorithm? **(9+6)**

9. (a) Explain (i) supervised learning, (ii) unsupervised learning, and (iii) reinforcement learning with examples. **(9+6)**

(b) How can protein secondary structure prediction problem be formulated as a supervised learning problem?

SECTION – B

There are **FOUR** questions in this Section. Answer any **THREE**.

10. (a) How does the gene tree discordance complicate the estimation of species trees? What are the biological reasons for gene tree discordance? Is there any other reason (in addition to the biological ones) that can introduce gene tree discordance? **(4+2+2=8)**

(b) Consider a gene tree gt = (((a,b),e),(c,d)), and a species tree ST = ((((a,b),c)d),e). Let $dup(gt,ST)$ be the minimum number of duplications required to explain the discordance between gt and ST. Similarly, we denote by $loss(gt,ST)$, and $XL(gt,ST)$ the minimum numbers of losses and extra lineages, respectively. Show that

$$Loss(gt,ST) = 2dup(\text{gt,ST}) + XL(gt,ST).$$

You have to show the reconciliations using appropriate figures indicating the duplications, losses and extra lineages. **(22)**

Contd P/3

CSE 495

Contd. Q. No. 10

(c) What is meant by the statistical consistency of a species tree estimation method? **(5)**

11. (a) Mention the advantages and disadvantages of Combined Analysis and Summary methods. **(4+4=8)**

(b) Suppose you are trying to construct a species tree on 15 different species. You have sampled 500 genes from each of these 15 species. Your supervisor has asked you to use a method called GT-est for constructing trees from sequence alignments, and SP-est (which is a summary method) for estimating species trees from gene trees. **(6+6=12)**

(i) How many times do you need to run GT-est and SP-est to estimate a species tree by summarizing gene trees?

(ii) How many times do you need to run GT-est and SP-est to estimate a species tree using "Combined Analyses"?

(c) Briefly explain how the population size and the number of generations affect the amount of deep coalescence. **(8)**

(d) Consider a set of k phylogenetic trees each containing n taxa. **(3+4=7)**

(i) How many quartets and triplets are there in this set of trees?

(ii) How many distinct quartetrs and triplets are there in this set of trees?

12. (a) Consider the following DNA sequence (of length 10) of an organism SP_1.

1	2	3	4	5	6	7	8	9	10
A	C	T	G	A	T	C	A	C	G

Let us assume that after 800 years, SP_1 has evolved into SP_1' through the following evolutionary events. **(10)**

(i) 'T' at position 3 is substituted by A

(ii) The substring "GAT" (starting from 4 to 6) is deleted

(iii) "GT" is inserted after the 'C' at position 9.

Show the alignment of SP_1 and SP_1' and indicate the substitutions, insertions and deletions.

(b) Find the best global alignment of the following two sequences using –2 as a gap penalty, –1 as a mismatch penalty, and 2 as the score for a match. You have to use the Needleman-Wunsch algorithm, and show the corresponding dynamic programming (DP) table. Please mark the path/that corresponds to the alignment, in the DP table. **(13)**

TCAATG

ACATG

(c) Consider the sequences and the penalty/score mentioned in Q.12(b). Find the local alignment of highest score of these two sequence using Smith-Waterman algorithm. Show the DP table and mark the path that corresponds to the alignment. **(12)**

Contd P/4

CSE 495

13. (a) For a set of three taxa {a,b,c}, prove that the most frequently occurring triplet in the gene trees will be identical to the true species tree on this three taxa, given a sufficiently large number of gene trees. **(15)**

(b) Construct a tree on the leaf set {a,b,c,d,c} which is consistent with each of the following triplets. You have to show the intermediate steps of your algorithm. **(15)**

ab|c	ac|d
ab|d	ac|e
ab|e	ad|e
bc|d	bd|e
bc|e	cd|e

(c) Consider the following set of non-trival cluster: {bc, de, fg, abc, defg, bcdefg}. Is this a compatible set of cluster? If yes, show the corresponding tree. If not, explain why. **(5)**
