Deciphering Chromosomal Mutations Caused by Radiation

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Target Grade Level: 7-12

Time Required: 1 block class/2 period classes - approximately 90 minutes

Standards:

MS-LS3-1 Heredity: Inheritance and Variation of Traits. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

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 through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

Objectives:

Students will:

- Be able to define and identify dicentric chromosomes.
- Be able to explain the effects of radiation on chromosomes.
- Be able to demonstrate the effects of radiation on chromosomes.

Central Focus:

This biology lesson plan involves the exploration of real-world applications of genetics. Students will review vocabulary related to chromosomes, learn about the effect of radiation exposure on chromosomes, and evaluate a chromosome assay for dicentric chromosomes.

Background Information:

Genetic material is stored in DNA molecules. During interphase, DNA exists in an uncondensed form called chromatin. During the S phase of the cell cycle, the DNA is replicated so that when the cell divides in the M phase, two identical cells are created. During mitosis, the chromatin condenses by wrapping around proteins. This condensed form of DNA and associated proteins is called a chromosome. A chromosome consists of two identical strands of condensed DNA called chromatids. The region where the chromatids are attached to one another is called the centromere.

Occasionally, mutations can occur in the DNA replication process. In order for the cells to be identical, there can be no mutations in the DNA. In the G2 phase, following the S phase, the DNA is checked for mutations and the cell will not continue on to mitosis if the DNA is too damaged. Mutations do not only occur during DNA replication, but can also be caused by outside influences.

Exposure to ionizing radiation (IR) induces a wide spectrum of DNA lesions including DNA single strand breaks, double strand breaks, oxidative DNA damage and DNA-protein crosslinks. Among them, double strand break (DSB) is the most critical lesion, which, when mis-repaired or mis-joined, results in the formation of asymmetrical (dicentric chromosomes and rings) and symmetrical (translocations) aberrations. Correlated with radiation dose, these aberrations are being used to predict the absorbed radiation dose in humans. At the Cytogenetics Biodosimetry Lab at Oak Ridge, dicentric chromosome assays are routinely used for estimating the absorbed radiation dosage in peripheral blood lymphocytes of humans after accidental or occupational exposures. In addition, studies are being done to meet the requirements of using this technique in the event of radiation / mass casualty events where tens and thousands of blood samples need to be analyzed for radiation dose assessment.

Students should be familiar with the steps of the cell cycle including the parts of interphase and the checkpoints which ensure that mutations are corrected by the end of the G2 phase. Students should be able to recognize the parts of a chromosome such as the centromere, telomeres, and chromatids. A lesson which includes reading karyotypes would be beneficial to the reading of chromosome assays and looking for mutations caused by radiation exposure. A prior lesson on chromosomal mutations would also help students better understand the causes of abnormalities in chromosome formation.

Materials:

- Internet access - Quizlet Live/PowerPoint presentation
- Overhead projector/interactive board - PowerPoint presentation
- Laptop/computer per student - Key Vocabulary Activating Strategy = Quizlet Live game/Pair-Share
- Camera per student – pair/share activity *could be cell phone, iPad, or computer camera

*The activity can be easily modified to exclude the use of individual student computers and phones by printing out the chromosome assays.

- Data Sheet - record collected information during pair-share activity
- Gummy worms - 6 per student
- Plastic knives - 1 per student/per partner pair *students can share plastic knives
- Skittles - 6 per student
- Paper plates - 1 per student*

Instructional Process:

1. Time: 10-15 minutes

Key Vocabulary (Activating Strategy) - Quizlet Live with the following terms to activate prior knowledge of related vocabulary/introduction of new vocabulary:

chromosome, cytogenetics, radiation, lymphocyte, chromosome assay, translocation, centric ring, mutation, centromere, chromatid, telomere, acentric fragments, cancer

*AS - Dicentric Chromosomes Quizlet Link ----> https://quizlet.com/_51mpml

2. Time: 30-35 minutes

Whole Class Activity - Introduction to the concept of radiation exposure and its effect on chromosomes using Gummy worms.

Activity Materials Needed for Each Student:

- 1 paper plate
- 3 pairs of matching sour gummy worms (chromosomes) = total of 6 per student
- 1 plastic knife (radiation)
- 3 Skittles of the same color (centromeres)
- Camera
- Computer

Students should wash hands and/or use hand sanitizer **before beginning this activity.

Step 1: Begin with three matching pairs of gummy worms. Arrange these pairs on the paper plate so that an obvious constriction is shown between each set of chromosomes.

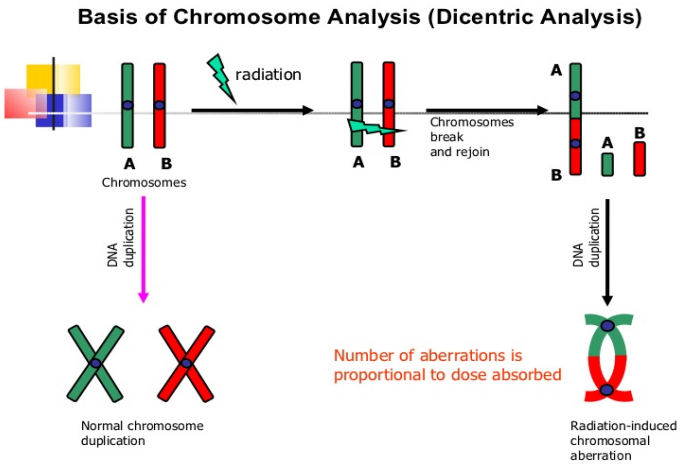
Step 2: Place a Skittle at the constriction point between each pair of gummy worms to represent a centromere.

Step 3: Take a picture of the three pairs of gummy worms representing three chromosomes.

Step 4: Create a Google slide presentation with a title and your name on the first slide, and then insert the picture on the second slide.

Label the following on the picture: **centromere and **chromatid**.

Step 5: Using a plastic knife, cut through two of the chromosomes below the centromeres. The radiation attacking the chromosomes is represented by the plastic knife.
*Teacher will guide students through the process of representing the formation of dicentric chromosomes using the image below (this image located in the Dicentric Lesson ppt- 1st slide):



Step 6: Move the four broken pieces of chromosome (gummy worm pieces above the cut) and their attached centromeres (both Skittles) to another area of the paper plate. Reattach them using the image above as a guide. There will be two pieces of gummy worm attached to one Skittle, and the other two pieces of gummy worm attached to the other Skittle. These will be connected to form a dicentric chromosome - one chromosome with two centromeres.

Step 7: Move the four pieces of gummy worm below the cut to another location on the paper plate. These will be arranged with two pieces from one chromosome lying parallel to one another, and the two pieces from the other chromosome lying parallel to one another. Both of these parallel pieces represent acentric fragments - no centromeres.

Step 8: Take a picture of the three pairs of gummy worms representing two normal pairs of chromosomes and a dicentric chromosome.

Step 9: Insert the picture on the third slide of presentation.

Label the following on the picture: **centromere, **chromatid, acentric fragment**, and **dicentric chromosome**.

Step 10: Share Google slides presentation with teacher. Use your name and block in the title.
**This presentation can be posted in Google classroom and will be automatically shared with the teacher when submitted.

*Teacher will explain the process through each step of the activity, answer questions, and address any misconceptions. Students will **NOT** eat any of the candy until the completion of the activity.

3. Time: 10-15 minutes

Teacher Guided Activity - Evaluation of a dicentric chromosome assay.

- Teacher will model how to evaluate a chromosome assay including the following:
  - the number of centromeres, the number of dicentric chromosomes, the number of centric rings, and the number of acentric fragments present for each cell
- Teacher will use slides 2 through 11 in the Dicentric Lesson plan PowerPoint to explain the equipment used and the scoring procedure guidelines to evaluate chromosome assays.
- Sample Chromosome Assays are located in the PowerPoint presentation on slides 13 and 14. Teacher will show students how to evaluate Sample #1 with a step-by-step explanation, and then ask for a student volunteer to come to the board to work through Sample #2 identifying the same components.

*Teacher should answer questions, correct mistakes, and address misunderstandings during this process entire activity including the samples.

4. Time: 20-25 minutes

   Pair-Share - Working in partners to determine the presence of dicentric chromosomes.
   --- Students will work with a partner to determine the cell ID, number of centromeres, number of dicentric chromosomes, number of centric rings, and number of acentric fragments for each of the chromosome assays given in the shared Google slide presentation titled **"Pair-Share Dicentrics Activity"**.

   --- Students will record all data in the table provided. Each student will be responsible for turning in his or her own data sheet.

   --- Each chromosome assay is worth 10 points. There are 10 assays. Total = 100 points.

   *Teacher will hand out the Dicentric Data Sheet to students when beginning this activity.
   *Teacher will use the Dicentric Data Sheet ANSWER KEY to grade this assignment.

Assessment/Follow-up:

5. Time: 5 minutes

   Ticket-Out-The-Door (Summarizing Strategy) - Students will complete a 3-2-1 activity to recap main ideas from this lesson. This activity is located on slide 16 of the Dicentric Lesson PowerPoint.

   *Teacher will have students write down the questions and answers on a half sheet of paper and turn in when leaving at the end of class.
   *This activity checks for student understanding and allows teachers the opportunity to re-address misconceptions.

Key Vocabulary:

chromosome	cytogenetics	lymphocyte	translocation
chromosome assay	radiation	centric rings	mutation
dicentric chromosome	centromere	acentric fragments	chromatid
telomere	cancer		

Sources:

Balajee, A. (2016). *Basic radiation biology*. [PowerPoint slides].

Balajee, A. (2017). *Dicentric chromosome assay: A High-throughput approach*. [PowerPoint slides].

Balajee, A. (2018) "Use of molecular cytogenetic tools for the assessment of ionizing radiation induced DNA damage in human lymphocytes" Oak Ridge Associated Universities.

Can changes in the structure of chromosomes affect health and development? - Genetics Home Reference - NIH. (2018, July 10). Retrieved July 16, 2018, from https://ghr.nlm.nih.gov/primer/mutationsanddisorders/structuralchanges
**Link on Cite Page --- https://ghr.nlm.nih.gov/primer/illustrations/dicentric.jpg

Livingston, G. K., PhD. (2014). Sensitivity of Human Lymphocytes to Low-Dose Radiation - ppt download. Retrieved July 15, 2018, from https://slideplayer.com/slide/1405550/ Radiation Emergency Assistance Center Training Site, Oak Ridge Institute for Science and Education, Oak Ridge, TN.

Safety and Cleanup Required:
Students should wash hands and/or use hand sanitizer prior to the gummy worms activity.
Students should use caution when cutting with plastic knives.
Students should not consume candy used in class for demonstration unless given permission by teacher.
Students should dispose of all waste products including food in a trash container before leaving class.

Name_____ Block _____ Date _____

Dicentric Data Sheet for Scoring Dicentrics, Centric Rings, and Acentric Fragment

***Directions*:** Work with a partner to determine the cell ID, number of centromeres, number of dicentric chromosomes, number of centric rings, and number of acentric fragments for each of the chromosome assays given in the shared Google slide presentation named "**Pair-Share Dicentrics Activity**". Record all data in the table below. Each chromosome assay is worth 10 points. Total = 100 points.

Cell ID	Number of Centromeres (only count objects with a centromere)	Number of Dicentrics (more than ONE centromere)	Number of Centric Rings (have a centromere)	Number of Acentric Fragments (no centromere)

Name_____ Block _____ Date _____

Dicentric Data Sheet for Scoring Dicentrics, Centric Rings, and Acentric Fragment ANSWER KEY

***Directions*:** Work with a partner to determine the cell ID, number of centromeres, number of dicentric chromosomes, number of centric rings, and number of acentric fragments for each of the chromosome assays given in the shared Google slide presentation named "**Pair-Share Dicentrics Activity**". Record all data in the table below. Each chromosome assay is worth 10 points. Total = 100 points.

Cell ID	Number of Centromeres (only count objects with a centromere)	Number of Dicentrics (more than ONE centromere)	Number of Centric Rings (have a centromere)	Number of Acentric Fragments (no centromere)
3	46	0	0	0
15	46	1	0	1
21	46	1	0	0
24	45	1	0	1
27	46	0	0	0
30	48	0	0	1
36	47	1	0	1
37	46	0	0	0
41	46	0	0	1
52	49	1	1	4