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Biomedical Engineering and Quality of Life Improvements

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Introduction

As a past science teacher, I am now in a position to help students in grades 6-8 with their Science Fair Projects each year. Because of the advances in technology, we are now able to expand the type of Science Fair Project a student may enter into the competition.

I am using this unit to become familiar with observational or natural experiments. Many of our students have an interest in investigating topics that do not allow for the traditional manipulative experiment. To perform an observational or natural experiment, the student does systematic and experimental work using experiments that have been done by others. They will need to know how to research their hypothesis and gather information from several sources. The activity will be of value and interest to the student, as he/she will have an opportunity to investigate an illness or disease of interest to them. They may have a family member or a friend dealing with an illness and wish to become more knowledgeable on how biomedical engineering has improved their chances of living with or being cured of a particular disease.

The investigation will include the following:

· What is the name of your disease?
· What is your hypothesis?
· What are some causes of your disease?
· How widespread a problem is your disease?
· Is there a particular group more susceptible to this disease?
· Are there preventative measures that can be taken to lessen the impact or prevent this disease?
· How is the disease detected?
· What is the treatment(s) for this disease?
· What are the pros and cons of the treatment(s).
· How has biomedical engineering helped in the treatment and/or prevention for this disease?

This unit will provide a "hands-on" approach that will allow me to gain experience and be better able to give the student hints and direction for completing a meaningful project. I have chosen to investigate the various treatments for Prostate Cancer and how biomedical engineering has improved and/or discovered different treatments for this disease.

One definition for Biomedical Engineering is a discipline that advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practices.

After we review and/or introduce the basic structure and function of the cell parts, we will discuss and research what things may happen when a cell mutates. The main focus of my unit will be to investigate the various treatments for Prostate Cancer and the pros and cons for each type of treatment. Having to investigate these options will prepare me to help students investigate and research their topic of interest.

My hypothesis is: If a person is diagnosed with prostate cancer, then the most effective treatment will depend on the age of the patient and how far the cancer has spread.

Introduction to the Cell

The Cell Theory states that all living things are made of cells and they are produced from other living cells. At this time, there is no accurate way to determine the number of cells in the body. Estimates range from 10 to 100 trillion in an adult. As you may or may not know, cells are very small with the larger cell being about the diameter of a human hair.

Living things are made of two kinds of cells, prokaryotic (no nucleus) and eukaryotic (having a nucleus.) Humans are made of eukaryotic cells.

The basic structure of a cell includes:

A. Cell Membrane- Encloses the cell and allows materials to pass into and out of the cell.

B. Cytoplasm: A jellylike substance inside that cell that is mostly water with the other parts of the cell in this substance.

1. Nucleus- The brain of the cell, contains the genetic material DNA arranged in chromosomes.
2. Mitochondria - Energy production for the cell.
3. Lysomes - Destroys harmful substances or worn-out cell parts.
4. Endoplasmic reticulum - Makes protein.
5. Golgi bodies - Stores the proteins.

If you are a teacher in the New Haven, and perhaps in other areas, you have access to the videos on United Streaming.com. There are several videos on the cell and at this time I would suggest the viewing of either:

The Living Cell - 20 Minutes - Grades 4-8

Structure and Function of Plant and Animals Cells

Or

Assignment Discovery: Cells - 24:40 Minutes - Grades 6-8

Microscopic Viewing of Cells

For this unit, viewing and discussing the parts and functions of the cell is adequate but, because we are interested in the growth of cancerous cells, we will look at the cell a little differently.

Under normal conditions, the cells divide producing new cells exactly alike. However, sometime cells multiply unchecked and damage surrounding tissues. This is what we define as cancer. This would be a good time to view the video:

Life Science: Cells - 20 Minutes - Grades 6-8

Segment shows growth or cancerous cells.

Prostate Cancer

Prostate cancer is like the name implies, cancer of the prostate gland. Outside of skin cancer, it is the most common cancer in American men. This gland is about the size of a walnut that surrounds the urethra at the base of the bladder. Although it is involved in sexual activity, it is not vital for the reproductive process and some believe this may be a reason for the high incidence of prostate cancer as the vital organs in the same area are practically immune to the formation of tumors.

It is estimated that one in six men will be diagnosed with prostate cancer during their lifetime with the highest rate of incidence being among African-American men and those that have a family history of the disease. Although the causes of this cancer are not completely understood, the high incidence group makes some believe there may be a genetic component while others believe high fat diets are a big contributor.

Some symptoms of prostate cancer are urinary problems such as frequent urination or sensation of incomplete emptying, constipation and loin or bone pain. If a person is experiencing any of these symptoms, they should get a diagnosis of the situation. The first step would probably be a Digital Rectal Examination (DRE) in which a doctor physically examines the prostate. This exam checks for hard lumps at the area where most prostate cancer cells first form in the rectum. Another test is the Prostate Specific Antigen (PSA) Blood Test which is a test performed on a blood sample. The PSA is produced by both normal and malignant prostate cells. This can detect elevated levels of the PSA. A big jump in the PSA level is an indicator of prostate cancer activity and action on this matter should be investigated. The PSA is not a reliable indicator for men with an inflamed prostate.

If the DRE or PSA indicate cancer might be present, a biopsy is the next step. This procedure takes small tissue samples using a biopsy gun, that contains a needle ½" long and 1/16"in diameter, to collect the sample. This procedure is repeated from 8 to 18 times in different parts of the prostate. The samples are then sent to the laboratory where they are examined under the microscope to help determine the extent of the cancer. If the biopsy is positive, other test will be given to determine the extent of the cancer.

1) Computed Tomography (CT)

This procedure involves radiography in which a three-dimensional image of the body structure is constructed by a computer from a series of cross-sectional images

Computed tomography was originally called computed axial tomography and CAT scan for short. The word tompography comes from the greek word tomos which means *slice* and graphia, *describing* .

This apparatus uses x-rays to generate what is called x-ray slice data as it rotates around the patient. The data is then combined together by a procedure called tomographic reconstruction. The newer machines allow for more detailed information about the patient that is being imaged.

CT scans are frequently used to determine the stage of cancer and to follow its progression. Pictures and more information on this device can be found at:

http://dpi.radiology.uiowa.edu/. ../paper6jt.html

2) Magnetic Resonance Imaging (MRI)

A procedure in which a magnet linked to a computer is used to create detailed pictures of areas inside the body.

A strong steady magnetic field is produced around the patient allowing for the gathering of images for study. The nature of hydrogen in the water molecule is what makes this procedure viable. A big plus for this procedure is that you can tailor the process for your diagnostic need.

More information MRI can be found at:

http://info.med.yale.edu/.../ techniques/mri_diagram/

3) X-Rays

High-energy radiation used in high doses to treat cancer (radiotherapy) or in low doses

to diagnose disease.

Basically, x-rays work by the body's absorption of x-ray photons. Compared to

bone, soft tissues do not absorb the x-ray photons very well and contrast media

(liquids that absorb x-rays) must be introduced to the body for readable images.

Prolonged exposure to x-rays can be harmful to the body. More information on

x-rays can be found at:

http://health.howstuffworks.com/x-ray4.htm

4) Isotope Bone Scan

An isotope is injected into a vein your arm and will be taken up by bones in your

body. A special camera called a "Gamma Camera" then takes pictures of the area.

This may take up to 3 hours.

For cancer patients, this scan is used to determine if the cancer has spread into the bones of the body. For more information, go to:

http://www.intelihealth.com/IH/ihtIH/WSIHW000/9339/23953.html

5) ProstaScint Scan - A scan used to check for lymph node invasion with men with

prostate cancer. The patient is given an iv injection of ProstaScint and 111 indium

chloride. Tomographic images are taken on the day of and four days after the injection.

For more information, go to:

http://www.prostate-cancer.org/education/staging/pscint.html

Progressions of Cancer

When we define how a cancer progresses, we categorize it as:

Localized - Remains confined within the prostate.

Locally Advanced - Spread into the tissues surrounding the prostate.

Advanced - Spread to other distant parts of the body. (Metastasis)

When cancer is found in a biopsy, there are now two detection and staging techniques we use to help determine how to continue with prostate cancer treatment. The Gleason Score is used to determine a tumor's aggressiveness and TNM Staging to determine how far the cancer has spread.

The Gleason Score use two samples from the biopsied tissue to determine where the number of most cancer is located. The area with the most cancer is called the primary area and the area with the next highest amount of the cancer is called the secondary area. A grade from one to five will be assigned to each sample depending on their "differentiation."

(The ability of a tumor to mimic normal gland architecture.) This number indicates the possibility of how likely the cancer is to grow and spread.

When we add both grades together, this is called the Gleason Score. Scores from 2-4 the cancer is not considered aggressive, 5-6 is said to be mildly aggressive, 7 moderately aggressive and 8-10 highly aggressive.

The TNM Staging determines how far the cancer has spread. A stage of T1 means the tumor is microscopic, T2 the tumor is confined to the prostate, T3&4 it has spread to tissue adjacent to the prostate and N+ or M+ it has spread to pelvic lymph nodes, lymph nodes, organs or bones.

Now that the severity of the Prostate Cancer has been determined, what method of treatment will be recommended to the patient?

Prostate Cancer Treatments

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1) Watchful Waiting: Careful Monitoring.

Watchful waiting is generally used for those with a low PSA and low Gleason scores. Age is also a factor in some cases. The very young or very old are sometimes encouraged to opt for the watchful waiting to avoid the possible side effects or more aggressive treatments such as incontinence or impotence.

Watchful waiting does not mean you do nothing but wait and see what happens. Careful monitoring is done during this period to keep track of the cancers progression. Most prostate cancers grow slowly so the longer you can safely avoid the more aggressive treatments, the longer your quality of life is less likely to be disrupted.

A risk for watchful waiting is that the cancer may spread rapidly between appointments.

2) Radical Prostatectomy: Removal of Prostate.

There are 3 types of this prostate surgery.

Retropubic - Incision made in the center of the lower abdomen to remove prostate.

Perineal- Incision made between the scrotum and sphincter to remove prostate.

Lapruropic and Robotic- Uses a tube like instrument to excise the prostate using a series of small incisions rather than just one to remove the prostate.

This type of surgery is used if the cancer is confined to the prostate gland. Because of the risks and side effects, it generally is used on patients who are young and in good health. The recovery period for this type of operation depends on the type of prostatectomy.

The risk factors of impotence and incontinence are very high but the success rate for these procedures is over 90%.

3) Radiation Therapy: External radiation at prostate cancer cells.

This is the most common treatment for prostate cancer. The patient is evaluated to decide the amount of radiation that can be used effectively to treat the cancer. He then goes for treatment once a day, Monday-Friday, for 5 to 9 weeks. During this treatment, the targeted area is irradiated with attention not to damage the surrounding organs to prevent side effects. This time frame is effective as normal prostate cells can repair themselves from small amounts of radiation while the cancerous cells do not possess this ability for repair. Having the week-ends off gives the body a chance to recuperate for the next series of treatments.

Studies, both long and short term, have success rates of around 85% when used with other therapies. Side effects include tiredness, diarrhea, upset stomach and a burning sensation while urinating.

4) Hormone Therapy: Suppresses, blocks or eliminates testosterone.

This therapy is used to slow or stop the growth and spread of prostate cancer. Hormone therapy can also be referred to as androgen deprivation or androgen ablation. Androgen is the hormone that tends to make men men. As stated above, this therapy removes the testosterone from the body or suppresses the body's use of testosterone. Medical and surgical castrations are two forms of androgen ablation.

There are four basic methods to deprive the body of androgen:

1. Castration - This involves the removal of the testicles.
2. Estrogen - This treatment is not used very often as it has a potential to cause serious cardiovascular problems. Basically the estrogen fools the system into thinking it is testosterone and stops the system from making more testosterone.
3. Anti-androgens - Prevents testosterone from interacting with the prostate gland.
4. Combined androgen-blockade - Uses castration and anti--androgens to interfere with testosterone production.

Hormone cancer is generally used in conjunction with other treatments. Some of the side effects may include impotence, weight gain, hot flashes, fatigue and loss of muscle mass.

5) Chemotherapy: Used in the treatment of advanced prostate cancer.

This therapy is not recommended for use in the early stages of the cancer as it damages the cells so badly that they die and it does not distinguish which cell will be killed. Chemotherapy is used when the cancer has spread to the bones. This therapy seems to relieve some of the pain suffered by the patient and slows the growth of prostate cancer in the advanced stages.

There are new and more effective chemotherapy drugs on the market today, but they have not been in use long enough to say that patients benefit by the earlier use of these drugs.

The side-effects that one may suffer are nausea, vomiting, hair loss and mouth sores.

6) Cryosurgery & Cryotherapy: Uses needles to apply freezing gases to the prostate.

Cryotherapy is not used as primary treatment for prostate cancer as it is relatively new and not enough data has been compiled at this time however, it is used for treating cancer that is unaffected by radiation.

Cryotherapy works by freezing and thawing which kill the cells by dehydration, changing pH levels or preventing the flow of red blood cells. The freezing process also activates an anti-tumor response by the body to produce antibodies the work to eradicate the tumor.

This treatment is effective for the early stages of prostate cancer. The treatment takes about 2 hours and one may need to stay over night. The side-effects may include moderate pelvic pain, blood in urine, scrotal swelling, mild urinary urgency and impotence.

7) Brachytherapy: Implant high or low dose radiation seeds in prostate.

The term, *brachytherapy* , means to administer from a short distance away. The two types of this therapy are:

1. LDR - Permanent low dose radiation.
2. HDR - Temporary high dose radiation.

LDR seeds permanently left inside the prostate and continuously emit radiation to the prostate. An improvement has now been made to this product by producing a covering that allow one direct the radiation in the direction you choose instead of being emitted in all directions. This surgery usually last for about ½ hour and regular activities are usually resumed in a couple of days. In some cases an overnight stay may be necessary.

The HDR treatment lasts from 5 to 15 minutes, and then the patient is returned to his room. This process is repeated one or two times meaning the patient will remain in the hospital until the treatment is completed which will take a day or two. When this treatment is completed, unlike the LDR, no radiation seeds will be left in the body.

Data says that that the success rate for these procedures is from 77 - 93% and is most effective with younger patients that are in good health. The side-effects may be bleeding at the insertion site, blood in urine, scrotal burning, incontinence or impotence.

Development and Approval of Procedures

Although we do not know the cause of prostate cancer, it is now being researched to determine if certain factors influence either to help prevent or promote this type of cancer.

Some of these investigations include the use of herbal supplements, diets high in fat, diets low in fruits and vegetables, consumption of vitamin E and selenium, certain infectious diseases and men's hormonal characteristics.

Biomedical Engineering has played a major part in the development of treatments for prostate cancer and more are in the testing stages such as using semen to test for prostate cancer and heat shock protein 90 that makes tumor cells degrade the proteins that promote cancer growth.

I think we all are aware that certain procedures must be followed before a drug or treatment is allowed to be performed on humans. The Center for Drug Evaluation and Research has the responsibility to ensure that the product is safe to put on the market.

The law requires that the drug must have an approved marketing application before it can be transported to other states. Because a wide sampling is usually used in the testing process, it is sometimes necessary to get an exemption to move the drug to some states for the clinical trial.

This preclinical trial will determine if the product is safe enough for human use. If the trials are positive, the drug legal status changes and under specific requirements it is now allowed to be tested on humans.

After the drug approval process, the drugs are monitored by the Center of Drug Evaluation for safety and effectiveness. Programs are set in place that will alert the agency of potential threats to the public health. Preventative actions are then taken by the agency to alleviate the danger.

Conclusion

My hypothesis (If a person is diagnosed with prostate cancer, then the most effective treatment will depend on the age of the patient and how far the cancer has spread)

was partially correct. As we have seen, many factors determine the treatment a patient will receive. The mental state of the patient is an important factor in determining how effective a treatment may be. If a patient has fears of being operated on, his mental state may be more harmful that the disease. But, thanks to Biomedical Engineering, new and more effective methods are being developed to make the process less invasive and reduce side-effects.

This paper was meant as guide for middle school students to complete an observational or natural science experiment. Because of the age level, the depth of the topic will be determined by the students interest and if a mentor is able to help them.

A mentored project can to go into greater depths than those without a mentor. Generally, the mentored

student receives the support, guidance and up to date information that a mentor can supply on the topic to produce a meaningful project.

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Lesson 1

Purpose: To evaluate information from three different web sites.

Hypothesis: If you know the affiliation of the web source to the topic, then you will be

better able to evaluate the information.

Procedure: Identify three different web sites for your topic.

Web Site #1: _____

Web Site #2: _____

Web Site #3: _____

Observation:

1. Do the web sites say the same thing about your topic? If not, why do you think the information is different.

2. Which web site are you more apt to believe? Why?

Conclusion: (Should you use more than one source when researching a topic?)

Lesson 2

Problem: How may a person research the success rate of a certain medical procedure?

Hypothesis: If a person uses several reputable sources for gathering information, then they will have a more reliable indication for the success rate for that procedure.

Procedure: Choose a medical procedure for the treatment of the disease you have chosen.

Observation: What did your research indicate about this procedure?

Conclusion: Would you recommend this procedure to someone? Why or Why not.

Lesson 3

Purpose: To become familiar with drug approval procedures.

Objective: Upon completion of the investigation, the student will be able to explain

Some procedures followed before a drug is approved for human uses.

Procedure: Research the procedure for putting a new drug on the market.

Research a drug that is used for the disease you have studied.

Observation: What is the name of the organization responsible for the drug approval application process?

What is the name of the drug you researched and what is the primary use for this drug?

Conclusion: Do you think the drug approval process is adequate? Why or Why not

Do you think the drug you researched is effective doing it's primary function? Why or Why not