The Evolution of the Sugarcoated American Food Market and the Paradox of Artificial Sweeteners

by
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DEDICATION

This thesis is dedicated to all the patients worldwide who suffer daily from obesity and type 2 diabetes. It is especially contributed to the children affected by these diseases that will not know a normal childhood and die an early death. To the parents who are consumed with guilt, to the unborn babies who will be suffer the effects of this disease on their mothers, and to the researchers, physicians, nutritionists, and administrators who are tirelessly working to slow these epidemics, this is for you.
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ABSTRACT:

MARY MOSES HITT: The Evolution of the Sugarcoated American Food Market and the Paradox of Artificial Sweeteners
(Under the Direction of Dr. Susan Pedigo)

Living in present-day America makes it hard to imagine an era when sugar was not as inexpensive and readily available as it is now. It is in little colorful packets on restaurant tables, filled to the brim in jars at coffee shops, or mixed into candy products located at the beginning of every cash register. Today, sugar is one of, if not, the most widely consumed food products in the world, but our love for sugar is nothing new. Humans have been experiencing the bliss triggered by sweet-tasting foods since their earliest diets, which included fruits and honey. Our diets became even more sugar dense when Europeans figured out how to affordably and effectively mass-produce cane sugar, gaining the common people access to what is now referred to as table sugar.

Consumption of this natural sugar has gained the negative reputation of displacing nutrition from diets and contributing to healthcare problems such as obesity and type II diabetes. The 20th century saw the invention of artificial sweeteners, a product created to keep the beloved sweet taste in the American diet while keeping the unwanted effects like weight gain out. In the face of the growing obesity epidemic, Americans have been turning to these engineered sugar substitutes as a tool to manage or even lose weight. Sugar-sweetened beverages, specifically carbonated soft drinks, are the greatest source of calories and added sugar in the American diet, and their high sugar and excess calorie content provides a platform to examine the paradox of artificial sweeteners, and how the American consumption patterns are correlating to a very ill America. More than one third of the United States is obese, and while there are levels of responsibility in the hands of
the consumers, food administrators and public health officials are not innocent, and their help is required to reverse this growing epidemic.
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LIST OF ABBREVIATIONS

Ace-K   Acesulfame Potassium
ADI     Acceptable Daily Intake
α-MSH   Alpha-melanocyte-stimulating hormone
AS      Artificial Sweetener(s)
BMI     Body Mass Index
CSD     Carbonated Soft Drink
FAO     Food Agriculture Organization
FDA     Food and Drug Administration
GI      Gastrointestinal
GLP-1   Glucagon-like peptide-1
GRAS    Generally Regarded as Safe
g       gram (s)
HFCS    High Fructose Corn Syrup
kcal    kilocalories
NHANES  National Health and Nutritional Examination Survey
NNS     Nonnutritive Sweetener(s)
NPY     Neuropeptide Y
PKU     Phenylketonuria
SSB     Sugar-sweetened beverage (s)
TAG     Triacylglycerol(s)
USDA    United States Department of Agriculture
WHO     World Health Organization
I. HUMANS HAVE SWEET DREAMS

Long before modern understanding of nutrition and the mechanisms of the body, humans were able to recognize their preference for sweet tastes. Foods containing sugar are not only energy-dense, but also have sweet flavors that activate reward areas in the brain. Our ancient ancestor’s fruit and plant based diet played an evolutionary role in shaping our desire for seeking out sweet foods, both for nutrition and enjoyment. With the variety of sweet-tasting foods available on the market today, it can be deduced that humans don’t just like the taste of sugar; they love it. These innate links correlate to the culture saturated with sugar we live in today, suggesting that the human drive for a sugar-rich diet is rooted in both nature as well as nurture (Breslin, 2013).

The value placed on sugar can be traced back as early as Judaism’s explanation of the Earth’s creation. According to the story, God forbade man to eat a specific type of fruit for its temptation and power, for which their desire was so overpowering that it led them to disobey a direct command from God (Holy Bible, 2001). The word “sugar” is derived from the Greek word “sakcharon,” but the root of the word for “sweet” highlights its importance. This adjective is derived from the Latin word suavis meaning “to persuade or make pleasing to,” and Americans are pleased as pie with sugar. Its prominence in our everyday lives is even revealed in more subconscious and subtle ways such as our terms of endearment. We call loved ones “honey,” “sweetheart,” or “sugar” whereas the French use “mon petit chou” or “my little cabbage” and the Germans say “schatz” or “treasure.”
These pet names reflect how different cultures call the people who are most dear to them after material things that are valuable to them (McGee 369).

Our deep-seated love for sugar has research connecting it to our first moments of life. It is suggested that humans have evolved biological factors that make them predisposed to sugar as a way to ensure that infants drink breast milk, which contains the disaccharide lactose that acts as a partial energy source for the baby. If infants rejected breast milk, it would lead to malnutrition and possibly even death (Urashima et al., 2012). Another biological factor playing a role in our attraction to sugar is our ancestors’ natural diet of fruit and plants, whose sugar-heavy makeup has transcended with a force that has not weakened through the course of human history. The composition of fruits and plants is discussed in a later chapter, but the scarcity of food during the earliest days of humanity curbed our affinity and our taste palates for what was available – high sugar content foods and animals (Breslin, 2013). These factors indicate a human predisposition to sugar before ever even tasting it, and the level of exposure to sugar experienced as a result of the country we live in is only fanning the flame (Avena et al., 2008).

Arguably the main factor playing a role in human sugar-seeking behavior is the concept of food reward. This neurological process is part of the brain’s overall responsibility of assigning judgment to our human experiences in order to encourage them to be repeated or avoided. When a necessary nutrient like sugar is consumed, a rewarding experience is triggered to encourage continued human consumption of that food. Defined as the momentary value a food has for the consumer at the time of ingestion, food reward is viewed as the final common pathway through which factors like hunger and food preference influence the level of consumption. Food reward makes
eating a more rewarding experience if a person is hungry and/or if the food tastes good to them, urging them to continue feeling satisfaction (Roberts, 2015).

Food reward is broken into two main branches: sensory and postingestive. The sensory begins when the tongue’s taste receptors detect sweetness. An orosensory stimulus forewarns the body about the intake of calories as well as signals the orbitofrontal cortex, the part of the brain responsible for making decisions like taking another bite of food. The encouragement to eat more food primarily comes from the mesolimbic pathway’s release of dopamine, giving the consumer the satisfactory feelings when he or she ingests sugary foods (Kobayakawa et al., 1999)(Small, 2006). This is how addiction to sugar forms, and it is achieved through the same neurological pathway triggered by sex and drug administration (Avena et al., 2008). More research is needed to understand the postingestive component of food reward, but it seems to depend on the metabolic products of the food that is consumed (Sclafani & Ackroff, 2004). If the postingestive branch is based on the nutritive content of food, then artificial sweeteners, explored in a later chapter, would eliminate this component of food reward since they are nonnutritive. This was illustrated in studies of food preference by Sclafani et al, which showed that starved rats preferred nutritive over nonnutritive sweetened foods (Sclafani & Ackroff, 1994). Further, functional magnetic imaging in normal weight men showed a prolonged signal depression in the hypothalamus that was produced by glucose ingestion that the artificial sweetener sucralose failed to create (Yang, 2010).

Humans seek to satisfy their inherently driven and culturally fueled craving for sweetness, even in the absence of energy need. This shares the same behavioral paradigm with other forms of addiction neurology like binge eating and craving and leads to
healthcare concerns like weight gain. Studies found that systematic reduction of dietary salt or fat without any flavorful substitution over the course of several weeks led to subjects preferring lower levels of those nutrients, and these findings give scientists hope that a similar approach will be effective in reducing sugar intake (Yang, 2010). Whether our innate attraction to sugar is the cause or the co-factor, sugar is everywhere in modern America, and unsweetening our diets may be the key to reversing the obesity epidemic.
II. SUGAR CLASSIFICATION: It’s a Carb

When thinking of sugar, one typically visualizes its white, crystallized form known as table sugar, commonly found on the shelves at the grocery store or in the spice cabinets of homes. This type of sugar is the refined form of the disaccharide sucrose and has become the standard reference for the word sugar. However, the term “sugar” is actually very extensive, with its broadest classification being a carbohydrate. Carbohydrates along with protein, fat, vitamins, minerals, and water make up the six nutrients essential for human life that body cannot synthesize on its own. Majority of carbohydrates have the empirical formula (CH\(_2\)O), but may also contain nitrogen, phosphorus, or sulfur in their chemical structure. Sucrose is only one of the many types of carbohydrates, both in structure and chemical composition.

Carbohydrates are the most abundant biomolecules on Earth. Photosynthesis alone creates an annual output of more than 100 billion metric tons of just one type of carbohydrate called cellulose, a linear polymer of glucose subunits. An elementary school student could proudly recite the basic concepts of this familiar process called photosynthesis, yet its importance to both plant and human life cannot be understated. During this process, plants convert water, carbon dioxide, and light into oxygen and sugar (glucose), and while the oxygen byproduct tends to be deemed the most valuable, the sugar products of this energy-yielding reaction are equivalently necessary to human survival. Humans possess the machinery to modify the chemical bonds in
sugars like sucrose but are unable to produce it the way that plants do, and these carbohydrates serve as the energy currency for both plants as well as animals (Nelson & Cox, 2008).

Carbohydrates are subdivided into three main categories, and in ascending order of complexity, they are monosaccharides, oligosaccharides, and polysaccharides. As mentioned, the root “saccharide” in the names of these three groups comes from the Greek word *sakcharon*, translated as “sugar” in English. The simplest sugars are monosaccharides and literally translate as “single sugars,” and the most abundant of these is six-carbon D-glucose, a very familiar sugar to humans and plants. Oligosaccharides are sugars composed of chains of monosaccharide units joined together by the characteristic glycosidic linkages and includes the familiar batch of sugars known as disaccharides, as they are composed of two, bonded monosaccharide units. These double sugars include sucrose as well as include lactose and maltose. The final subdivision of carbohydrates is polysaccharides, composed of a minimum length of twenty connected monosaccharide units. These complex sugars have a wide variety of structures and perform functions as diverse as contributing to the hard carapace on crabs to storing glucose units in liver for times of low blood glucose. Two main polysaccharides are cellulose and starch, and unlike cellulose, starch is able to be digested by humans. Polysaccharides are critical for health and nutrition but not a major emphasis of this study.

The common denominator for the carbohydrate categories is the monosaccharide structural component. These unassuming simple sugars have redefined the human diet as their colorless, crystalline solid structures are sweet to the taste. When one molecule of glucose and fructose are $\alpha,\beta1\rightarrow2$ glycosidic linked together, they form the disaccharide
sucrose, and this reaction is depicted in Appendix I. In this type of bonding, both of the anomeric carbons are linked together, making sucrose a nonreducing sugar that is not readily oxidized. Both glucose and fructose are six-carbon molecules that have identical formulas (C₆H₁₂O₆) and molecular structures that only differ by the placement of the carbonyl group. Though many types of sugars exist in nature, sucrose, and its monosaccharide components glucose and fructose, are the main three simple sugars found in any capacity in kitchens and the American diet. Sucrose and its monosaccharide components play a major role in the composition of naturally occurring foods like honey and fruits, making them central to this research.

One of the most revolutionary events in sugar’s edible history was the development of cane sugar plantations in the 17th century. Using sugarcane as a source of sugar dates back many millennia, but around 500 years ago was when these plantations developed the ability to mass-produce and distribute sugarcane, made possible by enslavement of humans. Since sucrose is an intermediate of photosynthesis, many plants possess this disaccharide. However, the greatest concentrations of sucrose are found within the plants classified under the *Saccharum* genus, which includes sugarcane and is considered to have originated in Asia. From the cane, farmers are able to harvest, refine, and crystallize the sweet, grainy product that is table sugar, which is nearly pure sucrose. Currently, Brazil is the world’s largest sugarcane producer at approximately 7.5 million cultivated hectares (100 acre units) that produced around 612 million tons of sugarcane in its 2009-2010 crop, of which half was used to produce sugar (Cheavegatti-Gianotto et al., 2011). Since this is a tropical crop, the majority of the United States is unable to farm it. The American sucrose market differs from other countries as a result of this and also has
around half its output cultivated from sugar beets, which yields a comparable product to sugarcane (Smith, 2015). The ability to affordably harvest and provide cane sugar to the masses is an event that revolutionized the sugar industry along with the human diet.
III. NATURAL SUGAR IN OUR DIET

Before humans discovered how to harvest sucrose from sugarcane, this disaccharide had an established presence in the human diet from being consumed in fruit and honey. Fruit set the bar high for the level of sweetness in our diets as this sweet-tasting food is composed of sugar content as high 60%, and it still serves as an integral part of our dietary regime (McGee 369). If humans thought life could not get any sweeter, their discovery of honey around 10,000 years ago proved this to be false as sugar accounts for nearly 90% of honey’s composition (da Silva et al., 2016). Though honey and fruit are both rich in sugar content, they are still viewed as healthier choices than stand-alone table sugar. Children are told to eat their fruits and veggies to grow up to be strong adults, and cooking shows and blogs are now filled with ways to substitute sugar with honey in recipes. Both table sugar and honey are naturally occurring products, but while table sugar goes through a purification procedure, raw honey is ready for consumption directly in nature. This aspect of honey may give it its health reputation, but this product has some chemical properties that when combined with the manufacturing processes required for mass distribution can make it a less natural additive to your food.

Like with fruit, the idolatry of honey is rooted in early literature and can be traced through the centuries. In the Holy Bible of Christianity, “the land of milk and honey” was the language used to describe the “promised” land, a place meant to be utopian and plentiful (Holy Bible, 2001). In 1926, A. A. Milne created the beloved character of
Winnie the Pooh who was very fond of food but especially of “hunny.” Today, honey is a food product enjoyed by people all over the world. Its nearly pure sugar composition contributes to this food’s energy value, viscosity, granulation, and popularity. Its composition along with its color, aroma and flavor vary depending on indigenous factors like the flower that provides nectar, geographical area, and climate in which it was produced. This sweet food contains a similar chemical composition to that of fruit except fruit has a higher structural component of water and fiber (McGee 372).

Monosaccharaides alone account for 70% to 80% of the total soluble solids in honey with fructose making up approximately 38.5% of this and glucose accounting for 31%. While sugar and water are its primary ingredients, honey is composed of around 200 substances including proteins, organic acids, vitamins and minerals, carotenoids, and most notably polyphenol. Flavonoids and phenolic acids are chemicals that exhibit a wide range of biological effects in the human body, including acting as the natural antioxidants that earn honey its reputation as a healthy alternative to table sugar (da Silva et al., 2016).

While table sugar is incorporated into food products, honey is a sweetener that is consciously added to food by consumers, and this aspect of honey can be both helpful and harmful. Specific caution with feeding honey to children under the age of two is encouraged at the risk of developing infant botulism. Research has shown honey to be a source for Clostridium botulinum, which produces the toxins and intestinal colonization that causes this infectious disease, and infants’ gut bacteria have not fully matured to move this bacteria through the body before causing harm like the adult digestive systems can (Midura et al., 1979). While it may be a naturally occurring product, time and the food production process affect honey’s innate qualities. Honey on the shelves at grocery
stores is not taken straight from the beehive like the raw honey found at farmer’s markets; it has gone through a manufacturing process. One of the most interesting aspects of honey is that during this processing and storage, it undergoes natural compositional changes, a reason that the less sensitive cane sugar became the more attractive option of the two. These changes usually occur as a result of chemical reactions like fermentation, oxidation, and thermal processing which all modify honey’s properties in some way (da Silva et al., 2016).

In one 24-week study, the change honey experiences during its shelf life were observed. Researchers found the sucrose concentration in honey when it was not stabilized experienced a 14% decrease at 4°C storage and a 79% decrease when stored at room temperature (20°C). In contrast, the fructose and glucose content increased 4% and 8.8% respectively in comparison to their initial values at 4°C, indicating the hydrolysis of sucrose into its monosaccharide constituents. These increased glucose and fructose percentages still did not account for a complete conversion of sucrose into glucose and fructose. Additionally, this research highlighted how honey’s hexoses oxidize as a result of a slow enolization and fast β-elimination of three molecules of water and form undesirable compounds like furans when it is heated or stored for a long period of time. Furans are the main degradation products of sugars and their occurrence in foods have been used as markers for the heat treatment of food. These flammable, highly volatile compounds are not considered to be good markers of floral honey and indicate a possible loss of freshness due to high temperatures or prolonged storage. Other products formed during sugar degradation and honey’s shelf life along with furans contribute to the physical transformations honey experiences in color, taste and odor. Thus, in order to
produce honey for commercial reasons, it is stored for almost a year before consumption to monitor change and create the best honey possible for the food market (da Silva et al., 2016).

In addition to the natural changes honey experiences during life after the beehive, the effort and money required to mass-produce honey at the consumer demand level today has led to a heightened presence of honey tampering. Recent decades have required the investigation of this adulteration as the evolution of cheap sweeteners like high fructose corn syrup (HFCS) led to the most common method of tampering with this high priced food. The Codex Alimentarius or “Food Code”, established by the Food Agriculture Organization (FAO) and World Health Organization (WHO), defines the authenticity of honey internationally by setting the identity and the essential quality requirements of honeys intended for direct human consumption. When using these guidelines to test authenticity, honey’s sucrose, glucose, and fructose levels are analyzed for any improper manipulation, and an increased presence may indicate a variety of adulterations, such as the addition cheap sweeteners (artificial or natural), harvesting honey before sucrose is transformed into glucose and fructose, or prolonged artificial feeding of honeybees with sucrose syrups for high commercial profits (da Silva et al., 2016).

Whether it is honey, fruit, or bread, if its structure contains carbohydrate content, then it is going to be broken into simple sugars by our digestive system. Carbohydrates are broken down into their monosaccharide constituents by both mechanical and chemical digestion, starting in the mouth. When we take a bite of a sugary food, mechanical digestion starts breaking down the food through chewing while chemical
digestion is kickstarted with the secretion of an enzyme by the salivary glands called amylase. Amylase hydrolyzes the glycosidic bonds between the glucose subunits that make up carbohydrate molecules, and it is this reaction that makes a chewed piece of bread or pasta taste slightly sweet if held in your mouth long enough. Chemical digestion of carbohydrates continues in the small intestine, where the pancreas secretes digestive enzymes like lactase and sucrase, which cleave the disaccharides lactose and sucrose into their monosaccharide constituents. These nutrients are transferred across the lining of the intestine and then into the bloodstream to be absorbed and used as energy by the body. Increased blood glucose levels occur after eating sugar-dense meals like a donut and a Coke, or starch-rich foods with a high glycemic index like bread and potatoes, and triggers the pancreas to release a hormone called insulin that stimulates the liver and muscle to uptake this excess glucose and store it as fat for later (Sadava et al., 2010).
IV. ARTIFICIAL SWEETENERS

Carbohydrates provide necessary nutrients for many processes of the human body, including glucose’s role as the principal fuel for the brain. If we do not consume or synthesize de novo enough of this six-carbon simple sugar, the consequences can lead to comas, permanent brain damage and even death. Similarly, there are physiological consequences of consuming too much glucose like the micro and macrovascular damage associated with type 2 diabetes, a more prominent problem for Americans (Zimmet et al., 2001). The level of sugar in the American diet is sometimes too much too quickly for the body to process and store, and the prolonged insulin signals lead to continued fat storage. A heightened consumption of nutritive sugars in the American diet have been identified as leading culprits in the growing obesity epidemic. It was their healthcare risks that provoked the invention of nonnutritive sweeteners to serve as safer sugar alternatives that do not raise blood glucose in an attempt to slow the rising disease rates (Malik et al., 2006).

Many of the artificial sweeteners on the market today were actually discovered by accident. During the 19th century researcher Constantine Fahlberg happened upon the first of these called saccharin while he was conducting experiments on coal tar derivatives. Despite the actual intentions of their research, the findings from scientists like Fahlberg are where the credit of inventing artificial sweeteners (AS) lies (Yang, 2010). Also known as high-intensity sweeteners and sugar substitutes, “artificial
“sweetener” has become a well-known term to Americans. These sweeteners owe their popularity to being many times sweeter than table sugar as well as non-caloric. Today, the United States Food and Drug Administration (FDA) has approved a total of six artificial sweeteners classified under the category “generally regarded as safe (GRAS),” for American consumers, and in chronological order they are saccharin, aspartame, neotame, acesulfame-potassium, sucralose, and advantame (FDA, 2014). Their structures and properties are appended in Appendix II.

While researching at Johns Hopkins in 1879, Fahlberg discovered the oldest artificial sweetener saccharin by breaking the modern conduct code of lab work and carrying out the typical but risky practice of tasting his experiment. Regardless of whether he was driven by dedication or insanity, Fahlberg’s discovery of the unassuming sweetener called saccharin became the first sugar substitute approved for use on the American food market. Saccharin’s approval as a sweetener occurred nearly eighty years after its discovery was part of the 1958 Food Additives Amendment to the Federal Food, Drug, and Cosmetics Act along with another artificial sweetener called cyclamate, no longer on the market today. This piece of legislation was born as a result of concerns about food additives and created the designation “generally regarded as safe (GRAS),” a more easily acquired label than “food additive.” To receive a GRAS determination, the substance in question is tested and evaluated through scientific procedures and from these studies is concluded to be safe under the conditions of its intended use (FDA, 2014). While the term is still in use today, measures taken to label a food or chemical GRAS have evolved, but these products still should be taken with a grain of salt. For instance, cyclamate, approved with saccharin by the FDA in 1958, was banned less than a decade
later for its carcinogenic potential. Despite this banned substance’s suggested links to cancer, cyclamate can still be found in products in over fifty countries including neighboring Canada, highlighting the inconsistency in the regulation of food products from country to country (Yang, 2010).

Government concern about saccharin’s safety intensified after the ban of cyclamate. Researchers found that it caused lab rats to develop bladder cancer, and by 1977 the FDA announced its intention to take back saccharin’s GRAS designation and remove it from the shelves as well (Price et al., 1970). However, American consumption of this product had already been taking place for two decades, and the announcement was met with such strong protests that it was brought before Congress to determine the fate of saccharin. They sentenced a happy medium, saccharin could remain, but any food product containing it as an ingredient was required to have a warning label while additional studies were to be conducted concerning this alarming link. The temporary relief that the warning label gave the consciences of federal food administrators became permanent when in 2000, the National Toxicology Program of the National Institutes of Health removed saccharin from the list of carcinogens along with the warning label required on its food products. Sold on the market today as Sweet and Low®, Sweet Twin®, Sweet’N Low®, and Necta Sweet®, saccharin is approved for use in beverages, fruit juice drinks, and bases or mixes as a nonnutritive sugar substitute for cooking, table use, and processed foods (FDA, 2014). Even with saccharin’s lengthy presence on the U.S. food market, regular artificial sweetener users became more prominent when the next generation of high-intensity sugar substitutes arrived.
Nearly a century after its predecessor, the next AS discovery came in 1965 as a result of chemist James Schlatter working for G.D. Searle & Company, also notable for its invention of the birth control pill. While working on creating new drugs to treat ulcers, Schlatter inadvertently discovered aspartame, most famous today for its inclusion in diet sodas. This artificial sweetener is one of the most exhaustively studied substances in the human food supply with more than 100 studies supporting its safety, though it does raise concerns for one particular group of people (FDA, 2015). Aspartame’s chemical structure is a methanol backbone linked to amino acids aspartate and phenylalanine, both included in the twenty common amino acids for which the human genome codes. However, there is a rare hereditary disease known as phenylketonuria (PKU), where victims have difficulty dissolving phenylalanine and are therefore encouraged to consume aspartame products with the highest caution. A distinguishing factor of this sweetener is that it can actually be metabolized, a property not shared by the other artificial sweeteners who pass through the human digestive system unchanged. At 4 kcal/g, aspartame is a nutritive sweetener, making it more similar to natural sugars in this regard, but the amount of calories consumed from aspartame is so small that it can be considered negligible. Along with being the only nutritive artificial sweetener, aspartame is also distinguishable from the others for not being heat stable, meaning it loses its sweetness when heated making it an ineffective sweetener in baked goods. Sold today under the brand names Nutrasweet®, Equal®, and Sugar Twin®, aspartame was approved for use in dry foods in 1981, carbonated beverages and carbonated beverage syrup bases in 1983, and as a general purpose sweetener in 1996 (FDA, 2015).
Next came sucralose, an artificial sweetener discovered by graduate student Shashikant Phadnis working for Tate & Lyle. Sucralose is synthesized directly from sucrose with the substitution of chlorine in place of sucrose’s three hydroxyl groups. Sold today under the brand name Splenda®, sucralose was approved for use in fifteen food categories in 1998 and as a general-purpose sweetener in 1999 (FDA, 2015). In 1984 a company called Monsanto purchased the Searle Corporation that discovered aspartame and converted the brand to NutraSweet. With the rising success of the artificial sweetener market, NutraSweet engineered another, which it named neotame. Sold under the brand name Newtame®, neotame was FDA approved for use as a general-purpose sweetener and flavor enhancer in foods in 2002. The very next year nonnutritive sweetener acesulfame potassium (acesulfame K or Ace-K) joined the food market. Discovered by Karl Class at Hoeschst in 1967, Ace-K has a structure and taste comparable to saccharin and cyclamate and is most commonly found in combination with other sweeteners in frozen desserts, candies, beverages, and baked goods (Yang, 2010). Sold under the brand names Sunett® and Sweet One®, Ace-K was approved for use in specific food and beverage categories in 1988 and as a general purpose sweetener and flavor enhancer in food in 2003. The most recent FDA approved artificial sweetener and flavor enhancer advantame was only just approved in 2014 (FDA, 2014).

For each of these high-intensity sweeteners, the FDA has established an acceptable daily intake (ADI), the amount that can be safely consumed over the course of a person’s lifetime (FDA, 2014). According to them, even a person who consumes a high level of AS will not exceed this established ADI, but whether consumed in excess or moderation, high-intensity sweeteners are exponentially sweeter than naturally occurring
sugars. Aspartame and Ace-K achieve the minimum amount of increased sweetness of the six high-intensity sweeteners at a level of sweetness 200 times greater than table sugar. Saccharin is 200-700 times sweeter, sucralose is 600 times sweeter, neotame is 7,000-13,000 times sweeter, and the most potent of all is advantame at a sweetness level 20,000 times greater than that of sucrose (Yang, 2010). It seems hard to fathom the reasoning behind creating substances that can achieve such extreme levels of sweetness, but the logic is the higher the sweetness level, the smaller the amount needed to be added to food, meaning a cheaper production cost. Tactful marketing of these artificial sweetener products as both “desirable” and “healthy” combined with the power of the human sweet tooth have contributed to increased number of sugary, processed foods available on the American market today.
V. THE AMERICAN DIET AND FOOD MENTALITY

In 1977, a Senate committee spearheaded by George McGovern published the first *Dietary Goals for the United States* that recommended Americans consume less fat and more carbohydrates. While these guidelines have altered through the years, the food industry followed suit, and grocery shelves began being filled with products bearing the labels “low-fat” and “fat free.” The institution of dietary guidelines along with a shift in food product content played a role in altering American diets as well as their mentality toward food. In 2014, a European market research firm collected consumption data of eight food categories from fifty-four countries, and according to their findings, Americans were ranked number one in sugar consumption, consuming on average 23.5 g more than second place Germany, but in fat consumption, the U.S. was ranked 16th (Ferdman, 2015). The graphical analysis of from this study’s sugar vs. fat consumption is appended to Appendix III. Consumption of fats, simple and complex carbohydrates is still a controversial and steadily researched topic, but regardless, four decades have passed since the first dietary guidelines, Americans are still sicker than ever.

Americans are probably familiar with the more recent dietary guidelines like the USDA Food Pyramid issued in 1992 and its 2011 replacement MyPlate. However, these nutritional goals are the work of the continued research and food guideline revisions that have been taking place since the turn of the 20th century. The USDA’s first food guides appeared in the 1916 publication *Food for Young Children*, and in 1941 the Food and
Nutrition Board of the National Academy of Sciences released the first Recommended Dietary Allowances, which listed intake for calories and nine essential nutrients. It was not until after WWII that the “Basic Seven” food guide focused on nutrient adequacy, suggesting numbers of daily servings for each of these food groups. These evolved into the “Basic Four” by 1956, specifying daily amounts for these food groups but lacked guidance on fat, sugars, and calorie intake. Two decades passed before The McGovern Report set quantitative goals for the intake of protein, carbohydrates, sugar, fat, fatty acids, cholesterol, and sodium in 1977, serving as a precursor to the first Diet Guidelines for Americans issued in 1980 that are now updated every five years (Welsh et al., 1993). Ironically, the senate committee that issued these guidelines formed out of concerns of hunger and malnutrition taking place in America, but instead issued its guidelines with the aim of combating the rates of illnesses like heart disease, obesity, and diabetes (Hite et al., 2010).

While these Dietary Goals have been expanded upon, their call for increased consumption of carbohydrates with reduced consumption of fat struck a chord with consumers that sparked a marketing shift in food companies. Believing that eating fat would make you fat does not take a stretch of the imagination, especially since the word “fat” was already becoming a negative buzzword with the aesthetics shift taking place in the 20th century. America was evolving into a body image and weight conscious society where thin was the new in, specifically with marketing strategies to promote skinny women as beautiful were escalating (Stearns, 2002). Fat also fit into the ideas behind the “you are what you eat” theory with the logic that if we removed fat from our diets, the calories and subsequent weight loss would follow.
As long as we break even with the amount of calories consumed and expended, weight gain should not occur. However, focusing solely on calories in vs. calories out can be problematic because a calorie is a unit of measurement not a nutritive identifier. The body processes a calorie of protein differently than it does a calorie of a carbohydrate. The focal point of these new dietary guidelines was cutting calories, and while per capita consumption of fatty foods did drop after the McGovern Report, calories from carbohydrates increased nearly 15% (Gifford, 2002). This idea of burning off more than is consumed is apparently ineffective, as more Americans are now overweight than normal weight. Just as the obesity rates have increased in the U.S., so has leisure time fitness (see table in Appendix III), suggesting that neither scenario alone is sufficient to reduce waistlines (Stern, 2008).

Our love-hate relationship with food and concern with body image played a role in creating the food market of fat replacers – the artificial ingredients increasing at a rate of nearly 6% a year (Walsh, 2014). By cutting the fat, we made a new market of products bearing the all-too-familiar dietary labels such as “fat-free” or “zero calorie.” These are markers of products made with NNS, and people are intuitively choosing them as the healthier alternative. In 2012, the International Food Information Council Foundation conducted a survey that asked American adults why they choose AS over natural sweeteners and received a 73% response that it had to do with reducing calorie intake (Roberts, 2015). The food industry has overenthusiastically responded to the cry of the people. From 1999-2004, 6,000 new products made with AS were launched in the United States, appearing in diverse range of items like spaghetti sauce, frozen foods, and granola bars. In 2004, the National Household Nutritional Survey as well as the National Health
and Nutrition Examination Survey (NHANES) both estimated that 15% of the American population was using artificial sweeteners compared to a 3% usage in 1965. Just four years later, an IRI Consumer Report conducted in 2008 found that 65% of Americans households purchased at least one product that year made with sucralose, the most popular AS on the market (Roberts, 2015)(Yang, 2010).

This dietary labels usually indicate the tampering or removal of ingredients, and with the removal of fat and natural sugars, something had to be added to these food products to maintain pleasurable tastes. The level of sweetness achieved by artificial sweeteners had already intensified the American sugar craze, and in recent years, the latest addition to the already sugarcoated food market was the invention of “added sugar” (Huth et al., 2013). Added sugars are those that are additionally incorporated into foods and beverages during their production (Newens & Walton, 2015). Since AS are non-caloric as well as cheap, manufacturers are able to pump them into their products and still achieve the “zero calorie” classification regardless of the amount of inherent sugar content per gram they may possess.

The average intake of added sugars for Americans from 2001-2004 was 22.2 teaspoons per day or 355 calories per day (Johnson et al., 2009). An analysis of the data from the 2003-2006 NHANES identified the top ten sources contributing to this statistic in the U.S. with the top three being ‘soft drink, soda,’ ‘candy, sugars, sugary food,’ and ‘cake, cookies, quick bread, pastry, and pie.’ According to the study, these sources account for 93% of added sugar consumption and 68% of the total sugar in the U.S. diet (Huth et al., 2013). American diets are dense in calories, largely from sugars, as supported by these statistics, and the majority of Americans are not consuming the
recommended intakes of basic food groups and experiencing an imbalance in energy intake and expenditure that is leading to illnesses (Huth et al., 2013). This increased consumption of sugary food is a tribute to the marketing job of the American food industry playing on our inherent links to sweetness, leading to their fat wallets and a fat America. Over the past three decades in the United States, an increase has been shown in both the number of overweight and obese individuals as well as in consumption of carbohydrates suggesting a correlation between the two events.
VI. CARBONATED SOFT DRINKS

The single greatest source of both added sugar and calories in the American diet is sugar-sweetened beverages (SSBs). Fruit juices, sports drinks, vitamin waters, and sodas are just part of the overwhelming variety of SSBs currently available on the U.S. market. We consume them with meals, drink them as snacks, use them for caffeine boosts, offer them in vending machines around every corner, and dispense them in soda fountains that keep us going back for free-of-charge refills. The escalated rate of consumption of these beverages has led to a displacement of more nutritious beverages like milk and water from the American diet as well as contributed to a very fat and chronically ill America. The most consumed SSBs are carbonated soft drinks, and this beverage group provides the perfect lens to expose the paradox of artificial sweeteners and links of sugar consumption to obesity and its subsequent problems (Roberts, 2015).

The non-alcoholic beverage industry is divided into two main subdivisions: hot drinks, which include tea and coffee, and soft drinks, which include juice, bottled water, sports and energy drinks, and carbonates like soda. The first marketed “soft drink” was a mixture of water, lemon juice, and honey in 17th century Europe. By the 19th century, a man named Joseph Priestley earned the nickname “the father of the soft drink industry” when his gas fermentation experiments led to the now distinctive feature of this category’s most popular drinks: carbonation. Carbon dioxide gas produces that familiar sound that follows breaking the seal on unopened can of Coke and gives the drink its
crisp taste and prolonged shelf life. A pharmacist in Atlanta, Georgia by the name of John Pemberton invented Coca-Cola, the first carbonated soda, in 1886 and revolutionized the soft drink industry. Soda, pop, coke, fizzy drink, cocola, regardless of the term you use, they all refer to the same extremely popular carbonated beverage made with a nutritive or nonnutritive sweetening agent, natural and artificial flavors, caffeine, and carbonated water (Korab, 2016).

Now, the global soft drink market is dominated by carbonated soft drinks (CSD), earning revenue of $337.8 billion in 2013. The leading soft drink manufacturers are the Coca-Cola Company and PepsiCo, Inc., both of which were founded in the Southern United States. Collectively, these two companies hold about 70% of the U.S. CSD market with Dr. Pepper Snapple Group, Inc., Monster Beverage Corporation, and Cott Corporation rounding out the top five key players. On a global scale the Coca-Cola Company is the largest non-alcoholic beverage company with more than 500 brands, including 17 brands that generate more than a billion dollars each in revenue while runner-up PepsiCo, Inc. has 22 brands that generate more than a billion dollars each in revenue. Coca-Cola is the world’s third-most valuable brand with a value of $81.6 billion, and PepsiCo, Inc. is ranked 24th with a brand value of $19.1 billion (Bailey, 2014).

Consumers crave sodas because they contain two addictive stimulants — sugar and caffeine — in very high amounts, earning these products their impressive monetary statistics. A 12-fluid ounce can of Coca-Cola contains 39 grams of sugar and around 34 milligrams of caffeine, while the same sized Pepsi drink contains 41 grams of sugar and 38 milligrams of caffeine and a Dr. Pepper contains 40 grams of sugar and 41 milligrams
of caffeine. Sugar and caffeine trigger pleasure-inducing areas in the brain through the same mechanisms discussed in chapter one and cause the release of a hormone called dopamine, forming an enjoyable, subconscious addiction. While regular sodas are made with nutritive sweeteners, the large amount pumped into these drinks can lead to harmful healthcare consequences, resulting in this popular type of beverage becoming the focus of many researchers’ attention (Bailey, 2014).

Sodas are little more than a pleasant way to consume excess amounts of sugar in liquid form, and as if the food products were not providing enough sugar to our diets, now Americans are drinking their calories and carbohydrates. Over the past forty years, there has been an increase of daily caloric sweetener consumption of 83 kcal a person with 54 of this kcal coming from soda alone. In the United States, a standard 12-ounce regular soda provides 150 kcal and 40 g sugar, equivalent to 10 teaspoons of table sugar. The American Heart Association recommends an added sugar intake of no more than 100 calories per day for women and 150 calories per day for men, equivalent to six and nine teaspoons of table sugar respectively, meaning one can of regular soda exceeds the daily limit for both genders (Johnson et al., 2009). Incorporating a CSD a day into the typical American diet without reducing sugar intake elsewhere can lead to a weight gain of 15 lbs (6.75 kg) in one year’s time (Malik, Schulze, & Hu, 2006). Along with their pleasurable sweet tastes, sodas’ easy access and low cost only make them more appealing to Americans and have led to the United States becoming the leading country in soda consumption.

Our consumption of sodas increased 135% between 1977-2001, and the industry has been particularly targeting children and teenagers with its marketing. The life-long
implications of poor dietary choices, specifically the consumption of soft drinks, at a young age have been better studied in recent years, and scientists and nutritionists now have more data to release to the public. Soda’s high added sugar content, low satiety, and incomplete compensation for total energy account for its contribution to the growing rates of overweight and obese Americans (Malik et al., 2006). They have also shown links between regular consumption of soda with insulin resistance, tooth decay, and type 2 diabetes mellitus (Roberts, 2015). With the mounting data validating the carbonated soft drink link, healthcare advocates are giving their best efforts to dissuade the population from consuming these sugary drinks or at least make sure we are educated on their effects. Mexico, which has the highest rates of obesity in the world, even imposed a 10% tax on sugary beverages as a way to discourage the consumption of these drinks, but these endeavors have been successful or not, the global obesity epidemic’s thirst has not been quenched (Bailey, 2014).
VII. THE OBESITY EPIDEMIC

Obesity has escalated to epidemic proportions in the last two decades, affecting the entire global population. Obesity has aggressively affected the United States of America, causing the nation to stand out amongst global counterparts. More than a third of the United States’ population is obese, making America one of the most oversized societies in an increasingly fat world. This statistic fails to include the estimated 35% of Americans who contribute to the billion overweight adults in the world, making the national number of obese or overweight Americans a staggering 65%, depicted in a graph in Appendix IV. The rise in pant size has been linked to a “Westernized lifestyle” - a calorie-dense diet and a relative lack of exercise that generates a net positive-energy balance (Roberts, 2015). Sugar and sweeteners are some of the many factors contributing to the obesity epidemic, as a result of their escalated level of consumption simultaneously increasing fat storage and appetite (Yang, 2010).

An overweight or obese clinical diagnosis is determined based on an individual’s body mass index (BMI). The formula for calculating BMI is (weight in kg)/(height in m)². A normal person’s BMI is less than 25, while those who are overweight fall into the range of 25-30. An obese individual’s BMI exceeds 30, indicating a life-threatening diagnosis. In 2014, the U.S. did not have a single state with obesity rates that fell below 20%. Five states and the District of Columbia had a prevalence of obesity between 20-
25%; twenty-three states, Guam and Puerto Rico had a prevalence of obesity between 25-
30%; nineteen states had a prevalence of obesity between 30-35%; and three states
(Arkansas, Mississippi and West Virginia) had a prevalence of obesity of 35% or greater. All three states with the highest population of obese individuals were reported to have
>30% of their high school students consume at least one regular soda a day (CDC, 2015).
While an estimated 35% of U.S. adult population is obese, an even more concerning statistic is that an estimated 17% of the population ages 2-19 is also obese (Ogden et al., 2014). These data suggest that this illness involves more than a society stricken with gluttony. Viewing obesity as a disease rather than a personal choice is supported by the high rates of adolescent obesity, indicating that there is more going on with this illness than the perception of society at large.

Obesity reflects complex interactions of genetic, metabolic, cultural, environmental, socioeconomic, and behavioral factors. In 1995, Dr. William Dietz conducted a case study on a seven-year-old girl whose diet consisted of the food available to her family through food stamps; she was consuming low-cost and high-fat sustenance. As a result of this diet, the seven-year-old girl was 220% over her ideal body weight. Dietz observed that despite the fact the girl was morbidly obese, she remained hungry because she was not receiving the nutrition she needed. To combat her obesity, the family did not need to restrict the quantity of her diet but rather combat her food insufficiency-eating pattern. Since obesity results from excessive energy intake and hunger is a reflection of an inadequate food supply, Dietz observed that this was a paradoxical situation, and that it was not just taking place with this one little girl. He found an increased prevalence of obesity and hunger in the same socioeconomic population, and
he hypothesized that either food choices or physiological adaptive responses to episodic food shortages were causing this paradox (Dietz, 1995). He became the first person to coin the term “hunger-obesity paradox” to describe the phenomenon where contradictory concepts of hunger and obesity coexist within the same person (Scheier LM, 2005). Subsequent studies that have expanded upon Dietz’ research confirmed the existence of his hypothesized paradox. Evidence shows that there is an existing association between obesity and food insufficiency. A 2001 study was the first large-scale one to provide evidence in support of the link between food insecurity and obesity, verifying that this association was present in the same people at the same time occurring at the national level in the United States (Townsend et al., 2001). A 2003 study provided the support that preventing obesity in impoverished communities requires increased food supplementation not food restriction (Adams et al., 2003).

A base level diagnosis assumes that obesity is the result of taking more calories in than are expended by the body’s energy-consuming activities, but Dietz’s hypothesis and the expanded data illustrate that obesity can involve more than the amount of food consumed. In regards to the food market, the link is the type of food being consumed just as much as the quantity. In particular, researchers have found that increased consumption of sugars and sweeteners are contributing to two-thirds of the American population being overweight or obese. Psychological stress and lack of conscious attention to food choices are likely factors driving the overconsumption of sweets, as these food items are both addictive and pleasure-inducing (Daubenmier et al., 2014). As discussed, carbohydrates encourage the body to store them as fat while simultaneously intensifying hunger, making losing weight very difficult. The body deals with excess fuel either by storing it,
burning it as energy, or diverting it to heat production (thermogenesis) as “waste” fuel. Humans have a complex set of hormonal and neurological signals to keep fuel intake and energy expenditure in balance and dealing effectively with obesity requires understanding how excess consumption of sugar causes these homeostatic mechanisms to fail (Nelson & Cox, 2008).

Another consequence of excess sugar consumption is the onset of type 2 diabetes mellitus, which is correlated to obesity. Glucose is released into the bloodstream after carbohydrate consumption, and an increased blood glucose level results in the pancreas releasing a hormone called insulin, causing the blood glucose to be taken up and stored by liver and muscle. Diabetic individuals are unable to efficiently remove glucose from the bloodstream in this manner either as a result of insulin not being produced or not being recognized by the tissues. The two clinical classes of diabetes are based on this insulin problem distinction. Type 1 diabetes or insulin-dependent diabetes mellitus refers to an individual incapable of producing insulin, and this disease is typically acquired during childhood. In contrast type 2 diabetes (non-insulin-dependent diabetes mellitus or insulin-resistant diabetes) refers to an individual whose insulin receptors are insulin-insensitive, and this disease is typically acquired during adulthood. The name “diabetes mellitus” means “excessive excretion of sweet urine,” an indicative symptom of the body’s inability to properly regulate and convert blood glucose. Both types of diabetes result in the excretion of large amounts of glucose in the urine, and this condition is known as glucosuria. A healthy individual assimilates blood glucose effectively and has little to no glucose appear in urine. In individuals with diabetes mellitus, blood glucose
levels are assimilated poorly and as a result exceed the kidney threshold (about 10 mM) and are excreted in urine (Nelson & Cox, 2008).

In 2010 around 220 million people worldwide were diagnosed as diabetic, primarily with type 2 diabetes, and the projected number of cases rises to 360 million for 2030. In the U.S., the prevalence of type 2 diabetes increased almost two-fold in a twenty-six year period (see Table 2 in Appendix IV). Obesity significantly increases the likelihood of an individual developing type 2 diabetes, but majority of obese patients do not acquire this co-illness. However, 80% of individuals who have type 2 diabetes are also obese. Like obesity this disease is life threatening (Kahnl et al., 2006), earning a global mortality rate of 2.9 million people in 2000. The number of deaths in the United States caused by type 2 diabetes has doubled in nearly every age range from 1980-2014, and this tracked data can be found in Table 3 in Appendix IV. Research has found genetic factors predisposing individuals toward type 2 diabetes with at least 10 genetic loci being reliably linked to the disease. Nearly 6% of the U.S. population shows some degree of abnormality in glucose metabolism, indicative of this diabetes mellitus or a tendency toward it.

Along with Type 2 diabetes mellitus, obesity significantly increases and individual’s chances of developing heart attacks, strokes, and cancers of the colon, breast, prostate, and endometrium. Other long-term-associated health outcomes for both overweight and obese individuals include dyslipidemia, coronary artery disease, insulin resistance, hypertension, hepatic steatosis, and cerebral vascular disease (Roberts, 2015). The U.S. spent an estimated $147 billion in 2008 on the medical costs of obesity, a significant increase from the already high annual price of $78.5 billion billed in 1998
(Finkelstein et al., 2009). The decrease in productivity and quality of life that result on overweight and obese individuals are linked to elevated medical, psychological, and social costs (Malik et al., 2006). While new data gives a better understanding of fighting this disease, the numerous factors contributing to this epidemic at both the individual and societal levels make a single solution to the problem unrealistic (Malik et al., 2006)(Roberts, 2015).
VIII. THE PARADOX

The hunger-obesity paradox is not the only paradox regarding food consumption in the United States. The public health concerns that have arisen from excessive soft drink consumption have not persuaded Americans to abandon sodas. While some individuals are happy with their diets, others have been making an effort to minimize the unwanted health effects from sugar consumption by switching to diet drinks, a happy medium that allows sweet drinks to remain in their diets. Sodas are designated “diet” when they are created with non-caloric, artificial sweeteners rather than the natural sugars that our bodies are able to metabolize. One would think that transitioning from beverages made with nutritive sweeteners to those made with NNS should result in management or even loss of weight, and there is evidence supporting these assumptions. However, there is emerging data indicating that these artificial sweeteners are doing more to the human body than just passing through undigested. Analyzing the switch from regular to diet carbonated soft drinks provides a platform to expose the paradoxical character of artificial sweeteners.

The good news is that in recent years the amount of literature available on artificial sweetener consumption has increased. The bad news is that these new, long-term studies conflict with the earlier data, specifically on their ambiguous role in weight management. In the overall body of research, there is evidence that directly links artificial sweetener consumption to weight loss and indirectly links it to weight gain, with the
latter indicating the paradox. Since artificial sweeteners are nonnutritive, research suggests that their mechanism for promoting weight gain is through the resulting cravings, reward phenomenon, and addictive behavior they produce when consumed (Liu et al., 2013). When the tongue’s tasting organs detect that a person has eaten something sweet, an orosensory stimulus is generated to forewarn the body about the intake of calories, including GI reflexes that prepare for the digestion of the calorie dense food that is sugar. However, when an individual consumes a non-caloric sweetener, the body is unable to distinguish an artificial sweet taste from a natural one, and it still triggers the same signaling cascade, leading to confusion in the body, unsatisfied hunger, and ultimately weight gain (Qurrat-ul-Ain & Khan, 2015).

A psychological component playing a role in consumption of products made with artificial sweeteners contributing to their paradox is the “Snackwell Effect,” a play on the conservation and energy economics term the “rebound (or take-back) effect.” In 1992 the brand of low-fat cookies called SnackWells were introduced by Nabisco and within two years surpassed the company’s longtime distinguished Ritz cracker as the number one snack in the nation (Walsh, 2014). The Snackwell Effect derived its name from this specific cookie, the origin of the phenomenon of new “fat-free” or other similarly branded food products made with NNS coming out on the market. Individuals purchasing these products with health motivations end up abusing the benefits of the low calorie/low fat content by eating more than they would have if they had purchased the higher calorie option. A USA Today article used an analogy of a couple who purchased an energy efficient washing machine but maintained the same energy bill because they were lulled
into complacency by their energy efficient purchase to explain this psychological effect occurring in consumer patterns (Washington, 2009).

Since SSBs are the greatest source of calories and added sugar in the American diet, extensive research has been conducted on these beverages’ effects on both normal and overweight individuals. Some studies suggest that this substitution does result in reduced caloric intake and modest degrees of weight loss. One study supporting this involved observing the effects of NNS on appetite by monitoring energy intake from an ad libitum meal following ingestion of a SSB, NNS, and water. The SSB group exemplified the greatest total energy intake, which was measured by factors like gastric inhibitory peptide, Ghrelin concentration, and Glucagon-like peptide-1 (GLP-1) with the NNS and water groups exemplifying lesser amounts. By ten weeks the NNS subjects had significantly lower effects on insulin, leptin, triglyceride, glucagon, and GLP-1 levels than the SSB group members. This study also noted that using NNS in beverages as a weight loss tool is most effective in individuals who previously consumed excessive amounts of SSB over those who consumed in moderation prior to making the switch. The drastic reduction in calorie intake results in these individuals lowering their BMI.

Majority of the existing data supporting weight reduction from the substitution of NNS in SSB comes from short-term studies like this one, and data from long-term studies is both lacking and needed (Raben et al., 2011).

Longitudinal and cross-sectional studies are starting to show an overall association of NNS consumption and weight gain, that previous short-term studies did not and are being criticized for failing to meet the Bradford-Hill criteria for causal inference, the minimum conditions needed to establish a causal relationship between two
items (Roberts, 2015). Now the body of data on SSB consumption has produced conflicting results, specifically on switching from nutritive sweetened beverages to nonnutritive sweetened beverages as a mechanism for weight management. Research has also found that sweet taste, whether delivered by sugar or artificial sweeteners, enhances human appetite, with aspartame having the most pronounced effect. More research is needed to understand the specifics of the mechanisms through which they accomplish this, but since high-intensity sweeteners do not satiate when consumed, it is hypothesized that they actually increase hunger by leading to immediate or delayed energy compensation. This key point of NNS consumption involves monitoring if additional calories are consumed exceeding the calorie savings from the NNS, like the Snackwell Effect indicates (Roberts, 2015). One 12-week dietary regimented program was conducted to study this and was carried out on two groups of participants: regular soda consumers and diet soda consumers. This study observed that those who consumed aspartame in diet drinks over those who consumed table sugar in regular soft drinks experienced a 25% immediate reduction in energy intake. However, it was also noted that knowingly ingesting aspartame was associated with increased overall energy intake, giving credence to this appetite effect of these artificial sweeteners (Yang, 2010).

While more research is needed, there is sufficient evidence existing for public health strategies to discourage consumption of sugary drinks, both nutritive and nonnutritive, as part of having a healthy lifestyle (Malik et al., 2006). The negative effects that the excess calories from consumption of sugary drinks are notable enough to educate the general population of the risks associated with these drinks, specifically their link to obesity and all of the subsequent healthcare issues that stem from this disease. The
GRAS classification of the six FDA approved high-intensity sweeteners should be an assurance of safe consumption (Roberts, 2015), but anything consumed in excess usually comes with unwanted effects, and the amount of sugar packed into the products on the American food market is providing more fuel to an already fully increasing obesity epidemic.

Increasing evidence suggests that artificial sweeteners do not activate food reward pathways in the same way that natural sweeteners do in more ways than this. Research suggests that they both activate the sensory component but in different ways. It was observed in lab rats that foods associated with regular feeding became preferred regardless of their nutritional value. There is strong correlation between the flavors and intensity of a person’s customary intake foods, and since artificial sweeteners are so many times sweeter than natural sugars, repeated exposure trains flavor preference more quickly and strongly. Artificial sweeteners encourage sugar craving and dependence just like any other sweet tasting food; however, their incomplete reward response continually fuels the food seeking behavior because without the postingestive component, satiation is never reached and eating remains rewarding (Yang, 2010).
CONCLUSION

This body of work chronicles how the combination of our innate attraction to sugar mixed with the neurological experience it triggers has contributed to the overwhelming presence of sugar in modern America. Whether by conscious choice or not, the consumption of sugary foods and drinks is abused in the United States, and the consequence has been a plethora of unwanted healthcare effects including but not limited to over 60% of Americans being either overweight or obese. Sugars encourage the body to store them as fat while simultaneously increasing hunger and triggering a rewarding and pleasurable addiction, making weight loss difficult. Thus natural sugars had already been identified as factors of the obesity epidemic, and their healthcare risks provoked the invention of artificial sweeteners in the 20th century to serve as safer sugar alternatives. The greatest source of calories and added sugar in the American diet is sugar-sweetened beverages, specifically carbonated soft drinks, and these high sugar, excess calorie drinks provided the perfect platform for analyzing the paradox of artificial sweeteners and a link of sweetener to obesity and its subsequent problem. In the face of the growing obesity epidemic, Americans turned to these engineered sugar substitutes to manage or even lose weight, but there is evidence that directly links artificial sweetener consumption to weight loss as well as indirectly linking it to weight gain. AS have been shown to achieve weight loss when used as a substitute in a diet loaded with natural sugars and sweeteners. However, even though the body does not digest them into glucose which can be
converted into fat, these artificial sweeteners still trigger the reward areas in the brain, forming addictive behavior; do not completely satiate, leaving us feeling hungry; and trigger insulin to be released in the blood, making us at higher risk of contracting resistance to this hormone and subsequently type 2 diabetes mellitus. While there are levels of responsibility in the hands of the consumers, the fact is more Americans are overweight than are not, suggesting more than just a society blinded with gluttony is contributing to this disease rate. The statistics and the research both show that the American diet is correlated to making us ill and even killing us, yet the shelves of grocery stores are still lined with processed sugary foods and beverages. Until this changes, America’s weight statistics will not, and the help of federal administrators and legislators is required to reverse this growing epidemic, allowing more Americans to lead a long, healthy life.
APPENDICES
APPENDIX I: Formation of Sucrose

Figure 1: The formation reaction of the disaccharide sucrose. Its monosaccharide units, glucose and fructose, become bonded by the characteristic glycosidic link, whose placement makes sucrose a nonreducing sugar.
### APPENDIX II: The Six FDA Approved Artificial Sweeteners and Their Structures:

<table>
<thead>
<tr>
<th>Sweetener</th>
<th>Discovered</th>
<th>FDA approved</th>
<th>Sweetness</th>
<th>Brand Names</th>
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</thead>
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<tr>
<td>Saccharin</td>
<td>1879</td>
<td>1958</td>
<td>200-700</td>
<td>Sweet and Low®, Sweet Twin®, Sweet'N Low®, and Necta Sweet®.</td>
</tr>
<tr>
<td>Sweetener</td>
<td>Discovered:</td>
<td>FDA approved as a sweetener:</td>
<td>Times sweeter than sucrose:</td>
<td>Brand name:</td>
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<tr>
<td>Sucralose</td>
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| **Discovered:** 1967    | **Discovered:** |}
| **FDA approved as sweetener:** 2003 | **FDA approved as sweetener:** 2014 |
| **Times sweeter than sucrose:** 200 | **Times sweeter than sucrose:** 20,000 |
| **Brand names:** Sunett® and Sweet One®. | **Brand names:** |
APPENDIX III: Chapter V Figures and Tables

Where people eat the most sugar and fat

Daily fat and sugar consumption

![Graph showing daily fat and sugar consumption with countries plotted based on sugar and fat levels.](image)

Source: Euromonitor

Some of the data collected by a 2014 study called Passport Nutrition conducted by a European market research firm. This database is original in its examination of the total amount nutrients coming from packaged food and soft drink products in fifty-four countries with the purpose of helping people track dietary trends and understand what they are consuming. It focuses on eight nutrients: energy, protein, carbohydrates, sugar, fat, saturated fat, fiber, and salt.

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<td>Met neither guidelines</td>
<td>44.3</td>
<td>36.2</td>
<td>56.9</td>
<td>45.2</td>
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</table>

Table 1: Participation in Leisure-time Aerobic and muscle-strengthening activities (rated based on 2008 Physical Activities Guidelines for Americans aged 18-44 years age group.)
The breakdown of clinically diagnosed BMI’s from 1999-2014 for men and women showing support that more Americans than not are overweight or obese. Data acquired from the National Center for Health Statistics 2016 Document, “Health, United States, 2015: With Special Feature on Racial and Ethnic Health Disparities”

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<td>19,404</td>
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<td>Over 65 years of age</td>
<td>25,216</td>
<td>54,161</td>
</tr>
</tbody>
</table>

Number of deaths due to Type 2 Diabetes Mellitus more than doubled from 1980 to 2014 in men and women ages 45 and older.

LIST OF REFERENCES
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