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Optimisation of Cancer Treatment Using Nanotechnology

Manish Rishi and Tejaswi Sachwani

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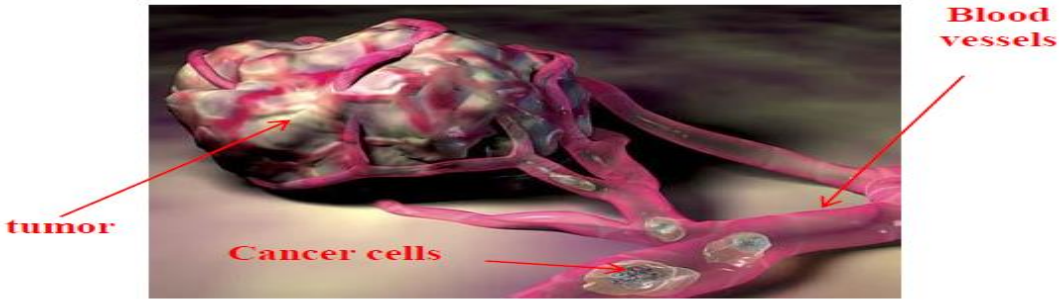
INTRODUCTION

The cells which persist to reproduce, fail to distinguish into defined cells and become eternal is known as cancer. Cancer is also known as unrestrained tissue expansion which can be benign or malignant. **Benign** tumors do not disseminate to other parts of the body and does not kills host cells. But in **malignant tumours** uncontrolled expansion of normal cells takes place and also kills the host cells. There exists an exponential increase in the cancer cells. Though the cancerous mass is usually noted in terms of the number of cells.



metastasis

Carcinogenicity is related with gradual changes in the cellular, genetic, and epigenetic traits that resulting in unrestrained cell division, eventually directing to the accumulation of a malicious mass. These malicious tumors (cancer) have the potential to infest other organs and spread to other parts of the body (metastasis) away from the point of its beginning which make the disease life-threatening. So, the **Cancer** is also named as a **malignant tumor** or **malignant neoplasm.**

Levels of cancer:

Stage 0 – It is also called carcinoma in situ stage. There is no sign of cancer in this stage. Only benign cell is present which has the potential to become malignant.

Stage I – It is also called pre or early stage cancer. The cancer is meagre and confined to only one part of the body. They are easily curable.

Stage II – The cancer is expanded and in developed stage.

Stage III – is similar to stage II. Cells are about to be malignant by infecting nearby tissues or lymph nodes.

Stage IV- It is also called metastasis stage. Cells become malignant and infect the other parts of the body.

OPTIMISED SOLUTION: "NANOTECHNOLOGY"

The word Nano is originated from the Greek word **Nanos,** which means **short old man** or **dwarf.**

In 1974, Professor Norio Taniguchi of Tokyo Science University coined the term "**nanotechnology**". But it was first predicted by the Physicist Richard Feynman on 29 December, 1959.

Nanotechnology is defined as the technology of handling atoms or molecules on minute level and fabricating products and devices. These atoms or molecules are in the form of nanoparticles. Nanoparticles vary in sizes, ranging from 1nm to 100nm or of the size obtained when 6 carbon atoms are consolidated in a row. A nanometer is defined as ***one billionth of a meter i.e.*** 10^{-9} m.

Nanotechnology is basically an implementation of Nano science. It mainly comprises of mutilations, segregation, integration and fabrication of objects by handling atom or molecule one by one. They also show the characteristics of self-assembly, reliability, drug coating and biocompatibility.

Nanotechnology is interdisciplinary fields of physics, chemistry, biochemistry and molecular biology. Here electronic, magnetic, optical and catalytic features are being reviewed. Sizes from 10 nm to 400 nm solid colloidal particles are also specified in Nanotechnology.

Approaches of Nanotechnology:

Nano devices can be created by two ways-

i) Top-down approach –The process in which material is carved and framed into smaller parts is called top down approach.

This process start with a larger parts and then moulding is being performed. Modelling is done using photolithography and then matter is being etched to get the desired structure.

Example – Fabricating sculpture from rock.

ii) Bottom-up approach – The process in which smaller parts are assembled and moulds into larger structure is called bottom-up approach.

Here atom by atom and molecule by molecule are assembled together. Self-assembly of atoms and molecules take place which is widely seen in chemical and biological systems. In medicine this approach is widely used for device fabrication.

Example- Fabricating building from bricks.

Cancer Biomarkers:

Biomarkers are also labeled as antigens**.** Nanoparticles play a vital role to target bio-markers or antigens that are extremely particular to cancer cells. They also acquire specific traits such as increased selectivity and sensitivity. This helps us to identify rotating cancer biomarkers at early stage.

MODELING METHODOLOGIES

Modelling of cancer can be done using discrete, continuous or hybrid mathematical procedures**.** Time space modelling of particular cells and their connections with other cells is called **discrete modelling method.** Drawback of this model is the need of large numbers of computation. As growth of cell increases, the need of computation also increases. This limits the model to small number of cells computation.

Continuous modelling is used to model large number of cells. It helps in reducing the cost of computation and affecting the firmness of individual cells, particularly when the features of the cell changes across small spatial and temporal scales.

Hybrid modeling is a combination of discrete and continuous modeling methods. It combines the features of both kind of modeling. It is basically used for modeling genetic systems. For example-Modeling of biological systems in which variations of drug occurs non-linearly.

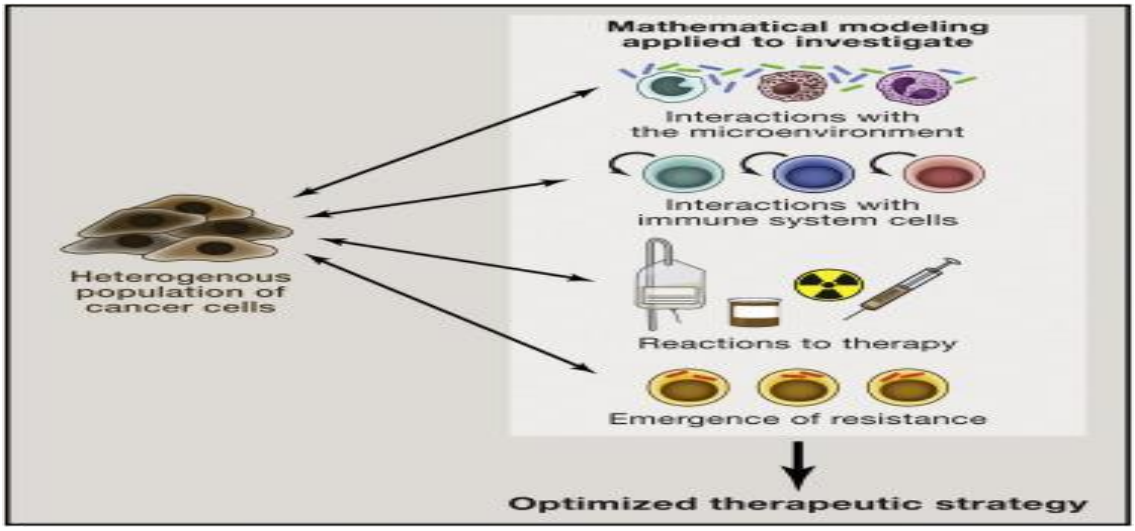
These modeling can be computed by the equations known as **Ordinary Differential Equations (ODE).**

The main purpose of modeling is to optimize the treatment of cancer. This project uses **COMSOL MULTIPHYSICS** software to load the different imaging, molecular, histological and treatment statistics.

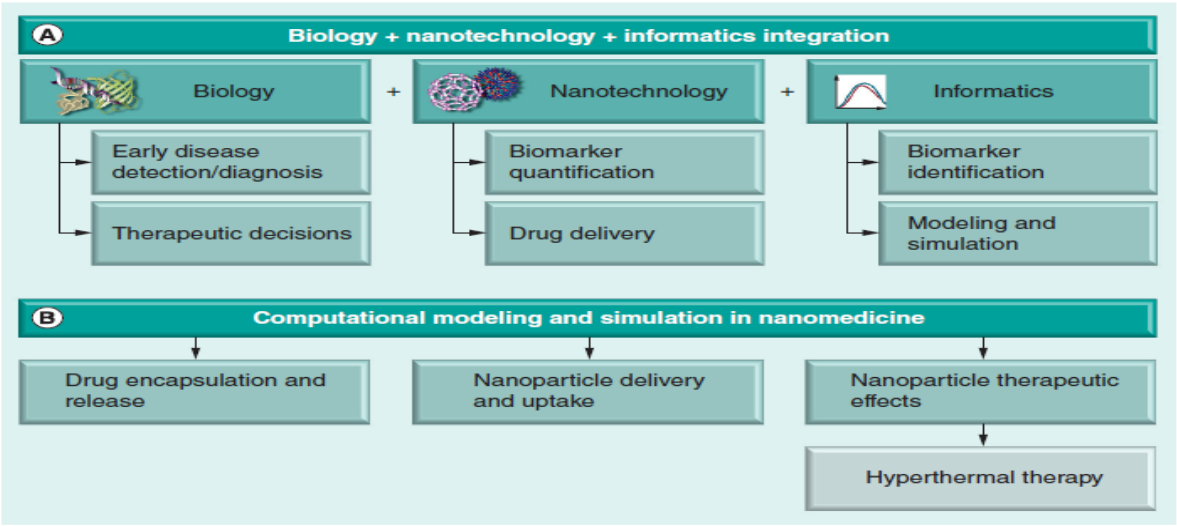
Mathematical modelling:

Mathematical modelling is a powerful tool to target only cancer cells. It is used to understand the behaviour of cancer and its interaction with therapy. It test hypotheses, confirms experiments, and simulates the dynamics of complex systems. It offers a platform to study cancer without losing patients' lives. These models are then validated using in vivo and in vitro experiments as well as patients' data.

Ordinary differential equations describe how properties of a real-world system evolve over time. The properties are called the state of the system. These ODEs can be used to describe the interaction between cancer growth and therapy by adding an anticancer treatment term.



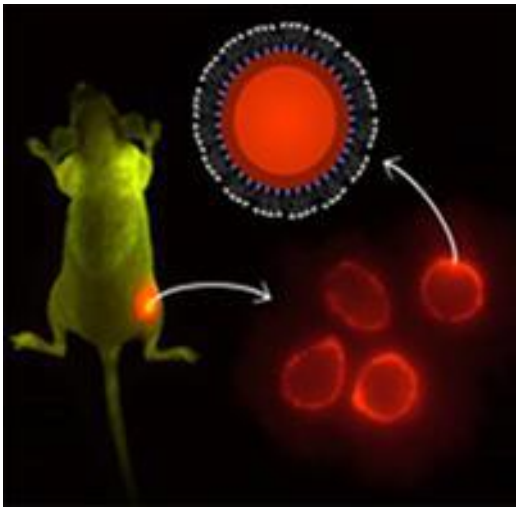
Computation modeling:



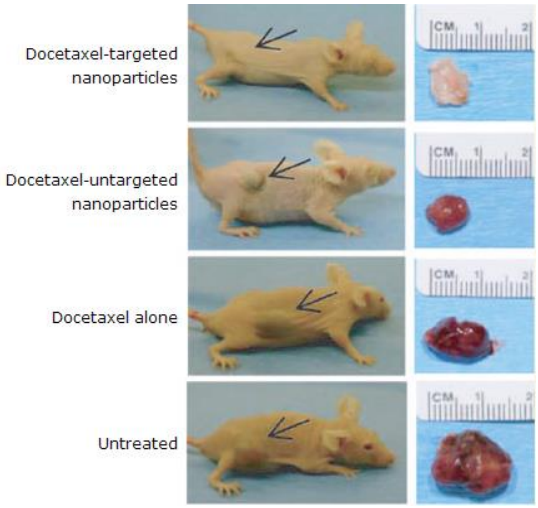
Computational methods for nanomedicine

Experiment:

Mice carrying the human prostate tumors



Treatment



Stage I – Mice is detected with tumor. Lower most figure show the same condition.

Stage II – Mice is treated with Docetaxel alone. Only 14% of the tumor is destroyed. So, the possibility of mice might survived is now 14%.

Stage III - Mice is treated with Docetaxel untargeted nanoparticles. Here, 57% of the tumor gets destroyed and possibility of mice survival is increased to 57%.

Stage IV - Mice is treated with Docetaxel targeted nanoparticles. Thus, complete tumor gets destroyed. After 3 months of treatment, mice get survived completely.

Hence, due to targeted nanoparticles toxicity gets reduced, which is highly dependent on amount of weight loss and white blood cell count.

ODE model:

According to **Gompertz** ODE model, we have following equations:

$$\frac{dN}{dt} = \lambda N \ln\left(\frac{K}{N}\right) \quad (1)$$

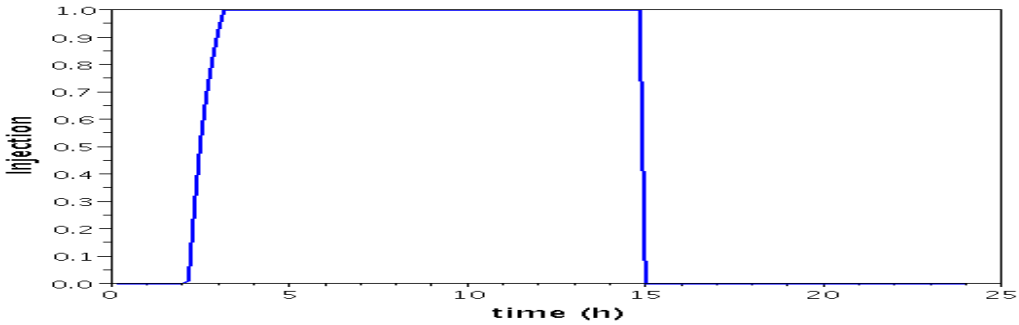
$$\frac{dK}{dt} = bN - (\mu + dN^{2/3})K - \eta g(t)K \quad (2)$$

where, **K** is the maximum tumor size or "carrying capacity" of the environment, **N** is the number of cells, **dN** is the difference in cell number, **b** is the rate of the tumour-induced vessel formation,

(μ + dN2/3) is the rate of spontaneous and tumour-induced vessel loss, **g (t) ≥ 0** represents the nanoparticle drug concentration and λ is the number of dividing cells.

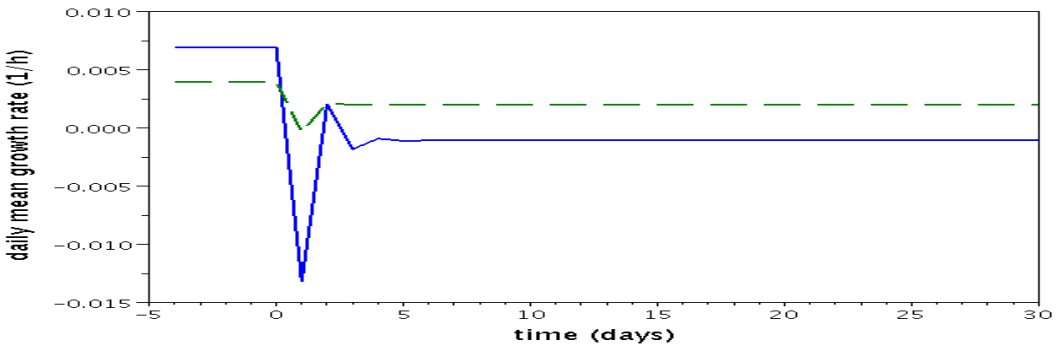
Simulation result:

Optimal periodic nanoparticle drug infusion strategy-

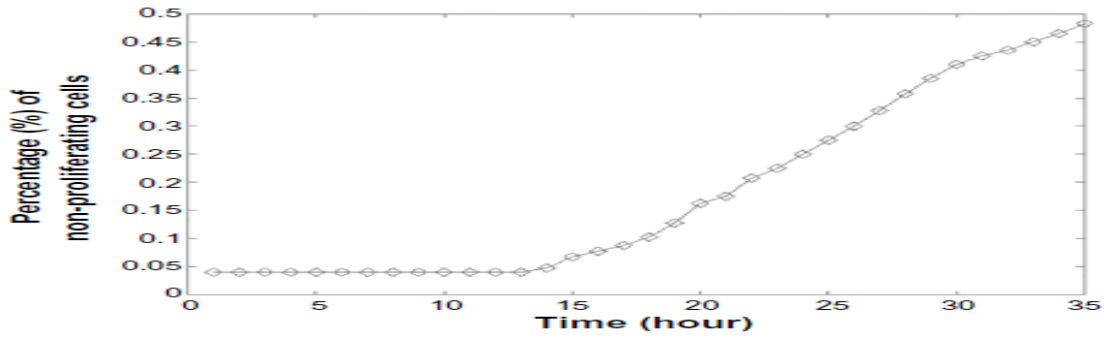


Here, healthy cells do no change phase, thus harming cancer cells only.

Optimization of cancer drug treatments using cell population dynamics-



Effect of nanoparticle loaded drug-



CONCLUSION

Top-down and bottom-up nanotechnology approach had played a relevant optimisation method in early imaging, diagnosing and treating the cancer This could be achieved precisely and effectively.
Cancer Nanomedicine i.e. nanoparticle loaded drugs has now replaced the conventional drugs. This also leads to **Nanotheranostics** method of treating the cancer, which will aid in diagnosing and treating the liquid tumors or cancer.

A paper based cancer diagnosis has been prepared by MIT professor **Sangeeta Bhatia**. It can image the cancer by determining biomarkers in the patient's urine. Paper strips test is analogous to pregnancy test. Indian Institute of Technology (IIT), Roorkee researchers under the guidance of Professor Dr. P.Gopinath has fabricated a carbon nanotube that will act as a Theranostic tool to diagnose and treat the cancer. It will also aid to carry out imaging and annihilation of cancer cells concurrently.

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