Technische Universiteit Eindhoven University of Technology

Tumor growth and the immune system

Project for the course on Modeling Dynamics

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Introduction

Protocols and treatments for cancer are developed on the basis of a thorough understanding of the role of critical parameters in the immune system that regulate the interaction between tumor cells and immune cells. Such protocols make use of vaccines, chemotherapies and immunotherapies so as to activate a process in the immune system that controls or blocks the tumor growth by interfering with its cell-division process.

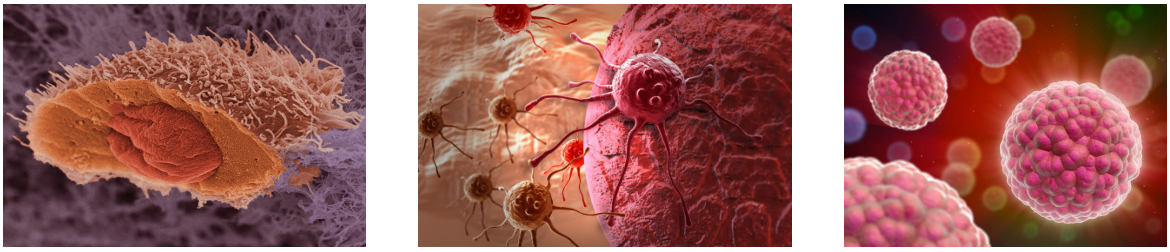

Figure 1: Tumor cells in tissue

Typical treatments for cancer amount to administrating therapeutic antibodies in drugs so as to make immune cells stronger and so as to eliminate tumor cells. A substantial amount of research is carried out to investigate the dynamics of the interaction between populations of cancer cells and populations of immune cells. Novel immunotherapies are the result of this research.

Modeling tumor growth

In all biological and oncological research on tumor development, it is particularly important to understand the dynamics of the tumor-immune system interaction. In this context, many models have been proposed that explain and describe the interaction between malignant (tumor) cells and normal (immune or healthy) cells in an organic tissue. In one such model, the immune system reacts on the presence of malignant cells by activating specific antibodies or 'hunting' cells (such as macrophages or T-lymphocytes) that neutralize or eliminate the malignant cells in a population. In turn, the 'hunting' or antibody cells belong to a population of 'resting' cells that are latent in the tissue and that do not directly interfere with the malignant cells.

A common model that represents this phenomenon is described by the equations

$$\begin{aligned} \dot{M} &= 1 + a_1 M(1-M) - a_2 MH \\ \dot{H} &= a_3 HR - a_4 H \\ \dot{R} &= a_5 R(1-R) - a_6 HR - a_7 R \end{aligned} \tag{1}$$

where

- M is the density of the malignant or tumor cells,
- H is the density of the active hunting cells and

- R is the density of the resting cells in the immune system.

All indicated parameters a_i are non-negative numbers. In particular,

- a_1 is the growth rate of tumor cells,
- a_2 is the rate of destruction of tumor cells by the hunting cells.
- a_3 is the conversion rate from resting cells to hunting cells,
- a_4 is the natural death rate of hunting cells,
- a_5 is the growth rate of resting cells,
- a_6 is the conversion rate from hunting to resting cells,
- a_7 is the natural death rate of resting cells.

Depending on the parameters, this model may exhibit various clinical conditions:

- unbounded growth: leading to the growth of a tumor.
- tumor dormancy: a steady state condition in which the size of the population of malignant cells and the size of the population of normal cells is balanced and constant.
- tumor recurrence: a cyclic pattern in which the population of malignant cells grows and reduces over time.
- tumor remission: a steady state condition of tumor eradication due to the influence of immune or normal cells.

The problem of understanding the interaction between malignant cells and the immune system of an organism deserves quite some attention. A system theoretic perspective on this understanding proves quite useful for studying the dynamic features of tumor growth and to understand the implication on specific treatments. In fact, such a perspective brings valuable insight in some key mechanisms that are used in immunology, oncology and cancer biology. This will be the purpose of this project.

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