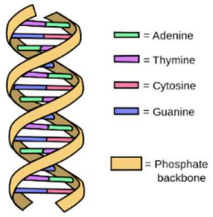
Code Cracking:

Decoding Cancer Causing Mutations

STEM Global Educator Workshop

NWABR | nwabr.org

Revised July 2020 with Remote Learning Adaptations



DNA

LESSON OVERVIEW

Time: 3 or more 50-minute class periods, if taught during synchronous in-personal instruction. Adaptations for remote learning may change this time estimate.

Subject & Grade Level(s): High School Biology, Grades 9-10

Brief Overview:

This lesson is intended to be integrated into a High School Biology genetics unit and allows students to investigate and understand that cancer is a result of an accumulation of mutations in the genes that control cell proliferation. Cancer has a global impact, impacting lives around the world. However, cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe. Students will learn about risk factors and prevention strategies to help them unpack some of the reasons for these disparities. In the culminating mini-project, students will conduct online research on the global disparities of cancer by investigating either a type of cancer across multiple countries/regions or the rates of different types of cancer in a single country/region. Optional extension activities are included.

This lesson plan is divided up into three parts which can be enacted over three class periods. Day One is focused on cancer as a molecular disease. Day Two is focused on mutations and the cell cycle. Day Three engages students in examining global disparities of cancer incidences and rates.

Teachers may choose to use this lesson as a launch event and puzzling scientific phenomenon for their genetics unit, using cancer as an authentic case for understanding different concepts in genetics. Alternatively, teachers may choose to leverage these activities as a culminating project for their genetics unit, where students will be challenged to apply their foundational understanding of genetics to a cancer-related phenomenon. Regardless of how teachers opt to position it, these activities will engage students in an exploration of the global burden of cancer.

Remote Learning Adaptations: Integrated into this lesson plan are suggestions for adapting the activities for remote teaching and learning settings. For remote instruction, this lesson assumes students have computer and internet access at home.

(Image credit: Forluvoft, 2008, Wikimedia Commons).

STUDENT UNDERSTANDINGS

Anchoring Phenomenon:

Cancer has a global impact, impacting lives around the world. However, cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe.

DNA is a molecule that contains all the information that allows an organism to develop, live, and reproduce. Genes are the areas of DNA that code for proteins, which are the workhorses of the cell. Cancer is a result of the accumulation of mutations in the genes that control cell proliferation. While a small number of these mutations are inherited, the majority are acquired either spontaneously or caused by external agents. Because cancer is a result of uncontrolled cell division its development is linked to mutations in cells that control cell proliferation.

Driving Questions:

Anchoring questions for the lesson: How can an understanding of genetics help us investigate why cancer (both rates of incidences and cancer related deaths) disproportionately affects people in different countries of the globe?

Day One investigative questions:

- What causes cancer?
- What are the exposures and events that lead to cancer?
- Are there preventative measures that can help reduce cancer risks?

Day Two investigative questions:

- What are genetic mutations?
- What types of genes are mutated in cancer cells?

Day Three investigative questions:

- What factors might account for disparities in cancer types and rates in different countries around the world?
- Given the limited funding dedicated to non-communicable diseases around the world, how could those resources best be spent?

NEXT GENERATION SCIENCE STANDARDS

This lesson builds toward the following bundle of high school level Performance Expectations (PEs). Hyperlinks direct to relevant sections of the Next Generation Science Standards and *A Framework for K-12 Science Education*.

Performance Expectation(s)
HS-LS1-1: From Molecules to Organisms—Structures and Processes. Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells. **HS-LS1-4: From Molecules to Organisms—Structures and Processes.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **HS-LS3-2: Heredity—Inheritance and Variation of Traits.** Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations from meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

Science and Engineering Practices (SEPs)	**Disciplinary Core Idea(s)**	**Crosscutting Concepts (CCCs)**
Constructing Explanations and Designing Solutions Developing and Using Models Engaging in Argument from Evidence	LS1.A: Structure and Function LS1.B: Growth and Development of Organisms LS3.B: Variation of Traits	Structure and Function Systems and Systems Models Cause and Effect

TEACHER PREPARATION

Materials:

Material	Description/Source	Quantity
Classroom computer	Computer with internet access, projector, and speakers (for live, in-class instruction).	1
Student computers	Computers need to have internet access. For remote instruction, this lesson assumes students have computer and internet access at home.	1/student or small group
Student Handouts	Make copies of the Student Handouts -OR- make digital copies of handouts available to students via your learning management system. • Code Cracking Vocabulary Terms *(Optional)* • Cancer: True or False? • Protein Synthesis • Mutation Practice • Socioeconomic Status & Cancer • Global Cancer Disparities (*Optional*) • Global Cancer Mini-Project • Global Health Careers *(Extension Activity)* Download and make copies of these Student Handouts -OR- make digital copies of handouts available to students via your learning management system: • **The Eukaryotic Cell and Cancer: Student Handout,** HHMI BioInteractive https://www.biointeractive.org/sites/default/files/Cellcycle-Overview.pdf • **Student Handout for Virtual Cell Cycle Lab** *(Optional),* Fairfield-Suisun Unified School District https://www.fsusd.org/cms/lib03/CA01001943/Centricity/Domain/2127/Cancer%20and%20Cell%20Cycle%20Virtual%20Lab.docx	1/student or small group
Teacher Resources	• Code Cracking Slide Deck (main slide deck used throughout lesson) • Cancer True or False Slide Deck (for use with live in-person or videoconference presentations) • Cancer True or False: Teacher Answer Key • Protein Synthesis: Teacher Answer Key • Say It with DNA Messages (Google doc for remote instruction) • Mutation Practice: Teacher Answer Key • Global Cancer Disparities: Teacher Answer Key (*Optional*) • Global Cancer Mini-Project: Scoring Rubric	N/A

Notes to Teacher for Preparing to Teach this Lesson:

- Internet-enabled computers are required for several activities in this lesson. Students will need to work individually or in small groups on computers.
    - **Remote instruction:** This lesson assumes students have computer and internet access at home.
- Make copies of the Student Handouts. Determine if/how you will use the optional handouts, *Student Handout: Code Cracking Vocabulary Terms* and *Student Handout: Global Cancer Disparities.*
    - **Remote instruction:** Make digital copies of handouts available to students via your learning management system.
- Review the slide deck and speaker's notes.
    - **Remote instruction:** Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides, Screencastify, or ScreenCast O Matic) for students to view from home.
- Consider if you want to incorporate any of the alternative or extension activities.
- You will need to have the following materials prepped for each day of instruction.
    - Day One:
        - Code Cracking Slide Deck
        - Cancer True or False Slide Deck *(Optional)*
        - *Student Handout: Code Cracking Vocabulary Terms (Optional)*
        - *Student Handout: Cancer: True or False?*
        - *Student Handout: Protein Synthesis*
    - Day Two:
        - Code Cracking Slide Deck
        - *Student Handout: Mutation Practice*
        - *Student Handout: The Eukaryotic Cell and Cancer (downloaded)*
        - *Student Handout: Virtual Cell Cycle Lab (Optional, downloaded)*
        - Student computers/tablets
    - Day Three:
        - Code Cracking Slide Deck
        - *Student Handout: Socioeconomic Status & Cancer*
        - *Student Handout: Global Health Disparities (Optional)*
        - *Student Handout: Global Cancer Mini-Project*
        - Student computers/tablets
    - Extensions:
        - *Student Handout: Global Health Careers (optional)*

ADAPTATIONS FOR REMOTE INSTRUCTION

This lesson plan has been updated to include adaptations for remote instruction settings. As written, the lesson is intended for in-person, live, classroom-based instruction. Suggestions are summarized in the table below for hybrid and fully remote teaching and learning settings. **Hybrid instruction** assumes several days each week of live, in-person, classroom-based instruction paired with several days of asynchronous, home-based, remote learning. **Asynchronous remote instruction** assumes no in-person, class-based instruction with all learning taking place in students' own homes. Suggestions focus on asynchronous learning. Teachers who can provide synchronous, live video conference meetings with students may sample from the original lesson plan or the hybrid setting suggestions. The adaptations described below should be considered in addition to the directions in the Procedure section of the lesson plan, which follows this section.

Learning Activity	Adaptations for Hybrid Instruction	Adaptations for Asynchronous Remote Instruction
Teacher Prep for Lesson	Decide what students will do during in-class days and what they will do from home during remote days. Make digital copies of handouts available to students via your learning management system. Focus in-person time in the classroom on group work, group discussion, and interaction between students.	Consider recording a video of you presenting the slides (i.e., by using Peardeck for Google Slides, Screencastify, or ScreenCast O Matic) for students to view from home. Make digital copies of handouts available to students via your learning management system. Consider using digital bulletin boards (i.e., Padlet, Google Jamboard app, or FlipGrid) as a way for students to communicate, share, and increase interaction. Consider curating all web links that students will need to access in one place (i.e, Wakelet, LinkTree, etc.). An example has been provided in this LinkTree page (https://linktr.ee/LaughingCrowLLC), but you may want to create your own in order to customize it.
Day One: Intro to Cancer (Slides 1-7)	It is preferable to kick off the lesson in-person if possible. If you will present the slide deck in class, follow the instructions as written in the	**For remote, synchronous live instruction:** If you will present the slide deck during a live videoconference, consider using a digital poll (i.e., poll function in Zoom Meeting, PollEverywhere, DirectPoll, etc.) in lieu of the *Student Handout: Cancer—True or False?* to elicit, view, and discuss responses in real time. Alternatively, consider using the *Cancer—True or False? Slide Deck* to run through

	Procedure. After students complete *Student Handout: Cancer—True or False?* review each question with the class and reveal the correct answer. You might choose to use the *Cancer True or False Slide Deck* for this purpose. If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right.	each response with the class, allowing students to vote using the chat or hand raise function in the videoconference app. **For fully remote, asynchronous instruction:** (Slides 1-4) Have students review Slides #1-4 of the *Code Cracking Slide Deck* and speaker's notes or view a video of you presenting the slide deck (preferable). After reviewing Slides #1-4, students should answer the T/F questions on *Student Handout: Cancer—True or False?.* Students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system. Alternatively, an online auto-corrected quiz could be created using a tool like Peardeck for Google Slides. (Slides 5-7) Have students review Slides #5-7 of the *Code Cracking Slide Deck* and speaker's notes or view a video of you presenting the slide deck.
Day One: Cancer Causes & Prevention (Slides 8-13)	This activity is discussion-based and would benefit from occurring in-person. If you will present the slide deck and discussion in class, follow the instructions as written in the Procedure. If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right.	**For remote, synchronous live instruction:** If you will present the *Code Cracking Slide Deck* during a live videoconference, consider how to use digital bulletin boards so students can see and respond to each other's responses. Breakout rooms may provide an opportunity for smaller group discussion. **For fully remote, asynchronous instruction:** Have students review Slides #8-13 of the *Code Cracking Slide Deck*. Digital bulletin boards allow students to respond to prompts, re-organize and categorize responses, and respond/react to each other's answers. Some examples include Padlet, Google Jamboard app, or FlipGrid. Use a digital bulletin board for students to post their responses for the following discussion prompts. Alternatively, you may have students type their answers and submit them to you using your classroom learning management system. • (Slides 8-11) *What types of events might cause mutations? Identify or sort which category each cancer risk factor falls into: physical, chemical and biological.* • *What are some things you can do to prevent cancer? How can people protect themselves from these exposures and events?*

		• (Slide 12) *Are there some things that are more difficult to prevent/protect against than others? Does where you live have anything to do with these factors. Do they think that people around the world have the same risk factors for cancer? Why or why not? What percent of cancers do students think could be prevented if these risk factors could be avoided?* • (Slide 13) *Why might certain risk factors might vary in high and low resource countries?*
Day One: Cancer as a Molecular Diseases (Slides 14-15)	This video-based activity would work in-person or at-home. If you will present the slide deck in class, follow the instructions as written in the Procedure. For remote instruction, see the column to the right.	(Slides 14-15) Have students review Slides #14-15 of the *Code Cracking Slide Deck*. Links to the two videos, **"What is DNA and how does it work?"** and **"What is a gene?"** have been included in the sample LinkTree for this lesson to make it easy for students to access them from home.
Day One: Exploring the Genetic Code (Slides 16-20)	This activity works well as a small group, in-person activity as described in the lesson Procedure. For remote instruction, the activity can be adapted for individual, at-home learning using the instructions provided in the column to the right.	(Slides 16-19) Have students review Slides #16-19 of the *Code Cracking Slide Deck*, which provide a brief explanation of the central dogma. It is important for students to understand that proteins are made up of amino acid sequences. The specific amino acid sequence for each unique protein is determined by the sequence of DNA bases. These DNA bases are read in triplets, or "codons" and each codon, or set of three bases codes for a specific amino acid. After reviewing the slides, students should work on *Student Handout: Protein Synthesis*. You will need to assign each student a different number (1-30) that will correspond to a DNA message available on the Say It with DNA Messages Google doc. You can make a copy of the Google doc and post to your learning management system or email each student their unique DNA message. Their task is to decode the DNA sequence strips using the handout, and then use the codon dictionary to come up with their own words or sentences. Students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system.

		See the lesson Procedure for an optional, fully online extension activity that has students decode DNA messages using an online bioinformatics database.
Day Two: Intro to Mutations (Slides 21-24)	This activity could be done in-person or at-home. If you will present the slide deck and mutation practice activity in class, follow the instructions as written in the Procedure. If students will review the slide deck and complete the handout on their own during a remote instruction day, follow the instructions in the column to the right.	(Slides 20-24) Have students review Slides #20-24 of the *Code Cracking Slide Deck* which covers what happens when there is a mutation and reviews the three types of mutations. Students then complete *Student Handout: Mutation Practice*. Students can be asked to complete their work on the digital version of the handout to submit to the instructor, or to submit answers to the instructor in some other format through the classroom learning management system.
Day Two: Cancer-causing Mutations (Slides 25-28)	This activity is discussion dependent and would work best in-person. If you will present the slide deck and discussion in class, follow the instructions as written in the Procedure. If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right.	(Slides 25-28) Have students review Slides #25-28 of the *Code Cracking Slide Deck* which explains that of the approximately 35,000 genes in the human genome, only a small number are associated with cancer. Consider using a digital bulletin board (i.e., Padlet) to allow students to answer prompts and respond/react to each other's answers. Alternatively, you may have students type their answers and submit them to you using your classroom learning management system. • *What kinds of genes might be associated with cancer?* [The mutations associated with cancer are mutations to the genes that regulate the cell cycle.]
Day Two:	This activity is accomplished completely online, so it is a good match for a remote	(Slide 29) Have students review Slide #29 of the *Code Cracking Slide Deck*, which introduces the eukaryotic cell and cancer.

The Eukaryotic Cell and Cancer (Slides 29-31)	learning day. In this case, follow the instructions in the column to the right. If you will present the slide deck and activity in class, follow the instructions as written in the Procedure.	Students can then explore HHMI BioInteractive's Eukaryotic Cell and Cancer Online Activity, as described in the lesson Procedure. For the HHMI online activity, students will need access to a student handout which is downloadable from the HHMI BioInteractive website as a PDF. This PDF document is fillable. Depending on their computer software, students may be able to fill it out and save a copy to submit, will need to print/scan/submit, or will need to type up their answers separately to submit to the instructor for grading/credit. If there is time, students can also be asked to complete the MHHE Virtual Cell Cycle Online Lab, as described in the lesson Procedure. Students will need access to a student handout which is downloadable from the MHHE website as a Word file which can be filled in directly and submitted to the instructor for grading/credit.
Day Three: Socioeconomics of Cancer Facilitated Discussion (Slides 32-33)	This activity is discussion-based and serves to launch the mini-project; it would work best in-person. If you will present the slide deck and discussion in class, follow the instructions as written in the Procedure. If students will review the slide deck on their own during a remote instruction day, follow the instructions in the column to the right.	(Slide 30) Have students review Slide #30 of the *Code Cracking Slide Deck* which introduces the day's investigative questions. They then investigate what factors can impact a person's health and cancer risk using a reading. After reviewing Slide #30, students should read *Student Handout: Socioeconomic Status & Cancer.* (Slide 31) Students review Slide #31 and then respond to prompts. Consider using a digital bulletin board (i.e., Padlet) to allow students to answer prompts and respond/react to each other's answers. Alternatively, you may have students type their answers and submit them to you using your classroom learning management system. • *How might socioeconomic factors impact a person's health?* • *What do you wonder about this topic?* • *What data would you need to answer those questions?* An optional reading from the National Cancer Institute is provided in the Procedure section that would allow students to go into more depth on the topic. (Slide 32) Students review the slide, which expands the topic to a global perspective on socioeconomic factors and cancer, while introducing the culminating mini-project.

Day Three: Culminating Mini-Project (Slide 34)	If conducted in-class, the mini-project allows for students to work in groups and present their projects to the class. This is encouraged—especially the presentations—because it allows for collaboration and discussion. If students will work on the project in groups in class, follow the instructions as written in the Procedure. However, the project is entirely computer-based, so it could translate well to at-home learning. If students will work on the project independently during a remote instruction day, follow the instructions in the column to the right.	**Research Project:** If working in pairs or small groups, consider what technologies are available to your school/district that would allow students to virtually meet-up to complete the assignment together and discuss their results. Otherwise, students will have to work on the project independently. See the Procedure for a description of the mini-project. Students will need access to a digital version of *Student Handout: Global Cancer Mini-Project* and will need to be able to access multiple websites from home. You may also want to use the optional *Student Handout: Global Health Disparities,* which serves as an excellent lead-in to the project. The links for research sources that are included in the project's handout have also been included in the sample LinkTree for this lesson to make it easy for students to access them from home. Whether accomplished in groups (meeting virtually) or independently, the mini-project challenges students to develop an explanatory model and a list of recommendations for how to best spend limited resources to reduce cancer rates. **Project Presentations:** Consider what technologies are available to your school/district that would allow students to virtually meet-up to share and discuss their results. Another option could be using FlipGrid or Google slides to allow for each group to share their presentations with one another. For example, each group could record a video presentation or audio narration and upload it to FlipGrid for everyone to view. The mini-project serves as the summative assessment for this lesson. Consider assigning an extension activity that focuses on careers in the global health field. See the Lesson Extensions section for a full description. Students are introduced to the field of global health using *Student Handout: Global Health Careers* which provides a reading about careers in this field. Students could then investigate different global health careers of interest using the poster and fact sheets offered online by the Washington

		Global Health Alliance. *All materials are provided online and amendable to remote learning.*

INSTRUCTIONAL PROCEDURE

Teacher Procedure (assuming synchronous, live, in-class instruction):

This lesson plan is divided up into three parts which can be enacted over three class periods (assuming 50-55 minute periods). Day One is focused on cancer as a molecular disease. Day Two is focused on mutations and the cell cycle. Day Three engages students in a research project looking at global disparities of cancer incidences and rates.

DAY ONE

Introduction to Cancer (10 minutes)

1. Teacher asks students what they know about cancer and why they think they will be studying it. Students give feedback (*Code Cracking Slide Deck*, Slides 1-2).

2. Presents key facts about the impact of cancer (Slide 3) emphasizing that these numbers represent human lives and community resources. In the US alone, people die of cancer at a rate greater than one per second. These numbers represent moms, dads, sons, daughters, our relatives, friends, and perhaps even our future selves. **The human and financial burden of cancer is enormous and impacts us all.**

3. (Slide 4). Inform students that we might not always have accurate ideas about cancer. Divide students into groups to answer T/F questions (*Student Handout: Cancer—True or False?)* followed by whole class discussion in which students share their responses. The last question on the handout introduces cancer as a result of mutations. Show Slide 5 to emphasize a key point: **Cancer is caused by changes in genes that normally control the growth and death of cells. Certain lifestyle and environmental factors can change, or mutate, normal genes into genes that allow and promote the growth of cancer.**

4. Introduce the overall driving question that students will be investigating during this lesson, which will extend for three days. Then, introduce the investigative questions for today (Slides 6-7).

Cancer Causes and Prevention (10 minutes)

5. Ask students to brainstorm about what types of events might cause mutations. Explain to students that these cancer risk factors fall into 3 categories: physical, chemical and biological. Have students identify which category each type of event falls into. (Slides 8-11).

6. Ask students to brainstorm about things they can do to prevent cancer and ask how people can protect themselves from these exposures and events.

7. Slide 12 asks: Are there some things that are more difficult to prevent/protect against than others? Does where you live have anything to do with these factors. Do they think that people around the world have the same risk factors for cancer? Why or why not? What percent of cancers do students think could be prevented if these risk factors could be avoided? Discuss these questions with students.

8. Show Slide 13 with key facts:

    - Around one third of deaths from cancer are due to the five leading behavioral and dietary risks: high body mass index, low fruit and vegetable intake, lack of physical activity, tobacco use, and alcohol use.
    - Tobacco use is the most important risk factor for cancer and is responsible for approximately 22% of cancer.
    - Cancer causing infections, such as hepatitis and human papilloma virus (HPV), are responsible for up to 25% of cancer cases in low- and middle-income countries.

9. Ask students why certain risk factors might vary in high and low resource countries? Based on just these key facts, students might note that the five leading behavioral risks are more prevalent in high resource countries, and that lower resource countries have more limited access to vaccines and antibiotics.

Cancer as Molecular Disease (10 minutes)

10. Use Slides 14-15. Note that students will need a basic understanding of DNA transcription and translation as a foundation for the rest of the unit. The following videos can serve either as a review or a brief introduction to these topics.

    "What is DNA and how does it work?" (5:23 minutes)
    Stated Clearly, 2012
    https://www.youtube.com/watch?v=zwibgNGe4aY

    "What is a gene?" (4:56 minutes)
    Stated Clearly, 2012
    https://www.youtube.com/watch?v=5MQdXjRPHmQ

Exploring the Genetic Code (20 minutes)

11. Introduce students to the coding activity and give a brief explanation of the central dogma, using slides 16-19. Remind students that proteins are made up of amino acid sequences. The specific amino acid sequence for each unique protein is determined by the sequence of DNA bases. These DNA bases are read in triplets, or "codons" and each codon, or set of three bases codes for a specific amino acid.

12. Distribute copies of *Student Handout: Protein Synthesis* as well as DNA strips cut from *Teacher Resource: Protein Synthesis—Teacher Answer Key*. Ask students to work alone or in small groups to decode the DNA sequence strips using the handout, and then use the codon dictionary to come up with their own words or sentences.

13. ***Optional****:* (Slide 20). Redistribute the DNA strips cut from *Teacher Resource: Protein Synthesis—Teacher Answer Key* for students to decode using a simple bioinformatics database that translates DNA to mRNA to an amino acid sequence. Students can then translate the amino acid abbreviation given to its single letter symbol. (Students click on DNA, enter their DNA sequence, click on "Convert" and then scroll down to see the results.

Example:
AGA ACA TAA CTC TTA ACA CTC TAA AGA CCA GCA CTC CGA TGA
Decodes to: **Science is great**

DNA Translator (DNA to mRNA to Protein Converter)
NucleiAcidicConverter, 2016 (built by a high school student)
https://skaminsky115.github.io/nac/DNA-mRNA-Protein_Converter.html

DAY TWO

Intro to Mutations (20 minutes)

14. (Slide 21). Begin class with a quick review of the previous day's decoding activities. Introduce today's investigative questions:
    - What are gene mutations?
    - What types of genes are mutated in cancer cells?

15. Ask students what they think would happen if there was a mutation (mistake in sequence resulting in a permanent change in the DNA's code.) Students can brainstorm responses and teacher helps them to understand that mutations can lead to a change in the cell's structure, function, or regulation.

16. Review the three types of mutations using Slides 22-24. Distribute copies of *Student Handout: Mutation Practice* for students to complete. Provide about 15 minutes for students to complete the activity.

Cancer-causing Mutations (10 minutes)

17. Use Slides 25-28 to explain to students that of the approximately 35,000 genes in the human genome, only a small number are associated with cancer. Ask students to brainstorm about what kinds of genes these might be. Remind students that cancer is out of control cell growth. The discussion should end with students understanding that the mutations associated with cancer are mutations to the genes that regulate the cell cycle.

The Eukaryotic Cell and Cancer (20 minutes)

18. Use Slides 29-31 to introduce the eukaryotic cell and cancer. Ask students explore the cell cycle online using the interactive websites listed below. The HHMI BioInteractive website provides cell cycle fundamentals and explains how cancer causing mutations affect cell cycle regulation. It has an accompanying handout that you will need to download and print. If you have time, the optional virtual lab can also be assigned.

    The Eukaryotic Cell and Cancer: Online Activity
    HHMI BioInteractive
    https://media.hhmi.org/biointeractive/click/cellcycle

    The Eukaryotic Cell and Cancer: Student Handout
    HHMI BioInteractive

https://www.biointeractive.org/sites/default/files/Cellcycle-Overview.pdf

Optional virtual lab: Students can look beyond the molecular level to how these genetic changes manifest on an observable level in cell samples from normal tissues and cancer tissues and calculate the difference in mitotic index which is an indicator of the number of cells actively dividing. Cancer cells have a higher mitotic index. The mitotic index is an important prognostic tool. Use the handout linked below with this lab.

Virtual Cell Cycle Lab
MHHE, requires Adobe Flash Player
http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/labs/BL_03/index.html

Student Handout for Virtual Cell Cycle Lab
Fairfield-Suisun Unified School District
https://www.fsusd.org/cms/lib03/CA01001943/Centricity/Domain/2127/Cancer%20and%20Cell%20Cycle%20Virtual%20Lab.docx

DAY THREE

Socioeconomics of Cancer Facilitated Discussion (15 minutes)

19. Use Slide 32 to introduce today's investigative questions:
    - What factors might account for disparities in cancer types and rates in different countries around the world?
    - Given the limited funding dedicated to non-communicable (not infectious) diseases around the world, how could those resources best be spent?

20. What factors can impact a person's health and cancer risk? Distribute copies of *Student Handout: Socioeconomic Status & Cancer* for students to read. Then, use Slide 33 to facilitate a discussion about how socioeconomic factors can impact a person's health. Students could Turn and Talk first before holding a whole class discussion. What do students wonder about? What data would they need to answer those questions?

    Note that additional information on cancer disparities and contributing factors is available from the National Cancer Institute. This would make a great additional student reading if you would like to go into more depth on this topic:

    Cancer Disparities
    National Cancer Institute, 2019
    https://www.cancer.gov/about-cancer/understanding/disparities

21. How might SES impact global rates of cancer? Expand the discussion to include a global perspective on socioeconomic factors and cancer and introduce the culminating mini-project.

Culminating Mini-Project (35 + minutes)

22. (Slide 34). A mini-project extends students' focus from cancer as a molecular disease to thinking about the global burden of cancer as a disease. This project can be extended to an additional class period, if desired, by providing additional time for in-class research and/or by asking students to also complete the optional *Student Handout: Global Health Disparities.* This handout engages students in activities that are a great lead-in to the mini-project.

    In this mini-project, student teams either: (a) investigate a specific type of cancer (i.e., stomach) across different countries/regions or (b) investigate a country/region and examine rates of different types of cancer (i.e., brain, breast, stomach, lung, etc.). Teams will engage in sensemaking of statistics, articles, data, and data visualizations from multiple sources (e.g., WHO, IHME Global Burden of Disease, Gapminder, Globocan). They will develop an explanatory model—using their understanding of the genetics of cancer—to develop an evidence-based explanation for these disparities. They will also develop a list of recommendations for how to best spend limited resources to reduce cancer rates. Students should work in pairs or small teams and use *Student Handout: Global Cancer Mini-Project*. The mini-project serves as the summative assessment for this lesson.

Student Assessment Opportunities:

- The Student Handouts provide opportunities for formative assessment. Teacher Answer Keys are provided for many of these handouts.
- Whole class discussions also provide opportunities for teachers to check-in on students' developing understanding of the lesson's anchoring phenomenon and daily driving questions.
- In addition, teachers could assign daily Exit Tickets to check student understanding of key concepts.
- The Global Cancer Mini-project serves as the summative assessment for this lesson. A scoring rubric is provided.

Student Handouts & Teacher Resources:

Student Handouts:

- Code Cracking Vocabulary Terms *(Optional)*
- Cancer: True or False?
- Protein Synthesis
- Mutation Practice
- Socioeconomic Status & Cancer
- Global Cancer Disparities (*Optional*)
- Global Cancer Mini-Project
- Global Health Careers *(Extension Activity)*
- Student Handout: The Eukaryotic Cell and Cancer *(Downloaded)*
- Student Handout: Virtual Cell Cycle Lab *(Optional, Downloaded)*

Teacher Resources:

- Code Cracking Slide Deck
- Cancer True or False: Teacher Answer Key
- Protein Synthesis: Teacher Answer Key
- Mutation Practice: Teacher Answer Key
- Global Cancer Disparities: Teacher Answer Key (*Optional*)
- Global Cancer Mini-Project: Scoring Rubric

Suggested Lesson Extensions:

- **Global Health Careers Reading and Research:** Introduce students to the field of global health using *Student Handout: Global Health Careers* which provides a reading about careers in this field. Students could then investigate different global health careers of interest using the poster and fact sheets offered by the Washington Global Health Alliance. *All materials are provided online and amendable to remote learning.*

  Poster: Pathways to Global Health Careers:
  https://www.wghalliance.org/resource/global-health-career-poster/
  Fact Sheet: Pathways to Global Health Careers:
  https://www.wghalliance.org/resource/global-health-career-fact-sheets/

  The following careers are related to cancer research and global health.

  - **Epidemiologist:** https://www.bls.gov/ooh/life-physical-and-social-science/epidemiologists.htm
  - **Biostatistician:** https://www.bls.gov/ooh/math/mathematicians-and-statisticians.htm
  - **Oncologist:** https://www.bls.gov/ooh/healthcare/physicians-and-surgeons.htm
  - **Biomedical Research Scientist:** https://www.bls.gov/ooh/life-physical-and-social-science/medical-scientists.htm
  - **International Aid Worker:** https://www.bls.gov/careeroutlook/2018/article/disaster-relief-careers.htm?view_full
  - **Social Worker:** https://www.bls.gov/careeroutlook/2018/article/social-workers.htm

  The careers of Epidemiologist, Biostatistician, International Aid Worker, and Social Worker are featured on the STEM Global Pathways to Global Health Careers poster and accompanying fact sheets (see the Health Sciences and STEM sections).

- **Alternative Activities:** The following resources provide activities that can be used as alternatives to the ones presented in the instructional procedure or can be used as lesson extensions, in particular for students who desire more depth of content. *All materials are provided online and amendable to remote learning.*

  DNA Translator (DNA to mRNA to Protein Converter)
  NucleiAcidicConverter, 2016 (built by a high school student)
  https://skaminsky115.github.io/nac/DNA-mRNA-Protein_Converter.html

Alternate Cell Cycle Activity: BioNinja
BioNinja, 2016
https://ib.bioninja.com.au/standard-level/topic-1-cell-biology/16-cell-division/cell-cycle.html

Optional Gene Card Activity: Classifying Cancer Genes and Examining Patient Data
HHMI BioInteractive
https://www.biointeractive.org/classroom-resources/classifying-cancer-genes-and-examining-patient-data?playlist=181755

Notes on Adaptations and Inclusivity:

- **Inclusivity for All Learners:** Consider how the lesson activities may need to be adapted to be accessible for all learners. For example, what accommodations may a student with a visual or mobility impairment need to engage in these activities? How might you elicit, build connections with, and leverage students' everyday expertise with genetics, cancer, and global health? How might you group students with diverse expertise and learning needs into teams so that they can support each other?
- **Videos:** The suggested review videos have a closed captioning option. Choose the "CC" option on the YouTube menu.
- **Scientific Vocabulary:** Students may need some support in understanding the terminology embedded in this lesson. This may be particularly true for emerging bilingual students and students with lower reading levels. Terms can be pre-taught or defined contextually as the lesson unfolds. A list of vocabulary terms and definitions is provided as an optional *Student Handout*. The following list captures some of the terms used in the lesson materials.
    - Age adjusted
    - Amino acid
    - Apoptosis
    - Base
    - Cancer
    - Cancer deaths
    - Cancer rate
    - Cell cycle
    - Central Dogma
    - Codon
    - Deletion mutation
    - Disparity
    - DNA (Deoxyribonucleic acid)
    - Frameshift mutation
    - Gene
    - Global disease burden
    - High-income country
    - Highly developed country (HDC)
    - Human Development Index (HDI)
    - Insertion mutation
    - Least developed country (LDC)
    - Low-income country
    - Mitosis
    - Mutation
    - Nucleotide
    - Oncogene
    - Point mutation
    - Protein
    - Protein synthesis
    - Proto-oncogenes
    - RNA
    - Socioeconomic status (SES)
    - Tumor suppressor genes
    - Upper middle-income country

TEACHER BACKGROUND & RESOURCES

Teacher Background Information:

Cancer Key Facts
World Health Organization, 2018
https://www.who.int/news-room/fact-sheets/detail/cancer

Cancer as a Genetic Disease
Cancer.net, 2018
https://www.cancer.net/navigating-cancer-care/cancer-basics/genetics/genetics-cancer

Cancer and the Cell Cycle
Khan Academy
https://www.khanacademy.org/science/biology/cellular-molecular-biology/stem-cells-and-cancer/a/cancer

Oncogenes and Tumor-Suppressor Genes
Cancer.org, 2014
https://www.cancer.org/cancer/cancer-causes/genetics/genes-and-cancer/oncogenes-tumor-suppressor-genes.html

Oncogenes, Tumor-Suppressor Genes, and DNA Repair Genes
CISN, 2013
https://cisncancer.org/research/what_we_know/advances/oncogenes.html#targetText=An%20oncogene%20is%20a%20proto,cycle%20checkpoint%20to%20be%20inspected.&targetText=Tumor%2Dsuppressor%20genes%20act%20to,DNA%20repair%20genes%20fix%20errors

What is Statistics?
ThoughtCo., Courtney Taylor, 2018
https://www.thoughtco.com/what-is-statistics-3126367

Cancer Disparities and Contributing Factors
National Cancer Institute, 2019
https://www.cancer.gov/about-cancer/understanding/disparities

Additional Instructional Resources to Use with Students:

Review videos:

"What is DNA and how does it work?" (5:23 minutes)
Stated Clearly, 2012
https://www.youtube.com/watch?v=zwibgNGe4aY

"What is a gene?" (4:56 minutes)
Stated Clearly, 2012
https://www.youtube.com/watch?v=5MQdXjRPHmQ

Cancer and the Cell Cycle
Khan Academy
https://www.khanacademy.org/science/biology/cellular-molecular-biology/stem-cells-and-cancer/a/cancer

Types of Mutations
Understanding Evolution, 2019, University of California Museum of Paleontology
https://evolution.berkeley.edu/evolibrary/article/0_0_0/mutations_03

DNA Translator (DNA to mRNA to Protein Converter)
NucleiAcidicConverter, 2016 (built by a high school student)
https://skaminsky115.github.io/nac/DNA-mRNA-Protein_Converter.html

Alternate Cell Cycle Activity: BioNinja
BioNinja, 2016
https://ib.bioninja.com.au/standard-level/topic-1-cell-biology/16-cell-division/cell-cycle.html

Optional Gene Card Activity: Classifying Cancer Genes and Examining Patient Data
HHMI BioInteractive
https://www.biointeractive.org/classroom-resources/classifying-cancer-genes-and-examining-patient-data?playlist=181755

Authorship: *The Code Cracking lesson plan and associated materials were developed by Wendi Russac of the Northwest Association for Biomedical Research, a non-profit organization located in Seattle, WA and adapted for a STEM Global Educator Workshop in November 2019. Lesson plan development, editing, and adaptations for remote instruction provided by Kristen Bergsman of Laughing Crow Curriculum LLC.*

Credit: The protein synthesis sentences on the *Student Handout: Protein Synthesis* are from the activity Say It with DNA: Protein Synthesis Tutorial, developed by Larry Flammer, 2004, Evolution & the Nature of Science Institute.
http://www.indiana.edu/~ensiweb/connections/genetics/dna.les.html