Thermoplasmonic Heating and Cancer Biology

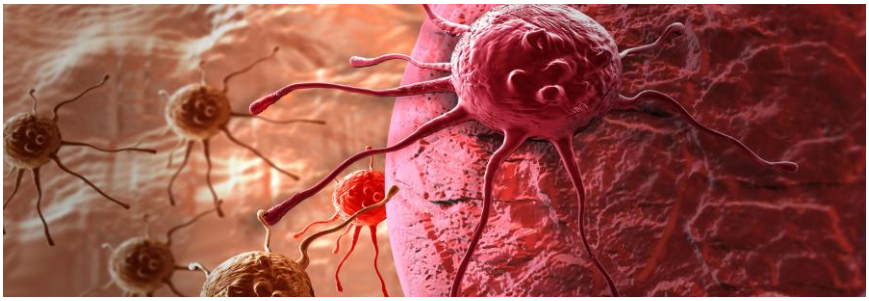
Subject Area(s) **Biology**

Associated Unit **The cell cycle and Cancer**

Lesson Title **Cancer Biology**

Header

Image 1
Cancer cell
Source/rights: https://commons.wikimedia.org/wiki/File:Cancer-cell.jpg



Grade Level **9 – 12th**

Lesson # 1 of 1

Lesson Dependency

Time Required

Summary

Students will learn the basic concepts behind cancer biology as well as the hallmarks for cancer. Through exploration activities, they will uncover mechanisms behind cancer drug treatments and screening protocols. Students will be introduced to the technology behind thermoplasmonic heating and brainstorm ways they can use this concept to fight against the spread of cancer.

Engineering Connection Students will learn about the process behind thermoplasmonic heating through a guided reading activity and classroom demonstration. They will be asked to develop their own experiments using thermoplasmonic heating.

Engineering Category Engineering design process

Keywords thermoplasmonics, cancer, mutation, cell cycle, tumors, screening, antigen, antibody

Educational Standards (List 2-4)

State STEM Standard SC.912.L.16.8 Explain the relationship between mutation, cell cycle, and uncontrolled cell growth potentially resulting in cancer.

ITEEA Standard Design

Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

NGSS Standard SC.912.L.16.8 Explain the relationship between mutation, cell cycle, and uncontrolled cell growth potentially resulting in cancer.

CCSS Standard Integration of Knowledge and Ideas

Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Pre-Requisite Knowledge Understanding cell division – meiosis & mitosis; DNA

Learning Objectives

After this lesson, students should be able to:

- **Understand the basic requirements for the development of cancer cells**
- **Recognize the challenges involved in developing therapeutic measures to fight against cancer**
- **Apply the concept of thermoplasmonic heating towards any science field**

Introduction / Motivation (5E – Engage)

Video link: https://www.youtube.com/watch?v=4kyk8Grh-Yg

Students will be shown an introductory cancer video followed by a 'think-pair-share' discussion activity. The teacher will then ask for a whole class group share out. Students will be guided through their "think-pair-share" via a discussion guide provided from the teacher:

Think

Write three solutions or ideas you have about this question or problem.

1.

2.

3.

Pair

Discuss your ideas with a partner. Check any ideas above your partner also wrote down. Write down ideas your partner had that you did not.

1.

2.

3.

Share

Review all of your ideas and circle the one you think is most important. One of you will share this idea with the whole group. As you listen to the ideas of the whole group, write down three you liked.

1.

2.

3.

Lesson Background & Concepts for Teachers (5E – Explain)

Refer to ppt attachment:

Students will be given a short power point presentation on 'The hallmarks of Cancer'. A 'Cornell Note Taking' guide will be provided by the teacher:

CORNELL NOTES SHEET	**Name: _____** **Class: _____ Topic: _____** **Date: ____/ ___/ ____ Period _____**
QUESTIONS	**NOTES**

SUMMARY: Write 4 or more sentences describing specific learning from these notes.

_____

_____

_____

_____

_____

Vocabulary / Definitions

Word	Definition
thermoplasmonics	using metal nanostructures to control temperature on the nanoscale
cancer	a group of diseases involving abnormal cell growth with the potential to invade or spread to other parts of the body.
mutation	the changing of the structure of a gene, resulting in a variant form that may be transmitted to subsequent generations, caused by the alteration of single base units in DNA, or the deletion, insertion, or rearrangement of larger sections of genes or chromosomes.
cell cycle	is the series of events that take place in a cell leading to its division and duplication of its DNA (DNA replication) to produce two daughter cells.
Tumors	a swelling of a part of the body, generally without inflammation, caused by an abnormal growth of tissue, whether benign or malignant.
screening	is a strategy used in a population to identify the possible presence of an as-yet-undiagnosed disease in individuals without signs or symptoms.
Antigen	a toxin or other foreign substance that induces an immune response in the body, especially the production of antibodies.
antibody	is a large, Y-shaped protein produced mainly by plasma cells that is used by the immune system to neutralize pathogens such as bacteria and viruses.

Associated Activities (5E – Explore)

Students will use a text-marking strategy to evaluate the benefits and challenges of using the 'Thermoplasmonic Heating' technology towards cancer screening. The article is given as:

"Thermosplasmonic Heating & Oral Cancer"

In 2016, the number of disease related deaths rose to 12.6 million. Among the greatest contributors were cancers and infectious diseases (5). Most afflicted patients are not aware of their diseased state until it has already progressed to a stage where it is difficult to treat. For example, oral cancer is ranked the 6th most common cancer in the world with only 60% of patients surviving a maximum of five years after initial diagnosis. Currently, the disease is first identified only through conventional examination of the oral cavity and usually only after the cancer has already metastasized. This makes the need for early detection techniques critical (2). Biomarkers for this type of cancer can be screened through the patient's saliva since any cancerous lesions in the mouth will have direct contact with saliva. Saliva can thus prove to be a useful, noninvasive method of screening for biomarkers involved in oral cancer (1). 'Point of Care' (POC) devices are used by health care professionals to obtain diagnostic results while with their patient. The goal of using these devices is to provide quick feedback with accuracy (3). A fairly new area of science and engineering involves the use of metals to regulate temperature on a nanoscale. This is called thermoplasmonics and could, theoretically, reduce the amount of time needed for complex reactions to take place, such as when incubation is required (4).

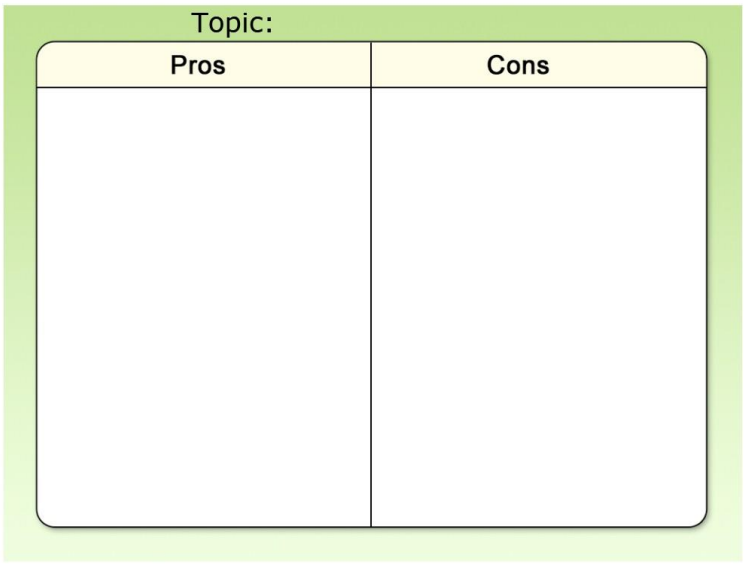
Practical thermal platforms for solar energy harvesting and manipulation of thermal radiation are necessarily highly absorbing, but also affordable and scalable. Nanoplasmonic metamaterial absorbers[1,2,3,4,5,6,7] offer a route towards low material consumption and compact designs while maintaining large optical cross-sections[8,9,10,11]. They exploit the collective oscillations of electrons in metallic nanostructures - localized plasmons - for the highly efficient coupling of light. In the same time, individual plasmon nanostructures in these materials act collectively as an effective absorbing layer, i.e., a metasurface. The emerging field of thermoplasmonics then addresses applications of light-heated plasmonic nanostructures in photothermal therapeutics and drug release[1,12,13,14,15], thermal optical data storage[16], enhanced catalysis[4,17,18], magnetic recording[19,20], solar thermal energy harvesting[6,21,22,23] and optoelectronics[24,25].

Whereas up to now the focus is on intricate design of nanoplasmonic metamaterials units, often by advanced electromagnetic simulations and highly demanding nanofabrication methods such as electron-beam lithography, recent advances in nanofabrication have led to simple and thereby cheap large-scale manufacturing methods of light absorbing plasmonic metasurfaces[26,27]. These approaches utilize amorphous arrangements of individual

nanoplasmonic structures (meta-atoms) with simple geometries, which as a whole develop desired collective absorptive properties. When developing realistic light absorbing nanoplasmonic systems, optimization primarily focuses on the size, shape and material composition of the individual particles. While local plasmon-enabled thermal gradients, confined to the nanoscale, are well-documented in these systems[28,29,30,31,32,33,34,35], large-scale (i. e., *macroscopic*) thermal effects due to plasmons are also of strong interest since their importance in e.g. catalysis has been demonstrated[36,37]. In the wake of the development of macroscopic plasmon metamaterial absorbers that aim, for example, at wafer-scale solar thermal harvesting, the comprehensive experimental characterization of such thermal effects comes handy.

The prime aim when developing absorbing plasmonic architectures is to enhance the non-radiative decay of the excited nanoplasmons. This is typically done by reducing the size of plasmonic nanoparticles or by changing the dielectric function of the material[38]. Although noble metal nanoparticles of Au or Ag are widely used in plasmon metamaterials due to their well-pronounced resonances in the visible and near-IR, they might not be the best choice as absorbing platforms. Under white light or solar illumination plasmonic nanostructures having markedly lower but instead spectrally broader absorption may be equal to or even surpassing Au-based superabsorbers.

Head and neck cancer comprises squamous cell carcinomas of the upper aerodigestive tract. There are similarities in their natural history, epidemiology and control. For these cancers premalignant changes can be identified. Smoking and drinking are the major risk factors. The geographical variations in incidence and mortality are indicative of differences in the prevalence of risk factors between countries. The dramatic increase in head and neck cancers is cause for great concern, particularly in Central-Eastern Europe. The great majority of these cancers could be prevented by reducing the prevalence of established risk factors. Screening could be used to detect both precancerous lesions and early invasive cancers; however, no study as yet has demonstrated a reduced incidence and mortality resulting from screening. When setting strategies for prevention, the socioeconomic differentials in incidence and mortality from head and neck cancers need to be taken into account.



Lesson Extension Activities (5E – Extension)

Students will use their new knowledge of thermoplasmonic heating and design a lab using this technology. Students Students can choose from any type of experiment to test:

DESIGN ASPECT 1: ***Defining the Problem and Selecting Variables***

BACKGROUND INFORMATION.

Introduce the biological principles…

…….and explain the concept(s) that is being investigated.
Show an independent understanding of what you plan to do in lab.
Provide the scientific name of any organism used (*Genus species*).

RESEARCH QUESTION.

Be sure your question is focused

The independent and dependent variables must be clearly identified. Often, but not always, the RQ is written as,
"What is the effect of __IV__ on __DV__?"

Explain what you plan to change, the **INDEPENDENT VARIABLE**. Indicate the range of the independent variable and list the levels of the IV that you included. Typically you should have a minimum of 5 levels of the IV.

You need to explain what will be measured, the **DEPENDENT VARIABLE.** State what will be measured (both qualitative and quantitative data) and explain how it will be measured.

For experiments in which you are determining the effect of a IV on and DV, you need to include an **HYPOTHESIS**. It will often take the form of a proposed relationship between two or more variables that can be tested by experiment.

Hypothesis statements are often written as:

If __*describe IV manipulation*__, then __*expected result on the DV*__ because __*explain why*__.

This should be a brief discussion (paragraph form) about the theory or 'why' behind your hypothesis and prediction. You should site credible references that support your explanation

DESIGN ASPECT 2: ***Controlling Independent Variables***

- At least three **INDEPENDENT VARIABLES** that will be **CONTROLLED** in your method are required, but more may be necessary. The controlled variables you list must be relevant to your investigation.
- You need to control for all variables that may reasonably affect the outcome of the investigation. **Materials used and measurement techniques are NOT controlled variables**
- You must explain why and how variables were controlled.
  Often students create a table to organize this information:

CONTROLLED VARIABLES	**WHY** in must be controlled	**HOW** it was controlled
1.		
2.		
3.		

DESIGN ASPECT 3: ***Developing a Method for Collection of Data***

- Make a list of the **EQUIPMENT** needed in the investigation. Be as specific as possible (example: '50 mL beaker' instead of 'beaker'); include the volumes of tubes and cylinders, the concentrations of solutions, the model and manufacturer of any complex apparatus. If you have to decide how much of a substance or a solution to use, state your reasoning or show the calculations.

- Include a **DIAGRAM OR PHOTOGRAPH** of how you set up the experiment. Be sure your diagram includes a title and any necessary labels. It is recommended that this be annotated to illustrate how the variables were involved.

- Describe the **METHOD** that you plan to use in the experiment. This should be a list of step-by-step directions. Provide enough detail so that another person could repeat your work by reading your report.
  You may need to try the experiment to know exact volumes.

  - Your procedure should include a few **MEASURES FOR PERFECTION** (i.e. cleaning test tubes prior to use, cleaning the microscope lenses, using the same ruler…). These make sure experimental measurements are consistent.

  - Your procedure must **CLEARLY STATE HOW YOU PLAN TO COLLECT DATA**. What measuring device will you use, what data will you record? What **qualitative observations** will you look for?

  - Explain how you set up the investigation so you had **MULTIPLE TRIALS** of data collection. The procedure must allow collection of "sufficient relevant data". The definition of "sufficient relevant data" depends on the context.

  - The planned investigation should anticipate the collection of enough data so that the problem question can be suitably addressed and an evaluation of the reliability of the data can be made.

  - As a rule, the lower limit is a sample size of five. Very small experiments could collect 15 pieces of data, but some professional trials collect 100 repeats of each piece of data. Obviously, you muct plan something within the limits of the time available for an investigation.

  - If you are **SAMPLING** only a portion of a population, you must explain how and why you ensured that the sample was randomly selected.

  - Your procedure must be safe and ethical. Organisms, including humans, can not be subject to harm in your investigation. Refer to the Experiment Ethics Document, and list any **SAFETY PRECAUTIONS** that were taken during the lab.

Assessment (5E – Evaluate)

Students will present their labs to the class and evaluated based on the following criteria:

Name: _____ Score: _____

Oral Presentation Rubric

	4—Excellent	3—Good	2—Fair	1—Needs Improvement
Delivery	• Holds attention of entire audience with the use of direct eye contact, seldom looking at notes • Speaks with fluctuation in volume and inflection to maintain audience interest and emphasize key points	• Consistent use of direct eye contact with audience, but still returns to notes • Speaks with satisfactory variation of volume and inflection	• Displays minimal eye contact with audience, while reading mostly from the notes • Speaks in uneven volume with little or no inflection	• Holds no eye contact with audience, as entire report is read from notes • Speaks in low volume and/or monotonous tone, which causes audience to disengage
Content/ Organization	• Demonstrates full knowledge by answering all class questions with explanations and elaboration • Provides clear purpose and subject; pertinent examples, facts, and/or statistics; supports conclusions/ideas with evidence	• Is at ease with expected answers to all questions, without elaboration • Has somewhat clear purpose and subject; some examples, facts, and/or statistics that support the subject; includes some data or evidence that supports conclusions	• Is uncomfortable with information and is able to answer only rudimentary questions • Attempts to define purpose and subject; provides weak examples, facts, and/or statistics, which do not adequately support the subject; includes very thin data or evidence	• Does not have grasp of information and cannot answer questions about subject • Does not clearly define subject and purpose; provides weak or no support of subject; gives insufficient support for ideas or conclusions
Enthusiasm/ Audience Awareness	• Demonstrates strong enthusiasm about topic during entire presentation • Significantly increases audience understanding and knowledge of topic; convinces an audience to recognize the validity and importance of the subject	• Shows some enthusiastic feelings about topic • Raises audience understanding and awareness of most points	• Shows little or mixed feelings about the topic being presented • Raises audience understanding and knowledge of some points	• Shows no interest in topic presented • Fails to increase audience understanding of knowledge of topic
Comments				