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Pharmacy: The Backbone of Healthcare

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SENIOR THESIS APPROVAL

This Honors thesis entitled

"Pharmacy: The Backbone of Healthcare"

written by

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the requirements for completion of
the Carl Goodson Honors Program
meets the criteria for acceptance
and has been approved by the undersigned readers.

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Pharmacy: The Backbone of Healthcare

An Honors Thesis

Jordan Raye Myers

Statement of Purpose

The field of pharmaceuticals is growing and changing everyday. Being a part of the creation of new medicines and new treatments is a dream. Throughout my life my favorite subject has always been science, specifically where the sciences of biology and chemistry intersect. Biology and chemistry have significant overlap in the field of pharmacy. I believe that the passion and love I have for combining these two sciences will reflect in my career as a pharmacist and open doors for me to positively impact the lives of patients and the pharmaceutical field. I chose to pursue a career in pharmacy in hopes of gaining knowledge, building connections, and impacting lives. Throughout my many years of shadowing healthcare professionals, I have found that pharmacy is the backbone of every field of medicine, and I look forward to fulfilling my role in what I consider to be the backbone of healthcare.

This thesis will walk through the many ways in which the different branches of science, specifically biology, chemistry, and physics fit into the field of pharmaceuticals. An example of the ways in which chemicals, good and bad, can impact and change the human body will be included at the end in the form of the scientific paper *The Effects of Friction on the Release of Bisphenol A from Infant Toothbrushes.*

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INTRODUCTION

The pharmaceutical field is growing and changing every single day. These constant changes are made possible because of the role that the different branches of science plays in pharmacy. Science is constantly discovering and creating new technologies, chemicals, and techniques. Along with patient interaction, the career of pharmacy consists of compounding medicines, discovering and developing new drugs, and using specific techniques and technologies to improve old drugs and create new ones. A medicine is defined as a drug used to diagnose, cure, treat, or prevent disease. Drug therapy, also known as pharmacotherapy, is an important part of the field of medicine and depends upon pharmacology as a science to continue growing and developing. It is crucial to the field of healthcare that pharmaceuticals stay up-to-date with science. Through the studies of biology, chemistry, and physics, the field of pharmaceuticals is capable of experiencing constant development and growth.

BIOLOGY

DRUG PATHWAYS

There are many different biological pathways that drugs use to be effective in the body. However, there are four stages that all drugs go through once they enter the body: absorption, distribution, metabolism, and excretion. The process begins when the drug is absorbed into the bloodstream. Once in the blood, the drug is distributed throughout the body by the circulatory system. Then, the drug is metabolized, and then excreted along with its metabolites.[1]

ABSORPTION

Absorption is the process of a drug moving from the administration site into the bloodstream. Absorption occurs differently for drugs depending on the means of administration.[1]

Oral administration involves swallowing pills, drinking a liquid, or eating a substance. When a drug is administered through this means, the majority of the absorption occurs in the small intestine. From there the absorbed drug is transported into the liver. The liver then sends the drug into the bloodstream.[1]

Intravenous injection or IV injection inserts drugs directly into the bloodstream for 100% absorption. This is one of the quickest means of absorption, but the effects of the drug tend to pass quickly.[1]

Subcutaneous injection inserts the drug into the fatty tissue beneath the skin. Fatty tissue is filled with capillaries and lymphatic vessels. These capillaries and vessels provide access to the bloodstream. This is the type of administration used for vaccines.[1]

Inhalation involves breathing drugs directly to the lungs. From the lungs the drugs can be absorbed into the bloodstream through the circulation of blood through the lungs and heart. This form of administration provides quick affects that go away within a matter of minutes.[1]

Transdermal administration is less common than the other forms of administration, but is growing in popularity. This involves patches that are placed directly onto the skin. The drug is absorbed into the skin where it reaches an abundance of capillaries and lymphatic vessels through which the drug is administered throughout the body. [1]

DISTRIBUTION

Distribution is the process of a drug being transported and spread throughout the body. Distribution occurs as the drug moves in the blood through the bloodstream to the tissues and binds to receptors. Distribution is also the cause of unwanted and sometimes negative side effects of drugs. There is no way to regulate which parts of the body the drug gets distributed to once it enters the bloodstream. As distribution occurs, the drug can interact with unintended receptors. This step is also what makes creating and compounding drugs difficult. For distribution to occur properly, drugs must be able to cross the blood brain barrier. The blood-brain barrier is a network of tightly woven

capillaries. Its purpose is to prevent foreign substances from entering the central nervous system and reaching the brain. The blood-brain barrier is also responsible for some negative side effects of drugs. When a drug is unable to cross the blood-brain barrier, they often cause the "high" feeling that people associate with street drugs. When drugs that are unable to cross the blood-brain barrier are used frequently, they can cause negative impacts on the brain and the body. Some drugs can cause permanent damage to the blood-brain barrier and even increase its permeability to make it ineffective as a barrier to toxins, viruses, and bacteria. [1]

METABOLISM

After distribution, the drug is then metabolized and broken down by the body. Most of metabolism occurs mostly in the liver with some help from the kidneys, GI tract and lungs. Enzymes in these organs help to create metabolites by breaking down the drug and preparing it for excretion. [1]

EXCRETION

After the drug is metabolized, the parts of the drug that were not used and the metabolites that were created during metabolism leave the body through urine or feces. Excretion can also occur through sweat, saliva or exhalation.

DRUG CLASSES

There are many different classes of drugs that have different effects on the body. These effects can be explained through pharmacodynamics, the action a drug takes on the human body, and pharmacokinetics, what the body does with the drug. Drugs use many different biological aspects to affect the body. Some drugs stimulate receptors, stimulate ion channels, act on enzymes or act on transporter proteins. [1]

AGONISTS

Agonists are drugs that bind to specific receptors and cause a specific process in the cell to activate. These drugs can be natural or artificial. Morphine is an example of an artificial agonist for the main opioid receptor. The opioid receptor is designed to bind to endorphins. Morphine works to relieve pain because it is similar in structure to endorphins. The similarities are shown in the figure below with morphine on the left and an endorphin on the right. The bold portion of the compounds shown in Figure A represent the portion of the compound that binds to the opioid receptor. The similarities in the portion of the structures allow morphine to bind to the opioid receptor.

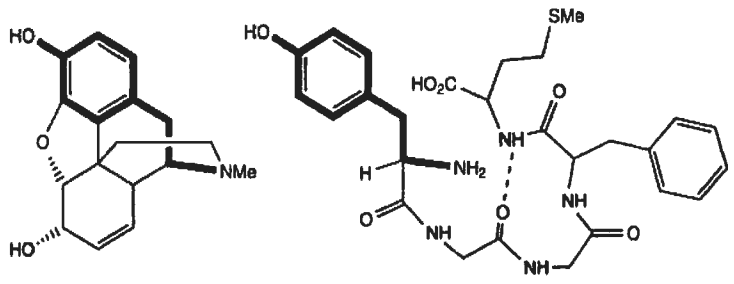

Figure A. Morphine (shown on the left) and endorphins (shown on the right) have a similar structure.

Agonists can also have negative effects on the body and humans can be exposed to them in many unexpected places. A common accidentally encountered agonist is Bisphenol A (BPA). BPA acts as an agonist for estrogen and binds to estrogen receptors in the body. This leads the body to think more estrogen is present than actually is. This can cause many negative effects on the body. See section "The Effects of Friction on the Release of Bisphenol A from Infant Toothbrushes" for an example of how these chemicals can affect the body. [2]

ION CHANNEL MODULATORS

Ion channel modulators target and control the activity of voltage-gated sodium, calcium, and potassium channels and ligand-gated ion channels. Ion channels regulate the flow of charged ions across the cell membrane and mediate membrane potential of the cell. The drugs that affect these ion channels include channel blockers and channel openers. Channel blockers prevent the opening of ion channels. Channel openers activate the sensitive channels causing them to open. An example of this is minoxidil, a drug that targets the potassium ion channel. Opening the potassium ion channel starts the process of relaxing a muscle. It closes the voltage-gated calcium channels and decreases the amount of calcium present in the cell. With less calcium available inside the cell to interact with calmodulin, there is less activation of myosin light chain kinases and less phosphorylation of myosin light chains. Minoxidil is effective in dilating resistance vessels, decreasing systemic vascular resistance, and lowering arterial pressure. Drugs with this function are normally combined with a beta-blocker to reduce

the effect of the reflex tachycardia and a diuretic to reduce retention of sodium and fluid.[3]

ENZYME INHIBITORS AND INDUCERS

Inhibitors and inducers are drugs that act on enzymes to inhibit them or cause them to work faster. However, most drugs that act on enzymes act as competitive inhibitors. Competitive inhibitors compete with the substrate, which is in the body and is intended to bind to the enzyme, for the active site, the spot on the enzyme where the substrate binds. Substrates have a specific shape which is intended to fit in the active site of an enzyme. Competitive inhibitors are designed to have the same shape as the specific substrate. This allows them to also bind to the active site in place of the substrate. An example of an enzyme inhibitor is Fluvoxamine, a selective serotonin-reuptake inhibitor used to treat obsessive-compulsive disorder. Antibiotics are also commonly enzyme inhibitors. [4]

TRANSPORT PROTEIN INHIBITORS

Transport protein inhibitors bind to transport proteins and prevent the transfer of ions and small molecules across membranes. Transport proteins span the width of the cell membrane in order to modulate the flow of ions and small molecules across the membrane. The most common use of these drugs is to prevent the reuptake of neurotransmitters, such as dopamine, serotonin, and noradrenaline. Preventing the reuptake of these neurotransmitters causes an increase in the levels of these

neurotransmitters. Fluoxetine, commonly known as Prozac, is a selective serotonin reuptake inhibitor (SSRI) antidepressant. It is used to treat obsessive-compulsive disorder, major depressive disorder, panic disorder, and bulimia nervosa.

CHEMISTRY

Chemistry is used in the field of pharmaceuticals to figure out what drug needs to be designed, what chemical composition needs to be used to achieve the desired effect, and how the drug needs to be shaped and sized. Chemistry is important to the pharmaceutical field because without it there would be no way to determine how a drug would interact with the body when swallowed or injected. In science and specifically in the field of pharmacy, structure determines function, and chemistry is a key element in creating and determining the structure of drugs. The structure of a drug is determined by its chemical makeup, and the structure of a drug determines how and with what a drug interacts in the body. The stereochemistry, structure, and resonance of a chemical compound can strongly affect the function and interactions of the drugs.

STEREOCHEMISTRY

The stereoisomer configuration of a compound is the way the molecules bonded to a chiral carbon are oriented around the center carbon. Different stereoisomers of a compound can have drastically different effects on the human body. Two drugs can be created that are of identical composition with different stereochemistry, and, for example, one of them can cure a disease, while the other can cause detrimental birth defects in children. An example of this is the drug thalidomide. This drug was used to treat the nausea associated with morning sickness in pregnant women. When this drug was originally developed, two stereoisomeric forms were combined into a mixture

making one drug. The two forms combined to make this mixture were mirror images of each other. One stereoisomeric configuration, the R (or clockwise) configuration, was effective and therapeutically active at treating the nausea. The other form, the S (or counter-clockwise) configuration, was not only ineffective at treating the nausea associated with morning sickness, but caused birth defects in the babies born to the mothers who had taken this drug during their pregnancy.

STRUCTURE

Structure determines function, and without the proper structure and composition, a drug cannot have the proper effect on the body. As seen with agonists, the structure and functional groups of a compound can affect how and what they bind to. Different receptors in the body have different binding sites with different shapes. The different shapes of the binding sites are designed to connect and bind specific structures and functional groups. In order for a drug to be effective, it must have the appropriate functional group and structure to fit in the specific receptor. The agonist drug, morphine, discussed earlier is able to be effective because the chemical structure of the drug allows it to bind to the opioid receptor. The drug has the appropriate ring structure and functional group to match the original substrate in the body (See Figure A). If the structure of the drug was not specifically designed to match the binding section of the substrate that is specific to the targeted receptor, then the drug would not be able to bind to the receptor and would not be effective. [5]

RESONANCE

Resonance is the ability of a molecule to delocalize at least one pair of its electrons, as shown in Figure B. This allows for increased stability of a compound, which makes the compound less reactive. When developing a drug, it is important that the chemical compound of the drug be stable. Stability of drugs is critical because drugs need to have a half-life long enough to result in a long shelf-life for the drug. Many medications have to last for weeks, months, and sometimes years. The more stable a drug is, the longer shelf-life the drug will have. Resonance allows compounds to delocalize electrons to rearrange charges to put the compound in the most stable form.

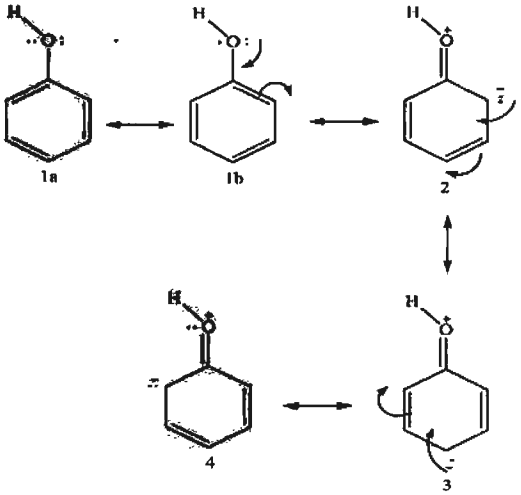

Figure B. Resonance is the ability of a molecule to delocalize at least one pair of its electrons.

PHYSICS

Physics is used in the development and administering of drugs. The process for making drugs into tablets requires physics, and intravenous fluid injections use principles of physics to properly enter the body. Physics also plays a critical role in the technology used in the pharmaceutical field, and the creation of the containers that medicines are packaged in.

MAKING TABLETS

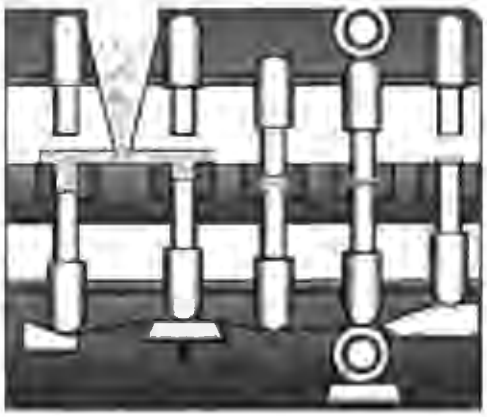

Figure C. Tablets are created through a compression process. [3]

In order for a drug to be turned into a tablet, it must go through a compression process. When making a tablet, it is important that the tablets are strong and hard to withstand the mechanical shock of production, packing, shipping, dispensing, and use. Pills have to be able to not crumble and crush before getting to patients.[6] If pills were to crumble in transport, then when taken by a patient, the pills would not have the right amount of drug in them to be an effective treatment. In order for pills to be strong and not crumble, they have to be compressed into tablet form under the right amount of pressure during production.The proper amount of powder of a drug is poured into a compressor

machine. The machine then applies a large amount of pressure to the appropriate amount of the powder and compresses it into a tablet as shown in the Figure C. [7]

INTRAVENOUS FLUIDS

For intravenous fluids to be effective, it is crucial that the drug enters the vein without blood squirting out. To make the drug get into the vein, the pressure of the fluid at the injection point has to be at 109kPa. To create an IV, the pharmacist can use Bernoulli's Equation shown below in Equation 1:

$$P_1 + \frac{1}{2} pv_1^2 + pgh_1 = P_2 + \frac{1}{2} pv_2^2 + pgh_2$$ Equation 1.

This equation considers the pressure of the fluid in the IV bag (P_1), the pressure of the fluid entering the vein (P_2), velocity of the fluid (v), elevation of the IV bag (y), acceleration due to gravity (g), and density of the fluid (p). This equation helps determine the height that the bag needs to be hung at in order for the fluid to enter the vein with the appropriate pressure. The pressure needs to be correct so that the fluid enters the body with the needed drip rate. Without this equation, it would be impossible for pharmacists to make effective IV bag setups.

PHARMACEUTICAL TECHNOLOGY

The technology used to identify an unknown drug and evaluate the effectiveness and function of drugs all require physics. Mass spectrometry is a technology that

evaluates the composition of a compound by measuring the mass-to-charge ratio of ions. This is done by spinning the compound at a high speed while it is surrounded by a magnet. This technology allows pharmacists to identify drugs if the labels are mixed up and to identify the exact composition of drugs when making changes during drug composition and development. Physics is also used to determine the flowability of powder, which is a critical piece of information for making medicines into tablets. This is done using the ring shear tester, which predicts particle size. Without physics to create new technologies, the field of pharmacy would not be capable of everything it is today. [8]

PACKAGING OF MEDICINE

Some medicines are sensitive to light and/or moisture. When exposed to these elements, the medicines expire quicker than when protected from these elements. Physics research has determined ways to protect medications from the elements that decrease the shelf-life of the drug. Physicists have developed a moisture control system for containers holding drugs that are in powder form and tablets that are moisture sensitive. Researchers have developed lids with foam discs in them to absorb moisture. They have also invented silica gel packets and other similar packets to be inserted into containers with medicines to protect them from moisture. In addition, there are drug containers that are tinted to protect medicines from certain light waves that may be harmful to them and decrease their shelf-life. Physics is also responsible for child-proof containers with "push and twist" lids to protect children from accidentally consuming harmful medication. [9]

DRUG INTERACTIONS

As with all chemicals, medications can have many different reactions when combined with other medications, food, vitamins, and chemicals. Humans can experience these interactions by accidentally mixing drugs or by consuming unknown chemicals. Common examples of unwanted interactions are listed below.

- Contraceptive Pills and Antibiotics
- Steroids and Alcohol
- Contraceptive Pills and St. John's Wort Herbal Supplement
- Oral Decongestants while having a high blood pressure condition
- Grapefruit juice and statins (drugs to lower cholesterol)

These interactions can cause temporary side effects or permanently harmful side effects, and sometimes in extreme cases, even death. If the possible danger of interactions is unknown when taking a medication, then unwanted reactions are more likely to occur. [10] See section "The Effects of Friction on the Release of Bisphenol A from Infant Toothbrushes" for an example of how humans can encounter unwanted chemicals.

"The Effects of Friction on the Release of Bisphenol A from Infant Toothbrushes"

The following paper was written in 2019 at the end of an undergraduate research project in Dr. Hubbard's lab at Ouachita Baptist University. The release of Bisphenol A from Infant Toothbrushes acts as a key example of the effects that chemicals and compounds can have on the human body, and how people can accidentally encounter compounds that can cause adverse reactions with medications. BPA does not have any known adverse reactions with medications. However, BPA is in many household items and is a good example of how humans can encounter a chemical without knowing. The effects discussed in the introduction section of the following paper exhibit examples of the negative effects that a compound can have on the development of the human body. For more information on the connections between the following research and the field of pharmacy, see section AGONIST under BIOLOGY.

ABSTRACT

Bisphenol A (BPA) is a compound which mimics estrogen, allowing BPA to bind to estrogen receptors in the body in place of estrogen. This mistaken binding results in BPA acting as an agonist and antagonist for certain mechanisms in the body, which can result in early development, reproductive issues, and cancer. Though BPA has been omitted in several infant products, there is no regulation on the amount of BPA that can be present in infant toothbrushes. Infants are more vulnerable to the effects of BPA because they are in such an early stage in the development of their endocrine systems. Previous research used fluorescence spectroscopy to detect BPA leaching from infant toothbrushes. BPA is excited at 278 nm and emits at 304 nm.

This project focused on the effects of brushing on the level of BPA released by adding friction and movement to the toothbrush while it was soaking in the solution. To execute this research, an apparatus was developed that mimicked a brushing motion to apply friction to the toothbrushes. Several infant toothbrushes were each placed in a 1:1 methanol:water solution for time increments varying from five minutes to six hours. Aliquots (5 mL) were collected from the solutions after the toothbrushes had been soaked for each time interval. Samples were analyzed using an Edinburgh Instruments FS5 spectrofluorometer. The excitation and emission intensities of the samples were collected and compared to a calibration curve to determine the concentration of BPA present in each sample. Data were correlated with samples that were collected without brushing to determine if the friction affected the amount of BPA leached from the toothbrushes.

INTRODUCTION

Bisphenol A (BPA) mimics estrogen in its makeup in that both compounds contain a phenol functional group. This commonality allows BPA to act as an endocrine disruptor for estrogen. When BPA binds to estrogen receptors in the body, the body responds as if there is more estrogen present than the body is actually producing. The body's response to the apparent abundance of "estrogen" caused by BPA can result in developmental issues, reproductive issues, and even cancer.[11] Infants are particularly susceptible to the effects of BPA because they are in such an early stage in the development of their endocrine systems. Infant toothbrushes are a relative source of BPA to infants because BPA is used to make hard plastics, such as toothbrushes. Most plastics have a regulation of 4μg per kg body weight per day,[12] however, this regulation has not been set on toothbrushes yet. Infant toothbrushes are important because babies come into contact with their toothbrushes daily. This frequent exposure can lead to issues later in life as the child continues to develop.[13] In previous research, it has been found that infant toothbrushes which are not labeled as being BPA free tend to contain BPA.[14] When toothbrushes are used to brush teeth, friction is applied to the toothbrush as a result of the brushing motion. There is no previous research regarding a relationship between BPA release from plastic toothbrushes and friction. This experiment studied the effects of friction on the release of BPA from infant toothbrushes.

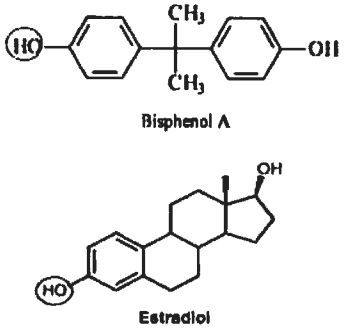

Image I. Bisphenol A compared to Estradiol to show similarities.

It was hypothesized that friction would increase the amount of BPA that is released from infant toothbrushes.

MATERIALS

- •Edinburgh Instruments FS5 Spectrofluorometer
- •1:1 Methanol:Water
- •Volumetric Flasks
- •Pasteur Pipets
- •Brushing Apparatus with Orbital Shaker
- •Various Infant Toothbrushes

Image 2. Infant toothbrushes used in experiment

METHODS

A variety of infant toothbrushes were chosen. A brushing apparatus was developed to apply friction to the toothbrushes in a way that mimicked the motion of brushing teeth. The toothbrushes were each individually attached to the brushing apparatus and inserted into a test tube that contained 90mL of 1:1 Methanol:Water.

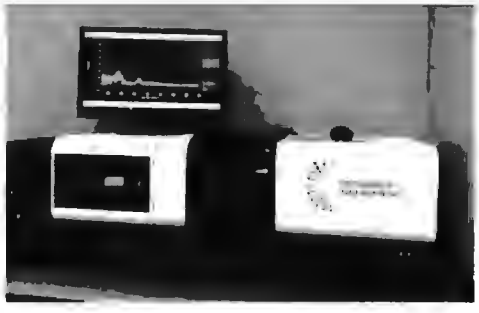

Image 4. Edinburgh Instruments FS5 Spectrofluorometer

Image 3. Brushing apparatus using orbital shaker

At each time increment (5min, 10min, 15min, 20min, 40min, 60min, 80min, 100min, 120min, 240min, 300min, 360min), a 5mL sample was taken from the solution in the test tube using a pasteur pipet. These samples were analyzed using the Edinburgh Instruments FS5 Spectrofluorometer to obtain the fluorescence emission intensities of the samples. The same steps were completed to collect samples from toothbrushes that were sitting in the solution without having friction applied by the brushing apparatus. The fluorescence emission intensities of the samples without friction were also obtained by running the samples in the spectrofluorometer. The intensities were then compared to one another. These same steps were followed in a replicate run of this experiment in an effort to confirm the results.

RESULTS

A calibration curve of standard stock solutions was created to develop a relationship between BPA concentration and intensity. This is used for calculating BPA concentration in the samples from the fluorescence emission intensities that were obtained from running the samples in the spectrofluorometer. A dilution set of BPA stock solution was also run through the spectrofluorometer in order to get example

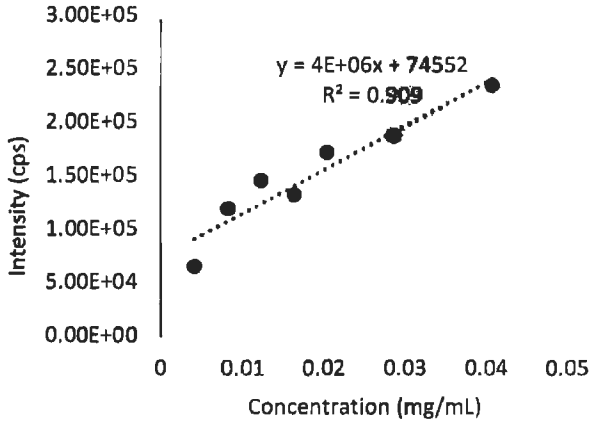

Figure I. Calibration curve of emission intensities compared to concentration of the BPA stock solution in each sample (initial concentration 0.102 mg/mL BPA in1:1 M/W).

spectra to use for comparison to detect the presence of BPA in the samples. The results showed higher fluorescence emission intensities of the samples in which the brushing apparatus was applying friction to the toothbrushes compared to the fluorescence emission intensities of the samples without having friction applied by the brushing apparatus. Toothbrushes F, H, and I had the largest difference in the emission intensities between the samples with the brushing apparatus applying friction to the toothbrush and the samples without the brushing apparatus.

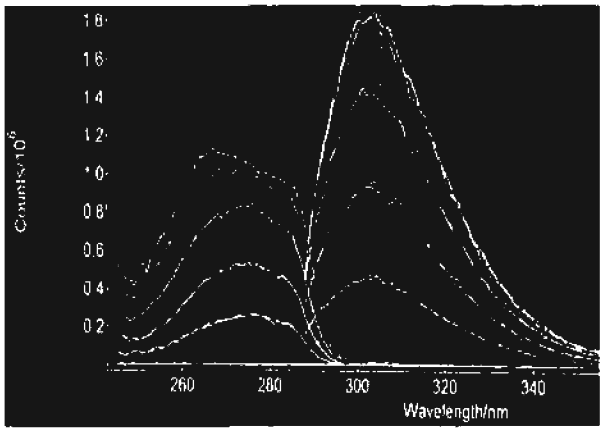

Figure 2. Excitation and emission spectra for calibration curve of BPA stock solution.

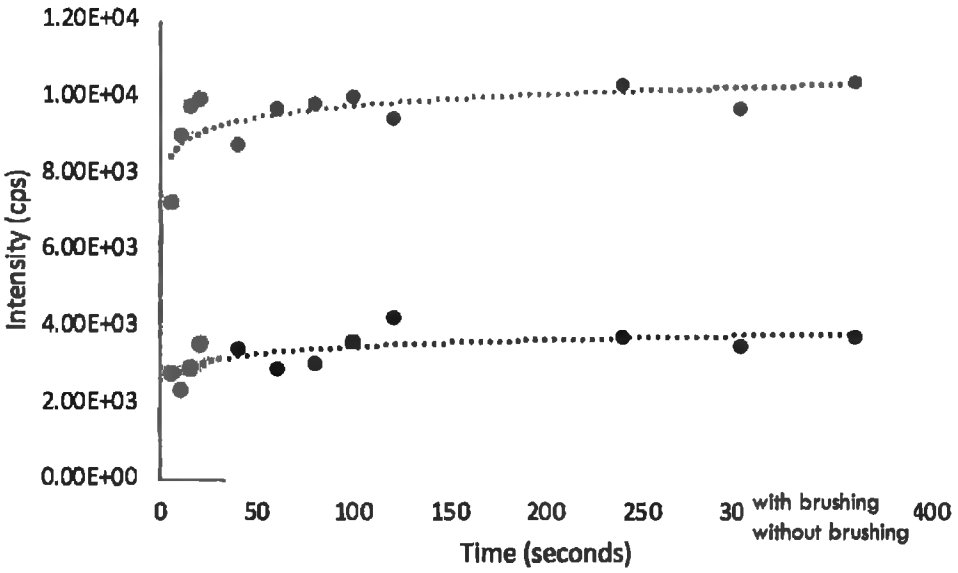

Figure 3. Fluorescence emission intensities over time comparing Toothbrush H with brushing and without brushing.

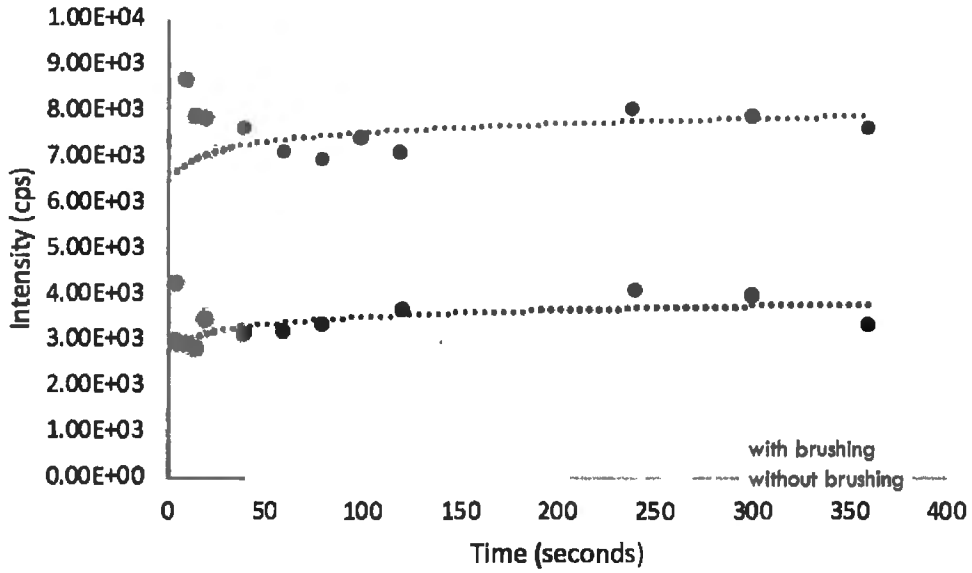

Figure 4. Fluorescence emission intensities over time comparing Toothbrush H with brushing and without brushing in the replicate run of this experiment.

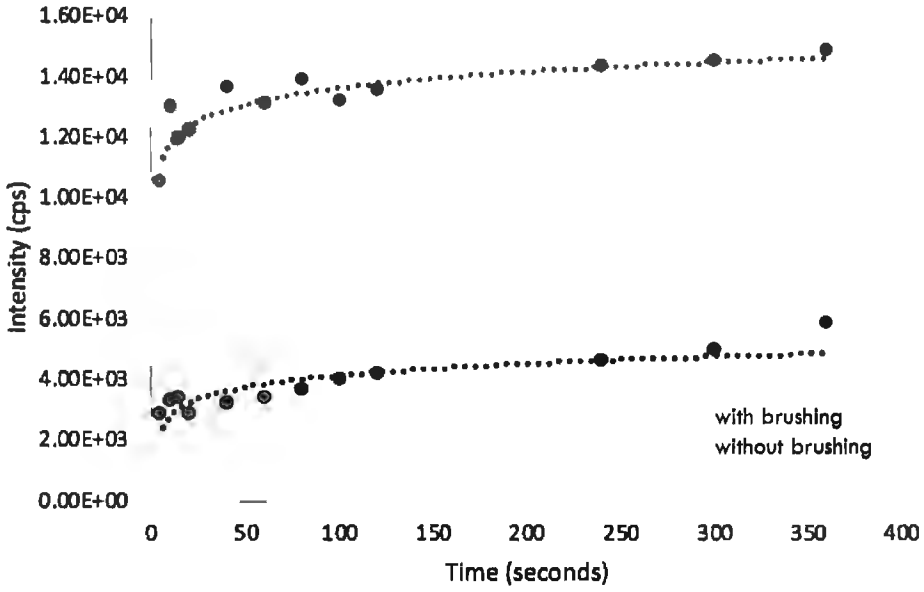

Figure 5. Fluorescence emission intensities over time comparing Toothbrush I with brushing and without brushing.

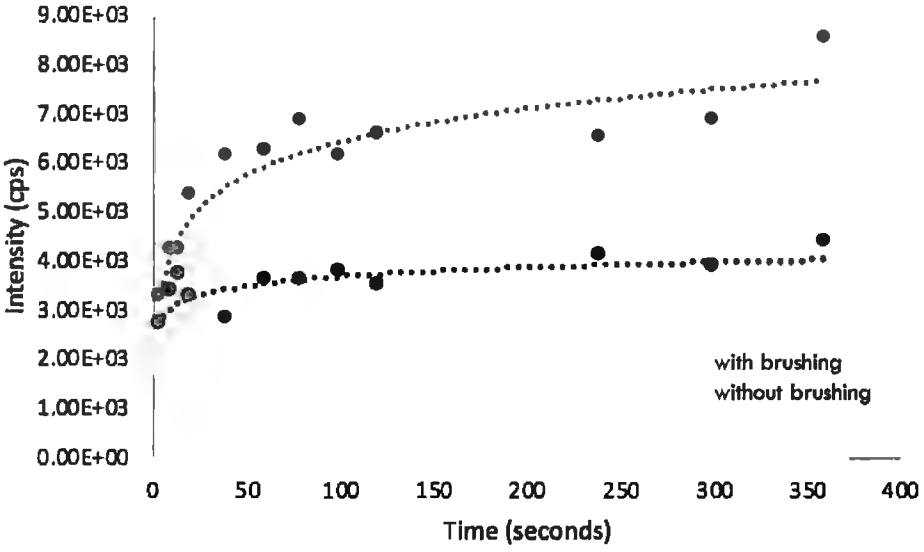

Figure 6. Fluorescence emission intensities over time comparing Toothbrush I with brushing and without brushing in the replicate run of this experiment.

The four figures above (3-6) show the fluorescence emission intensities of two toothbrushes, Toothbrush H and Toothbrush I, with friction being applied by the brushing apparatus and without friction in both runs of this experiment. These graphs show minor variance, but the pattern of higher intensities with brushing versus without brushing remains the same in both runs of the experiment. Table I on the following page shows the comparison of the emission intensities of brushing and not brushing at 1 hour and 6 hours along with the factor increase between brushing and not brushing of both time frames.

Toothbrush	1 hr with brushing (cps)	1 hr not brushing (cps)	Factor Increase	6 hr with brushing (cps)	6 hr not brushing (cps)	Factor Increase
A	4.64E+03	2.46E+03	1.886	7.19E+03	4.33E+03	1.661
E	6.88E+03	3.98E+03	1.729	6.12E+03	3.36E+03	1.821
F	1.30E+04	3.66E+03	3.552	7.74E+03	6.00E+03	1.290
H	9.69E+03	2.88E+03	3.365	1.04E+04	3.75E+03	2.773
I	1.30E+04	3.30E+03	3.939	1.48E+04	5.76E+03	2.569
J	6.74E+03	2.95E+03	2.285	8.11E+03	6.24E+03	1.300
L	6.22E+03	3.15E+03	1.975	9.80E+03	4.88E+03	2.008
M	6.87E+03	4.25E+03	1.616	7.48E+03	4.02E+03	1.861
N	6.14E+03	2.46E+03	2.496	1.08E+04	4.24E+03	2.547

Table I. Comparison of the emission intensities of brushing and not brushing at 1 hour and 6 hours. The factor increase shows how much more BPA was released with brushing versus without brushing.

EXPERIMENTAL CONCLUSIONS

The findings in this experiment show that friction does increase the amount of BPA that is released from an infant toothbrush. This is an important finding because of the large amount of friction that is applied to a toothbrush while it is being used in oral hygiene. Particularly for infants, there are different types of friction applied, which makes this an even larger issue. Babies often chew on infant toothbrushes while also brushing with them. This additional friction allows extra opportunity for the BPA in the toothbrush to be released into the mouth of the infant. The oral cavity has two possible ways for BPA to enter the body. These ways include both ingesting by swallowing and dermal absorption through the cheeks and lips. BPA has a longer duration of remaining in the body when dermally absorbed. The fact that BPA can enter the body through both possible ways from the oral cavity makes toothbrushes a major source of BPA exposure. Based on the results of this experiment, it was concluded that friction does increase the amount of BPA that is released from an infant toothbrush. This conclusion allowed the hypothesis to be accepted. The results showed that all toothbrushes that were tested showed some degree of difference between the fluorescence emission intensities of the samples in which the brushing apparatus was used to apply friction to the toothbrush and the samples in which the brushing apparatus was not used. This conclusion was further confirmed in the replicate run of this experiment. The pattern of the intensities being higher values on the samples in which friction was applied continued through every toothbrush in both runs of the experiment. This continuity of the pattern further confirmed the hypothesis.

CONCLUSION

The field of pharmaceuticals involves the three major branches of science: biology, chemistry, and physics, and requires all three of these sciences in order to grow and develop. Pharmacy requires biology to create the plan for how a drug will target the body and the pathway it will take for effectiveness. It requires chemistry to create and develop the compounds that are used in medicine, and it requires physics to put the compounds into the proper form and ensure the drugs are stored properly to protect them from damaging elements. These three branches of science are also important to the field of pharmacy because they help pharmacists to understand how combining different compounds can have negative effects. Items such as toothbrushes, foods, and vitamins can release chemicals into the body that can react with medications, and some actions can cause an increase in the amount of these harmful chemicals that is released. Through extensive research, scientists are working to better understand the relationships that chemicals have with each other, how common items expose humans to unwanted chemicals, what actions increase the exposure of chemicals, and how to use all of this knowledge to create new medications in order to grow and develop the pharmaceutical field.

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