October 4, 2024 - Picked topic and began to compile resources for use in the project. Also chose a project title, “A Novel Approach to Radioisotope Therapy”.

November 5, 2024 - Started base research on various radioisotopes:
How Radiation Therapy Is Used to Treat Cancer. (n.d.). American Cancer Society. https://www.cancer.org/cancer/managing-cancer/treatment-types/radiation/basics.html#:~:text=about%20radiation%20therapy-,What%20is%20radiation%20therapy%3F,destroy%20or%20damage%20cancer%20cells.

- Other names for radiotherapy -
  - Radiation treatment
  - Radiotherapy
  - Irradiation
  - X-ray therapy
- Uses high energy particles or waves to destroy cancer cells
  - Gamma rays
  - X-rays
  - Protons
  - Electron beams
- Usually a local treatment
- Can also be taken through mouth or by vein,
- Concentrates at tumor site, little effect on the rest of the body.
- Over half of people with cancer receive radiation therapy
- Sometimes works alone, sometimes works with other drugs
- Don’t normally reach all parts of body, so can’t use if cancer has spread all over
- Can be used to . . .
  - cure/shrink early stage cancer/tumors (preoperative/neoadjuvant therapy = to shrink tumor, after surgery to stop it from returning = adjuvant)
  - Stop cancer from coming back elsewhere
  - Treat symptoms caused by advanced cancer
  - To treat cancer that has come back
- Can be given in 3 ways
  - External radiation/external beam radiation
  - Internal radiation
  - Systemic radiation
- EXTERNAL
  - Machine directs high energy waves at tumor/cancer

- Done at a treatment center
- Given over a long period of time (1-2 times per week)
- Does not have to follow specific guidelines at home (not radioactive)

- INTERNAL
  - Called brachytherapy
  - Radioactive source is placed inside of person near the tumor
  - Can stay, can be removed
  - Special safety precautions needed, person is arguably 'radioactive'
- SYSTEMIC RADIATION
  - Drugs given by mouth or vein
  - Travel throughout the body
  - Precautions needed at home
- Radiation therapy can potentially increase risk of future cancer
- Can also pose risks to pregnant women
- If radiation and other treatments are given together, they are more effective, side effects may be worse

Radiation Therapy for Cancer. (2019, January 8). Cancer.gov. https://www.cancer.gov/about-cancer/treatment/types/radiation-therapy

- Slows/stops growth by damaging DNA
- Depends on . . .
  - the type of cancer
  - the size of the tumor
  - the tumor's location in the body
  - how close the tumor is to normal tissues that are sensitive to radiation
  - your general health and medical history
  - whether you will have other types of cancer treatment
  - other factors, such as your age and other medical conditions
- Internal can be liquid or solid
- Brachytherapy is when a solid (can be seeds, ribbons, or capsules)
- Treatments are often just used to treat symptoms, known as palliative treatments

October 6, 2024 - Wrote my thesis: Future isotopes of radioactive elements, specifically those discovered through the island of stability, will have the ability to provide better and more effective cancer radiation therapy.

November 15, 2024 - Continued collection of possible research topics

December 2, 2024 - Continued research on radiotherapy:

The Institute of Cancer Research, London. (n.d.). *Science Talk - The exciting potential of radioactive elements in canc*. https://www.icr.ac.uk/blogs/science-talk/page-details/the-exciting-potential-of-radioactive-elements-in-cancer-treatment

- Element Lutetium has been shown to have some potential for future radiation therapy
- Lutetium - 177 (a radioactive isotope of the element) may be able to replace less effective forms of cancer research
- Emits beta radiation (high energy beams of electrons)
- Shows high success rates specifically in types of reproductive cancer - mainly in men, but also in women.
- Delivers a large amount of radiation, but only to a small area - only 2 millimeters, meaning that there is very little damage to surrounding tissue.
- Radium (specifically radium-233) is currently one of the most commonly used forms of radiotherapy.
    - It is particularly effective for bone cancer, considering that radium is very similar to the compound calcium, naturally finding its way towards bone cancer cells, where there are high concentrations of calcium.
- Radioisotopes of strontium and samarium are used in a similar way, also emitting alpha radiation
- There is another type of radiotherapy, called SIRT (selective internal radiation therapy) using yttrium-90 injecting beads into the cancer patient, though is not widely available
- Iodine is used for cancer of the thyroid

Internal radiation therapy. Canadian Cancer Society. https://cancer.ca/en/treatments/treatment-types/radiation-therapy/internal-radiation-therapy#:~:text=Radioisotope%20therapy%2C%20sometimes%20called%20radiopharmaceutical,in%20a%20container%20like%20brachytherapy.

- Can be given in low or high dose
- Types of brachytherapy:
    - Interstitial - Directly into tumor, used often for head or neck cancer

    - Intracavitary - places inside a bodily cavity, mainly used for female reproductive cancer
    - Intraluminal - Places it inside a specialized applicator inside a bodily passage, often used for cancer of the esophagus or lung. It is often used in combination with external radiation therapy to give an extra boost of radiation (more serious cases)
    - Plaque or surface - Small implant of the surface, often for eye or skin cancer
- Radioimmunotherapy binds to antibodies to help the body naturally fight cancer (white blood cells in combination with the radiation treatment)

Radiopharmaceuticals Emerging as New Cancer Therapy. (2020, October 26). Cancer.gov. https://www.cancer.gov/news-events/cancer-currents-blog/2020/radiopharmaceuticals-cancer-radiation-therapy

- Radioactive iodine has been used to treat cancers, specifically of the thyroid for over 80 years, proving to be fairly safe, while still allowing the properties needed
- Radium-223 dichloride for bone cancer - Xofigo
- Hypothetically could link a radioisotope to a targeting molecule in a body to link to a target protein on a cancer cell
- FDA has approved various radiotherapies, one of which can be used to treat non-Hodgkin lymphoma
- If cancer spreads, easier to treat if it is developed, being that external beam therapy cannot work if there is small deposits throughout the body, as is the case with much recurring cancer (if radiation therapy is used and the cancer returns)
- If this experimental therapy is used, it would allow for “cold” (tumors that the immune system is unable to recognize) tumors to be recognized by the body, with dead protein and DNA from these cells spilling out into the bloodstream.

December 3, 2024 - Began data collection on commonly used radioisotopes
Continued research on radioisotope therapy:

Radioisotope Therapy | The University of Kansas Cancer Center | Kansas City. (n.d.). https://www.kucancercenter.org/cancer/cancer-treatments/radioisotope-therapy#:~:text=Radiisotope%20therapy%20is%20a%20procedure,damage%20to%20surrounding%20healthy%20ces:

- Some types of radiotherapy combine liquid radiation and amino acids, so the therapy is better accepted by the body - particularly used for cancers of the kidney
- Also provides another option to people with cancer in various parts of their body, as liquid radiation in combination with amino acids allow for a natural honing device, meaning that radiation is significantly less toxic to the other tissues.

- Digestive issues or issues with internal organs (liver and kidney) sometimes create difficulties with radiotherapy

Radioisotopes in Medicine - World Nuclear Association. (n.d.). https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-medicine:

- External radiation is sometimes called teletherapy
- Internal radiation is sometimes called radiosurgery
- Iodine-131 is used for thyroid cancer (most successful form of cancer treatment
- Iridium-192 for breast and head
- Some are used for therapeutic procedures - palliative, not to cure, only to reduce pain
    - Strontium-89
    - Samarium-153
    - Rhenium-186 (newer)
- Lutetium-177 dotatate or octreotate used for neuroendocrine tumors
    - For nerve cells
- Newer field is targeted alpha therapy (TAT)
    - Bismuth-213
        - Clinical trials for melanoma, cystic glioma (a type of glioblastoma, or the least curable brain cancer, with a large non cancerous component), and leukemia
    - Lead-212 for pancreatic, ovarian, and melanoma
    - Boron-10 and gadolinium-157 for malignant brain tumors (including all types of glioblastoma)
    - Yttrium-90 for non-Hodgkin's lymphoma, liver cancer

December 20, 2024 - Continued collecting data

	Half-life	Type of radiation	Group	Amount of radiation (MeV)	Type of cancer	Type of radiotherapy
Radium-223	11.4 days	Alpha	Alkali metals	28.2	Bone (for comfort)	Systemic radiation
Lutetium-177	6.7 days	Beta	Transition metals	0.000149	Reproductive cancer	Systemic radiation
Strontium-89	50.6 days	Beta	Alkali earth metals	1.463	Any cancer affecting bones	Systemic radiation

Samarium-153	46.3 hours	Beta & gamma	Transition	0.81 (max)	Bone pain from cancer	Systemic radiation
Rhenium-186	3.7 days	Beta & Gamma	Transition	1.1	glioblastomas	Systemic radiation
Bismuth-213	45.6 minutes	Alpha	Nitrogen group	7	Myeloma, glioma, melanoma, leukemia	TAT
Lead-212	10.6 hours	Beta	Carbon group	2.6	Broad range, mainly reproductive	TAT
Iodine-131	8 days	Beta & gamma	Halogens	1.6 (max), 0.2 (mean)	Thyroid	Systemic radiation
Yttrium-90	64.2 hrs	Beta	Transition metals	0.93	Any inoperable cancers	Brachytherapy

January 6, 2025 - Continues research, began running tests on my data

Radionuclide therapy. (n.d.). https://www.iaea.org/topics/radionuclide-therapy

- The availability of cancer treatments and radioactive medicine has skyrocketed due to research, making this even more important.
- Ideally target malignant tumors
- Not affect the healthy cells
- Alpha and beta emitters are ideal
- Gamma is not as helpful

Canadian Nuclear Association. (2021, January 21). *Medical isotopes - Canadian Nuclear Association*. https://cna.ca/nuclear-medicine/medical-isotopes/#:~:text=Isotopes%20that%20are%20commonly%20used,life%20of%20about%20110%20minutes.

- Cobalt-60 is one of the most common treatment

Yttrium-90 Internal Radiation Therapy | UPMC Hillman Cancer Center. (n.d.). UPMC Hillman Cancer Center. https://hillman.upmc.com/cancer-care/surgical-oncology/koch-regional-cancer-therapy-center/treatments/yttrium-90

January 7, 2025 - Began working on my problem and organized my research, filling in the project requirements on the CYSF website.

January 25th - Refined my thesis and organized my research

February 4th - Continued to organize my research and finished work on the problem section of my project

Radiotherapy in Society:

In modern society, cancer is considered to be a kind of death sentence. However, with new and improved cancer care, the survival rates are now skyrocketing, as well as simply the quality of lives of those living with cancer symptoms, due to palliative care. Despite the fact that cancer is still the leading cause of death within Canada and plagues societies across the world, radiation therapy remains incredibly important to moving on from this era. Since its creation, radiation therapy has earned a place amongst the most effective cancer treatment, and has greatly improved the lives of cancer patients overall. However, there is still a long way to go before radiation therapy cannot continue to be developed, making this an even more important issue.

New radiotherapies:

For many years, the focus of cancer research has been chemotherapy, or the nature of cancer cells themselves. However, with radiation and nuclear sciences rising in popularity, radiation therapy has once again returned to the forefront. Radiation has the potential to save nearly four million lives currently, and would continue to save up to one million lives per year. This not only shows the importance of radiation therapy, but also the blatant need of a reliable and effective cancer treatment. In addition, this could ensure the lengthened lifespans and reduction of symptoms of nearly four million people, continuing to prove the overall importance of this field of research.

Cancer Patients:

Often, when people think of cancer, they separate it from the patients, almost assuming they are dead already, their problems in the past. This comes with the stigma of cancer being a death sentence. However, the only reason for developing these therapies is for the patients themselves, including those currently suffering. Even if current radiotherapy cannot necessarily save every patient, it has shown itself time and time again to have the incredible ability to improve their lives through palliative care and help with symptoms. Thus, radiotherapy is worth developing and has the unmatched potential to improve the lives of millions of people across the globe.

Reproductive Cancer Patients:

Many different types of radiation therapy currently being developed centre around the growing prevalence of reproductive cancers, in both men and women. For example, Lutetium-177 was recently developed, and is solely used for these types of cancers. Reproductive cancers, in men and women, are very difficult to treat. Despite this, the creation and development of various radiation treatments throughout the years have increased lifespans, and decreased the overall difficulty of treatment. Even if radiation has potential in various different groups and types of cancer, these types of cancer are some that will likely see the largest decrease with the increase of radiation therapy creation and research.

Incurable Cancer Patients:

Currently, much of the cancer that patients are suffering from is currently deemed 'incurable'. However, this is only the case with the current treatments available. This is a growing issue in our society, and it is imperative that something is done to ensure that the lives of these patients are improved, either through a therapy that has the potential to provide a cure or through improved palliative care. The number of people with these dangerous forms of cancer is projected to decrease by over 100,000 people by 2026, assuming that radiotherapy continues to be developed. Overall, radiation therapy has the potential to improve if not save many lives, and it is incredibly important that it continues to be developed.

Overall, cancer is an issue that has been prevalent in Canada for decades, and likely will remain this way for decades to come. However, it is important to acknowledge the possibility of creating a better life for cancer patients, and contributing to the eradication of the disease itself through the future development of radiation therapy.

February 6, 2025 - Continued work on the research section of the science fair.

Potential Future Therapies:

There are many different types of revolutionary radiotherapy being developed. For example, radioimmunotherapy binds to antibodies near the cancer cell to help the body naturally fight cancer (white blood cells in combination with the radiation treatment allow for a greater possibility of the cancer being killed and the patient being unharmed on the whole). In addition, Radioactive iodine has been used to treat cancers, specifically of the thyroid for over 80 years, proving to be fairly safe, while still allowing the properties needed. Being that most of the body's iodine is stored in the thyroid, iodine remains incredibly useful, though more effective means of using this iodine for this cancer treatment are still under review, due to the usual health and safety issues involved in creating a new radiotherapy. Despite the fact that this form of radiotherapy is already in existence, developing it further would both allow for a longer lifespan for cancer patients and a higher likelihood of getting over the disease. Hypothetically, scientists could link a radioisotope to a targeting molecule in a body to link to a target protein on a cancer cell, known as targeted alpha therapy (TAT). TAT among them, FDA has approved various radiotherapies, one of which can be used to treat non-Hodgkin lymphoma, a very difficult cancer to treat. Being that it does involve the immune system, lymphoma is one of the cancers for which targeted alpha therapy holds the most potential. If cancer spreads, TAT makes it easier to treat if it is developed, being that external beam therapy cannot work if there are small deposits throughout the body, as is the case with much recurring cancer (if radiation therapy is used and the cancer returns). If this experimental therapy is used, it would allow for “cold” (tumors that the immune system is unable to recognize) tumors to be recognized by the body, with dead protein and DNA from these cells spilling out into the bloodstream. Additionally, some types of radiotherapy combine liquid radiation and amino acids, so the therapy is better accepted by the body - particularly used for cancers of the kidney. This also provides another option to people with cancer in various parts of their body, as liquid radiation in combination with amino acids allow for a natural honing device, meaning that radiation is significantly less toxic to the other tissues.

February 11, 2025 - Continued research

February 19, 2025 - Collected the data for the three isotopes explored in relation to future glioma treatment

	Half-life	Type of Radiation	Group	Amount of radiation (MeV)	Type of Cancer	Type of Radiotherapy
Polonium-210	140 days	alpha	chalcogens	5.38 MeV	Glioma	Systemic/TAT
Bohrium-270*	2.4 minutes	alpha (partially unknown)	transition metals	124 MeV	Glioma	Systemic/TAT

Francium-212	20 minutes	alpha and beta	alkali metals	1.2 MeV	Glioma	Systemic/TAT

February 26, 2025 - Began tests on the data (a paired t test)

Rhenium and polonium

Group 1 (MeV) mean: 3.3

Group 2 (half life) mean: 71.9

Rhenium and francium

Group 1 (MeV) mean: 1.2

Group 2 (half life) mean: 1.9

Rhenium and bohrium

Group 1 (MeV) mean: 62.6

Group 2 (half life) mean: 1.9

Bismuth and polonium

Group 1 (MeV) mean: 6.2

Group 2 (half life) mean: 1.9

Bismuth and francium

Group 1 (MeV) mean: 4.1

Group 2 (half life) mean: 0.02

Bismuth and bohrium

Group 1 (MeV) mean: 65.5

Group 2 (half life) mean: 0.0167

March 1, 2025 - Started the data section:

After running various tests on the data above, it was determined that these two of the three isotopes listed have potential for immediate development in radiation therapy, both for different reasons. Firstly, the polonium isotope listed above had properties that were incredibly similar to both the rhenium and bismuth isotope currently used to treat gliomas. The type (alpha) and amount (5-7) are nearly the same as the bismuth isotope listed. In addition, its placement on the periodic table ensures that it shares other properties, such as the behavior of the particles themselves. Thus, polonium-210 has a high potential relating to cystic gliomas and glioblastomas, due to its overall similarity to bismuth-213. Polonium is widely regarded as extremely toxic, which is only true due to its radioactivity. Thus, using emerging alpha therapy techniques, polonium has a high potential for treating glioblastomas, especially considering its compatibility with the human systems.

In addition to polonium, francium-212 has also shown potential for use in future radiation therapy. Similarly to polonium, it shows incredible similarity to bismuth, regardless of the fact that it is also incredibly toxic. Again, the only reason this isotope is considered toxic initially is due to its own radioactivity. Conversely, the radiation factor is present with francium, though there is also the question of reactivity. Due to the fact that francium is an alkali metal, it is incredibly reactive. However, if it could be bonded with something else (much as the radium in Xofigo is bonded), it may have immense potential in various types of cancer, including gliomas. Francium had the best results of the three tested isotopes, showing that it could have a large impact on radiation therapy if this theory is correct. In addition, it is similar in properties to other radiotherapy isotopes (including radium), making this even more likely to have a future in the field. As such, francium remains a possibility of an incredibly effective cancer treatment regardless of the issues surrounding it.

March 3, 2025 - Finished the data section:

Considering the fact that bohrium is a very radioactive element, including the fact that it is extremely unstable, the current isotopes that are known of bohrium would not be proper candidates for radiation therapy. Despite this, there is a scientific theory, known as the island of stability theory, that states that many transuranium (after uranium on the periodic table) elements likely have significantly more stable isotopes than the ones currently known to the scientific world, based upon trends in the periodic table. Being that bohrium fits the criteria that applies to elements theorized to be on the island of stability, future isotopes of bohrium have a high potential for radiation therapy. Assuming that other, more stable isotopes of bohrium would have similar properties to bohrium-270, it does have an especially high potential in certain cancers, including various forms of brain cancer (most notably, glioblastomas) due to its overall similarity to the element rhenium. Thus, bohrium may have the ability to revolutionize radiotherapy entirely, though this would likely occur in the distant future.

Overall, these three isotopes have the potential to change the way irradiation is viewed. Being that they could all positively impact brain cancer patients, they may also be able to support the creation of a more effective glioma treatment. Therefore, the isotopes listed above have the potential to change radiation therapy entirely, as well as the overall lives of these patients.

March 6, 2025 - Started the method section:

To test the collected data, I used a t test (in order to compare current isotopes used with potential future isotopes). Before doing so, I picked three isotopes (polonium-210, francium-212, and bohrium-270) that were similar in properties to rhenium and bismuth, two existing isotopes used in glioma treatment. Firstly, a paired t test using polonium and rhenium showed that the likelihood of these data patterns being coincidental is quite low, sitting at five percent. These two isotopes proved to be fairly similar, though the half life of polonium is significantly longer. Secondly, francium came back even more similar through the t test, having a closer average half life and very close MeV levels. Bohrium scored closer to bismuth, but there were still barriers involving the MeV. Overall, francium had strikingly similar results to both bismuth and rhenium, polonium scoring fairly moderately.

March 7, 2025 - Finished the method section:

After determining that all three of the elements shown above (bohrium, francium, and polonium) had the potential in cancer treatment, it can be seen that others may be immediately applicable while others may require further scientific research. A clear example of this would be bohrium, which tested very similar to rhenium considering their close proximity on the periodic table, though did not match up in terms of MeV and halflife, two factors that would make the therapy both dangerous and impractical. However, it could be incredibly effective when used in combination with continued scientific efforts to uncover more about the later elements. Thus, francium and polonium could be the future of potential glioma treatment. On the whole, francium scored very high when placed with both bismuth and rhenium, meaning that it could have a future with radiation therapy. Overall, this could change the lives of many different cancer patients, and may even allow for the elongated lives of many.

March 10, 2025 - Completed the presentation section

March 11, 2025 - Recorded presentation