Strathmore
UNIVERSITY

STRATHMORE INSTITUTE OF MATHEMATICAL SCIENCES (SIMS)

MASTER OF SCIENCE IN BIOMATHEMATICS

END OF SEMESTER EXAMINATION

BMA 8203: BIOMATHEMATICS II

Date: December 13, 2018 Duration: $2\frac{1}{2}$ Hours

Answer **Question ONE** and any other **two** questions.

Question I (20 marks)

1. (a) Why is mathematical modeling important in Biomedical Science?.(**2 Marks**)
   (b) Differentiate between deterministic and stochastic models. Why would a researcher prefer using deterministic model in studying disease progression dynamics? (**4 Marks**)
   (c) Explain how/why some biological processes experience delays in their developments. (**4 Marks**)
   (d) Differentiate between cell division and cell cycle and discuss why cell division is important. (**4 marks**)
   (e) Discuss the four stages in cell cycle. (**4 Marks**)
   (f) Highlight briefly the importance of Calcium in the Intracellular as well as Extracellular Signaling. (**2 Marks**)

Question 2 (20 marks)

2. In HIV In-Host modeling, Happiness considered the virus-to-cell infection in an HIV latent infection model as shown in the flow diagram below. Time delay was included in the model,

the delay (τ) is the time between the integration of viral DNA into the host cells DNA and the reactivation for viral production.

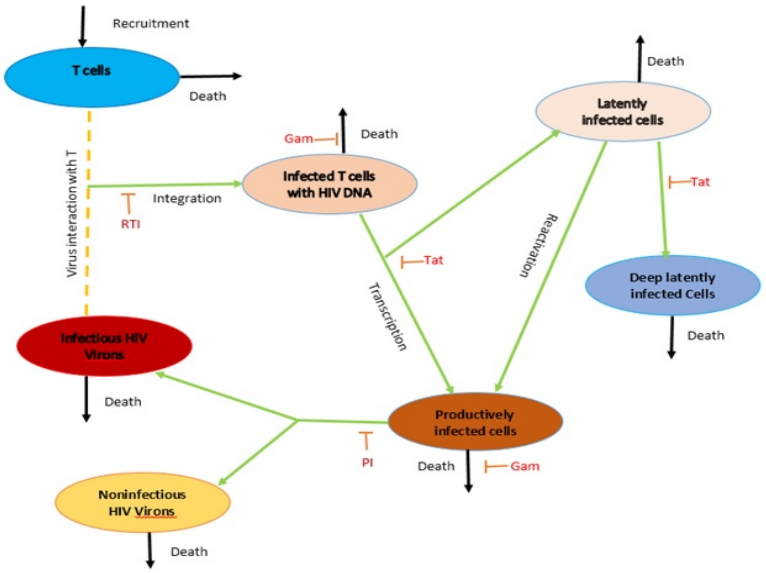

Figure 1: Flow diagram of HIV In-Host Dynamics with Therapy

The differential equations from Figure 1 were derived as follows:

$$
\begin{aligned}
\frac{dT(t)}{dt} &= \Lambda - \beta S(t)V(t) - \mu_s S(t), \\
\frac{dT_I(t)}{dt} &= \beta(1-\omega_1)S(t)V(t) - (\alpha + \omega_4\mu_I)I(t), \\
\frac{dI_L(t)}{dt} &= \alpha\omega_2 T_I(t) - \gamma I_L(t-\tau)e^{-\mu_L\tau} - (\rho\omega_2 + \mu_L)I_L(t), \\
\frac{dI_d(t)}{dt} &= \gamma\omega_2 I_L(t) - \mu_d I_d(t), \\
\frac{dI_p(t)}{dt} &= \alpha(1-\omega_2)I(t) + \gamma I_L(t-\tau)e^{-\mu_L\tau} - \omega_4\mu_p I_p(t), \\
\frac{dV(t)}{dt} &= N(1-\omega_3)\mu_p I_p(t) - \delta V(t), \\
\frac{dV_n(t)}{dt} &= N\omega_3\mu_p I_p(t) - \delta V_n(t)
\end{aligned}
$$

(i) Describe the variables and parameters in the model and comment on their biological meaning . (**12 Marks**)

(ii) State possible investigations that would be done using the model (**2 marks**)

(iii) How can this model be improved, and what other investigations can be done using the improved model. (**2 marks**)

(iv) Happiness introduced time delay in the model, what is the importance of the time delay in the model? discuss the biological meaning of the term including time delay. (**4 marks**)

Question 3 (20 marks)

3. The Figure below shows the cell cycle dynamics

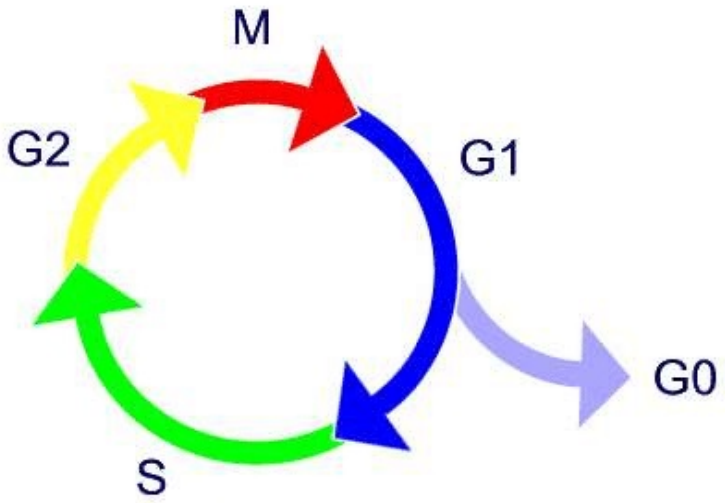

Figure 2: Cell Cycle Dynamics

(i) Discuss the process of tumor growth in relation to the four phases of cell cycle. (**6 marks**)

(ii) Discuss how you can model the process depicted in Figure 2 mathematically. (**6 marks**)

(iii) Why is it that the concept of cell cycle is important in understanding the mechanism of chemotherapy? (**3 marks**)

(iv) Discuss how the model discussed in (ii) can be solved and how is the model important?. (**5 marks**)

Question 4 (20 marks)

4. Let the chemical reaction below represent food transportation process in human body.

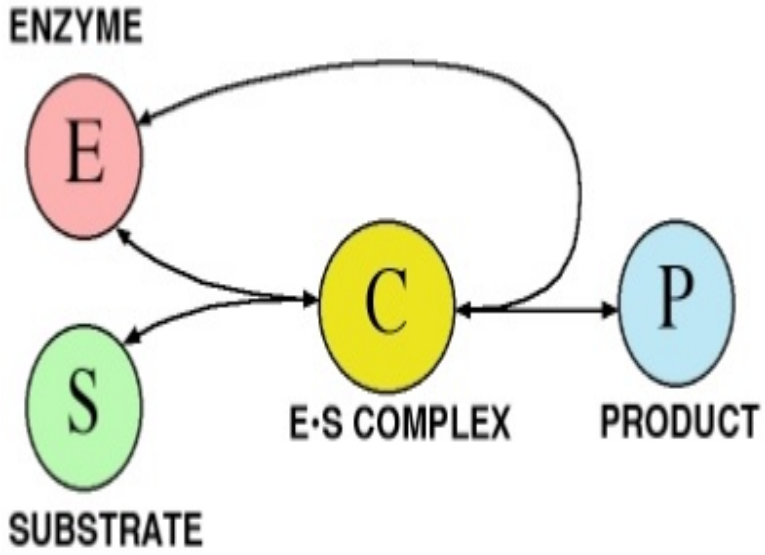

Figure 3: Chemical reaction kinetics

Where S represents the extra cellular food molecules, E the unbounded receptor molecules(enzymes), C the bounded receptor enzymes and P the intra-cellular food molecules.
The chemical notation for the process is denoted by:

$$S + E \underset{k_2}{\overset{k_1}{\rightleftharpoons}} C \longrightarrow^{k_3} P + E$$

(i) Using the law of mass action, formulate the ordinary differential equations describing the dynamics of enzyme and food concentrations over time. (**8 marks**)

(ii) Discuss the meaning of k_1,k_2 and k_3 in relation to food processing. (**4 Marks**)

(iii) Apply the law of mass conservation and show that the equations derived in (i) can be reduced to: (**8 marks**)

$$\begin{aligned} \frac{ds}{dt} &= -k_1 s(e_{tot} - c) + k_2 c \\ \frac{dc}{dt} &= k_1 s(e_{tot} - c) - (k_2 + k_3)c \end{aligned}$$