

# Exposing the human gut microbiome biology essay



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In western populations, obesity is increasingly becoming a major preventable cause of death. Although health care providers understand the basic and most common proximate causes for obesity, the alarming rates of obesity within the United States suggest that other traits are critical to understanding the increasing prevalence. New evidence indicates that diet plays a central role in shaping the human gut microbiota, which is critical to how the body digests and extracts energy from foods. Additionally, a growing number of recent studies conclude that a high-fat, high-sugar diet promotes obesity. Therefore, I hypothesize that the rapid adaptability of our gut microbes to a “ Western” diet increases vulnerability to obesity.

Exposing the Human Gut Microbiome to the “ Western” Diet Contributes to Obesity: Why Do Human Gut Microbes React Negatively to the “ Western” diet?

The prevalence of obesity has reached epidemic proportions within the United States. The incidence and implications of this increase is startling. Contributing to more than 300, 000 annual deaths, (U. S. Department of Health & Human Services: Office of the Surgeon General), obesity is quickly overtaking tobacco use as the leading cause of preventable mortality in the United States. (Mokdad, Marks, Stroup, & Gerberding, 2004).

The terms “ obesity” and “ overweight” are both labels that denote ranges of weight that exceed healthy amounts. (Centers for Disease Control and Prevention, 2010). Obesity refers to a disproportionately high amount of body fat; while overweight designates excess weight from water, muscle mass, bone density, and body fat combined. (National Institutes of Health,

2010). Although both represent a weight range that is unhealthy for a given height and age, the critical difference is in degree-obesity signifies a life-threatening body fat percentage. (Centers for Disease Control and Prevention, 2010). The dominant and most accurate predictor of body fat-body mass index (BMI)-calculates and assigns a numerical value for an individual's amount of body fat based upon his or her height and weight. In general, an overweight adult will have a BMI between 25 and 29.9, whereas a BMI of 30 or more indicates obesity. (Centers for Disease Control and Prevention, 2010). A BMI greater than 39 signifies a morbidly obese adult. (Patel, 2005)

Because healthy fat ranges vary during early maturation and puberty, pediatricians consult growth charts to reference a corresponding BMI percentile that is specific to sex and age for children. (Centers for Disease Control and Prevention, 2009). The BMI-for-age percentile allows the pediatrician to properly assess a child's growth by comparing it to a charted ranking. To determine a BMI-for-age percentile ranking, a pediatrician first locates the child's age on the horizontal axis and then traces that age upward until it intersects the appropriate BMI on the vertical axis. (Centers for Disease Control and Prevention) The point of intersection denotes the child's BMI-for-age percentile. According to growth charts published by the Centers for Disease Control and Prevention ("CDC"), overweight children are plotted between the 85th and 95th percentile. (Centers for Disease Control and Prevention, 2009). A BMI-for-age rank in the 95th percentile means that only five of one hundred children of the same age and sex have a higher BMI-for-age ranking. (Centers for Disease Control and Prevention). A BMI-for-

age percentile above 95 is defined as obese. (Centers for Disease Control and Prevention, 2009). Based upon these definitions, more than one-third of American children have greater than an 85th percentile BMI, and more than half of those children are obese. (Hassink, 2007, p. xi).

Each numerical increase in BMI multiplies the risk for a number of health problems, including: diabetes, hypertension, stroke, heart disease, cancer, and even death. (Patel, 2005) The risk of early mortality is 50-100% greater for an obese person. (Patel, 2005). Compared to the national average, a diagnosis of obesity (a BMI value between 30 and 35) shortens the average lifespan by two to four years, and morbid obesity (a BMI greater than 39) decreases an individual's lifespan by ten years. (Prospective Studies Collaboration, 2009, p. 9). For instance, a person with a BMI of 27 will likely lose one to two years from his or her lifespan. (Hassink, 2007). The striking decrease in life expectancy associated with morbid obesity is approximately equivalent to the reduction caused by a lifetime of " persistent cigarette smoking." (Prospective Studies Collaboration, 2009, p. 9).

Even more disconcerting, however, is the increasing emergence of obesity in children. Nearly 23 million American children are dangerously overweight or obese. (Robert Wood Johnson Foundation, 2009). Correlating to approximately one in every five children in the United States, (Dietz, 1995), the occurrence has tripled in the past three decades. (U. S Department of Health and Human Services, Office of the Surgeon General). Many physicians and health-care providers attribute the steadily increasing prevalence of obesity in children primarily to sedentary, inactive lifestyles and excessive

caloric intake. (Hassink, 2007, p. 1). Regardless of the causes, obesity is as debilitating for children as it is for adults.

Indeed, obesity is one of the most prevalent nutritional diseases affecting American adolescents. (Dietz, 1995). In fact, more than thirty illnesses that occur with increased frequency in overweight and obese children, (Overweight and Obesity: Health Consequences), caused approximately 799 of the 45, 667 overall deaths of people between the ages of 1 and 24 in 2006, possibly implicating obesity in as many as 2% of all adolescent deaths. (Melonie Heron, et al., 2009). Shockingly, these percentages are only increasing. The prevalence of obesity among U. S. children ages two through nineteen has nearly doubled since 1994. (Ogden, Carroll, & Prevention, 2010).

The proximate causes of obesity

Generally speaking, obesity is the result of energy imbalance within the body. (U. S. Department of Health and Human Services, 2004). Calories contained in foods provide the body with the energy to necessary to support basic life functions. (U. S. Department of Health and Human Services, 2004). When the number of calories consumed matches the number of calories the body expends, an individual will maintain a constant body weight. (U. S. Department of Health and Human Services, 2004). Conversely, energy imbalance results when an individual's caloric intake exceeds his or her physical expenditure, which leads to weight gain and obesity. (U. S. Department of Health and Human Services, 2004). It is important to note, however, that researchers have proposed many biological influences that

may be involved in creating this imbalance. For example, this list includes genetic predisposition and hormone imbalance. (Biological Causes of Obesity).

Researchers have identified hundreds of genetic markers that are associated with obesity. (Hassink, 2007, p. 2). In families in which one or both parents are obese, the child is at an increased risk for also becoming obese.

(Hassink, 2007, p. 2). A 2009 study estimated that 3 genetic variations, affecting the PTER gene (phosphotriesterase-related gene), the NPC1 gene (endosomal/lysosomal Niemann-Pick C1 gene), and the MAF gene (encoding the transcription factor c-MAF), account for nearly 50% of all childhood obesity. (Meyre, et al., 2009). Although the PTER gene is the variant most strongly associated with childhood obesity, science has yet to understand the function of the PTER gene. (Imperial College London, 2009). Researchers believe that the NPC1 gene, accounting for approximately 10% of all childhood obesity, is related to regulating hunger. (Imperial College London, 2009). Finally, the MAF gene controls the production of insulin and glucagon, which seems to affect satiation. (Imperial College London, 2009). The MAF variant accounts for nearly 6% of early-onset obesity. (Imperial College London, 2009).

Other scientists point to an imbalance of the hormone leptin as the predominate cause of obesity. Fat cells within the human body produce leptin, which aids in regulating various systems including appetite. (Zuk, 2007). In laboratory studies, researchers observed that the amount of leptin the body produced seemed to be directly related to the amount of fat cells within the body. (Zuk, 2007). As such, leptin acted as a control to reduce <https://assignbuster.com/exposing-the-human-gut-microbiome-biology-essay/>

appetite and promote weight loss when the amount of fat increased in the body. (Zuk, 2007).

Unfortunately, treatments focusing on hormone control have been unsuccessful. Commentators suggest that the evolution of the regulatory system selects for weight gain rather than weight loss because a primary risk was starvation. (Zuk, 2007). Thus, scientists propose that, when during starvation, the body produced higher leptin levels to stimulate appetite and encourage the body to increase fat storage. (Zuk, 2007). The resulting problem is that weight loss in an overweight person resembles starvation to the brain, which notifies the regulatory system to compensate for the reduction in leptin by increasing appetite and encouraging weight gain. (Zuk, 2007). The body is not able to recognize that the new weight is actually a healthier one because of evolutionary limitations. (Zuk, 2007).

Nevertheless, the prevailing cause for the energy imbalance remains overconsumption and under-exertion. One aspect of this imbalance occurs because of the change in the macronutrient content of the modern diet-the higher proportion of energy-dense foods and drinks increases the likelihood for overconsumption. (Pollard, 2008, p. 38).

### **The Modern “ Western” Diet**

Many researchers and authors refer to the “ Western” diet in their studies and articles; however, very few provide a substantial explanation for how he/she has defined the “ Western” diet. Most often, researchers identify that, for the purpose of the study, a “ Western-style diet [is a] high-fat, sugar-rich diet.” (Fleissner, Huebel, El-Bary, Loh, Klaus, & Blaut, 2010).

For the purpose of this paper, a typical “ Western diet” is high-fat, high-sugar. It is also high in animal proteins, and “ with a trend towards [fast-foods], confectionary, processed, fried and refined foods.” (Research Australia, 2010). This style of diet will “ tend to be higher in total fat, saturated fat, refined sugar and sodium.” (Research Australia, 2010).

Studies clearly demonstrate that many Western children’s diets are completely deficient. The Bogalusa Heart Study uncovered that between 1973 and 1994 a majority of 10-year-olds in the United States exceeded the American Heart Association’s dietary guidelines for total fat, saturated fat, and dietary cholesterol. (Nicklas, Elkasabany, Srinivasan, & Berenson, 2001). The study noted that, instead of consuming dietary fats through whole grains, vegetables, and fruits, the majority of children intake dietary fats from refined carbohydrates and high-energy, nutrient-deficient foods. (Nicklas, Elkasabany, Srinivasan, & Berenson, 2001). The researchers hypothesized that the detrimental changes in food choices and nutrient intake resulted because of national changes in food consumption and the influences of industry and media advertisements in the United States. (Omar, 2009).

For example, one study seeking to better understand the effects of advertising noted that brand-name advertising for fast-food chains and food manufacturers finance most of Saturday morning children’s television. The study further observed, “[that] much of... [children’s television] advertising [in the United States] is for high-fat, high-sugar, and high-salt foods.” (Omar, 2009, p. 171). Accordingly, the study tested what influence fast-food wrappers had on the participants preferences. (Omar, 2009). Identical  
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hamburgers were placed in either a major fast-food chain's wrappers or an unknown packaging. As evidence of the media's influence, the study found that the children preferred the taste of the food in the fast-food chain wrappers. (Omar, 2009). It also reported an association between a preference for fast-food chain packaged food and how often the child regularly eats fast food and/or how many televisions are in the home. (Omar, 2009).

Another study purports to provide empirical evidence in human that conclusively links the Western diet to obesity. (Price, 2010). Paolo Lionetti, a pediatric gastroenterologist studied the variation of the microbes within healthy children from Burkina Faso-a village in western Africa-and healthy children in Italy. (Price, 2010). The Italian cohort acted to represent a typical "Western" diet, "low in fiber but high in animal protein, sugar, starch, and fat," whereas, Lionetti intended for the African children's diet to represent dietary habits before the advent of agriculture. (Price, 2010). Accordingly, the African children ate a "high-fiber, low-fat, vegetable-heavy diet." (Price, 2010). The results suggest that not only did the African children possess a healthier diversity of microbes in their gut, but also that the composition of their bacteria lessens a propensity for obesity. (Price, 2010).

## **The Role of Microbiota**

The beneficial relationship between humans and their gut microbiota has a long evolutionary history, (Zuk, 2007, p. 56), and recently, the interplay between diet and the gut microbiota has become a growing area of interest. (Sonnenburg, 2010). Essentially, the gut microbiota can be perceived as a "microbial metabolic organ of sorts" consisting of trillions of bacteria. (Flier, J. <https://assignbuster.com/exposing-the-human-gut-microbiome-biology-essay/>

S, & Mekalanos, J. J., 2009). The complex community of microorganisms and bacteria co-evolved with our own physiology. (Flier, J. S, & Mekalanos, J. J., 2009). These trillions of bacteria provide the host with a number of valuable functions. First, the microbiota digests components of food that the human enzymes cannot degrade. (Sonnenburg, 2010). Additionally the bacteria are crucial to the modification of the immune system. (Flier, J. S, & Mekalanos, J. J., 2009). Finally, researchers speculate that the microbiota within the gut mediate other “ physiological functions that are currently unknown.” (Flier, J. S, & Mekalanos, J. J., 2009).

Humans do not automatically possess the internal collection of microbes. (Zuk, 2007, p. 56). Some scientists propose that, because an enhanced ability to obtain energy-rich food is a driving factor within human evolution, the microbiota adapts to accompany the dietary changes that have occurred throughout human history. (Sonnenburg, 2010). Thus, the anthology of microbes is partially assembled at birth, and partially from our food and the environment. (Zuk, 2007, p. 56).

The fact that the microbiota can evolve to adapt to the colonization of novel food environments is further evidenced with the recent discovery of a new resident bacterium within the intestines of some Japanese people, which contains similar genetic material as a marine bacterium. (Sonnenburg, 2010). Possessing this bacterium enables the body to digest components of seaweed that would otherwise be discarded as waste. (Sonnenburg, 2010). The researchers hypothesized that microbes in Japanese people acquired the genetic material through lateral gene transfer to adapt to the colonization of

novel food environments. (Sonnenburg, 2010). In that instance, the body adapted to a diet high in seaweed.

Likewise, the modern lifestyle has dramatically altered the types and number of bacteria in our bodies. (Zuk, 2007, p. 57). Most commentators identify diet as a critical factor in the development of the gut microbiota. (Zuk, 2007, p. 57). The interaction between diet and bacteria is reflected in the following explanation, “ the nutritional value of food is influenced in part by an individuals’ gut microbial community (microbiota) and its component genes (microbiome).” (Turnbaugh, Ridaura, Faith, Rey, Knight, & Gordon, 2009). As Lionetti concluded, the study comparing the microbiota of Burkina Faso children with Italian children clearly demonstrated that “ diet is the most important thing for having a diverse, healthy gut.” (Price, 2010). Simply put, changes in diet rapidly results with changes in microbiota.

## **How Does the Adaptability of our Gut Microbes Increase Vulnerability in a Novel Environment?**

The gut microbiota rapidly responds to a Western diet.

More importantly, some research is beginning to reveal that the kinds of microbes that a person acquires can cause obesity. (Zuk, 2007, p. 260). Specifically, the results demonstrated that a high-fat, high-sugar diet causes a rapid modification in the resident microorganisms, which promotes obesity. (Flier, J. S, & Mekalanos, J. J., 2009).

In one groundbreaking study conducted by Turnbaugh et al., scientists transplanted human microbiota into germ-free mice to observe the relationship between the microbiota and diet. (Flier, J. S, & Mekalanos, J. J., <https://assignbuster.com/exposing-the-human-gut-microbiome-biology-essay/>

2009). Using germ-free mice is a simple method to examine the contributions of the gut microbiome because the mice do not possess any gut flora of their own. (Flier, J. S, & Mekalanos, J. J., 2009). Indeed, they are completely devoid of any “germs,” including any type of bacteria. Without the gut microbiota, the germ-free mice are resistant to obesity induced by high-fat and high-sugar diets; however, the reintroduction of microbiota “increases fat mass and restores sensitivity to diet-induced obesity.” (Flier, J. S, & Mekalanos, J. J., 2009).

The study first proved that human microbiota could be transplanted into the guts of the germ-free mice. (Flier, J. S, & Mekalanos, J. J., 2009). After successfully transplanting human microbes, Turnbaugh et al. refer to the mice as “humanized.” (Flier, J. S, & Mekalanos, J. J., 2009). The second major conclusion was that when the “humanized” mice are exposed to a high-fat and high sugar (“Western diet”), the resident microbes rapidly change. (Flier, J. S, & Mekalanos, J. J., 2009). Finally, the “humanized” mice have an increased body fat compared to the mice without the humanized gut microbiome. (Flier, J. S, & Mekalanos, J. J., 2009). This remained true even when the researchers transplanted the gut microbiota from high-fat-fed humanized mice into a new group of germ-free mice that were fed low-fat diets. (Flier, J. S, & Mekalanos, J. J., 2009). The results of this study indicate that the composition of gut microbiota is closely associated with long-term diet patterns. (Chenhong Zhang, et al., 2010).

The question arises as to why the trend towards a more “Western” diet seems to cause negative health consequences in humans. Given that humans partially assemble the gut from our food, (Zuk, 2007), it would seem <https://assignbuster.com/exposing-the-human-gut-microbiome-biology-essay/>

that the bacteria that is prevalent (or lacking) in a “ Western” diet causes detrimental effects in the gut. For whatever reason, even though the microbiota rapidly adapt to the foods within the Western diet, those alterations cause negative health effects.

The way that bacteria differ within the Western diet may illuminate several important factors. The Western diet is largely composed of highly processed foods, which contain fewer bacteria for the gut to accumulate. (Zuk, 2007). Additionally, the majority of meat products come from animals treated with antibiotics, which kills the healthy bacteria that would normally allow the human gut flora to properly digest and store food. (Zuk, 2007). Furthermore, most of the components within a typical Western diet are heat processed-“ e. g. bread, snack items, breakfast cereals, roast meat, cakes, pastries, baked potatoes.” (Touhy, Hinton, Davies, Crabbe, Gibson, & Ames, 2006, p. 849).

A complex network of reactions, which is known as the Maillard reaction, occurs during the thermal processing of foods. (Touhy, Hinton, Davies, Crabbe, Gibson, & Ames, 2006). This is a chemical reaction that occurs between an amino acid and a reducing sugar. It is colloquially referred to as the ‘ browning reaction’ because it is the phenomenon that is responsible for browning meats and beer, and converting bread to toast. After undergoing the Maillard reaction, foods lose essential amino acids, vitamins, and some metals. (Touhy, Hinton, Davies, Crabbe, Gibson, & Ames, 2006). Additionally, evidence indicates that the Maillard reaction interferes with the ability of human enzymes to digest the protein. (Touhy, Hinton, Davies, Crabbe, Gibson, & Ames, 2006).

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Consequently, the Western diet may be depriving the gut of the bacteria it needs to regulate digestion. Although the microbiota co-evolved within our physiology to adapt to novel environments, in a sense, the current food environment is toxic. It is not that “Western” diet interferes or limits the ability of the gut microbiota to adapt. Instead, the highly adaptive properties of the gut microbiota, which co-evolved to confer the body with the ability to obtain energy from food, are detrimental in the context of a “Western” diet. It is not unlike ingesting a virus that the body adapts to and begins to mimic, as opposed to rejecting.

#### Alternative evolutionary causes for the obesity epidemic

The simplest explanation for the obesity epidemic is that the current nutritional environment is novel in human evolutionary history. (Gluckman, Beedle, & Hanson, 2009). This evolutionary approach follows from the view that, “the changes that have taken place in our environment, including dietary and lifestyle shifts, occurred at a faster rate than the human genome could adapt to, and thus [concludes that] humans are still biologically adapted to environments of their ancestors.” (Jew, AbuMweis, & Jones, 2009, p. 925). As such, our species’ metabolism is not selected for a low-protein, high-fat, and high-sugar diet. (Gluckman, Beedle, & Hanson, 2009). This is an extremely basic example of evolutionary mismatch-“cultural and dietary change[s] have outpaced the capacity of evolutionary processes to compensate.” (Gluckman, Beedle, & Hanson, 2009, p. 197). Because of the evolutionary mismatch, proponents hypothesis that the biological systems that are responsible for human appetite control are not able to recognize the disproportionate amounts of energy in high-fat and energy-dense foods.

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(Pollard, 2008). This mismatch causes the body to be incredibly inefficient at regulating this sort of modern food intake. (Pollard, 2008).

However, this explanation fails to account not only for the research regarding microbiota, but also research that reveals that behavioral and cultural factors play an extremely critical role in eating habits and obesity rates. The current food environment varies drastically throughout the world, and even throughout the United States. Indeed, different cultural groups and races experience varying incidence rates for obesity. To this effect, research reveals that Caucasian children have the lowest occurrences of obesity, and black children have the highest rate of obesity, followed by Hispanic children. (U. S. Department of Health and Human Resources, 2005).

A competing hypothesis for obesity supposes that neglect of the evolutionary forces driving diet is causing the negative health effects. The hypothesis asserts that, even though the “ Western” diet is at odds with the evolution of a healthy, reproductive society (because of the increasing health risks associated with obesity), humans enjoy high-fat, high-sugar foods because of our evolutionary heritage. Historically, humans experienced alternating periods of feast and famine, which resulted in the development of metabolically thrifty genes that permitted more efficient food use and fat deposition in times of food abundance to prepare for times of famine. Thus, it is possible that we are just recklessly ignoring human evolution-humans have an inherent preference to ingest fats because of their previous scarcity in the ancestral food environment.

However, just because humans evolved in a different environment does not necessarily mean that reverting to a Paleolithic diet is the solution. (Zuk, 2007). Furthermore, even assuming that humans have an evolutionary propensity to like high-fat foods, one must question why the body has not adapted to a modern diet. In fact, obesity rates are continually rising. Thus, not only has the body not adapted, the problem is actually worsening.

Another biological trait might also be at work-gut microbes.

The microbiota rapidly adapts to diet. Unfortunately, the “ Western” diet fails to provide enough essential macronutrients or health bacteria for the body to properly function. As such, this rapid adaptation is no longer beneficial.

Instead of improving the body’s ability to extract nutrients and store fats (much like the benefit Japanese individuals acquired to digest components of seaweed) the “ Western” diet impairs digestion and energy storage.