



Canadian School of Natural Nutrition

NN101 Fundamentals of Nutrition

Part I & II

Booklet for CSNN Students

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1. Introduction: Optimal Wellness

Life is filled with choices. There are hundreds of choices made everyday and many of these choices relate to food and lifestyle habits. Some may feel that these food choices are insignificant, not understanding that when making these choices time after time, the impact they may have on one's health.

The journey begins with one question: What does it mean to be healthy or have optimal wellness?

This may represent something different to each individual. It may be as simple as not having an illness or disease or it may mean having the energy to live each day. Optimal wellness is a much wider scope of health, as it entails all aspects of health: physical, mental, emotional, and spiritual. It is a representation of being the very best version of yourself.

The relationship of food towards health of the human body is nutrition. Food not only nourishes the body; it is the foundation of our health plus a source of pleasure and enjoyment. Most people understand that eating healthy and being active reduces the risk of common health issues such as obesity, high blood pressure, high blood sugar, digestive disorders, and memory problems.

No single food or nutrient will maintain health. It is the balance of all the macronutrients, micronutrients, fibre, and water that is necessary for health. There are a few more factors when it comes to overall wellness such as age, gender, lifestyle, and genetics that also play a role in being healthy.

The next question is regarding diet: What is considered a balanced diet?

There is no one diet that is right for every being and there is no one right way to eat. Healthy eating and diet are as individual and different as each person. We are all biochemically unique, so our dietary needs are individual to each of us.

Food is broken down into different groups or categories such as fats, carbohydrates, protein, vitamins, minerals, and fibre. Water has its own category, which some foods will supply water, but the largest source of water is drinking it. All food will provide a certain amount of each of the above groups of nutrients, which the benefit of whole, natural food is that these nutrients work synergistically together. Food also contains much more than these nutrients. There are many other substances in food that promote health and protect the body from illness. These are components such as plant sterols, enzymes, phytonutrients, pre and probiotics, which give food its colour, flavour, and health promoting properties. These components can be found in spices, fruits, and vegetables such as purple cabbage, beets, sauerkraut, garlic, onion, apples, and sprouts. These other components and phytonutrients provide several health benefits including supporting immunity and reducing the risk of heart disease and cancer.

Even though we each have individual requirements, everyone needs a full range of these same nutrients for general health. Nutrients are the chemical components supplied by food to give the body the ability to grow, maintain and/or repair bodily tissues. These nutrients can perform

different functions in the body such as provide energy, support immunity, and aid in the regulation of body processes such as protein needed to manufacture antibodies, enzymes, and neurotransmitters.

The final question: Why choose certain foods over others?

We all have different tastes and preferences when it comes to our food choices, which can impact the reason why we choose certain foods to consume, but are these choices healthy or the best choice?

Let's take a closer look at the average food choices and diet. This is commonly referred to as the Standard American Diet (SAD) or 'Western Diet'. This diet mainly consists of processed, packaged foods that are high in refined sugars, trans and poor-quality fats, chemical preservative, and additives such as candy, potato chips, French fries, hot dogs, ice cream and so on. Not only do these types of foods contain anti-nutrients, but there is also an issue with portion sizes, which contributes to many health issues such as heart disease, diabetes, and obesity.

A 2010 report from the National Cancer Institute on the status of the American diet found that three out of four Americans don't eat a single piece of fruit in a given day, and nearly nine out of ten don't reach the minimum recommended daily intake of vegetables. On a weekly basis, 96 percent of Americans don't reach the minimum for greens or beans (three servings a week for adults), 98 percent don't reach the minimum for orange vegetables (two servings a week), and 99 percent don't reach the minimum for whole grains (about three to four ounces a day). (Nutritionfacts.org, 2010)

Poor diet was once associated with undernutrition. Today, it is often associated with excess, particularly excesses in calories, saturated fats, trans fats, added sugars, and sodium. The poor diets and sedentary lifestyles of the American public have led to high rates of obesity, overweight, and diet-related chronic diseases, including cardiovascular disease (CVD), hypertension, dyslipidemia, type 2 diabetes, osteoporosis, and certain types of cancer. (Wartella et al, 2010)

The fact that our food and lifestyle choices greatly impact our health needs to generate more education and awareness to the public on how to make better choices, so let's get started.

Welcome to Fundamentals of Nutrition and the Natural Nutrition Program!

2. Digestion and Elimination

Some refer to the gastrointestinal system (GI Tract) as our Internal Ecosystem; one that relies on the delicate balance of all its parts working together. A well-known concept is that “we are what we eat” and nowhere is this more evident than with our digestive system. Our entire body is made up of the nutrients that we obtain from food, and the ability to absorb and utilize those nutrients depends upon an efficient digestive system. Furthermore, doctors, researchers, and nutritional practitioners state that healthy digestion is the missing link to overall health and that poor digestion plays a key role in many illnesses. Throughout this handout, we will explore how all of the organs and processes of the GI Tract are closely linked.

The digestive system is composed of two parts:

- **The Alimentary Canal** is a long tube-like tract (gastrointestinal tract/GI tract) measuring 20 to 25 feet. It runs between the mouth and the anus. This tract consists of the oral cavity (mouth), pharynx (throat), esophagus, stomach, small intestine, and large intestine.
- **The Accessory Organs** include the teeth, tongue, salivary glands, liver, gallbladder, and pancreas.

The GI Tract is referred to as the “Upper” and the “Lower” GI Tracts:

- **The upper tract’s** primary functions are digestion and absorption. It consists of the mouth, stomach, small intestine, and all contributing accessory organs.
- **The lower tract’s** primary function is elimination, and it consists of the large intestine/colon.

Digestion: the process of breaking down food by mechanical and chemical action so that its substances can be used by the body.

- Proteins are broken down into amino acids
- Fats are broken down into fatty acids and glycerol
- Carbohydrates are broken down into glucose
- Vitamins, minerals, and water are also utilized in the process

Good digestion depends upon the smell, sight, and taste of food to initiate the release of digestive juices and the availability of enzymes.

Metabolism: the sum of all physical and chemical processes by which living organisms are produced and maintained.

- Catabolism: breaking down (ex: digestion)
- Anabolism: building up

Absorption: the process of nutrients passing from the intestines into the lymph system (Gut Associated Lymphoid Tissue/GALT) and/or bloodstream.

Digestive Enzymes: are secreted at various points along the digestive tract and are the necessary catalysts to all metabolic functions in the breakdown of food. They unlock the complex molecules

of macronutrients (protein, fat, and carbohydrates), breaking them down into their smaller components (amino acids, fatty acids and glycerol, and glucose) in order to pass through the wall of the intestine. If enzymes and digestive juices are not available, food will not be adequately digested and thus, nutrients will not be absorbed. An enzyme is usually named for the substance it breaks down (enzymes are denoted with the suffix 'ase', ex: protease = protein). There are a few exceptions to this rule (ex: papain also helps digest protein).

Digestive Juices: are a broad term applied to the various fluids that assist in the breakdown of foods. The most common secretions include saliva, hydrochloric acid (HCl), mucus, bile, and bicarbonate. These digestive juices help to maintain a sterile digestive environment by neutralizing toxins and bad bacteria. It is critical that the amount of food consumed does not exceed the amount of digestive juices, as this can impact the digestive process. Gastric juice specifically refers to digestive fluids in the stomach.

Secretory Glands: are found all along the digestive tract. They release secretions into a duct (exocrine) or directly into the bloodstream (endocrine). Some secretory glands such as the pancreas also function as digestive organs.

The Organs and their Processes:

The Mouth

Digestion begins in the mouth with mastication. Mastication, also known as chewing, is a muscular contraction that begins the mechanical breakdown of all foods. Chewing turns whole food in to a bolus. Chewing is one of the most important and simplest ways to support good digestion, as it physically breaks down the food, mixes food with saliva, and lubricates the "bolus" so that it can be swallowed more easily. It is the function of swallowing that propels the bolus through the pharynx (throat) and esophagus and initiates peristalsis (a succession of waves of involuntary muscle contractions that transport food or waste products through the digestive system).

Chemical digestion also begins in the mouth with saliva that contains ptyalin (also known as amylase). This alkaline digestive fluid begins the breakdown of starches. There are no starch digesting enzymes in the stomach, as it is an acid environment needing hydrochloric acid (HCl) for protein digestion. Carbohydrate digestion continues in the small intestine with enzymes secreted by the pancreas.

The Stomach

Between the esophagus and the stomach is the lower esophageal sphincter (LES). The pressure in the LES is usually higher than that of the stomach, except upon swallowing food, which allows the bolus to pass into the stomach. This is the structure commonly implicated in heartburn.

The stomach acts as a holding tank. When emptied it is about 50 ml in size (sized of your fist). However, it can expand to accommodate 1 to 1.5 litres of food and fluid. Some sources indicate that the stomach can hold up to 4 litres (holiday dinner), although this is not an ideal volume.

The stomach walls contain six different sets of glands that produce and secrete a variety of gastric juices. The secretion of gastric juice is controlled by both nerves and hormones. The most important

gastric juices are hydrochloric acid (HCl) and pepsinogen (activated to pepsin with HCl). During infancy, gastric glands also produce rennin, an enzyme that helps digest milk protein. The chemical digestion in the stomach is responsible for the breakdown of protein into smaller chains of amino acids plus helps process minerals for absorption. The stomach also produces intrinsic factor, which is essential for the absorption of vitamin B12.

The mucosa lining of the stomach is exposed to the corrosive acidity of gastric juice, which these enzymes that can digest the stomach itself. The stomach is protected from self-digestion by the mucosal barrier. This mucus protects the stomach lining from the action of acid and enzymes. However, when there is an imbalance of gastric acid versus mucus; irritation and ulceration (too much HCl), or bacterial growth (too much mucus) can upset the health of the stomach.

More mechanical digestion occurs in the stomach as muscles churn, mix and break food into smaller fragments. At this stage the bolus is now referred to as chyme.

The Liver

The liver is the largest internal organ (weighs about 3.1 lbs) and one of the most complex. It is referred to as a chemical factory with over 500 different functions.

When digested food is absorbed into the blood stream, it is not delivered directly to the cells in the body. First, it must travel to the liver via the Portal Hepatic Vein. Once digested food or molecules are in the liver, toxins are neutralized, and nutrients are metabolized into an active and usable form. Toxins are exported via bile, urine and stool and usable nutrients are sent through the vena cava to the heart and pumped into circulation to reach the appropriate parts of the body.

The liver has many other metabolic functions, which include:

- Producing about 800 to 1000 ml of bile per day from cholesterol
- Processing of amino acids into proteins
- Conversion of glucose into glycogen for storage
- Regulation of hormones and the metabolization of sugar, protein, and fats in the body
- With the help of vitamin K, the liver produces proteins that are important in blood clotting.
- The liver also helps to breaks down old or damaged blood cells

The Gallbladder

There are only two functions of the gallbladder:

1. To concentrate and store bile (an alkaline substance made up of cholesterol, salts, water, phospholipids, bilirubin, and mucus).
2. Release bile into the duodenum to help reduce the acid state of chyme to a more alkaline condition. Bile acts as a detergent, decreasing the surface tension of fat, which allows for the emulsification and absorption of fats. Bile also influences bowel motility. Bile slows motility in the small intestines to enhance the absorption of nutrients while increasing motility in the large intestines to aid elimination. An increased level of bile in the colon can

impair water/fluid absorption and lead to diarrhea. This is seen with individuals with bowel disorders such as irritable bowel syndrome (IBS) and inflammatory bowel disease (IBD).

The Pancreas

The pancreas is a secreting organ that works in unison with the other digestive organs. Along with bicarbonate to neutralize hydrochloric acid (HCl) from the stomach, the pancreas also secretes alkaline enzymes into the duodenum in order to complete the digestion of macronutrients:

- Amylase to digest carbohydrates
- Lipase to digest fats
- Protease to digest proteins

In a healthy digestive tract, the amount and type of secretion is proportional to the food eaten. For example, when food coming from the stomach is strongly acid, the pancreas is stimulated to secrete a larger amount of digestive juices, as this is part of the body's buffering system to balance our acid-alkaline levels. The level of acidity triggers the pancreatic secretions, it is important not to overtax the system, as the pancreas may become fatigued and/or some enzymes may become depleted. The secretion of digestive enzymes from the pancreas is an exocrine function.

The pancreas also produces hormones that are secreted into the blood (an endocrine function) such as insulin and glucagon. Both insulin and glucagon are essential in balancing blood glucose levels.

The Small Intestine

The small intestine is comprised of three different sections: the duodenum, the jejunum, and the ileum.

More churning and mixing happen in the small intestines, but the first section, the duodenum, is the centre of chemical digestion. A flow of enzyme-rich juice from the pancreas and bile from the gallbladder complete the digestion of all macronutrients (fats, carbohydrates, and proteins).

Between the stomach and the small intestine is the pyloric sphincter, which acts as a gate that monitors how much chyme can pass from the stomach into the duodenum (approximately 1 - 5 ml twice per minute), as the small intestine can only process a small amount of food at a time.

The small intestine is the primary site of absorption, which heavily relies on the health of the intestinal lining in all three of its sections. The intestinal lining is a permeable barrier, which has an intricate structure to allow for maximum absorption. It is equipped with large folds of mucosal tissue that holds on to digested matter long enough to allow the villi (finger-like projections) and micro-villi (part of the villi, they increase the surface area of the villi) to grab into and absorb all of the nutrients from food. The surface coat of the micro-villi is often referred to as the "brush border", as it further hydrolyzes the digested materials to ready it for absorption.

The process of absorption generally takes 24 hours (depending on the macronutrient).

Proper absorption hinges on proper digestion and for proper digestion, the right amount of enzymes need to be secreted at the right time. If digestion goes awry, the intestinal lining acts as the final filter to reduce unwanted or undigested substances from entering the bloodstream yet still allowing nutrients to be absorbed. However, if the tissue of the intestinal tract is weak and porous, this line

of defence is compromised and the opposite can happen, resulting in a lack of nutrients entering the blood stream, while toxins and microorganisms are permitted to pass through (ex: leaky gut syndrome). Factors that can damage the intestinal lining include medications (NSAIDs), pesticides, additives, gluten, and an overgrowth of bad bacteria (dysbiosis).

The Large Intestine

The large intestine (colon) is approximately five feet long, which the primary function is elimination. The large intestine also absorbs electrolytes. The ileocecal valve separates the small and large intestine. By the time the food reaches the large intestine, most of the nutrients have already been removed. The remaining substance is made up of:

- Fibre and cells, which make up the bulk of feces.
- Water – the remnants of food are still very wet when they reach the colon. Food will lose about two-thirds of its weight as water is squeezed out and absorbed in the colon.
- Bacteria (intestinal flora) help to further break down the food (fibre and cells) and convert it into feces.

Beneficial Bacteria (Probiotics)

Probiotics are beneficial microorganisms, known to exert numerous positive effects on human health. There are about 2 to 6 lbs (0.3% overall body weight), or 700 different species of bacteria living in the human body. Besides helping with elimination, they produce some B vitamins such as pantothenic acid (B5), biotin (B7), folate (B9), cobalamin (B12), vitamin K, and short chain fatty acids, which synthesis of short chain fatty acid by probiotics improves mineral absorption. Beneficial bacteria also aid the breakdown of toxic chemicals, strengthening the intestinal lining, and keep harmful bacteria in check to reduce any type of overgrowth (dysbiosis). Some other functions of probiotics include supporting immune function and producing certain neurotransmitters such as GABA and serotonin that act on the central nervous system. An imbalance of good and bad bacteria in the upper GI tract leads to the fermentation of food and the production of gas (belching, bloating, and flatulence). In the colon, it can lead to health problems such as IBS, constipation, and Crohn's disease. Other health disorders that an imbalanced gut bacteria can lead to include allergies, obesity, diabetes, and depression.

The balance between good and bad bacteria depends upon many factors such as the food we ingest (fibre vs. sugar), our emotions (stress), pharmaceuticals, timing of meals, intestinal peristalsis, and the presence of bile and HCl. Fermented foods such as miso, raw cheese, yogurt, and sauerkraut, and probiotic supplements can encourage the growth and maintenance of friendly bacteria in the body.

A Few Tips to Better Digestion, Absorption and Elimination:

- Maintain healthy bacterial balance
- Food combining
- Eat Fibre
- Allow sufficient time between meals for “clean-up”
- Manage fluids around meals

- Exercise
- Sleep
- Stress Management

How Long Does Food Take to Digest:

- Liquids – a few minutes
- Fruits – thirty minutes to an hour
- Non-Starch Vegetables – slightly longer than fruit
- Starches – two to five hours
- Proteins – four to six hours
- Fats – delay digestion
- Coffee/tea/spices – accelerate digestion

Proper Food Combining

Eating foods in the right combination will enhance digestion plus allows for better absorption and utilization of the nutrients within the food being consumed. Food combining helps those with digestive issues by giving their digestive system a much-needed break. Food combining is not only for people suffering from digestive issues, but also for those with other health issues such as allergies, slow bowel motility, poor liver function, and a slower metabolism.

If food cannot be broken down in the digestive process, the nutrients from that food cannot be utilized, leaving us deficient in those nutrients. It also slows transit time and bowel motility, which gives the bacteria in the intestinal tract more opportunity to feed on the undigested food particles. This especially gives the bad bacteria in the gut more time to grow and ferment. With a slower transit time, this contributes to constipation and poor motility, which allows toxins to be absorbed back into the body that was in the process of being eliminated.

These toxins can be reabsorbed into the bloodstream, making its way back up to the liver, which overburdens the liver leading to poor liver function. Even consuming healthy foods, if the food cannot be properly digested, assimilated, and absorbed, it will not provide a benefit.

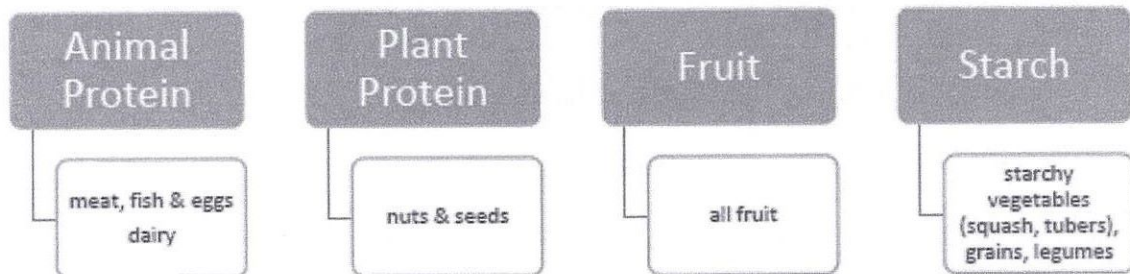
Understanding where and how the different food groups are digested gives the bases for proper food combining. There are different resources when it comes to food combining, which may not all be the same and it's not to say that food combining needs to be followed consistently, but it does help repair the digestive process leading to better health. Proper food combining may seem complex in the beginning and may take a bit of meal planning, but once it has been incorporated into daily meals, it can become much easier.

The first rule to good digestion is to chew food well!

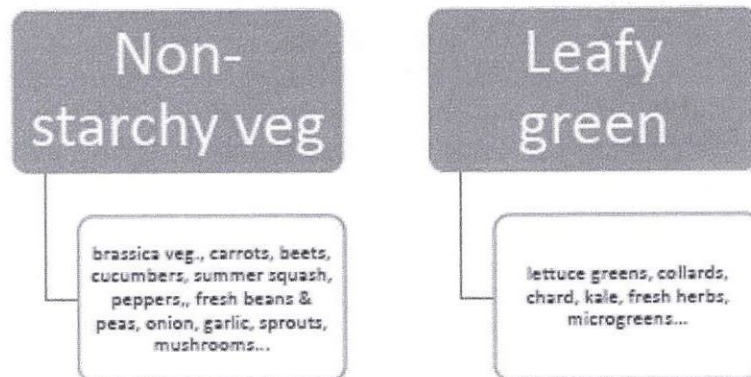
The basic principle of food combining is to keep meals simple.

Modern Food Combining

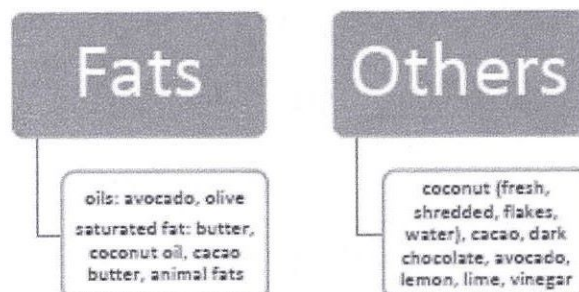
Step 1: Choose one of the following to start a meal or snack:



Step 2: Add a variety of non-starchy vegetables and/or leafy greens



Step 3: Add a healthy fat or other neutral food



3. Macronutrients

Water:

Water is the most important substance when it comes to health. You can live longer without food than water. Water is made up of two elements: hydrogen & oxygen (H₂O)

Water is essential for life. Without water, humans can survive only for days. Water comprises from 75% body weight in infants to 55% in elderly and is essential for cellular homeostasis. The role of water in health is generally characterized in terms of changes from an ideal hydrated state, generally in comparison to dehydration. The concept of dehydration encompasses both the process of losing body water and also the state of dehydration. (Popkin et al, 2010)

To reduce the risk of becoming dehydrated, humans have a network of physiological controls to maintain body water and fluid intake by thirst. Maintaining a constant water and mineral balance in the body requires the coordination of sensitive detectors at different sites throughout the body, which are linked by neural pathways with integrative centers in the brain that process this information. The mechanism of thirst is quite well understood, the reason drinking is often encountered is related to the large capacity of kidneys to rapidly eliminate excesses of water or reduce urine secretion to temporarily economize on water. However, this excretory process can only postpone the necessity for drinking or for stopping drinking an excess of water. The kidneys play a key role in regulating fluid balance. The kidneys function more efficiently in the presence of an abundant water supply. If the kidneys economize on water, producing a more concentrated urine, there is a greater cost in energy and more wear on their tissues. This is especially likely to occur when the kidneys are under stress, for example when the diet contains excessive amounts of salt or toxic substances that need to be eliminated, so drinking enough water helps protect this vital organ. (Popkin et al, 2010)

Most drinking obeys signals of water deficit. Apart from urinary excretion, the other main fluid regulatory process is drinking, mediated through the sensation of thirst. Thirst motivates water consumption by both positive and negative mechanisms. Thirst positively reinforces drinking behavior by magnifying the rewarding sensory properties of water: a glass of water tastes wonderful when you are thirsty, but much less so when you are quenched. At the same time, thirst negatively reinforces drinking behavior by virtue of the fact that thirst itself is an unpleasant state, which motivates you to consume water in order to eliminate this unpleasant feeling. These two motivational mechanisms act in unison to promote drinking behavior. (Leib et al, 2016)

Everyone experiences thirst from time to time, it plays a little day-to-day role in the control of water intake in healthy people living in temperate climates. We generally consume fluids not to quench our thirst, but as components of everyday foods (e.g. soup, fruit), as beverages used as mild stimulants (tea, coffee) and for pure pleasure. A common example is alcohol consumption, which can increase individual pleasure and stimulate social interaction. Drinks are also consumed for their energy content, as in soft drinks and milk, and are used in warm weather for cooling and in cold weather for warming. Such drinking seems also to be mediated through the taste buds, which communicate with the brain in a kind of “reward system” the mechanisms of which are just beginning to be understood. This bias in the way of human beings rehydrating themselves may be advantageous because it allows water losses

to be replaced before thirst-producing dehydration takes place. The brain's decision to start or stop drinking and to choose the appropriate drink is made before the ingested fluid reaches the digestive system. The taste buds in the mouth send messages to the brain about the nature of the beverage. (Popkin et al, 2010)

Hydration status is critical to the body's process of temperature control. Body water loss through sweat is an important cooling mechanism in hot climates and in physical activity. Water, or its lack of (dehydration), can influence cognition. Mild levels of dehydration can produce disruptions in mood and cognitive functioning. Blood volume, blood pressure, and heart rate are closely linked, which blood volume is normally tightly regulated by matching water intake and water output. Water deprivation and dehydration can lead to the development of headache and issues such as constipation and overall toxicity. The skin contains approximately 30% water, which contributes to plumpness, elasticity, and resiliency. The skin also plays an important role in maintaining body water levels and reducing water loss. (Popkin et al, 2010)

Water consumption and water requirements are linked in fairly complex ways. This is partially because of age, physical activity, diet, climate, and energy expenditures affect the need for water. Due to a large shift in beverage consumption over the past century, this has led to a high consumption of our energy intake from caloric beverages such as sugar-sweetened beverages, juice, milk, diet beverages and diuretics such as coffee, compared to consuming water.

It is suggested to consume six to eight 8-ounce glasses of water per day. However, this is just an estimate. Water consumption is individual and varies based on requirements such as age, weight, height, gender, activity level, diet, and climate. A basic calculation is to multiply one's weight by $\frac{2}{3}$ to calculate how much water is needed per day. Then you need to take into consideration your activity level, as water will leave your body through sweat when you engage in exercise. An additional 12 ounces of water per day for every 30 minutes of exercise is needed to stay hydrated.

Source of water is also an individual preference. There are many different sources of water such as tap water, spring water, well water, and different types of filtered water. Filtered water can be from a carbon filter, distilled, or reverse osmosis.

Tap water and public drinking water goes through a treatment process, which include coagulation, flocculation, sedimentation, filtration, and disinfection. During coagulation, chemicals with a positive charge are added to the water. The positive charge neutralizes the negative charge of dirt and other dissolved particles in the water. Flocculation is the gentle mixing of the water to form larger, heavier particles called flocs. Often, water treatment plants will add additional chemicals during this step to help the flocs form. Sedimentation is one of the steps water treatment plants use to separate out solids from the water. Once the flocs have settled to the bottom of the water, the clear water on top is filtered to separate additional solids from the water. During filtration, the clear water passes through filters that have different pore sizes and are made of different materials such as sand, gravel, and charcoal. These filters remove dissolved particles and germs, such as dust, chemicals, parasites, bacteria, and viruses. Activated carbon filters also remove any bad odors. After the water has been filtered, water treatment plants may add one or more chemical disinfectants such as chlorine, chloramine, or chlorine dioxide to kill any remaining parasites, bacteria, or

viruses. (CDC, 2022)

Water may be treated differently in different communities depending on the quality of the source water that enters the treatment plant. The water that enters the treatment plant is most often either surface water or ground water. However, this treatment process does not filter all contaminants and may produce new pollutants that can impact health.

Environmental Working Group found that public drinking water contains approximately 316 different contaminants.

Lead is a toxic metal that can cause damage to health even at low doses. Corrosion of household plumbing systems and erosion of natural deposits are major sources of lead pollution in public drinking water. The amount of lead found in the water varies depending on how long the water is exposed to the pipes, the amount of corrosion on the pipes, the water's acidity, and the temperature of the water. Lead in drinking water can cause a variety of adverse health effects.

Mercury is a liquid metal that can be found in various natural deposits. Erosion of natural deposits, discharge from refineries & factories, landfill runoff and cropland runoff are just a few of the ways that mercury can get into public drinking water. Being exposed to high levels of mercury over time can cause kidney damage.

Chlorine is a powerful oxidant added to the water by several municipal water systems to control microbes. Chlorine can be absorbed through physical consumption as well as through your skin while bathing. Chlorine can severely dry skin and hair and cause irritating effects to your eyes and nose.

Chloramines are formed when ammonia is added to water that contains free chlorine. Chloramines are typically added as secondary disinfectant. Chlorine and chloramine, when combined with naturally occurring materials in water, form disinfectant byproducts (DBP's), which have been shown to cause cancer in laboratory testing.

Chemicals from landscape usage and agriculture such as herbicides and pesticides enter the drinking water system by accumulation in public soil and water sources. Most commonly, they enter the water system from rainfall and irrigation which wash herbicides off farmlands and into lakes and rivers. Atrazine is an herbicide commonly used on golf courses, which can interfere with the body's hormonal activity and reproductive organs. There are hundreds of these different chemicals used with very few studies on how these contaminants may impact our health.

Pharmaceuticals are synthetic chemicals that are found in prescription, therapeutic and veterinary medication. They commonly make it into the water stream from poorly controlled manufacturing facilities and improper disposal.

Volatile Organic Compounds (VOCs) comprise various organic chemicals, which are released as gases from different liquids or solids. The nature and impact of the health effects are dependent on the VOCs concentrations and, also, on the exposure time. VOCs are present in different household, industrial or commercial and products, but their accumulation in air and water has primarily gained attention. Among VOCs, trichloroethylene and vinyl chloride are the most toxic and carcinogenic compounds. Natural sources of VOCs involve emissions from plants, forest fires occurring from natural causes plus domestic and industrial processes such as food extraction, fertilizers and pesticides use, septic system, chlorination,

traffic, hydrocarbon fuels burning, petroleum storage and distribution, textile cleaning, printing, and pharmaceutical industries.

The most common exposure pathways to VOCs from contaminated waters were identified as drinking, bathing, food, swimming, or laundries. (David & Niculescu, 2021)

The Fluoride Debate:

Fluoride is the ionic form of fluorine, the thirteenth most abundant element in the earth's crust. It is released into the environment naturally in both water and air. Its concentration in water is variable. Water is the major dietary source of fluoride. The variability in water content explains much of the variability in total fluoride intake. Other important sources of fluoride are tea, seafood that contains edible bones or shells, medicinal supplements, and fluoridated toothpastes. Fluoride compounds are also produced by some industrial processes that use the mineral apatite, a mixture of calcium phosphate compounds. Dietary fluoride is absorbed rapidly in the stomach and small intestine. One-quarter to one-third of the absorbed fluoride is taken up into calcified tissues, whereas the rest is lost in the urine. In bone and teeth, fluoride can displace hydroxyl ions from hydroxyapatite to produce fluorapatite or fluorohydroxyapatite. About 99% of total body fluoride is contained in bones and teeth, and the amount steadily increases during life. The recommended intake for fluoride is expressed as an adequate intake rather than recommended dietary allowance, because of the limited data available to determine the population needs. The adequate intake for fluoride is 0.7 mg daily for toddlers, rising to 3 mg daily for adult women and 4 mg daily for adult men. It remains unclear whether fluoride is truly essential, although fluoride may have some beneficial effects. Once taken up into bone, fluoride appears to increase osteoblast activity and bone density, especially in the lumbar spine. Fluoride has been suggested as a therapy for osteoporosis since the 1960s, but despite producing denser bone, fracture risk is not reduced. Indeed, there is some evidence that nonvertebral fractures may be increased. The only known association with low fluoride intake is the risk of dental caries, acting through both pre-eruptive and post-eruptive mechanisms. The American Dental Association strongly supports fluoridation of community drinking water supplies; however, strong contradictory opinions also are held. (Aoun et al, 2018)

The first 'artificial' water fluoridation for caries control was introduced in 1945 and 1946 in the United States (US) and Canada, respectively, and it was expected that caries prevalence would be reduced by as much as 50%. Much of the research on the efficacy and effectiveness of individual fluoride modalities in preventing and controlling dental caries was conducted before 1980, when dental caries was more common and more severe. (Aoun et al, 2018)

Fluoride is naturally found in fresh water. Soil, plants, and foods contain trace amounts of fluoride (NIH, 2022). Calcium fluoride is a natural source, which most drinking water and dental product have sodium fluoride. Synthetic industrial fluoride compounds lack calcium and are listed toxic substances. Calcium fluoride (CaF_2) is found in natural minerals and is not labeled a toxic compound.

To reduce exposure to these types of chemicals, water filtration systems help purify water and reduce many of these other contaminants. Waters in the U.S. can contain natural calcium fluoride along with other calcium and magnesium salts, but pure pristine fresh drinking

water does not contain fluoride. The chief ingredient in normal teeth enamel is hydroxyapatite that contains calcium phosphate, not fluoride. After nearly 7 decades of adding industrial fluoride compounds into public water supplies in the U.S. and other countries that have agreed to this policy, the principal documented effects of ingested fluoride on teeth are to increase incidence of abnormal permanent enamel fluorosis during teeth development. The reported adverse consequences of adding fluoride lacking calcium into public water supplies include effects on man, animals, and the environment. Ingested industrial fluoride incorporates chiefly into bone with an ion exchange process that is irreversible and thus not physiologic. (Sauerheber, 2013)

Sodium fluoride at 60 mg/kg single oral dose without calcium causes acute heart failure in research animals and caused lethal heart failure reported in a child after swallowing concentrated dental gel. Twenty-five ppm artificial fluoridated water leads to chronic heart failure in research animals. Industrial synthetic fluorides are fully soluble and are all toxic calcium chelators. (Sauerheber, 2013)

More than 80% of fluoride toxicity is seen in children before the age of 6 years, due to ingestion of fluoride-containing toothpaste or mouthwashes.

Acute toxicity is characterized by nonspecific gastrointestinal disturbances such as pain, nausea, vomiting, and diarrhea. In severe cases, this may progress to renal and cardiac dysfunction, coma, and ultimately death. In children, as little as 8.4 mg/kg may produce symptoms. Chronic fluoride toxicity is usually caused by high fluoride concentrations in drinking water or the use of fluoride supplements. Chronic ingestion of high doses leads to dental fluorosis, a cosmetic disorder where the teeth become mottled. In more severe cases, it leads to skeletal fluorosis, in which bone is radiologically dense, but fragile. Fractures can occur, and there may be calcification of ligaments and tendons, leading to reduced joint mobility. (Aoun et al, 2018)

Three of the main water filtration systems include:

- Activated charcoal is the most common type of water filter. It is activated by exposing carbon to chemicals at high temperatures and steam in the absence of oxygen, which gives the carbon a larger surface to attract, attach and absorb contaminants. It removes chlorine, heavier metals, volatile organic compounds (VOCs), particulate matter, bacteria, parasites, and most viruses. It also removes unpleasant appearance (sediment), odor, and taste. It will not remove fluoride or beneficial minerals from the water. The size of the pores matter, as if contaminants are smaller than the pores, they will slip through the filter. Another negative point about carbon filters is that they can be a breeding ground for bacteria, so change this type of filter frequently.
- Distilled is considered pure water, as after the process, there is only H₂O. The process is boiling water and collecting the condensation, which will remove all organic matter plus all minerals. This type of water has a flat taste, which depending on individual preference, may not appeal to the average person. A distilling system is more expensive than activated charcoal and reverse osmosis. Another disadvantage is that it takes a lot of electricity to heat the water plus all the sediment and mineral

build-up must be cleaned from the holding container, which requires chemicals.

- Demineralized water has the potential for adverse health effects from long-term consumption and is of interest not only in countries lacking adequate fresh water but also in countries where some type of home water treatment system is used. Although drinking water is not the major source of our calcium and magnesium intake, the health significance of supplemental intake of these elements from drinking water may outweigh its nutritional contribution expressed as the proportion of the total daily intake of these elements. Even in industrialized countries, diet that is not deficient in terms of the quantity of calcium and magnesium may not be able to fully compensate for the absence of calcium and in particular, magnesium in drinking water. (Verma & Kushwaha, 2014)
- Demineralized soft water, when used for cooking is known to cause substantial losses of all essential elements from food (vegetables, meat, grains). Such losses may reach up to 60% for magnesium and calcium or even more for some other microelements (e.g., copper 66%, manganese 70%, cobalt 86%). In contrast, when hard water is used for cooking, the loss of these elements is much lower, and in some cases, even higher calcium content was reported in food as a result of cooking. Since most nutrients are ingested with food, the use of low-mineral water for cooking and processing food may cause a marked deficiency in total intake of some essential elements that was much higher than expected with the use of such water for drinking only. The current diet of many persons usually does not provide all necessary elements in sufficient quantities, and therefore, any factor that results in the loss of essential elements and nutrients during the processing and preparation of food could be detrimental for them. (Verma & Kushwaha, 2014)
- Reverse osmosis (RO) is filtered tap water, that under pressure is pushed through three to seven different types of filters. This process removes 100% of all organic matter, along with all minerals. There are reverse osmosis systems that provide a filter to re-mineralize the water. Depending on the type of RO system, it is beneficial to have a system that re-mineralizes the water.
 - 1st is a sediment filter, which reduces suspended particles in water such as dirt or sediments.
 - 2nd is a granular activated carbon filter, which reduces chlorine, chloramines, and other water treatment by-products.
 - 3rd is a carbon block filter that reduces herbicides, pesticides, fertilizers, and insecticides.
 - 4th is the reverse osmosis (RO) filter, which is a thin film composite (TFC) RO membrane filter that reduces total dissolved solids, heavy metals, microorganisms, and tiny impurities from the water.
 - 5th is a ceramic filter that reduces 99% E. coli bacteria and salmonella from the water.
 - 6th is a re-mineralizing filter to add healthy organic minerals back into the

water, leaving the water pH balanced.

- 7th is a carbon block filter that reduces and absorbs odors, leaving the water with a fresh clean taste.

Carbohydrates:

Carbohydrates are one of the three macronutrients in the human diet, along with protein and fat. These molecules contain carbon, hydrogen, and oxygen atoms. Carbohydrates are produced by a process called photosynthesis, which is when plants take in carbon dioxide CO₂ from the atmosphere and water H₂O from the soil, and with the energy from the sun combine the two of them together to create a series of complex chains called sugar or starch, which these hydrated carbon molecules form carbohydrates. A very suitable name!

Carbohydrates play an important role in the human body. They act as an energy source, help control blood glucose and insulin metabolism, participate in cholesterol and triglyceride metabolism, and help with fermentation. Carbohydrates is an umbrella term that encompasses sugar, fruits, vegetables, fibers, and legumes. (Holesh et al, 2023)

A healthy diet should include 45% to 65% carbohydrates, as part of the daily intake, equaling about 200 g to 300 g per day. Carbohydrates contain 4 kcal/gram. Fibre is an important carbohydrate as well, which should consist of about 25-35 g of fibre per day, as it is found to reduce the risk of heart disease, strokes, diabetes, and digestive issues such as constipation.

- Simple Carbohydrates: One or two sugars (monosaccharides or disaccharides) combined in a simple chemical structure. These are easily utilized for energy, causing a rapid rise in blood sugar and insulin secretion from the pancreas. Examples of monosaccharides are glucose, galactose, and fructose, and examples of disaccharides are lactose, maltose, and sucrose. Foods sources of simple carbohydrates include candy, carbonated beverages, corn syrup, fruit juice, and table sugar.
 - Monosaccharide: The most basic, fundamental unit of a carbohydrate. These are simple sugars with the general chemical structure of C₆H₁₂O₆. Examples: glucose, galactose, fructose
 - Disaccharide: Compound sugars containing two monosaccharides with the elimination of a water molecule with the general chemical structure C₁₂H₂₂O₁₁ Examples: sucrose, lactose, maltose
- Complex Carbohydrates: Three or more sugars (oligosaccharides or polysaccharides) bonded together in a more complex chemical structure. These take longer to digest and therefore have a more gradual effect on the increase in blood sugar. Examples: amylose, cellulose, and dextrin. Foods sources include apples, broccoli, lentils, spinach, unrefined whole grains, and brown rice.
- Starches: Complex carbohydrates contain a large number of glucose molecules. Plants produce these polysaccharides. Examples include potatoes, chickpeas, pasta, and wheat.

- Oligosaccharide: The polymer contains three to ten monosaccharides. Examples: maltodextrins and raffinose.
- Polysaccharides: Polymers containing long chains of monosaccharides connected through glycosidic bonds. Examples: amylose and cellulose.
- Fiber: Non-digestible complex carbohydrates that encourage healthy bacterial growth in the colon and act as a bulking agent, easing defecation. The main components include cellulose, hemicellulose, and pectin.
 - Insoluble: This type of fibre does not dissolve in water and remains in the intestines, thereby softening and bulking the stool. Benefits include regularity of bowel movements and a decreased risk of diverticulosis and constipation. Examples: bran, brown rice, and outer skin of fruits and vegetables such as yam or apple.
 - Soluble: This type of fibre can dissolve in water to become a gel or gum like consistency to help decrease blood cholesterol and LDL levels, reduce straining with defecation, and help to maintain blood glucose levels. Examples are fleshy fruit, oats, milled chia or flax seeds, and legumes.
 - Resistant starch is a form of starch that is also considered a dietary fiber. It is a complex carbohydrate that resists digestion. It passes through the small intestine to the colon, where it is fermented. This type of fibre helps feed the beneficial bacteria in the large intestine, which is considered a prebiotic and include inulin and pectin. Other prebiotics are fructo-oligosaccharide (FOS) and galacto-oligosaccharides (GOS). Prebiotics are food for probiotics and include sources such as leek, asparagus, artichoke, chicory, garlic, and slightly green bananas. All prebiotics are fibre, but not all fibre is a prebiotic.

The body is not able to digest fibre, and therefore fibre does not provide calories or energy. It has a variety of health benefits including bulking stool for easier excretion, prebiotic properties, satiety, and intestinal issues. Individuals who eat high fibre diets tend to have low serum cholesterol and higher HDL levels than people who consume a low fibre diet, as lower of cholesterol also decreases the risk of heart disease.

Carbohydrate digestion begins in the mouth, where salivary amylase starts the breakdown. After breaking down throughout the digestive system, monosaccharides are absorbed into the bloodstream. As carbohydrates are consumed, the blood sugar levels increase, stimulating the pancreas to secrete insulin. Insulin signals the body's cells to absorb glucose for energy or storage. If blood glucose falls, the pancreas makes glucagon, which stimulates the liver to release stored glucose called glycogen. Glycogen is stored in the liver and muscle tissue, which is a vital source of energy when the body needs such as physical activity.

Liver glycogen helps to maintain blood glucose levels during sleep. When blood sugar levels are low, muscle glycogen is broken down to provide fuel for the body to function. The human body has the ability to store enough glycogen to provide a full day's energy needs. Replenishing glycogen is important, which is why the largest percentage of the diet should consist of complex carbohydrates.

A glycemic index is a tool used to track carbohydrates and their individual effects on blood sugar. This scale ranks carbohydrates from 0 to 100 based on how rapidly the rise in blood glucose occurs upon consumption. Low glycemic foods (55 or less) produce a gradual increase in blood sugar, which include foods such as steel-cut oatmeal, oat bran, muesli, sweet potatoes, peas, legumes, most fruits, and non-starchy vegetables. Medium glycemic foods (56 to 69) include quick oats, brown rice, and whole-wheat bread. High glycemic foods (70 to 100) increase the risk of type 2 diabetes, heart disease, and obesity. These foods include white bread, cornflakes, white potatoes, pretzels, rice cakes, and popcorn. (Holesh et al, 2023)

Over the past number of years both sugar alcohols (polyols or nutritive sweeteners) and high intensity sweeteners (non-nutritive sweeteners) have gained popularity. The consumption of sugar-free foods is growing because of their low-calorie content and the health concerns about products with high sugar content. This is also due to their ability to reduce the risk of dental caries. Sugar alcohols include maltitol, sorbitol, xylitol, erythritol, and mannitol. Sugar alcohol also adds texture to foods, reduces browning during cooking, and helps to maintain moisture. Consuming too much sugar alcohol can contribute to diarrhea and intestinal upsets in some people.

While glucose is virtually completely absorbed in the upper part of the small intestine, xylitol is normally only partly absorbed in the upper part and is present in considerable amounts in the lower region of the small intestine. However, this depends on the quantity of xylitol consumed. When xylitol is administered in an isolated form in beverages, the xylitol molecules are no longer sufficiently absorbed in the small intestine and will reach the colon contributing to diarrhea. (Mäkinen, 2016)

Moderate doses of xylitol and sorbitol are almost totally absorbed and metabolized, chiefly in the liver cells, which eventually they contribute to the formation of glucose and liver glycogen. The liver plays a central role in metabolism and directly impacts levels of many blood metabolites. Glycose and glycogen metabolism are the main metabolic pathways in the healthy liver to control normal glucose homeostasis in the human body. Those with poor liver function or have a liver disorder may not be able to metabolize sugar alcohols properly, which may create reactions in the body such as bloating, intestinal upsets, hives, and possibly other allergic reactions. (Ismail et al, 2020)

Sugar alcohols are in many dental products and can reduce the risk of dental caries by reducing bacteria in the mouth.

Research has shown that the consumption of stevia can alter the gut microbiome and can create an imbalance. (Kasti et al, 2022)

High intensity sweeteners that are several hundred times sweeter than sucrose are being consumed as sugar substitutes. These include products such as aspartame, saccharin, and sucralose, which can contribute to certain symptoms in the body. Both saccharin and sucralose can change the composition of the gut microbiota (Ruiz – Ojeda et al, 2019)

Aspartame is a sweetener introduced to replace the commonly used sucrose. It was discovered by James M. Schlatter in 1965. Being 180–200 times sweeter than sucrose, its intake was expected to reduce obesity rates in developing countries and help those struggling with diabetes. Aspartame consists of two amino acids (L-phenylalanine and L-aspartic acid). It is hydrolyzed and absorbed in the gastrointestinal tract (GI) through the action of esterase

and peptidases. Digestion releases methanol (10%), aspartic acid (40%) and phenylalanine (50%), which are absorbable in the intestinal mucosa. These metabolites can be harmful at high doses, the metabolism products of aspartame are believed to be more toxic than the original substance itself. Methanol is firstly oxidized in the liver to formaldehyde and again to formic acid; however, while methanol is known to damage the liver, formaldehyde and formate are also responsible for the destruction of liver cells. It also changes the composition of the gut microbiota. (Czarnecka et al, 2021)

Aspartame is suspected of causing neurological and behavioral disorders in humans. It causes neuropsychiatric reactions such as headache, convulsions, and depression. In the body, aspartame is transformed into phenylalanine, aspartic acid, and methanol. These metabolites can affect the neurochemical state of the brain and influence the level of neurotransmitters. (Czarnecka et al, 2021)

The world is experiencing an obesity pandemic. According to the World Health Organization (WHO), over one billion adults throughout the world are overweight, i.e., with a body mass index (BMI) ≥ 25 kg/m². Of these, at least 300 million are considered obese (BMI ≥ 30). Overweight and obesity are associated with numerous comorbidities of great public health concern, including hypertension, cardiovascular disease, diabetes, and depression, as well as breast, endometrial, colon, and prostate cancers. As a result of the aggressive marketing of food industry companies, the role of artificial sweeteners has changed from sugar substitutes to health substitutes. (Czarnecka et al, 2021)

Despite the fact that many national authorities have recognized artificial sweeteners as safe and well-tolerated, a lot of controversies about the effects of sweeteners on human health still exist. Some longitudinal cohort studies show an association between artificial sweeteners consumption and reduced risk of diabetes, overweight and obesity. However, there are other longitudinal cohort studies that found a positive association between the consumption of artificial sweeteners and the risk of hypertension, stroke, and cardiovascular events. Importantly, it cannot be excluded that the associations found in these observational and prospective cohort studies are largely explained by an increase in artificial sweetener intake to compensate for an unhealthy diet or lifestyle. (Pang et al, 2020)

There are studies that link aspartame consumption to weight gain, increased appetite, diabetes, metabolic disorders, and obesity-related diseases, as artificial sweeteners are sweet, encourage sugar craving and sugar dependence. (Yang, 2010)

Protein:

Protein is another macronutrient that is a vital part of the human diet and is present in various foods such as eggs, meats, dairy, seafood, legumes, nuts, and seeds. Just like carbohydrates, protein also contains 4 kcal/gram, and the dietary requirement of protein is 0.8 grams of protein per kilogram (kilograms can be converted into pounds by dividing it by 2.2) of body weight. Protein consists of four elements: carbon, hydrogen, oxygen, and nitrogen. It is the element nitrogen that makes proteins different from carbohydrates and fats. Proteins are structures composed of amino acids, which depending on the resource, there are 20-22 amino acids found in biological chemistry. Amino acids are considered the building blocks of protein.

These amino acids are classified as essential, non-essential, or conditionally essential. Essential amino acids must be supplied by food sources in the diet, as the body is not able to make them in adequate amounts. All essential amino acids must be supplied and available in the body in sufficient quantity to be able to synthesis body proteins to function as tissue repair, growth of hair and muscle, and hemoglobin. This process and these essential amino acids are supplied from the diet or from the body's own cells. These cells are constantly broken down and replaced. Proteins are made (anabolism) and broken down (catabolism) daily, which 60-70% of amino acids are recycled from old tissue. The liver is the main site of protein metabolism. The liver regulates the amount of amino acids available for protein synthesis, which is known as the amino acids pool.

Non-essential amino acids can be supplied in adequate amounts from the body. They are obtained from other amino acids.

Conditionally essential amino acids are required during times of growth, illness, or stress, when the body depends on them to be supplied in sufficient amounts to maintain health.

****Refer to the handout on amino acids for details of the classification of the singular amino acids and some of their individual functions in the body.**

Animal-based protein sources such as eggs, dairy, meat, and seafood provide all nine of the essential amino acids in adequate amounts, which are deemed complete protein. Soy-based foods are unique because they also provide all nine essential amino acids in sufficient quantities. Other plant-based foods that contain all nine essential amino acids include hemp, quinoa, and spirulina.

Most other plant foods, including whole grains, nuts, legumes, and seeds, possess high levels of some amino acids and low amounts of others, which are referred to as incomplete protein.

This includes the different eating styles of omnivorous, vegetarian (lacto/ovo), and vegan. Omnivore is a common type of dietary lifestyle that includes consuming both plant and animal sources of food. This type of eating style provides all essential amino acids and nutrients, and can be healthy provided the quality and quantity of food consumed. There are a few different types of vegetarian eating styles. Vegan and vegetarian diets have gained popularity over the past decade.

Characteristically, vegans do not consume any animal-derived products including eggs, dairy, meat, and fish. Vegetarians exclude meat and fish but may consume milk and/or eggs. A subclass of the vegetarian diet may consume fish but not meat, termed pescatarians. The prevalence of vegetarian and vegan diets differs globally. In developing regions, meat-free diets are traditionally adopted owing to religious, social, ecological, or economic constraints as opposed to personal choice. In industrialised countries, most individuals are afforded the choice of food consumption and level of dietary restriction. Populations in developed countries may adopt these diets for environmental, ethical, religious, health beliefs or social reasons. Presently, well-planned vegan and vegetarian diets have been regarded by the Dietetic Association and other organizations in industrialised countries to be suitable throughout the lifespan, inclusive of infancy and pregnancy. However, concerns have been raised regarding the ability of these diets to adequately provide essential micronutrients, such as iodine, iron, and B12. (Eveleigh et al, 2020)

It would be wrong to assume that animal-based foods provide more protein than plant-based ones. A cup of tofu contains the same number of grams of protein as 3 ounces of steak, chicken, or fish. A half-cup of lentils has more grams of protein than an egg. Not all plant foods are low in the same amino acids, so eating a variety of plant-based foods can provide all nine of the essentials. For example, pairing protein sources such as rice and beans or hummus and pita bread or oatmeal topped with almond butter. However, in terms of volume, it may be necessary to eat more plant-based foods to get a similar amount of protein and amino acid profile provided by animal-based proteins. (LaPelusa & Kaushik, 2022)

Protein has several important functions in the body including structural support such as fibrous proteins like collagen or elastin, for maintenance and growth (nitrogen balance), water and pH balance of the body, hormones, enzymes, antibodies, hemoglobin, and neurotransmitters. In the absence of carbohydrates and/or fats, protein can be used for an energy source.

Nitrogen balance reflects the equilibrium between protein intake and losses. A positive nitrogen balance is associated with periods of growth, tissue repair, and pregnancy. A negative nitrogen balance occurs during physical or emotional stress, illness, trauma, starvation, when an individual is on a low-calorie diet, or even when the quality of protein consumed is poor. This can also happen if the diet is very low or deficient in the essential amino acids. An individual with a healthy diet, weight and no illness should have a nitrogen equilibrium.

Excess nitrogen is excreted from the body, as nitrogenous wastes form toxic ammonia. The urea cycle is the primary mechanism by which humans convert ammonia to urea. Urea is made in the liver and excreted in urine, feces, and sweat.

When food reaches the stomach, hydrochloric acid (HCl) denatures the protein, unfolding it and making the amino acid chain more accessible to enzymatic action. Then, pepsin, a protein produced by gastric cells, splits any available protein into smaller oligopeptide chains, which then move on into the duodenum. The second set of digestive enzymes, made by the pancreas, further split oligopeptides into tripeptides, dipeptides, and individual amino acids. All of these products can be taken up by intestinal cells where dipeptides and tripeptides are converted into amino acids. Some amino acids are part of the process of synthesizing intestinal enzymes and new cells. Most amino acids enter the bloodstream and are transported to other parts of the body. (LaPelusa & Kaushik, 2022)

Fats:

Dietary fats and oils are also referred to as lipids, which are composed of the same elements as carbohydrates: carbon, hydrogen, and oxygen. Lipids are deemed insoluble, as they do not dissolve in water. Dietary fat is the second most important energy-producing macronutrient after carbohydrates, but carry more energy than both protein and carbohydrates by providing 9 kcal/gram. A molecule of fat has the structural backbone of one glycerol molecule joined to one (monoglyceride), two (diglyceride), or three (triglyceride) chains of fatty acids molecules, which consist of chains of carbon atoms with hydrogen and some oxygen atoms attached. These chains vary in length and composition, which can determine the fats appearance, taste, and smell

Dietary fats and especially their caloric content and individual constituents, such as essential fatty acids (EFA) and fat-soluble vitamins, are indispensable for growth, development, and maintenance of good health. The nutritional value of dietary fats and their fatty acid composition cannot be considered in isolation since they are part of a diet that in its optimal form is balanced to fulfill the nutritional requirements of adults, and, in infants, children, and adolescents, should also be appropriate for growth and development. (Musket, 2010)

Dietary fats are a vital part of a healthy diet and provide essential functions in the human body such as:

- Source of fuel and energy
- Satiety
- Flavour
- Helps the absorption of fat-soluble vitamins (vitamins A, D, E, and K)
- Source of essential fatty acids (EFAs)
- Supports and protects internal organs plus provides insulation for the body
- Provides cellular membrane structure
- Helps lubricate body tissues
- Protective covering around the nerves - myelin sheath
- Needed for normal brain development and growth

Symptoms of a lack of these essential fats in the diet include dry skin and hair, poor wound healing, slow growth, fatigue, lowered immunity, poor vision, allergies, and memory issues. The key with dietary fats is the type and quality of fat consumed. There can also be health issues from consuming an excess of the wrong types of fats, which include a risk factor of developing illnesses such as heart disease, cancer, and obesity.

Dietary fats differ in the degree of saturation, which depends on if there are as many hydrogen atoms attached to carbon atoms throughout the fatty acid chain and there is only a single bond between the hydrogen and carbon atoms. If there is an equal amount of both hydrogen and carbon atoms, the fat is saturated. Saturated fats are solid at room temperature and are considered chemically stable. Sources of saturated fats are any animal products such as meat, dairy, coconut oil, and fish. Even though saturated fats are stable, they can become rancid over time, which creates a bad smell and should be discarded. Many different resources state that the consumption of saturated fats is bad for health, but this depends on how much saturated fat is consumed and the quality.

Research studies show the difference between commercially raised animals and grass-fed. The fatty acid composition differs between these two sources. Beef from grass-fed contains lesser total fat than that from grain-fed in all breeds of cattle. Reduced total fat content also influences the fatty acid composition of beef. A 100 g beef meat from grass-fed cattle contained 2,773 mg less total saturated fatty acids (SFA) than that from the same amount of grain-fed. Grass-fed also showed a more favorable SFA lipid profile containing less cholesterol-raising fatty acids. Grass-fed beef also contains an increased level of total omega

3 PUFA, which reduced the omega 6 to omega 3 ratio thus can offer more health benefits than grain-fed. (Nogoy et al, 2022) Red meat is nutrient dense and regarded as an important source of essential amino acids, vitamins A, B6, B12, D, E, and minerals, including iron, zinc, and selenium. Cattle produced under extensive grass-based production systems generally have fat that is more yellow, which is caused by carotenoids from the lush green forages. It is associated with a healthier fatty acid profile and a higher antioxidant content. (Daley et al, 2010) Even coconut oil has gotten a bad reputation, as it is a saturated oil. Coconut oil is from a plant source, which plants are not a source of cholesterol plus the fatty acids in coconut are a medium-chain triglycerides (MCT), which are less harmful, help raise HDL levels and are even beneficial in weight management programs. MCTs are metabolized differently, they provide immediate energy and can be used to control obesity. MCT has high satiety value, which reduces over consumption of food. (Jadhav & Annappure, 2022)

An unsaturated fat has carbon atoms that are linked by one or more double bonds, which there is a hydrogen atom missing. Depending on how many hydrogen atoms are missing determines how unsaturated the fat is, which relates to a monounsaturated (one double bond) or polyunsaturated (more than one double bond), which these types of fat are liquid or an oil at room temperatures, and are mostly of plant origin such as olive, hemp, canola, flax, and avocado oil.

Monounsaturated oils are known as oleic acid or referred to as omega 9. Food sources that have the highest percentage of oleic acid are olive or avocado oil. Other food sources may have a smaller percentage, which include sunflower, palm, and safflower. Omega 9 oil is not considered essential as the body can produce it in small amounts. Oleic acid does provide health benefits such as reducing inflammation, reduce bad cholesterol (LDL) while raising good cholesterol (HDL), and even reducing the risk of some cancers.

Polyunsaturated oils have a few more subsets of fatty acids, which are alpha-linolenic acid (omega 3) and linoleic acid (omega 6), and both of these omega oils are broken down further to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) supplied from omega 3 oils alpha-linolenic acid (ALA) and gamma-linoleic acid (GLA), dihomogamma-linolenic acid (DGLA) and arachidonic acid (AA), all supplied from omega 6 oils linoleic acid (LA).

**** Refer to the handout on Essential Fatty Acid Pathways.**

Both omega 3 and omega 6 are deemed essential, as they need to be supplied by the diet. These two omega oils also provide many health benefits such as reducing inflammation, reduce bad cholesterol (LDL) while raising good cholesterol (HDL), reducing the risk of heart disease by lowering blood pressure and making the platelets in blood less sticky (anti-coagulation). (Dijuricic & Calder, 2021)

Omega 3 and 6 oils provide these health benefits through a hormone-like substance called prostaglandins, which control many physiological functions in the human body. Three series of prostaglandins have been identified. Omega-6 fatty acids gamma-linoleic acid (GLA) and dihomogamma-linolenic acid (DGLA) convert into Prostaglandin E1 (PGE1), while omega-3 fatty acid is converted into Prostaglandin E3 (PGE3). PGE1 and PGE3 can be referred to as 'good' prostaglandins.

Arachidonic acid from omega 6 found in animal fat sources such as dairy products, meat, eggs, and fish is converted into Prostaglandin E2 (PGE2), which is considered the 'not so good' prostaglandins.

- PGE1 Series has beneficial effects in the body such as making blood platelets less sticky (anti-coagulant), helps to lower blood pressure, decreases inflammation, and enhances immunity.
- PGE2 Series, in excess, has negative effects such as making blood platelets sticky (coagulant), increases blood pressure, increases the inflammation response, and reduces immune function.
- PGE3 Series provides the same beneficial effects as PGE1 and blocks the detrimental effects of PGE2 by reducing the 'not so good prostaglandins' from being made.

All of the omega oils are needed for normal body functions and process, but they need to be balanced and in the right amounts to sustain health. Even arachidonic acid provides benefits such as the protective nature of inflammation and proper brain function. It is when there is an imbalance between omega 6 and omega 3 that acute and chronic health disorders can develop, which include heart disease, cancer, and Alzheimer's disease. (Tallima & Ridi, 2018)

Up until about 100 years ago, the omega 6 to 3 ratio has been around 4:1 or less. However, the typical Western diet now provides an omega 6 to 3 ratio that is approximately 20:1 in favor of omega 6. This prompts the inflammatory responses and enables chronic low-grade inflammation that is responsible for several health conditions. (DiNicolantonio & O'Keefe, 2021)

Various food sources of fats have a degree or percentage of some to all the different types and classifications of fat, so how are foods categorized? For example, avocados are a monounsaturated fat (omega 9), and avocado oil consists of 71% monounsaturated fatty acids, 13% polyunsaturated fatty acids, and 16% saturated fatty acids (SFA). The 13% polyunsaturated fatty acids are a 13:1 ratio of omega 6 to omega 3 in avocado oil. (Dreher & Davenport, 2013)

Another example is fatty fish such as sardines, mackerel, anchovies, and salmon, which is a source of saturated fat, but it is also one of the best sources of polyunsaturated fatty acids, especially omega 3 fatty acids high in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Fish also contains omega 6 oils, but at a lower ratio compared to omega 3. (Taşbozan & Gökçe, 2017)

The process of hydrogenation was developed by a German chemist Wilhelm Normann back in 1901, which he experimented with hydrogenation and successfully induced the hydrogenation of liquid fat, producing semisolid fat (margarine). This process adds hydrogen atoms to unsaturated oils to make them saturated, which increased their self-life. Hydrogenated oils such as margarine and vegetable spreads gained popularity in the 1920s and continued into the 1960s, as these oils had a longer self-life, had a higher smoke point for cooking, and because an unsaturated fat was now saturated, it did not create oxidative damage (free radical damage), as this process made an unstable oil into a stable solid.

An oil can be partial or fully hydrogenated, which can be found in many food products such as crackers, candy, commercially baked goods, fried foods, packaged cookies, and microwave popcorn. The hydrogenation process does pose health consequences, as this

process produces trans fats. The production of trans fats is a result of partial hydrogenation. They not only increase low-density lipoprotein cholesterol but also decrease high-density lipoprotein cholesterol, thus increasing the risk of cardiovascular disease. Canadians have one of the highest dietary intakes of trans fat in the world. Health Canada has made recommendations to decrease the trans fat intake of Canadians. In 2002, Health Canada introduced mandatory nutrition labelling of most prepackaged foods, as well as new and revised requirements for nutrient content claims. In 2007, the Minister of Health announced that Health Canada would adopt the Trans Fat Task Force's recommended limits for trans fats in foods. Those recommendations were to limit the trans fat content of vegetable oils and soft, spreadable margarines to 2% of the total fat content, and to limit the trans fat content for all other foods to 5% of the total fat content, including ingredients sold to restaurants. Health Canada also announced that it would develop regulations to enforce the limits if significant progress had not been made after a two-year voluntary reduction period. (Marchand, 2010)

Rancid fats can also create health conditions. Rancidity can happen when fat is exposed to heat, light, or oxygen, which results in a bad smell, changes in color, and a negative change called oxidation. Unsaturated oils are more susceptible to oxidation and becoming rancid, but this process can also happen to saturated fats. Consuming rancid fats create free radical damage in the body, which can accelerate the aging process, contributed to weight gain, higher LDL cholesterol, and cancer.

There are three main classifications of lipids:

- Triglycerides make up more than 95% of lipids in the diet and are commonly found in fried foods, butter, milk, cheese, and some meats plus foods such as avocados, olives, corn, and nuts. Their structure is three fatty acid chains attached to a glycerol molecule. They are the lipids that have previously been discussed as saturated and unsaturated fats.
- Phospholipids make up about 2% of dietary lipids. Phospholipids have a similar structure to triglycerides, but only two fatty acid chains attached to a glycerol molecule, and they contain a phosphate and a nitrogen compound instead of one of the fatty acids. They are water-soluble and are found in both plants and animals. Phospholipids are crucial for building the protective barrier, or membrane, around the body's cells. Phospholipids are manufactured in the body to form cell membranes. In blood and body fluids, phospholipids form structures, which fat is enclosed and transported throughout the bloodstream. They also act as a precursor to many neurotransmitters in the body, which affect cognitive function, and support the health of the brain and nervous system. Two unofficial B vitamins are lipotropic agents (choline & inositol), which are phospholipids. The most common source is lecithin, which is found in soybeans, sunflower seeds, and egg yolks. These lipotropic agents help to emulsify fats in the body, which can help the absorption of fat-soluble nutrients, helps to lower LDL cholesterol, and support brain function.
- Sterols are the least common type of lipid. Cholesterol is perhaps the best-known sterol. Cholesterol is a waxy substance that has many important functions in the body such as being part of the structural component of the cell membrane, cholesterol is required to manufacture steroid hormones such as cortisol, estrogen and testosterone,

cholesterol is needed to synthesis vitamin D, and to produce bile salts. The body gets only a small amount of its cholesterol through food (about 20%), the body produces most of it. The liver is responsible for producing up to 1000 mg of cholesterol per day. Cholesterol doesn't dissolve in water (or blood). To be able to transport it in the blood, our bodies pack cholesterol into tiny parcels, together with various proteins and other things in our blood. Cholesterol is transported in the bloodstream as spherical particles called lipoproteins. The two most commonly known lipoproteins are low-density lipoproteins (LDL) and high-density lipoproteins (HDL).

- HDL cholesterol: HDL (high-density lipoprotein) cholesterol levels are a measure of the proportion of “good” cholesterol in your total cholesterol. Normal to high HDL cholesterol levels are associated with a lower risk of cardiovascular disease than low HDL cholesterol levels.
- LDL cholesterol: LDL (low-density lipoprotein) cholesterol levels are a measure of the proportion of “bad” cholesterol. High LDL cholesterol levels are associated with a higher risk of cardiovascular disease. Cholesterol isn't the only risk factor. Many other things can influence levels both positive and negative such as age, smoking, diabetes, family history, high blood pressure, and diet. Excessive sugar, alcohol, stress, and trans or bad fats in the diet result in higher LDL cholesterol levels. Exercise, omega 3 oils, and having a healthy weight and diet will increase HDL cholesterol. The risk of cardiovascular disease can only be properly assessed if all the factors are considered together.

The digestion of lipids begins in the mouth through exposure to lingual lipases, which are secreted by glands in the tongue to begin the process of digesting triglycerides. Digestion continues in the stomach through the effects of both lingual and gastric enzymes. The stomach is also the major site for the emulsification of dietary fat and fat-soluble vitamins. Lipids enter the duodenum as fine lipid droplets and then mix with bile and pancreatic enzymes to undergo further chemical and physical changes. Emulsification continues in the duodenum in preparation for absorption across the intestinal wall.

Bile and pancreatic enzymes lipase and bile salts, which function cooperatively to ensure the efficiency of lipid digestion and absorption. Once inside the intestines, short and medium chain fatty acids and glycerol are directly absorbed into the bloodstream. However, larger fat molecules such as long-chain fatty acids, monoglycerides, fat-soluble vitamins, and cholesterol need help with absorption and transport to the bloodstream. This help comes from phospholipids, which transport these larger fat molecules into the lymph system and then is absorbed into the bloodstream. It is within the lymph vessels that surround the intestinal tract where prostaglandins execute the different PGE series (1, 2, or 3).

4. Micronutrients

Micronutrients are the vitamins and minerals found in both plant and animal foods. They are termed essential, as they must be acquired through diet, except for some B vitamins and vitamin K that the bacteria in the gut can produce. Vitamins and minerals are not a source of energy, they do not provide calories like macronutrients do. Vitamins and minerals are vital for growth, immunity, and overall health. Some of the vitamins and minerals act as coenzymes, which help other enzymes complete their function. Coenzymes can help with body processes such as energy metabolism and neuronal functions making them critical for brain and muscular function (Tardy et al, 2020). Any depletions or states of deficiency will lead to health problems and deficiency diseases.

Micronutrients play a central part in metabolism and in the maintenance of tissue function. An adequate intake of all micronutrients is necessary for health. Single micronutrient deficiency states are comparatively easily recognized and treated. Subclinical deficiency, often of multiple micronutrients, is more difficult to recognize. (Shenkin, 2006)

Vitamins

Vitamins are termed organic, as they contain carbon. There are two classes of vitamins:

- Fat-soluble vitamins, which need fats in the diet for absorption and they are stored in body. These are vitamins A, D, E, and K.
- Water-soluble vitamins are not stored in the body and are easily excreted from the body. These are all of the B vitamins, vitamin C and P.

Fat-soluble Vitamins:

Vitamin A has two different types known as **preformed vitamin A (retinol)** and **provitamin A (carotenoids)**. Retinol is named for the importance to vision and the retina of the eye, playing a vital role in reducing night-blindness. Beta carotene is the best-known carotenoid, which is a precursor of vitamin A. There are over 600 different carotenoids, of which only about 40 carotenoids are present in a typical human diet and about 20 carotenoids have been identified in human blood and tissues (Milani et al, 2016). Carotenoids are converted into preformed vitamin A in the liver. One IU of vitamin A activity is defined as 0.3 microgram of retinol and as 0.6 microgram (μg) of β -carotene. One RE is equal to 3.33 IU of vitamin A activity from retinol and to 10 IU of vitamin A activity from β -carotene.

Food sources of retinol are from animal sources and include egg yolks, liver, cheese, butter, and fish liver oil. Carotenoid sources are from plants and are orange, yellow or red coloured fruits and vegetables such as leafy greens, broccoli, spinach, tomato, yam, and carrots.

Various functions of vitamin A in the body are eyesight, growth and tissue repair, healthy skin (needed for all epithelial and mucosal tissue), provides antioxidant and immune functions. It protects against cancer and help regulate genetic processes.

Absorption is reduced from alcohol intake, vitamin E deficiency, cortisone medications, exercise, and higher iron intake. The mineral zinc influences several aspects of vitamin A metabolism, including its absorption, transport, and utilization. Zinc is also needed to release stored vitamin A from the liver into the blood for the body to use. Conditions such as diabetics and hypothyroid need to take retinol, as these individuals have a reduced ability to convert the beta into preformed

vitamin A, which can contribute to a deficiency state. The liver can store about a year's supply of vitamin A, which can create issues with toxicity. Vitamin A toxicity can occur from either the topical or oral form of Vitamin A. The most severe adverse effect of systemic retinoids is teratogenicity (birth defects). The most common adverse effect of topical vitamin A is skin irritation, erythema, and peeling (Olson et al, 2020). Retinol toxicity can be reached if 50,000 IUs is taken a day over a period of time, which safe daily intake is 10,000 IUs.

Symptoms of toxicity are bone or joint pain, fatigue, insomnia, loss of hair, fissures of the lips, loss of appetite and weight. Toxicity is not a common problem with consuming beta-carotenoid, but consuming too much might cause the skin to become a yellowish orange colour.

Vitamin D (Calciferol) is known as the sunshine vitamin, as it is manufactured through sunlight on oil like substances in the skin. Vitamin D occurs in two forms that are equally well utilized in the body. Vitamin D2 (ergocalciferol) is produced commercially by ultraviolet (UV) irradiation of the plant sterol ergosterol; vitamin D3 (cholecalciferol) is formed by the action of sunlight on the precursor 7-dehydrocholesterol in the skin.

The active form of vitamin D promotes intestinal absorption of calcium and phosphorus and influences bone mineralization. Vitamin D works with the parathyroid hormone to regulate blood calcium levels. Vitamin D also supports overall immunity and can reduce the incidence of infections such as colds and flus. Vitamin D has other roles in the body, including modulation of cell growth, neuromuscular and immune function, and reduction of inflammation. Vitamin D is useful with conditions such as diabetes, cataracts and visual issues, allergies, asthma, sciatica pain and skin issues.

Deficiency of vitamin D can result in a disease called Rickets, which is a malformation of the bone that cannot calcify or harden. Rickets occurs in children who are strictly breastfed without supplementation, during winter months or living in a northern latitude, or those with a darker skin tone. The lack of mineralization occurs in the bone, teeth, and growth plate cartilage. The deficiency of vitamin D in adult is known as osteomalacia, which occurs mostly in women who have low dietary intake of vitamin D, lack of sun, or have kidney or liver issues.

Food sources of vitamin D include fatty fish, egg yolks, butter, liver, sundried mushrooms and tomatoes, and foods that have been fortified with vitamin D such as milk or orange juice.

Toxicity of vitamin D is more related to excessive sun exposure or supplementation. Consuming food rich in vitamin D is unlikely to create toxicity of this nutrient.

Vitamin E (Tocopherols) is an important antioxidant that is thought to protect polyunsaturated fatty acids from oxidative destruction in cell membranes. Vitamin E activity in foods is due to the presence of tocopherols and tocotrienols—compounds of plant origin. The most important of these is alpha-tocopherol; less active are beta-tocopherol, gamma-tocopherol, and alpha-tocotrienol. Vegetable oils are the richest source of vitamin E. Other good sources include nuts, seeds, whole grains, and wheat germ. The vitamin E content of animal foods is generally low (NIH, 2021). Vitamin E can be taken internally (oral) and used topically on the skin.

Some other functions of vitamin E include cardiovascular protection, as it helps to thin the blood (anticoagulant), fertility, reducing the risk of heart disease and reducing cholesterol deposits.

Vitamin K was discovered in 1939 by Henrick Dam, who named the molecule vitamin K according to the Danish word for blood clotting *koagulation*.

Vitamin K is needed in the liver for the formation of several blood clotting factors (coagulation). **Vitamin K1 (phylloquinone)** is synthesized by plants, whereas **vitamin K2 (menaquinones)** are synthesized by bacteria. The human body can obtain vitamin K from dietary sources, as well as through synthesis by the gut microflora. Consuming fermented foods such as kefir and sauerkraut can provide vitamin K.

A growing body of evidence supports that vitamin K has beneficial effects on bone and cardiovascular health. Vitamin K2 serves an important role in cardiovascular health through regulation of calcium homeostasis. Its effects on the cardiovascular system are mediated through activation of the anti-calcific protein known as matrix Gla protein. In its inactive form, this protein is associated with various markers of cardiovascular disease including increased arterial stiffness, vascular calcification, insulin resistance and heart failure indices which ultimately increase cardiovascular mortality. Supplementation of vitamin K2 has been strongly associated with improved cardiovascular outcomes through its modification of systemic calcification and arterial stiffness (Hariri et al, 2021)

Food sources include both plant and animal such as most green plants such as dark leafy greens, broccoli, alfalfa, and kelp. Animal sources of vitamin K include liver, organ meats, milk, yogurt, egg yolks and fish liver oils.

Vitamin K deficiency may occur as a result not only of an inadequate dietary supply but also because of many health problems, including liver disease, cystic fibrosis, alcoholism, or diseases that may cause malabsorption (inflammatory bowel disease). Some medications are also a cause of vitamin K depletion (Rodríguez-Olleros Rodríguez & Díaz Curiel, 2019)

Toxicity rarely occurs from vitamin K found in natural sources.

The use of growth hormones and antibiotics in animal feed can also have an impact on the nutrient content of meat. Some studies have shown that the use of growth hormone can increase the fat content of meat and decrease its nutritional quality. Similarly, the overuse of antibiotics can lead to the development of antibiotic resistant bacteria, which can have a negative effect on both animal and human health.

Water-soluble Vitamins:

There are several water-soluble B vitamins that make up a group or complex. These include folate, thiamine, riboflavin, niacin, pantothenic acid, biotin, vitamin B6, and vitamin B12. Deficiency of any of these water-soluble vitamins results in a clinical syndrome that may result in severe morbidity and mortality.

B vitamin or B complex is the number one vitamin for the overall health and function of the nervous system. The main role of B Vitamins on several functions in the peripheral and central nervous system (PNS and CNS) including cellular energetic processes, antioxidative and neuroprotective effects, and both myelin and neurotransmitter synthesis. Neurotropic B vitamins play crucial roles as coenzymes and beyond in the nervous system. Particularly vitamin B1

(thiamine), B6 (pyridoxine), and B12 (cobalamin) contribute essentially to the maintenance of a healthy nervous system. (Calderón-Ospina & Nava-Mesa, 2019)

B vitamins found together in nature, which foods high in a certain B vitamin will be rich in several of the other B vitamins. Pure deficiencies of a single B vitamin are rare. However, refined foods such as white sugar and flour are very deficient in B vitamins. High doses of singular B vitamin can deplete other B vitamins, so it is best taken in a complex. Requirements depend on the individual, B vitamins are easily excreted and there are factors that deplete this nutrient such as stress, sugar, alcohol, coffee, processed and refined foods.

Food sources of B vitamins include brewer's yeast, wheat germ and bran, beans, peas, nuts and seeds, liver, eggs, meat, dark leafy greens, and some of the B vitamins are produced by our intestinal bacteria.

Deficiency of certain B vitamins can cause a deficiency disease such as beriberi, pellagra, or anaemia.

Vitamin B1 (Thiamin) deficiency causes Wernicke's encephalopathy (Wernicke-Korsakoff syndrome) and beriberi. The former is characterized by the abnormal eye movement, gait ataxia, and cognitive impairment, also amnesia and infusions in severe cases. The latter is subdivided into dry beriberi and wet beriberi. In dry beriberi, peripheral neuropathy such as impaired sensory and motor neuronal conduction occurs. Wet beriberi involves the cardiovascular system with such signs and symptoms as edema, tachycardia, cardiomegaly, and congestive heart failure (Tanaka et al., 2020)

Vitamin B3 (Niacin) deficiency results in a condition known as pellagra. Pellagra includes the triad of dermatitis, dementia, and diarrhea and can result in death. In addition, niacin deficiency can occur through genetic disorders, malabsorptive conditions, and interaction with certain medications. Pellagra is caused by low levels of niacin or its precursor, tryptophan. Similar to a sunburn, brown discoloration and skin lesions on the skin typically exposed to the sun, such as hands, elbows, knees, and feet, are present. Initially, neurological changes such as anxiety, poor concentration, fatigue, and depression can manifest, but dementia and delirium may occur as pellagra advances (Redzic et al., 2023).

Vitamin B12 (Cobalamin) deficiency is a form of anemia (megaloblastic), also known as cobalamin deficiency, is a condition that develops when your body can't make enough healthy red blood cells because it doesn't have enough vitamin B12. Megaloblastic anemia can also happen with low levels of another B vitamin folate, as these two B vitamins work synergistically (Hariz & Bhattacharya, 2023). Typical symptoms of anemia are fatigue, paleness, shortness of breath, headaches, or dizziness and if left untreated, one may start to notice brain and nervous system symptoms, as vitamin B12 is also needed for the brain and your nerves to work properly. Some of these symptoms include confusion, slower thinking, forgetfulness, memory loss, mood, or mental changes, such as depression or irritability (NHLBI, 2022)

B1 (Thiamin) is a cofactor for multiple enzymes, all of which are involved in glucose breakdown and energy production. Deficiency can result in adenosine triphosphate (ATP) depletion and often affects highly aerobic tissues such as the brain, nerves, and heart first. Wernicke-Korsakoff syndrome is a thiamin deficiency often presentation in those with an alcohol use disorder,

secondary to malnutrition and malabsorption, which makes this nutrient essential to address alcoholism.

Thiamin is also a coenzyme needed in the production of hydrochloric acid (HCl), which is requirement for the digestion of proteins.

Food sources of thiamin include germ, bran, husks of seeds and grains, Brewer's yeast, molasses, pork, avocados, and dried fruit. This nutrient is lost in the refining process, so it is fortified in many products such as cereals and products containing grains. The microbes in the intestinal system also produce thiamin.

B2 (Riboflavin) was named in 1930 for its yellow colour and that it contained the sugar ribose. It is important for the growth, development, and function of the cells in your body. It is a coenzyme for energy production (ATP) and needed for normal cell growth and the healthy hair, skin, and nails. Riboflavin is yellow and naturally fluorescent when exposed to ultraviolet light. Moreover, ultraviolet, and visible light can rapidly inactivate riboflavin, so it is always packaged in opaque containers. Because of this sensitivity, lengthy light therapy to address jaundice in newborns or skin disorders can lead to riboflavin deficiency (NIH, 2017)

Riboflavin is found in a lot of food sources, so deficiency is not common. However, women on hormone replacement therapy (HRT) or birth control pills (BCPills), any type of antibiotic use, or under stress will require additional B2. Food sources include brewer's yeast (richest source), milk, nuts and seeds, whole grains, leafy greens, seaweed, eggs, organ meats, and legumes.

Bacteria in the large intestine produce free riboflavin that can be absorbed by the large intestine in amounts that depend on the diet. More riboflavin is produced after ingestion of vegetable-based than meat-based foods. (NIH, 2017)

Symptoms of deficiency in B2 include cracking and peeling of the lower lip, splitting in the corner of the mouth (fissures), sore, red tongue, eye redness or sensitivity to light, burning eyes, fatigue, and nerve tissue damage.

B3 (Niacin) is also known as nicotinic acid and niacinamide, as it was first discovered during the oxidation of nicotine from tobacco. All tissues in the body convert absorbed niacin into its main metabolically active form, the coenzyme nicotinamide adenine dinucleotide (NAD). More than 400 enzymes require NAD to catalyze reactions in the body, which is more than for any other vitamin-derived coenzyme. The body also converts some tryptophan, an amino acid in protein, to NAD, so tryptophan is considered a dietary source of niacin (NIH, 2017)

Some of the functions of niacin include being a coenzyme in energy production, needed for the formation of red blood cells and fat metabolism. Niacin is used for fatigue, helps regulate blood sugar levels, and mega doses are used in mental disorders such as depression, anxiety, and schizophrenia. It is also used to help lower blood cholesterol and hypertension, which helps to reduce heart attacks and strokes.

The deficiency disease is Pellagra, which includes the 4 D's: dermatitis, diarrhea, dementia, and death.

Deficiency symptoms involve nervous system symptoms, which mild deficiency symptoms can include the skin being sensitive to light, decreased energy, sore, red tongue, canker sores, nausea, and diarrhea to full-blown psychosis, if deficiency is not corrected.

Niacin, either alone or in combination with a statin, safely and effectively addresses most lipid abnormalities in patients with mixed dyslipidemia. Therapeutically used for more than 50 years, niacin is the most effective clinically available agent for increasing high-density lipoprotein cholesterol. Taking niacin in high doses creates a flushing effect. Flushing symptoms occur following vasodilatation of small capillaries under the skin, a response that can be mediated via histamine/bradykinin or prostaglandins. (Kamanna et al., 2009)

Food sources of niacin include organ meats, fish, poultry, peanuts, Brewer's yeast, legumes, avocados, and whole grains.

B5 (Pantothenic Acid) was named for the Greek word 'pantos', which means everywhere. It is found in every living cell. It is a component of coenzyme A and fatty acid synthase, both of which are necessary for energy production and the formation of hormones. B5 is essential for the function of the adrenal cortex. It is also needed for the synthesis of neurotransmitters such as acetylcholine to help with cognitive function. Another function of B5 is that it helps reduce premature aging and wrinkles to promote healthy skin.

Symptoms deficiency include exhaustion of the adrenal glands (anti-stress vitamin) for physical, emotional, and psychological stressors, fatigue, digestive upsets, cramps, difficulty sleeping, and tingling sensations in the hands and feet. Deficiency of this vitamin can be caused by diet high in refined or processed foods, and chronic stress.

Food sources include liver, organ meats, yeast, egg yolks, fish, chicken, cheese, whole grains, peanuts, and many vegetables such as apples, carrots, cabbage, broccoli, and tomatoes. It is also manufactured by intestinal bacteria.

B6 (Pyridoxine (pīr'ī-dōk'sēn)) is a coenzyme forms performs a wide variety of functions in the body and is extremely versatile, with involvement in more than 100 enzyme reactions, mostly concerned with protein metabolism. Vitamin B6 also plays a role in cognitive development through the synthesis of neurotransmitters and in maintaining normal levels of homocysteine, an amino acid in the blood that relate to healthy cardiovascular and brain function. Vitamin B6 is involved in gluconeogenesis and glycogenolysis, immune function, and hemoglobin formation. The brain needs vitamin B6 to convert tryptophan to serotonin. Certain disorders such as epilepsy responds well to B6.

Vitamin B6 is also needed for shifts in female hormones such as menstruation, pregnancy, and menopause. B6 has been shown to improve progesterone levels and lower levels of this vitamin can result in symptoms such as morning sickness with pregnancy and PMS. Pregnancy conditions such as pre-eclampsia, toxemia (a hypertensive disorder), and gestational diabetes can be helped with vitamin B6.

Oral contraceptive will create a deficiency of this vitamin.

Symptoms of deficiency include fatigue, nervousness, anxiety, and depression

The richest sources of vitamin B6 include fish, beef liver and other organ meats, eggs, dried beans, Brewer's yeast, nuts, avocados, potatoes, whole grains, and other starchy vegetables (squash), and fruit (other than citrus such as banana).

B9 (Folic Acid, Folacin or Folate) is needed for cellular division, the growth and reproduction of all cells, which is important during times of growth such as childhood and pregnancy. Deficiency can result in neural tube defects, which prompting folate supplementation during pregnancy and megaloblastic anemia. <https://www.ncbi.nlm.nih.gov/books/NBK538510/> Folate is another B vitamin needed to maintain homocysteine levels.

Folate is the most fragile vitamins; it is easily destroyed by heat and processing foods. Deficiency symptoms include anemia, fatigue, headaches, forgetfulness, irritability, anorexia, weight loss, and diarrhea. Folate deficiency may also be a feature of alcohol use disorder.

Extra folate is stored in the liver, so deficiency is slow to develop. However, causes of deficiency can include poor nutrition, smoking, alcohol, drug use, stress, illness, pregnancy, intestinal absorption problems, and use of oral contraceptives. A deficiency in the mineral zinc impairs the enzymes needed to digest folate.

Food sources of folate include dark leafy green vegetables such as spinach, kale, beet greens, bean sprouts, asparagus, liver, and wheat germ. Many foods are fortified with folate to reduce the risk of deficiency. The gut bacteria also produce a small amount of folate.

B12 (Cobalamin) is a complex molecule containing carbon, hydrogen oxygen, phosphorus, nitrogen, and the mineral cobalt. It is needed by the body in the tiniest amount, but it is essential for the health of the entire nervous system. Vitamin B12 is required for the development, myelination, healthy red blood cell formation and DNA synthesis. It stimulates growth and appetite in children, is known as the energy vitamin, increases iron bioavailability, and is used for longevity and to reduce fatigue. Vitamin B12 is the third B vitamin needed to maintain homocysteine levels.

Absorption of B12 requires gastric acid and pepsin in the stomach plus a mucoprotein enzyme called 'intrinsic factor'. Vitamin B12 is not freely absorbed. B12 is the only vitamin not found in a strict vegan diet. The body actually stores a small amount of B12 in the liver, which symptoms of a deficiency may not show up for up to 5 years. Megaloblastic anemia from B12 deficiency presents similarly to folate deficiency, which these two vitamins should be supplemented together. Intestinal disorders such as celiac and Crohn's can create issues with B12 absorption due to causing an intrinsic factor related malabsorption of B12.

Food sources include any type of animal food such as dairy, eggs, meat, and fish. It is manufactured by bacteria & yeasts (or fermented foods) such as soy sauce, miso soup, tempeh, kefir, and kombucha plus it is manufactured by intestinal bacteria.

B7 (Biotin) was recognized in 1931 as a substance found in the liver that addressed a syndrome called egg white injury. It is necessary for the metabolism of protein, fats, and carbohydrates. Deficiency can lead to muscle pain, heart problems, anemia, and depression. Additionally, since

biotin is a contributor to keratin, biotin has become popular as a supplement to improve the quality of hair, skin, and nails. (Lukstad & Sharma, 2023)

Biotin helps reduce and maintain blood sugar levels by increasing insulin secretion by affecting beta cells of pancreatic islets, as well as enhance glycolysis pathway. Biotin also improves insulin function in muscles. (Hemmati et al., 2013)

Deficiency symptoms include fatigue, nausea, loss of appetite, muscle pain, depression, loss of energy, insomnia, dry, flaky skin, and increased LDL cholesterol levels. Deficiency can be created by eating raw egg whites, as raw egg whites contain a high volume of intact avidin, which strongly binds biotin. When egg whites are cooked, the avidin denatures and does not bind to biotin. (Lukstad & Sharma, 2023)

Food sources include egg yolks, liver, brewer's yeast, whole grain rice, nuts, and milk. It is also manufactured by intestinal bacteria. There is no known toxic level.

Choline (Ch) and Inositol (Ino) are unofficial B vitamins. These are lipotropic B vitamin that are needed for the utilization of fats.

Choline was discovered in 1862, but not recognized as being essential for human until 1998. Choline is essential for liver and brain function. It is necessary for bile production and to emulsify fats aiding in weight loss and reducing cholesterol levels. It is a precursor to acetylcholine, which is a neurotransmitter that boosts memory. Choline is needed for the health of the myelin sheaths of the nerves, and helps liver & gallbladder function. It is present in all living cells.

Best food source of choline is lecithin and other food sources are egg yolks, brewer's yeast, wheat germ, fish, peanuts, sunflower seeds, liver, organ meats, and intestinal bacteria produce choline too.

Inositol (Vitamin B8) is a key component of cell membrane phospholipids. Its primary function is the structure and integrity of the cell membrane, which helps the chemical signaling between brain. Inositol is seen in large amounts in the brain where it promotes communication between multiple millions of brain cells. The major neurotransmitters which are serotonin, dopamine, GABA, norepinephrine, and acetylcholine, depend on inositol. (López-Gamero et al., 2020)

It also promotes healthy hair and skin, reduces the progression of atherosclerosis, and reduces cholesterol. Inositol contributes to improving glycemic responses, which can help conditions such as diabetes and insulin resistance.

Food sources include Brewer's yeast, liver, molasses, legumes, peas, almonds, peanuts, dried prunes, and whole grains. It is non-toxic and requirements are individual.

PABA (Para-aminobenzoic acid - Vitamin B10) has antioxidant properties that helps to protect against UVB rays, which is why it is used for sun protection. PABA also contributes to healthy hair, reduces premature graying of hair. It is a coenzyme in protein metabolism.

High doses of PABA can effect the liver causing nausea and vomiting, loss of appetite, and skin rashes.

Deficiency of PABA is not common, but symptoms can include fatigue, depression, nervousness, headache, graying hair, and digestive upsets can occur.

Food sources include liver, brewer's yeast, wheat germ, spinach, mushrooms, and whole grains. There is no RDA for PABA, but a safe intake is 100mg per day.

Vitamin C (Ascorbic Acid) is the most widely known vitamin. Humans, primates, fruit bats & guinea pigs are the only mammals that cannot synthesize vitamin C. Isolated in 1928, vitamin C is essential for the development and maintenance of connective tissues. The therapeutic effect of vitamin C was explored by Linus Pauling however his work on therapeutic role of vitamin C in his later years generated much controversy, yet he was the first to introduce the concept of high doses of vitamin C for the treatment of various conditions from common cold to cancer. Since then, mega doses of vitamin C have been widely used to reduce and address a large number of disorders like diabetes, atherosclerosis, common cold, cataracts, glaucoma, macular degeneration, stroke, heart diseases, cancer and so on. (Chambial et al., 2013)

Vitamin C is needed for collagen growth, wound repair, bone formation, enhancing the immune system, absorption of iron, strengthening blood vessels, and acting as an antioxidant. When deficiency occurs, it can result in scurvy, which can present with swollen and bleeding gums, loss of teeth, poor wound healing, and poor tissue growth. Poor gum health is the first sign of a vitamin C deficiency. High doses vitamin C protect the body and help detoxify heavy metals and toxins such as pesticides and food additives.

Some other functions include decreasing the severity of the common cold and flu, acts as a coenzyme and anti-inflammatory. In higher doses, vitamin C is an antihistamine to help with disorders such as allergies, asthma, and respiratory illnesses. (Ghalibaf et al., 2023)

New findings support the notion that high-dose consumption of vitamin C is associated with a decreased risk of the oral cavity, stomach, esophagus, pancreas, cervix, breast, and rectum cancers, and cancers with non-hormonal origins. Numerous mechanisms have been suggested to support the role of vitamin C in addressing cancer, including that of increasing the immune system activity, stimulating collagen synthesis, reducing metastasis by inhibiting certain enzymatic reaction, inhibiting tumor-causing viruses, correcting for the lack of vitamin C, which is normally linked with cancer patients, wound healing in patients with cancer subsequent to surgery, improving chemotherapy sensitivity, decreasing chemotherapy toxicity, and neutralizing certain carcinogens. (Mussa et al., 2022)

Vitamin C is water-soluble, which makes it easily excreted from the body. Stress, smoking, alcohol, and medications such as aspirin and oral contraceptives deplete this vitamin. Certain illness such as diabetes, bowel disorders and eating disorders require higher amounts of vitamin C. Vitamin C is needed for the absorption of iron, so those with low iron or anemia need more vitamin C.

Up to 90% of vitamin C is consumed in the form of vegetables and fruits. Lack of exposure to these foods has been the most frequent cause of the deficiency. Additionally, vitamin C is heat-sensitive, and historically, preparation (boiling or cooking) has removed the nutritional value. Vitamin C is naturally found in fresh fruits and vegetables such as grapefruits, oranges, lemons, limes, cherries, potatoes, spinach, broccoli, bell peppers, and tomatoes. (Maxfield & Crane, 2019)

Taking too much vitamin C can create issues such as bloating, abdominal pain, and diarrhea.

Vitamin P (Bioflavonoids) works synergistically with vitamin C. Most substances in this category belong to the family of flavonoids. Vitamin P has also been used to define the activity of some flavonoids, including quercetin, myricetin, and rutin. Flavonoids, a group of natural substances with variable phenolic structures, are found in fruits, vegetables, grains, bark, roots, stems, flowers, tea, and wine. These natural products are well known for their beneficial effects on health, which is attributed to their antioxidative, anti-inflammatory, anti-mutagenic and anti-carcinogenic properties coupled with their capacity to modulate key cellular enzyme function. (Panche et al., 2016)

Vitamin P is important for collagen health and increases the strength of the capillary walls. It helps to reduce bruising and the breaking of tiny blood vessels. It increases the absorption of vitamin C, which a deficiency in vitamin C can relate to a deficiency in vitamin P.

Minerals:

Minerals are found in the soil and rock of the earth. They are the ash that remains when plant or animal tissue is burned or decomposed. They make up the basic components of all matter and living tissue. Minerals are inorganic and they are found on the periodic table. The body is 4-5% minerals, of which the highest percentage in the body is found in the skeletal system, our tissues, blood, nerve, muscle, and organs.

Macrominerals make up more than 0.01% of total body weight and trace minerals make up less than 0.01% of total body weight. Like vitamins, minerals do not provide energy or calories, but they are essential to our physical and mental health. Acquiring a full spectrum of all minerals is important, as certain minerals are absorbed in lower amounts and some minerals compete with each other for absorption. If the food that we eat is grown in mineral deficient soil, our body will soon become mineral deficient.

Macrominerals are typically needed at levels higher than 100 mg/day to include calcium (Ca), chloride (Cl), phosphorus (P), magnesium (Mg), sulfur (S), sodium (Na) and potassium (K). On the other hand, microminerals are needed in amounts lower than 100 mg/day and to include elements such as iron (Fe), zinc (Zn), iodine (I), selenium (Se), manganese (Mn), chromium (Cr), copper (Cu), molybdenum (Mo), cobalt (Co), silicon (Si). Macrominerals are required by the body to sustain its basic functions and are optimally obtained by eating a balanced diet. In fact, they are essential for a wide variety of metabolic and physiological processes in the human body, especially in homeostasis as well as metabolism, along with their well-known importance for proper functioning organs and overall good development and growth of our bodies. Many medical conditions could arise in cases of excessive intake or deficiency. (Farag et al, 2023)

Macrominerals

Out of the seven macrominerals, five of them are electrolytes, which are essential for basic life functioning, such as maintaining electrical neutrality in cells and generating and conducting action potentials in the nerves and muscles.

Macrominerals:

- Calcium (Ca) - electrolyte
- Chloride (Cl) - electrolyte
- Magnesium (Mg) - electrolyte
- Phosphorus (P)
- Potassium (K) – electrolyte
- Sodium (Na) – electrolyte
- Sulfur (S)

Calcium is the most abundant mineral found in the body. It is needed for functions in the blood, nerve, muscle, and tissue, which helps to regulate heart and muscle contractions, and nerve conductions. Calcium is needed for the development and maintenance of the bone, and calcium is also needed for cell division.

Other nutrients are needed for the absorption of calcium, which are magnesium, vitamin D, phosphorus and HCl. High calcium intake reduces the absorption of magnesium, phosphorous, zinc and manganese. Stress, age, oxalic, and phytic acid will also decrease absorption. Poor absorption can contribute to the formation of kidney stones, calcium deposits in the joints plus calcium is also part of the plaque that forms atherosclerosis leading to higher risks of heart disease.

Hormonal shifts in women such as menopause can affect bone health and lead to higher susceptibility to bone loss. Bones become soft and porous denoting osteoporosis. Bone loss is greatest with inactivity. Exercise has been shown to increase absorption of calcium

Food sources include dairy, broccoli, nuts, and seeds, collards, sardines or salmon with bones, dried fruit, seaweed, and leafy greens. Depending on the person, an adequate range for adults is between 500 to 1200mg.

Chloride is a component in the production of hydrochloric acid (HCl). It is an electrolyte that works closely with sodium to regulate body fluids.

High amounts of chloride are found in all forms of salt as sodium chloride and play a role with fluid retention in the body. If consumption is high, it can lead to health conditions such as hypertension and edema. There is no concern with deficiency.

Sources of this mineral are table salt, sea salt, seaweed, olives, and some vegetables such as celery, lettuce, and tomato. An intake range is 1.7 to 5 grams, which is easily provided by diet.

Magnesium is mainly involved in adenosine triphosphate (ATP) metabolism, proper functioning of muscles, neurological functioning, and neurotransmitter release.

Magnesium is the fourth most abundant mineral in the body after calcium, potassium, and sodium and the second most abundant cation within the body's cells after potassium. Approximately 99% of total body magnesium is located in bone, muscles, and non-muscular soft tissue. Less than 1% of total magnesium is in blood serum. Magnesium has been recognized as a cofactor in more than

300 enzyme systems that regulate diverse biochemical reactions in the body. Magnesium is also crucial for energy production (ATP), oxidative phosphorylation, and glycolysis. Magnesium also plays a key role in the active transport of calcium and potassium ions across cell membranes, a process that is important to nerve impulse conduction, muscle contraction, vasomotor tone, and normal heart rhythm. (Farag et al, 2023)

Magnesium works with calcium in body functions such as muscle contractions, calcium stimulates the muscle while magnesium relaxes the muscle. Magnesium is considered the 'anti-stress' mineral.

Low levels of magnesium have been associated with a number of chronic disorders as Alzheimer's disease, asthma, attention deficit hyperactivity disorder (ADHD), insulin resistance, hypertension, migraine headaches and osteoporosis. In addition, magnesium deficiency exacerbates potassium mediated arrhythmia. (Farag et al, 2023)

Deficiency is common, as magnesium is easily excreted from the body by urine and sweat. Stress, alcohol, and certain medications can deplete this mineral.

Magnesium supplements are well tolerated, but overdoses of magnesium could lead to diarrhea that can be associated with nausea and abdominal cramping. The diarrhea and laxative effects of magnesium salts are due to the osmotic activity of unabsorbed salts in the intestine and colon and the stimulation of gastric motility. (Farag et al, 2023)

Magnesium to plants is like iron to us, the central atom in chlorophyll, which is a plant's green pigment, is magnesium. Food sources are seafood, any dark green vegetables, nuts and seeds, legumes, and whole grains. Requirements for magnesium are 6 mg per kg = 150 lbs is 410mg.

Phosphorus is found in every cell for biochemical reactions. It is vital in energy production (ATP), protein synthesis for growth, maintenance and repair of all tissue and cells. It is a component of phospholipids, plays a role in kidney functions, regularity of the heartbeat and nerve conductivity.

Eighty-five percent of the total body phosphorus is in the bones and teeth in the form of hydroxyapatite; the soft tissues contain the remaining 15%. Phosphate plays a crucial role in metabolic pathways. It is a component of many metabolic intermediates and, most importantly, of ATP and nucleotides. Vitamin D3, PTH, and calcitonin regulate phosphate simultaneously with calcium. The kidneys are the primary avenue of phosphorus excretion. Phosphate imbalance is most commonly due to one of three processes: impaired dietary intake, gastrointestinal disorders, and deranged renal excretion. (Shrimanker & Bhattarai, 2023)

There should be a 1:1.5 ratio of phosphorus to calcium, but the SAD diet creates imbalances with this ratio. Foods such as soda pop contain phosphoric acid, which is corrosive to the body and displaces minerals such as calcium.

Food sources include all sources of animal protein, legumes, seeds, nuts, whole grains, Brewer's yeast, wheat germ, bran, and most fruits and vegetables such as apples, cauliflower, asparagus, and tomatoes.

Potassium is needed for cellular and electrical functions in the body. It works hand-in-hand with sodium to regulate water balance, and the acid-base balance in blood and tissue. The sodium-potassium pump helps generate muscle contractions and regulates the heartbeat. It is needed for nerve impulses.

Potassium is necessary for biochemical reaction, energy production (ATP), normal growth and building muscle. Toxicity is uncommon, as it is easily excreted from the body. Fatigue is a common symptom of deficiency. Potassium is excreted by the kidneys, which those with a kidney disorder should watch intake.

Food sources are fruits and vegetables such as banana, avocado, spinach, beet greens, whole grains, wheat germ, seeds, nuts, and fish. There is no RDA, and an intake range is between 1.9 to 5.6 grams.

Sodium is one of the essential electrolytes in the extracellular fluid. It is responsible for maintaining the extracellular fluid volume and regulating the membrane potential of cells. Sodium is exchanged along with potassium across cell membranes as part of active transport. Sodium regulation occurs in the kidneys. (Shrimanker & Bhattarai, 2023)

The functions of sodium are similar to potassium, muscle contractions and nerve impulses. Where sodium goes, water goes, which contributes to health issues such as hypertension and edema.

Sodium is found in many foods such as seafood, beef, poultry, and vegetables such as celery and beets. Table salt is also a source of sodium, which is added to many foods. The SAD diet, which is low in fruits and vegetables and high in packaged foods, provides an excessively high intake of sodium.

Sulfur is the third most abundant mineral found in our body, after calcium and phosphorus, and the sixth most abundant macromineral in breast milk. Sulfur has potential beneficial effects on a variety of dermatological disorders such as acne and skin lesions, and is added as an active ingredient in acne ointments and antidandruff shampoos. Sulfur is needed for a number of chemical reactions involved in the metabolism of drugs, steroids, and xenobiotics. For instance, sulfation is a major pathway for detoxification of pharmacological agents by the liver. (Farak et al, 2023)

Sulfur is present in keratin, a protein needed for health of the skin, nails, and hair. Sulfur can be identified by its odour.

A diet rich in sulfur containing compounds could inhibit the development of inflammation by regulating the pro-inflammatory signaling pathway. (Farak et al, 2023)

Fruits and vegetables are among the sulfur-rich sources with beneficial effects on human health. In particular, cruciferous vegetables including broccoli, cabbage, cauliflower, and other plants of the family Brassicaceae are rich sources of sulfur. Onion (*Allium cepa*) and garlic (*Allium sativa*) are some of the oldest cultivated plants in the world and are rich sources of natural organosulfur compounds (OSCs). Other sulfur-rich sources include brussels sprouts, dairy products, fish, legumes, meats, nuts, raspberries, and wheat germ. (Farak et al, 2023)

Microminerals:

Chromium (Cr) exists in two main forms: trivalent chromium (III) and hexavalent chromium (VI). Trivalent chromium is the type found in food and supplements and is not toxic. Hexavalent chromium is found with industrial pollution and is toxic and carcinogenic. Chromium plays a role in carbohydrate, lipid, and protein metabolism by potentiating insulin action. It is essential for glucose tolerance factor (GTF) and carbohydrate metabolism, which is important for weight loss, diabetics, and insulin resistance.

The human body contains about 4 to 6mg of chromium, which the highest concentrations are found in the liver, kidneys, muscle, spleen, heart, and bone. Only a small amount of chromium is absorbed from food ranging from about 0.4% to 2.5%, which makes deficiency common with age, food grown in deficient soil, and the refining process. Vitamin C can help with absorption and the use of antacids, oxalates or phytates can reduce absorption.

Studies show that people with type 2 diabetes have lower blood levels of chromium. Those with diabetes have a greater risk of developing heart disease, as high blood sugar promotes arterial plaque, which can lead to heart disease.

Food sources include Brewer's yeast, black pepper, molasses, whole grains, meats, shellfish, chicken, wheat germ, and many fruits and vegetables such as apples, tomatoes, orange, banana, carrot, and celery.

Cobalt (Co) is an essential component of vitamin B12, which supports the red blood cell formation and the health of the nerves. A deficiency in this mineral can result in the B12 deficiency disease pernicious anemia. There is no RDA for cobalt, which the average intake 5 to 8mcg daily.

Cobalt toxicity can happen from occupational or environmental exposure. Sources of common cobalt exposure include artist's pigmentation (cobalt blue), dyes, porcelain, cement, rubber, super alloys, drill production, cutting tools, catalysts, orthopedic implants, dental hardware, vitamin supplementation, electroplating, outdated treatments for anemia, and welder's steel production. (Chen & Lee, 2022)

Food sources of cobalt include lots of the same food rich with B12 such as all meats, organ meat, clams, oysters, fish, sea vegetables, and legumes.

Copper (Cu) is present in all body tissue for the formation of hemoglobin and energy production (ATP). It is also a coenzyme in the body acting as a defense against oxidative damage by the copper-containing superoxide dismutases (SOD).

Only small amounts of copper are typically stored in the body, and the average adult has a total body content of 50–120 mg copper. About 50% to 80% of copper is absorbed, which most copper is excreted in bile, and a small amount is excreted in urine.

Symptoms of copper toxicity include abdominal pain, jaundice, anorexia, severe thirst, diarrhea, and vomiting and neurological symptoms such as anxiety, depression, and other mental health problems have been reported.

Toxicity is more common than deficiency, but deficiency can relate to iron levels. Copper, like iron, is required for normal erythropoiesis; copper deficiency causes an iron-deficiency-like anemia, as high iron consumption can cause copper deficiency anemia. (Ha, 2016)

Iron, zinc, and phytates interfere with copper absorption, whereas protein and soluble carbohydrates tend to improve copper absorption. Copper pots and pans, copper pipes and birth control pills can raise copper levels to a toxic amount. Oral contraceptives with estrogenic effects are known to elevate serum copper and if copper levels are elevated, it inhibits the detoxification of estrogen from the body.

Copper and zinc have a seesaw effect, as zinc reduces the amount of copper your body absorbs and vice versa. The levels of zinc and copper are important in the body, but just as important is the zinc-copper ratio, which the ideal ratio between zinc and copper is 8:1.

Food sources include buckwheat, whole wheat, shellfish, organ meat, oysters, legumes, nuts, mushrooms, tofu, sesame seeds, asparagus, and some leafy greens such as spinach.

Iodine (I) is an essential component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3). Thyroid hormones regulate many important biochemical reactions such as metabolism, growth and development. Iodine is one of the main building blocks of both hormones. Our bodies can't produce this trace element, so we need to get enough of it in our diet. Iodine is absorbed into our bloodstream from food in our bowel. It is then carried to the thyroid gland, where it is eventually used to make thyroid hormones.

Thyroid hormones are responsible for energy production (ATP), cellular respiration plus nerve, bone formation, reproduction, the health of the skin, hair, nails, teeth, and one's mental health.

The earth's soils contain varying amounts of iodine, which in turn affects the iodine content of crops. In some regions of the world, iodine-deficient soils are common, increasing the risk of iodine deficiency among people who consume foods primarily from those areas. Salt iodization programs, which many countries have implemented, have dramatically reduced the prevalence of iodine deficiency worldwide. In the absence of sufficient iodine, TSH levels remain elevated, leading to goiter, an enlargement of the thyroid gland that reflects the body's attempt to trap more iodine from the circulation and produce thyroid hormones.

Symptoms of low thyroid function include slower metabolism (weight gain), fatigue, constipation, cold hands and feet, dry hair and lower immunity. Absorption is affected by goitrogenic foods such as brassica vegetables, soy, flax, and millet. Goitrogenic foods contain certain components that compete with iodine uptake in the thyroid.

Food sources include anything from the sea such as fish, shellfish, and seaweed. Most fruits and vegetables are poor sources of iodine, and the amounts they contain are affected by the iodine

content of the soil, fertilizer use, and irrigation practices. Dairy products do contain iodine, as well as eggs.

Iron (Fe) is an essential component of hemoglobin, an erythrocyte (red blood cell) protein that transfers oxygen from the lungs to the tissues. As a component of myoglobin, another protein that provides oxygen, iron supports muscle metabolism, is needed for energy production, and the strength and endurance of the muscles plus healthy connective tissue. Iron is also necessary for physical growth, neurological development, cellular functioning, and synthesis of some hormones. (NIH, 2022)

Dietary iron has two main forms: heme and nonheme. Plants and iron-fortified foods contain nonheme iron only, whereas meat, seafood, and poultry contain both heme and nonheme iron. Most of the 3 to 4 grams of elemental iron in adults is in hemoglobin. Much of the remaining iron is stored in the form of ferritin or hemosiderin (a degradation product of ferritin) in the liver, spleen, and bone marrow or is located in myoglobin in muscle tissue. . (NIH, 2022)

Iron deficiency is common, especially among young children, women of reproductive age, and pregnant women. Iron deficiency is associated with poor diet, malabsorptive disorders, and blood loss. First sign of iron deficiency is anemia and fatigue.

Vitamin C (ascorbic acid) enhances iron absorption plus other acids such as citric acid also helps absorption, as it combines with iron to make it a soluble compound. Meat, fish and poultry also increase the absorption of nonheme iron. Taking a higher amount of calcium can inhibit the uptake of iron. Also, phalates, oxalates, antacids (need HCl to absorb iron), low stomach acid, and polyphenols found in coffee and tea can reduce absorption of iron by 50%.

Adults with normal intestinal function have very little risk of iron overload from dietary sources of iron. However, supplements containing 25 mg iron or more can reduce zinc absorption and plasma zinc concentrations. High-dose iron supplements can lead to gastrointestinal effects such as gastric upset, constipation, nausea, abdominal pain, vomiting, and diarrhea. Hemochromatosis, a disease caused by a mutation in the hemochromatosis (HFE) gene, is associated with an excessive buildup of iron in the body. (NIH, 2022) Food sources include red meat, spinach, broccoli, tomatoes, beets, raisins, figs, dark chocolate, hard cheese, molasses, quinoa, tofu, and legumes.

Manganese (Mn) is needed for enzymatic activity, energy production, protein metabolism, and bone and cartilage formation. Manganese is a cofactor for many enzymes including superoxide dismutase (SOD).

Through the action of these enzymes, manganese is involved in amino acid, cholesterol, glucose, and carbohydrate metabolism, reactive oxygen species scavenging, reproduction, and immune responses. Manganese also plays a role in blood clotting and hemostasis in conjunction with

vitamin K. The human body contains about 10 to 20 mg manganese, of which 25% to 40% is in bone. (NIH, 2019)

Manganese deficiency might cause bone demineralization, as a deficiency can be recognized by poor bone and cartilage creating achy joints, loose creaking knees, poor growth in children, skin rashes, hair depigmentation, decreased serum cholesterol, and altered mood and increased premenstrual pain in women. Manganese deficiency might also alter lipid and carbohydrate metabolism and cause abnormal glucose tolerance (NIH, 2019). Some factors that affect the absorption of manganese such as taking large amounts of calcium and/or phosphorus. Dietary iron intakes and iron status (measured by serum ferritin concentration) appear to be inversely associated with manganese absorption.

Manganese is present in a wide variety of foods, including whole grains, clams, oysters, mussels, nuts, soybeans and other legumes, rice, seeds (hemp seeds), leafy vegetables, coffee, tea, and many spices such as black pepper. (NIH, 2019)

Molybdenum (Mo) (muh-lib-duh-nem) is needed as a cofactor for enzymatic activity, uric acid formation, and mobilization of iron from the liver for the body to use. Molybdenum can also protect the body from the cancer-causing effect of nitrites in processed meats and food.

Adults absorb 40% to 100% of dietary molybdenum. The body contains about 9mg, which is mainly found in the liver, kidneys, adrenal glands, bone, and skin.

Deficiency in this mineral is rare. Exposure to larger amounts from mining or metalwork can lead to symptoms such as weight loss and diarrhea.

Legumes are the richest sources of molybdenum. Other foods high in molybdenum include whole grains, nuts, dairy, potato, corn, spinach, and beef liver. (NIH, 2021)

Selenium (Se) is a powerful antioxidant that protects against illnesses such as cancer and heart disease. It is a component of glutathione peroxidase. It is a constituent of more than two dozen selenoproteins that play critical roles in reproduction, thyroid hormone metabolism, DNA synthesis, and protection from oxidative damage and infection. Selenium is needed for longevity, heavy metal detoxification, and the health of the hair and skin. Selenium works synergistic with vitamin E for fertility in both males and females. Men need more selenium for sperm production and motility.

The skeletal muscle is the major site of selenium storage, accounting for approximately 28% to 46% of the total selenium. Low selenium levels are associated with low thyroid function, as selenium is needed for the conversion of the thyroid hormones thyroxine(T4) to the more active triiodothyronine(T3). Selenium deficiency could exacerbate iodine deficiency.

Food sources of selenium depend on soil content. Brazil nuts, seafoods, and organ meats are the richest food sources of selenium. Other sources include Brewer's yeast, wheat germ, shellfish, fish, seeds, garlic, onions, and radishes.

Silicon (Si) is also known as silica, which is used to strengthen hair, nails, skin, and in tissue repair. It is needed for the elasticity of the skin and collagen production.

Silicon is necessary for the growth and bone calcification and as a biological cross-linking agent of connective-tissue-based membrane structures. (Jugdaohsingh et al., 2015)

Silicon represents about 0.05% of total body weight. There is no known toxicity or deficiency states.

Food sources include the hulls of oats, rice, alfalfa, sugarcane, avocados, onions, strawberries, and dark greens. Herbs such as horsetail and nettles are used in supplements as a source of silica.

Zinc (Zn) has many functions in the body for cellular metabolism such as it is a cofactor for enzymatic activity. It is needed for growth of tissues and cell formation, for taste and smell, wound repair, and insulin activity. Zinc is necessary to manufacture gastric acid (HCl) and many digestive enzymes. It is known to help acne and skin issues, as it is needed to utilize vitamin A for new skin cells.

90% of zinc is found in the muscle and bone and the other 10% is located in the organs and body fluids.

Zinc also is an antioxidant and has anti-inflammatory actions. Zinc provides immune function support by activating T-lymphocytes and it is also found in cold lozenges. Zinc is crucial for normal development and function of immune cells such as mediating innate immunity, neutrophils, and natural killer (NK) cells. (Prasad, 2008)

Zinc is an essential mineral for the male reproductive system, as zinc is needed to produce testosterone. Zinc concentrations are high in the seminal fluid and has a multifaceted role in the sperm's functional properties such as increase sperm count, motility, and overall male fertility. (Fallah et al., 2018)

Zinc is one of the most well studied essential metals for the alleviation of heavy metal toxicity. Zinc aids in the detoxification of lead and cadmium. (Zhai et al., 2015)

Excessive intake of zinc can lead to toxicity, which can cause copper deficiency and neurologic diseases, as zinc has a seesaw relationship with copper.

Because zinc has many functions throughout the body, zinc deficiency affects many different tissues and organs. Zinc deficiency can affect, for example, skin; bones; and the digestive, reproductive, central nervous, and immune systems.

Zinc deficiency adversely affects the growth and function of T and B cells. The manifestations of a moderate deficiency of zinc include growth retardation and male hypogonadism in adolescents, rough skin, poor appetite, mental lethargy, delayed wound healing, cell-mediated immune dysfunctions, and abnormal neurosensory changes. (Prasad, 2008)

The richest food sources of zinc include meat, fish, and seafood. Oysters contain more zinc per serving than any other food, but beef contributes 20% of zinc. Other foods sources include shellfish, turkey, herring, egg yolks, and pumpkin seeds. The amount of zinc absorbed from food ranges from 5% to more than 50%, depending on the amount of plant-based foods (phytate) in the diet.

5. Inflammation and Immunity

The immune system is one of the many different body systems that plays a vital role in the overall health of the body. Let's look at the word immunity. What does this entail? Is it solely the actions of the immune system? Is it the entire body? This would include all of the body systems working together to contribute to homeostasis. Considering that all body systems work together for overall health and wellness, and this encompasses immunity, then every single nutrient is needed in some way or another for immunity.

The Immune System:

The immune system plays an important role, it is our defense system. It protects the body from harmful substances, germs, and cell changes that could make you sick. When the immune system is working properly, you don't even notice that it's doing its job to protect you. However, if it becomes suppressed or stops working properly, it can't fight off germs. This is common when the immune system is not functioning well, you are more susceptible to infections such as colds and flu. Germs that the body has never encountered before are likely to make you ill. When you have a strong immunity, being exposed to germs can still create certain symptoms, but the severity and duration of the illness is reduced.

The main tasks of the body's immune system include:

- Fighting disease-causing germs (pathogens) such as bacteria, viruses, parasites, or fungi, and to remove them from the body.
- To recognize and neutralize harmful substances from the environment.
- To fight disease-causing changes in the body such as cancer cells.

There are two subsystems within the immune system, which are known as the innate (non-specific) immune system and the adaptive (specific) immune system. Both subsystems are closely linked and work together whenever a germ or a harmful substance triggers the immune response. The innate immune system provides a general defense against harmful germs and substances, so it's called the non-specific immune system. It protects the body by using various immune cells such as natural killer cells and phagocytes (cell that eat up debris and pathogens). The main job of the innate immune system is to fight harmful substances and germs that enter the body. The adaptive (specific) immune system produces antibodies, which are used to fight germs. The first time the body is exposed to a specific germ, it produces an antibody that is specific to that germ. This creates an arsenal of antibodies for many different germs that the body is exposed to over the years, so when the body is exposed to a germ again, it has the ability to fight that germ and illnesses quickly. This is also known as an "acquired" (learned) or specific immune response. Because the adaptive immune system is constantly learning and adapting, the body can also fight bacteria or viruses that change over time.

The immune system can be activated by many different things that the body doesn't recognize as its own. These are called antigens, which include things such as the proteins on the surfaces of bacteria, fungi, and viruses. When these antigens attach to special receptors on the immune cells, a whole series of processes are triggered within the body. Once the body has come into contact

with a disease-causing germ for the first time, it will store this information about the germ and produce the needed antibodies to fight it. The amazing thing about the immune system and these antibodies is that they have memory, so if you are exposed to that germ, it recognizes the germ right away and can fight the infection faster. The body's own cells also have proteins on their surface, which those proteins don't usually trigger the immune system to fight the cells. Sometimes the immune system mistakenly thinks that the body's own cells are foreign cells, and it attacks these healthy, harmless cells in the body. This is known as an autoimmune response.

Inflammation:

Inflammation is the body's natural response to injury, irritation, or infection. Inflammation is known as "an internal fire". Inflammation is the immune system's response to harmful stimuli, such as pathogens, damaged cells, toxic compounds, or irradiation, and acts by removing injurious stimuli and initiating the healing process. Inflammation is therefore a defense mechanism that is vital to health. The inflammatory process is a normal process. If you stepped on a rusty nail and you didn't have a natural inflammatory process, what would happen?

Functions of the inflammatory response include:

- Reduces the spread of damaging agents or microbes.
- Disposes of cell debris and pathogens through phagocytosis.
- Sets the stage for repair.

Inflammation is beneficial to the body, as this process helps to neutralize harmful microorganisms, helps to repair a wound, and cleans up the debris resulting from an injury. During an acute inflammatory response, cellular and molecular events and interactions efficiently minimize impending injury or infection. This mitigation process contributes to restoration of tissue homeostasis and the resolution of inflammation. However, uncontrolled acute inflammation may become chronic, contributing to a variety of chronic inflammatory diseases. (Chen, 2017)

There are four common signs of the inflammatory process, which include:

- Redness (rubor) due to hyperemia.
- Swelling (tumor) due to the increased permeability of the microvasculature and leakage of protein into the interstitial space.
- Heat (calor) created by the increased blood flow to the injured area and the metabolic activity of the cellular mediators.
- Pain (dolor) due to changes in the perivasculature and associated nerve endings.

Some of the common contributing factors of inflammation include:

- SAD diet
- Infection
- Physical injuries
- Allergies & food sensitivities
- Drugs – misuse of antibiotics
- Chronic stress

- Insomnia & poor sleep habits
- Environmental toxins
- Smoking
- Excessive alcohol intake
- Adipose tissue (fat cells)

One common ongoing source of inflammation in the body relates to leaky gut, which refers to the intestinal lining being semi-permeable. With intestinal permeability, if partially undigested foods (not chewing/digesting properly), toxins or allergens pass through the intestinal lining into the blood and lymphatic system (GALT – gut-associated lymphoid tissue); the immune cells attack these foreign invaders, leading to an allergic response and inflammation.

The intestinal lining will become damaged due to repeated exposure from allergens and toxins, which damage the microvilli. This further contributes to the development of more and new allergies. Once the microvilli are damaged, digestion is impaired & the absorption of nutrients from food decreases. With absorption being reduced, one cannot fight off inflammation naturally, as they are deficient in the vitamins and minerals needed to help fight inflammation.

Poor digestion also leads to inflammation, as low hydrochloric acid (HCl) contributes to larger food particles entering the bloodstream from the intestinal lining. Low HCl also leads to poorly digested protein, which amino acids are needed to manufacture the enzymes needed to help digest and break down food properly. Poor digestion overburdens the immune system leading to the inflammatory process, which then triggers more inflammation to continuously cycle through the blood. Inflammation then becomes chronic, affecting the nerves, organs, joints, and many other body tissues.

Inflammation is a common pathogenesis of many chronic diseases, including cardiovascular, bowel diseases, diabetes, arthritis, obesity, and cancer. When inflammation becomes chronic, it denotes any illness ending in 'itis' such as arthritis, bursitis, hepatitis, nephritis, gastritis, sinusitis, and tendonitis. Systemic inflammation can happen in the body without one being aware. It can contribute to the development of illnesses such as Alzheimer's, diabetes, osteoporosis, and cancer.

Most people today suffer from systemic silent inflammation, not relating it to the root factor of other symptoms or conditions they may be suffering from. Blood tests for inflammatory markers such as C-reactive protein (CRP) are a means of determining your level of silent inflammation. This type of test can be required through a licenced medical doctor.

Stress is a state of threatened homeostasis provoked by a psychological, environmental, or physiological stressor. All stress creates an inflammatory state caused by the over-production of pro-inflammatory agents in the body. Both pro-inflammatory and anti-inflammatory mechanisms depend on the type and intensity of stressors. Acute stressors seem to enhance immune function, whereas chronic stressors are suppressive. Intense stressors over-activate the immune system, leading to the imbalance of inflammation and anti-inflammation. (Liu et al., 2017)

Stress also creates issues with the permeability of the intestinal lining. Raised cortisol levels affect the intestinal lining causing it to become more permeable, which contributes to leaky gut. Stress can affect digestion, as when one is stressed, they are in a fight-or-flight response instead of rest and digest. This contributes to poor digestion and increases the inflammatory response.

The role of cortisol in the body is well-known as an anti-inflammatory agent. At normal levels, cortisol neither promoted nor suppresses inflammation. At high levels, when dealing with stress (acute), cortisol suppresses inflammation. However, when dealing with systemic inflammation, the body produces more cortisol creating higher than normal levels, which can create a resistance to its natural anti-inflammatory effects in the body. Chronically elevated cortisol levels are both inflammatory and catabolic, which can contribute to many different health disorders.

The role of inflammation and free radical damage (oxidant stress) contributing to the development of heart disease is evident. Repeated injury from oxidative stress and free radicals triggers an ongoing inflammatory response, which over time, contributes to the build-up of plaque in the arteries aiding the development of atherosclerosis. Any type of rupture in this plaque forms a thrombosis (clot), which can create a high risk of having a myocardial infarction (heart attack) or stroke. (Aimo et al, 2019)

Another factor in systemic, chronic inflammation is adipose tissue (fat cells), especially around the abdomen (visceral or belly fat). Obesity was known as a fat deposit disease; now research shows that obesity is a low-grade chronic and systemic inflammatory disease. Excess weight contributes to inflammation because fat cells secrete chemicals such as C-reactive protein and interleukin-6, which promote inflammation. Visceral fat produces large amounts of inflammatory cytokines. Obesity creates a higher risk factor of developing insulin resistance and diabetes, which contributes to a higher risk of heart related disorders such as high cholesterol, high blood pressure, heart attack and stroke. (Ellulu et al, 2017)

Exposure to chemicals, irritants, and pollution can also create inflammation in the body. We are exposed to certain chemicals that have the ability to stimulate the body to produce an allergic reaction after repeated exposure. Other chemicals that we are exposed to, that have known carcinogenic or mutagenic properties, can cause an inflammatory reaction, possibly organ damage, and even cancer. One example of a chemical that can cause hypersensitization is formaldehyde. When we are exposed to carcinogenic agents, it alters the DNA structure of the cell, which causes the cells to replicate abnormally. These abnormal cells are mutated or cancerous cells; the T-cells of our immune system recognize these mutated cells and initiate a response to destroy them. The inflammatory response is one of the processes initiated by the immune system to deal with these mutated cells in the body.

The fact that the immune system drives the inflammatory process in disease is well established. Western medicine offers little in the way of actual answers in dealing with illnesses promoted by inflammation. The typical approach is to suppress the immune response with immune suppressive agents or steroids. Both approaches are designed to reduce inflammation, but neither stops the underlying contributor to disease nor allow for damaged tissues to regenerate. Unless one turns off the actual causes of inflammation, all that is done is delay the inevitable and potentially destroy more body processes (healthy immune function).

Inflammation needs to be addressed at the root, which this can be done with proper diet, lifestyle, and mindset.

Avoiding pro-inflammatory foods such as omega 6 oils from saturated fat, rancid and hydrogenated oils, commercially raised meat and dairy, processed meats, refined sugar, and flours. Limit alcohol intake, avoid artificial food additives (MSG), junk foods, and packaged foods. Common food allergens such as dairy, gluten, soy, and peanuts increase inflammation and should be avoided. Nightshade vegetables such as potato, tomato, peppers, and eggplant are known to create inflammation in people that are sensitive to this group of vegetables.

Nutrients that have anti-inflammatory properties include:

- Vitamin A
- Vitamin C
- Vitamin D
- Vitamin E
- Zinc
- Flavonoids such as rutin, apigenin, and quercetin
- Proteolytic enzymes bromelain and papain
- Omega 3
- Melatonin
- Probiotics

There are many foods that are rich in the above anti-inflammatory nutrients that can be added to the diet on a daily basis to help reduce inflammation in the body.

Anti-inflammatory foods include:

- Dark green vegetables such as kale, spinach, and beet greens
- Bright coloured vegetables such as beets, carrots, and purple cabbage
- All types of fruit such as berries, cherries, apples, peaches, apricots, oranges, pineapple, and pomegranate
- Fatty fish
- Avocados and olives
- Flax, chia, and pumpkin seeds
- Onions, garlic, and turmeric

Since stress is a contributing underlying factor of inflammation, adding lifestyle suggestions to help reduce and manage stress can benefit the body.

Stress management suggestions include:

- Moderate daily exercise
- Yoga
- Sauna
- Lymph baths with Epsom salts
- Skin brushing

- Lymph massage
- Have a positive mindset and include laughter, smile, and give gratitude
- Stop smoking
- Reduce exposure to chemicals by using natural cleaning and body care products

1. Nutrition: Stage of Life

Eating habits are vital to children's health and well-being, potentially impacting physical, emotional, and psychological development. Given the exceeding worldwide occurrence of childhood obesity and related health issues, the relevance and urgency of understanding children's eating habits has become paramount. Studies have found that the prevalence of unhealthy eating habits and obesity in children is alarmingly high, with significant long-term consequences. Engaging in unhealthy eating habits during childhood can set a trajectory for adverse health outcomes, including obesity, diabetes, and cardiovascular diseases well into adulthood. The prevalence of childhood obesity has been connected to unhealthy dietary habits, with high consumption of energy-dense and nutrient-poor foods and a low intake of fruits and vegetables. Furthermore, the consequences of such unhealthy eating habits extend beyond physical health, impacting mental health, cognitive development, academic performance, and emotional well-being. Healthy childhood eating habits are crucial as they create the foundation for long-term dietary patterns, influencing the threat of developing diseases like obesity, diabetes, and cardiovascular problems later in life (Abdoli et al, 2023).

The health of children must start before birth, even prior to conception.

Pediatric Nutrition: Conception & Prenatal:

To increase the chances of a healthy pregnancy, incorporating sound prenatal nutrition is key, not only for the outcome of the pregnancy, but also the birth of a healthy baby.

From a biological perspective, there is a critical period spanning the weeks around conception when gametes mature, fertilization occurs and the developing embryo forms. These are the events most sensitive to environmental factors such as the availability of macro and micronutrients or exposure to smoking, alcohol, drugs, or other teratogens. For prevention of neural tube defects, a minimum of 4-6 weeks folic acid supplementation is required to reach adequate levels before neurulation begins three weeks after conception. In relation to individual action, the preconception period starts whenever a couple decide they want to have a baby, as the time to conception is unknown. Since about a third of fertile couples having regular sex without contraception will conceive within one month, optimising nutrition, including folic acid supplementation, should coincide with the decision to become pregnant. The preconception period may reflect the time required by individuals to achieve desired health outcomes in preparation for pregnancy, such as six or more months to attain a healthy BMI. Maternal motivation to improve health at this stage can be strong. (Stephenson et al, 2018)

A person who is healthy at the time of conception is more likely to have a successful pregnancy and a healthy child. Observational studies show strong links between health before pregnancy and maternal and child health outcomes, with consequences that can extend across generations. Health around the time of conception, once a neglected topic, is now a focus of increasing interest, reflected in numerous recent reports from national and international health agencies. (Stephenson et al, 2018)

Both maternal underweight and overweight are associated with substantial risks for maternal and child health. Obesity is associated with increased risk of most major adverse maternal and perinatal outcomes, from inability to conceive to complications of pregnancy (pre-eclampsia, gestational diabetes) and delivery (macrosomia), congenital anomalies, stillbirth, and low birth

weight, unsuccessful breastfeeding, and even maternal death. Although the benefits of preconception weight loss remain to be established through clinical trials, observational studies indicate the likely effects of preconception weight loss on pregnancy outcomes. In a population-based study in Canada with 226,958 singleton pregnancies, a preconception weight loss of 10% was associated with clinically meaningful risk reduction in pre-eclampsia, gestational diabetes, preterm delivery, macrosomia, and stillbirth. (Stephenson et al, 2018)

With fetal overnutrition from maternal obesity, Diabetes Mellitus (DM), and high fat and sugar intake may result in macrosomia or large gestational age (LGA). These conditions that present excess glucose and lipid supply to the fetus are increasingly common and associated with several complications. There is increasing evidence that persistent, very high fetal glucose concentrations can inhibit fetal neuronal development, leading to reduced neuronal number, dendritic proliferation, and synapse formation, ultimately leading to reduced cognitive function in such offspring later in their lives. In addition, maternal overnutrition plays an important role in the early origins of childhood obesity and inflammatory diseases, such as non-alcoholic fatty liver disease (NAFLD), the most common liver disease worldwide affecting 1 in 3 youth with obesity. Data in humans demonstrated that liver fat is 68% higher in neonates born to mothers with obesity. (Marshall et al, 2021)

During extremes of maternal undernutrition, the fetus develops chronic (fetal growth restriction) FGR, a prime example of “survival at the expense of growth.” This phenotype includes decreased pancreatic growth, development, and insulin secretion; increased capacity for glucose uptake in peripheral tissues (such as skeletal muscle); reduced utilization of amino acids for protein synthesis and cell growth; and development of hepatic insulin resistance with increased glucose production in an ovine model that produced hypoxia and reduced nutrient supply in the fetus. Recent data indicated that nutritional support and exercise before pregnancy may be more efficacious in promoting healthy placentation and fetal growth than during pregnancy for maternal underweight. (Marshall et al, 2021)

Diet and nutrition before pregnancy may modify maternal and perinatal outcomes via effects on BMI (as above) or other nutritional factors, including micronutrient deficiencies. WHO estimates that around two billion people are deficient in micronutrients, with women being at particular risk because of menstruation and the high metabolic demands of pregnancy. Globally, maternal undernutrition and its consequences, including fetal growth restriction, stunting, wasting, vitamin A and/or zinc deficiency, together with sub-optimal breastfeeding, is estimated to account for 3.1 million child deaths annually, or 45% of all child deaths in 2011. (Stephenson et al, 2018)

The period around conception (two to three months before and after) is a critical period for optimizing gamete function, and early placental development. In this period, folic acid supplementation can reduce the risk of neural tube defects by as much as 70%. Other benefits of folic acid supplementation during periconception may include decreased risk of pre-eclampsia, miscarriage, low birth weight, small for gestational age, stillbirth, neonatal death, and autism in children. The consequences of maternal-fetal iron deficiency also fit a critical period model in which repletion after an undetermined time-point fails to rectify structural impairments to developing brain structures. (Stephenson et al, 2018)

In experimental animal models, dietary restriction of iron from the beginning of gestation can induce a 40–50% decrease in brain iron 10 days after birth and preconception zinc deficiency compromises fetal and placental growth and neural tube closure. These preconception risk factors

can set patterns that have a cumulative effect on health into adulthood and for future generations, as shown by mounting evidence of the long-term impact of poor maternal nutrition and obesity for the child. (Stephenson et al, 2018)

Pregnancy is a time of rapid and profound physiological changes from the time of conception until birth. Nutritional requirements increase during pregnancy to maintain maternal metabolism and tissue accretion while supporting fetal growth and development. (Mousa et al., 2019)

What should a healthy diet for a pregnant person look like? The message should be “eat better, not more.” This can be achieved by basing diet on a variety of nutrient-dense, whole foods, including fruits, vegetables, legumes, whole grains, healthy fats with omega-3 fatty acids that include nuts and seeds, and fish, in place of poorer quality highly processed foods. Such a diet embodies nutritional density and is less likely to be accompanied by excessive energy intake than the Standard American Diet consisting of increased intakes of processed foods, fatty red meat, and sweetened foods and beverages. Women who report “prudent” or “health-conscious” eating patterns before and/or during pregnancy may have fewer pregnancy complications and adverse child health outcomes. Comprehensive nutritional supplementation (multiple micronutrients plus balanced protein energy) among women with inadequate nutrition has been associated with improved birth outcomes, including decreased rates of low birthweight. A diet that severely restricts any macronutrient class should be avoided during pregnancy. Fad diets as promoted by the popular press are widespread and may be especially harmful during pregnancy because of resulting micronutrient deficiencies or ketosis. (Marshall et al, 2021)

Energy intake requirements in pregnancy match the demands of resting metabolism, physical activity, and tissue growth. Energy balance in pregnancy is, therefore, defined as energy intake equal to energy expenditure plus energy storage. One of the key factors for achieving optimal pregnancy outcomes is energy balance or the relationship between energy intake, energy expenditure and energy storage in maternal and fetal tissues. The energy intake requirement for a pregnant woman reflects the amount of energy needed to support maternal and fetal metabolism (energy expenditure) and fetal growth and accumulation of energy depots during pregnancy (energy storage). Individual energy requirements depend on numerous factors such as maternal pre-gravid body size, physical activity, and the physiological demands of pregnancy in each trimester. (Most et al, 2019)

Total daily energy expenditure (TDEE) increases by approximately 15 kcal per day per week or by 420 kcal per day from pre-pregnancy to delivery. Energy expenditures from the second to the third trimester are linearly related to weight gain with an estimated 45–170 kcal/d increase. Independent of BMI, the weight gain recommendations during the first trimester are 0.5 to 2.0 kg for all women. To date, no study has assessed the composition of early pregnancy weight gain, specifically for women that adhered to this recommendation. Using a conservative estimate for the energy density of overall weight gain (7400 kcal/kg), the energy requirements for weight gain in early pregnancy are ~3,700–14,800 kcal, or 40–165 kcal/d over 13 weeks. Several studies have assessed the energy requirements for weight and fat mass gain during the second and third trimesters, yet few studies have determined these requirements specific to women who gained the recommended amount of weight. Pregnant women with a normal weight and recommended weight gain (BMI 19.8–26 kg/m² and 11.5–16 kg, respectively) accumulated ~4 kg of fat mass between 14- and 37-weeks gestation. The energy intake requirements to support this energy deposition in fat is ~240 kcal/d over 22.7 weeks. For underweight or overweight women, gains in fat mass were 6.0 and 2.8 kg, and the respective energy intake requirements were 360 kcal/d and

165 kcal/d. For women with obesity, we have recently shown that recommended weight gain is achieved with an average 2.5 kg loss of fat mass (15 to 36 weeks of gestation). The Institute of Medicine estimates the energy requirements during the second and third trimester to be 340 kcal/d and 452 kcal/d. The energy intake requirements model by Thomas et al. (2012) estimated surplus energy requirements to be only 400–600 kcal/d for underweight and normal-weight women, and 220–350 kcal per day for overweight or obese pregnant women. (Most et al, 2019)

Pregnancy has traditionally been considered a time for weight gain, not weight loss. The obligatory weight gain during pregnancy is approximately 8 kg which accounts for the fetus, the placenta, amniotic fluid volume, and adaptations to maternal tissues (e.g., uterus, breast, blood volume). (Kominiarek & Rajan, 2016)

Protein is involved in both structural (keratin, collagen) and functional (enzymes, protein transport, hormones) biological roles. Globally, the primary sources of protein are plant-based foods such as legumes, grains, and nuts (57% of daily intake) followed by animal-based foods such as meat (18%) and dairy (10%), although small amounts may also be derived from alternative sources such as algae, bacteria, and fungi (mycoproteins). Pregnant women in developed countries report consuming 14.7% to 16.1% of total energy from protein, which is adequate based on current recommendations. Adjustments in protein metabolism occur within several weeks of conception in order to maintain maternal homeostasis while accommodating increased fetal demands and preparing for lactation. Whole-body protein turnover studies suggest that protein turnover in early pregnancy is similar in pregnant and non-pregnant women, but a 15% and 25% absolute increase in protein synthesis occurs during the second and third trimesters. Overall, a protein intake of 10–25% of total energy appears to be safe, whereas the risks associated with high protein intake or supplement use cannot be ascertained from the small number of existing trials. Until more evidence is made available, protein intake during pregnancy should be kept at a moderate level (within 25% of total energy). (Mousa et al., 2019)

Recommended protein intake during pregnancy is 60g/day, which represents an increase from 46g/d in non-pregnant states. In other words, this increase reflects a change to 1.1g of protein/kg/day during pregnancy from 0.8g of protein/kg/day for non-pregnant states. (Kominiarek & Rajan, 2016)

Different sources of carbohydrates have variable digestion rates, thus their effects on blood glucose and insulin levels also vary. The glycemic index (GI) quantifies glycemic responses induced by carbohydrates from different foods. High GI foods, including rice, white bread, and potatoes, cause a sharp rise in blood glucose levels which decline rapidly, whereas low GI foods such as fruits or dairy have slowly digestible carbohydrates which result in a lower postprandial glucose response. Glycemic load (GL) takes into account both the quality (GI) and quantity of carbohydrates in food and is obtained by multiplying the GI by the carbohydrate content of a given food. Dietary fibre describes a variety of plant-based carbohydrates that are resistant to digestion by human gastrointestinal enzymes. These include soluble fibre (fruits, vegetables, legumes), insoluble fibre (nuts, wholegrain bread, or cereals) or resistant starch. Diets high in fibre and with a low GI and GL can promote laxation, reduce blood cholesterol, and modulate blood glucose and hence may be beneficial in pregnancy. (Mousa et al., 2019)

Carbohydrates should comprise 45-64% of daily calories and this includes approximately 6-9 servings of whole grain daily. Total fat intake should comprise 20-35% of daily calories, similar to non-pregnant women. (Kominiarek & Rajan, 2016)

Essential fatty acids include linoleic and alpha-linoleic acid as well as their long-chain derivatives, arachidonic acid (AA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are key structural components of cell membranes and are vital for tissue formation. Dietary sources include oil-rich fish such as mackerel or salmon, as well as fish oil supplements (mainly omega-3). Over the course of pregnancy, maternal concentrations of essential fatty acids decrease by approximately 40%, with AA (n-6) and DHA (n-3) reducing by ~23% and ~52% by the time of birth. Therefore, dietary intake of fatty acids, particularly long-chain polyunsaturated fatty acids (PUFAs) such as DHA and EPA, is important during pregnancy to meet the requirements of the mother as well as the developing fetus. DHA can influence the development of the brain and retina in the fetus, while EPA may reduce the synthesis of thromboxane A₂ (a known vasoconstrictor that gets activated during times of tissue injury and inflammation) from AA, thereby potentially reducing the risk of preeclampsia and timing to parturition. (Mousa et al., 2019)

Studies regarding the risks and benefits of fish during pregnancy can often seem contradictory. This is in part due to that most fish contain competing benefits and risks in the forms of omega-3 fatty acids and mercury. Omega-3 fatty acids are critical for fetal brain development and have been associated with improved vision in preterm infants, as well as better cardiovascular health later in life. Higher mercury levels in children, however, have been associated with deficits in memory, learning, and behavior. Ideally, pregnant women would consume those fish that are low in mercury and high in omega-3 fatty acids such as salmon, sardines, and anchovies. High mercury fish such as shark, swordfish, tilefish, and king mackerel should be avoided. The Federal Drug Administration (FDA) and the Environmental Protection Agency (EPA) websites offer information regarding local fish and their mercury content. (Kominiarek & Rajan, 2016)

Folate is a water-soluble B vitamin present in leafy green vegetables, nuts, and liver. Some breads and breakfast cereals are fortified with folic acid, the synthetic form of folate. Folate functions as a coenzyme in one-carbon transfers during methylation cycles and is therefore integral for the synthesis of DNA and neurotransmitters. It is also involved in amino acid metabolism, protein synthesis and cell multiplication, making it particularly important during embryonic and fetal stages of pregnancy where there is rapid cell division and tissue growth. Folate deficiency results in the accumulation of homocysteine, which can increase the risk of adverse outcomes including preeclampsia and fetal anomalies. There is no universal cut-off for deficiency in pregnancy, but folate concentrations usually decline during gestation, likely due to increased folate demands to facilitate increases in blood volume, hormonal changes and fetal and uteroplacental organ development. (Mousa et al., 2019)

Deficiencies in folate have been associated with megaloblastic anemia in pregnancy, though not with other pregnancy outcomes such as preterm birth or stillbirths. (Kominiarek & Rajan, 2016)

Iron supplements have routinely been recommended in pregnancy because iron needs nearly double during pregnancy. A standard prenatal vitamin contains 27 mg of elemental iron. Vitamin C supplements can assist with iron absorption, whereas milk and tea can inhibit iron supplementation. (Kominiarek & Rajan, 2016)

Iron is a vital nutrient and cofactor for the synthesis of hemoglobin and myoglobin, as well as for several cellular functions including oxygen transport, respiration, growth, gene regulation and the proper functioning of iron-dependent enzymes. Intracellular homeostasis and proper balance of iron stores are therefore tightly regulated. Yet, iron deficiency remains the leading single-nutrient

deficiency worldwide, affecting over two billion people including $\geq 30\%$ of pregnant women in the industrialized world, with higher rates in developing countries. Iron deficiency results from poor dietary intake of absorbable iron (or insufficient intake to meet increased demands in pregnancy) and/or loss of iron through parasitic infections (e.g., hookworm) or blood loss. Plant-based foods such as green leafy vegetables contain non-heme iron, which makes up the major fraction of dietary iron. However, heme iron from foods such as animal meats and fish has a higher bioavailability and is absorbed more efficiently, making it the main source of dietary iron for mammals. In pregnancy, the demand for iron increases from 0.8 to up to 7.5 mg/day of absorbed ferritin, although the exact upper limits in the third trimester are debated. (Mousa et al., 2019)

Vitamin A is a fat-soluble vitamin derived from either preformed retinoids or provitamin carotenoids. Retinoids, such as retinal and retinoic acid, are obtained from animal sources including eggs, dairy, liver, and fish liver oil. Carotenoids such as beta-carotene are obtained from plant sources such as dark or yellow vegetables including kale, sweet potatoes and carrots and can be converted to vitamin A in the liver where vitamin A is stored. Physiological functions of vitamin A include vision, growth, bone metabolism, immune function, and gene transcription as well as antioxidant activities. Some additional vitamin A is needed during pregnancy to support growth and tissue maintenance in the fetus and to provide fetal reserves and aid in maternal metabolism. Pregnant women have a basal requirement of 370 $\mu\text{g/day}$ and a daily intake of 770 $\mu\text{g/day}$ is recommended, which is thought to be supplied by maternal liver stores in women without deficiency. (Mousa et al., 2019)

Vitamin A is essential for cell differentiation and proliferation as well as development of the spine, heart, eyes, and ears. Offspring of mothers with vitamin A deficiency have a higher mortality rate, which may be associated with decreased immune function. Although most micronutrients have a wide safety margin with little concern for teratogenic effects, vitamin A is one exception. Excessive doses of Vitamin A ($>10,000$ IU/day) have been associated with cranial-facial (face, palate, ears) and cardiac birth defects. The maximal supplement in pregnancy is 8000 IU/day. It is the retinol form of Vitamin A that is associated with teratogenic effects, not the carotenoid version found in food sources such as carrots. (Kominiarek & Rajan, 2016)

Vitamin D is a fat-soluble vitamin known for its role in maintaining calcium homeostasis and bone integrity. Extra-skeletal functions of vitamin D are also widely recognized including its role in glucose metabolism, angiogenesis (the formation of new blood vessels), inflammation, and immune function, as well as in regulating gene transcription and expression. Vitamin D is obtained primarily via subcutaneous synthesis following ultraviolet-B radiation (sun exposure) and is also found in a few foods including oily fish or fortified dairy products and in supplements in the form of cholecalciferol (vitamin D3) or ergocalciferol (vitamin D2). In pregnancy, the fetus relies completely on maternal vitamin D stores for its development. (Mousa et al., 2019)

The relationship between low vitamin D and adverse maternal outcomes such as pregnancy induced hypertension, high blood pressure in diabetic pregnancy, gestational diabetes mellitus, recurrent pregnancy loss, preterm delivery, primary Caesarian section, and postpartum depression has been documented in recent years. Randomized controlled trials are available to support the need for, and benefits of, vitamin D supplementation in pregnancy. While older studies were relatively smaller, and limited to 3-4 months duration, newer data proves the safety and efficacy of 4000 IU vitamin D, administered daily over 6 months of pregnancy. The recommended daily intake of vitamin D ranges from 400 to 600 IU (by the IOM), 400 IU (by the National Institute

for Health and Clinical Excellence, United Kingdom), and to 1500-2000 IU (by the Endocrine Society), and 2000 IU (by the Canadian Society). Results of the recently conducted randomized controlled trial on vitamin D supplementation in pregnancy suggest a safe dose of 2000-4000 IU/day. (Mithal & Kalra, 2014)

B-complex vitamins including vitamins B1 (thiamine), B2 (riboflavin), B3 (niacin), B6 (pyridoxine) and B12 (cyanocobalamin) are water-soluble vitamins required for the production and release of energy in cells and for the metabolism of protein, fat, and carbohydrates. These vitamins act as coenzymes in several intermediary metabolic pathways for energy generation and blood cell formation. Vitamin B12 functions alongside folate to convert homocysteine to methionine, a process which is essential for the methylation of DNA, RNA, proteins, neurotransmitters, and phospholipids. Deficiency in these vitamins can therefore impact on cellular growth as well as on nerve tissue development due to its high-energy demand. Most prenatal supplements include B-complex vitamins, yet, with the exception of vitamin B12, the individual metabolic roles of B vitamins are not well defined in pregnancy. B-complex vitamins are obtained primarily from animal sources including meat, poultry, fish, and dairy products and can also be found in fortified cereals, legumes, and leafy green vegetables. The requirement for these vitamins is heightened in pregnancy due to increased energy and protein needs, particularly during the third trimester. However, adaptive responses during pregnancy reduce urinary excretion of some B vitamins, including riboflavin, to help meet increasing demands. (Mousa et al., 2019)

Calcium is an essential nutrient for bone mineralization and a key intracellular component for maintaining cell membranes. It is involved in several biological process including signal transduction, muscle contraction, enzyme, and hormone homeostasis, as well as neurotransmitter release and nerve cell function. Milk and dairy products are the best sources of calcium, and it can also be derived from leafy green vegetables, nuts or fortified foods including flour and dairy alternatives. In pregnancy, calcium is actively transported across the placenta and maternal calcium demands increase, particularly during the third trimester. More efficient uptake and utilisation of calcium occurs naturally during pregnancy via physiological adaptations, including increased calcium absorption stimulated by hormones (vitamin D, estrogen, lactogen and prolactin) and enhanced retention of calcium by kidney tubules. Increased calcium needs may therefore be met by diet alone (1.2 g/day recommended); however, supplementation of 0.3–2.0 g/day is recommended by some to preserve maternal calcium balance and bone density and to support fetal development, particularly in women with low dietary calcium intake (<1 g/day). (Mousa et al., 2019)

Iodine is an essential nutrient for regulating growth, development, and metabolism via the biosynthesis of thyroid hormones including thyroxine (T4) and triiodothyronine (T3). Iodine is obtained mainly from fortified salt, but it can also be sourced from kelp and seafood, as well as dairy or plant foods in places with iodine-fortified animal feed or iodine-rich soil. During pregnancy, metabolic demands and hormonal alterations result in a substantial increase in iodine requirements. This is because early in gestation, thyroid hormone production increases by 50% and renal excretion of iodine increases by 30–50%, while later in gestation, iodine passes the placenta for fetal thyroid hormone production. Maternal and fetal thyroid hormones regulate key processes in the development of the fetal brain and nervous system, including the growth of nerve cells, the formation of synapses and myelination. Only small amounts of iodine (150–290 µg/day) are required to reduce deficiency. (Mousa et al., 2019)

Zinc is an important catalytic component of over 200 enzymes and structural component of several nucleotides, proteins, and hormones. It has critical ubiquitous roles in biochemical functions including protein synthesis and nucleic acid metabolism, as well as cellular division, gene expression, antioxidant defences, wound healing, vision, and neurological and immune function. Zinc is present in many foods, but higher levels can be found in meat, seafood, milk, and nuts, whereas diets high in fibre or phytate can reduce the bioavailability of zinc. Zinc deficiency is proposed to contribute to about half a million maternal and child deaths annually, mostly in developing countries. Zinc deficiency in pregnancy has been associated with impaired immunity, prolonged labour, preterm and post-term births, intrauterine growth retardation, low birth weight (LBW) and pregnancy-induced hypertension.

Despite a large body of evidence supporting the importance of adequate nutrition in pregnancy, around 20% to 30% of pregnant women worldwide suffer from some vitamin deficiency (Mousa et al., 2019). Consuming a healthy diet rich in whole natural foods along with a good quality prenatal supplement can ensure all nutrient needs are met during pregnancy.

Lactation

Human milk provides personalized nutrition and is associated with long-term health benefits for infants and mothers. According to the 2012 American Academy of Pediatrics policy statement, “Given the documented short- and long-term medical and neurodevelopmental advantages of breastfeeding, infant nutrition should be considered a public health issue and not only a lifestyle choice.” Milk composition is influenced by maternal dietary intake during lactation and maternal adipose nutrient stores, which together are responsible for the nutrients available for milk biosynthesis and ultimately maternal milk and nutrient production. To meet all infant nutritional needs, human milk is constantly changing, composition varies by infant age, between breasts, within a feed, throughout the day, during lactation, among women, and among populations. (Marshall et al, 2021)

Regarding individual macronutrients, maternal diet does not have a major impact on milk protein content or the total amount of fat in human milk, but it affects the types of fatty acids (FAs) present in breast milk. Maternal adipose stores remain an important source of nutrients for human milk, although women with greater fat mass do not produce more or higher fat milk. Different lipids are the most variable component of human milk. Lipid composition variability is inversely related to the degree of breast fullness and milk volume. In addition to macronutrients and essential micronutrients, there is moderate evidence that flavours from the maternal diet during lactation are transferred into breast milk and that infants can detect diet-transmitted flavours, which may impact future taste preferences. The ratio of omega-6 vs omega-3 FAs in human breast milk seemed to promote postnatal fat development. (Marshall et al, 2021)

Breast milk is recommended as the infant’s sole source of nutrition for the first 6 months of life. It is recommended that complementary foods be added to the infant’s diet at 6 months of age and that breastfeeding continue up to two years of age and beyond. High maternal self-efficacy is associated with prolonged breastfeeding. A woman’s confidence in her breastfeeding ability is positively influenced by her exposure to breastfeeding and her personal breastfeeding experience. In addition, maternal attitudes toward breastfeeding have an impact on duration. Those who perceive breastfeeding to be healthier, easier, and more convenient breastfeed longer than those

who perceive that breastfeeding is restrictive, inconvenient, and uncomfortable. (Dieterich et al, 2013)

Breast milk has evolved to provide the best nutrition, immune protection, and regulation of growth, development, and metabolism for the human infant. Breast milk is critical in compensating for developmental delays in immune function in the neonate, and responsible for reducing permeability of the intestine to prepare it for extrauterine life. The predominant antibody in breast milk, secretory IgA (sIgA), confers its immune protection by inhibiting the adherence to or penetration of the gastrointestinal (GI) tract by pathogens and by phagocytosis or cytotoxicity of pathogens. sIgA is higher in colostrum than mature milk, is present in a form resistant to digestion, and provides key temporal and ubiquitous immune protection. Additional, acquired secretory antibodies such as IgM and IgG, depend on prior maternal exposure to pathogens, and provide the infant with environment-specific immune protection. (Dieterich et al, 2013)

The favorable gut microbiome that results from breastfeeding protects the infant from pathogenic bacteria and has also been associated with reduced asthma and reduced obesity rates in children. This microbiome is a function of the interaction between human milk's microbiota such as Bifidobacteria and Lactobacilli, and the oligosaccharides which serve as fuel for these bacteria; these components resist digestion and have important antimicrobial activity. The healthy microbiome promotes integrity of the intestinal barrier and competitively inhibits pathogen binding, thereby preventing inflammatory responses. Additionally, the gut microbiota contributes to regulation of the expression of genes that affect fat metabolism and deposition. (Dieterich et al, 2013)

Microbiota of the healthy GI tract are one of many examples of the functional efficiency of breast milk as they provide both immune protection and nutrients by synthesizing several essential micronutrients, namely vitamins B12, B6, folate, and vitamin K. Lactoferrin is another key example of functional efficiency as it aids in iron absorption, provides a significant proportion of digested amino acids, and provides immune protection by promoting epithelial growth and restricting bacterial access to iron. Digested milk fat globules yield monoglycerides and medium- and long-chain fatty acids with additive antimicrobial properties, and undigested milk fat globules function as vehicles for small proportions of sIgA. (Dieterich et al, 2013)

Finally, breast milk contains hormones, neuropeptides and growth factors that may affect growth, development, and self-regulation of food intake, contributing to the differences observed between breastfed and formula-fed infants. Leptin suppresses appetite, and infant serum leptin is positively correlated with maternal concentrations. Ghrelin, which stimulates appetite, is found in higher concentrations in foremilk than in hindmilk. This concentration difference may also contribute to the better self-regulation of intake in breastfed infants compared to formula-fed infants, and is thus a potential explanation for increased bottle-emptying behavior that is observed among bottle-fed infants. (Dieterich et al, 2013)

Nutrient needs during lactation depend primarily on the volume and composition of milk produced, and on the mother's initial nutrient needs and nutritional status. Among women exclusively breastfeeding their infants, the energy demands of lactation exceed pre-pregnancy demands by approximately 640 kcal/day during the first 6 months post partum. If the mother ingests lower amounts of a nutrient than she requires to meet her own needs and to cover

nutrients secreted in the milk, she can draw upon body stores. (Institute of Medicine (US) Committee on Nutritional Status During Pregnancy and Lactation, 2016)

Best way to ensure the quality and quantity of milk production plus meet the required daily needs of all nutrients is to keep consuming a prenatal diet full of nutrient rich whole foods plus a prenatal supplement.

The advantages of breastfeeding for mothers are not as well studied as those for infants, but there is adequate evidence to state that women who breastfeed are likely to have improved health in the short-term, and are at lower risk of developing future diseases. Breastfeeding is often mentioned as a facilitator of mother-infant bonding, breastfeeding is associated with postpartum weight loss, and it is also associated with favorable metabolic changes, as during lactation, insulin-sensitivity improves and may have lasting effects. A decrease in risk for reproductive cancers has been observed among women who have breastfed, possibly reduce their reduced lifetime exposure to hormones such as estrogen. (Dieterich et al, 2013)

Childhood to Adolescents:

Childhood to adolescents is a time of growth and development, both physically and mentally. Providing a nutrient rich diet is important to meet these demanding needs during this time of growth. A variety of healthy foods during this time can also support overall immunity and reduce the risk of long-term health effects later in life.

Empty calories from added sugars and solid fats contribute to 40% of daily calories for children and adolescents aged 2–18 years, affecting the overall quality of their diets. Approximately half of these empty calories come from six sources: soda, fruit drinks, dairy desserts, grain desserts, pizza, and whole milk. Most youth do not consume the recommended amount of total water. (CDC, 2022)

Previous studies of childhood diet have usually focused on only a few food groups/nutrients or relied on older data. Researchers analyzed the daily eating habits of more than 31,000 youths, ages 2 to 19, they rated each child's diet as poor, intermediate, or ideal, based on dietary scores. Diets were evaluated using the American Heart Association (AHA) 2020 continuous diet score, which reflects consumption of fruits and vegetables, whole grains, fish and shellfish, sugar-sweetened beverages, and sodium. Diets were also evaluated using the AHA secondary score, which adds nuts, seeds, legumes, processed meat, and saturated fat. The analysis revealed that, whichever score was used, diets of children in the U.S. have improved modestly, but remain poor for most children. Older youth (ages 12-19) had worse diet quality compared to younger children, with 67% eating poor quality diets. Disparities related to low household income, less parental education, and less food security (having access to enough food) persisted or worsened over time. (NIH, 2020)

Current food systems are oriented toward the production of cheap, energy-dense products that maximize profit, failing to provide children and adolescents the healthy and sustainable foods they need to achieve optimal growth and development. Children and adolescents worldwide do not consume enough micronutrient-rich foods, such as fruits, vegetables, pulses, and whole grains; conversely, they consume an excessive amount of energy-dense, ultra-processed products with high content of sugar, fat, and/or sodium. These eating patterns largely deviate from the scientific targets for healthy and sustainable diets. The eating habits of children and adolescents

are shaped by their interaction with the processes and conditions of the food systems, from production to consumption. Food systems characterized by the wide availability and affordability of ultra-processed products create social norms around processed, marketed foods, perpetuating poor food habits that are hard to break. For this reason, introducing major transformations to the current food systems is paramount in guiding children and adolescents toward healthy and sustainable eating habits. Two broad strategies have been proposed to achieve this objective: (1) introducing changes in the food environment and food supply chains to improve the availability, affordability, and desirability of healthy and sustainable foods; and (2) triggering society-led changes by equipping citizens with the capacity to take personal responsibility for their health and well-being. (Ares et al, 2023)

Food literacy is a key individual trait for the second strategy. Food literacy is defined as “the ability of an individual to understand food in a way that they develop a positive relationship with it, including food skills and practices across the lifespan to navigate, engage, and participate within a complex food system. It is the ability to make decisions to support the achievement of personal health and a sustainable food system considering environmental, social, economic, cultural, and political components.” Food literacy includes the competencies citizens need to relate to the food systems and to promote their transformation. Childhood and adolescence are important periods for the development of food literacy. (Ares et al, 2023)

Food literacy undergoes major changes through childhood and adolescence, which encompass physiological, cognitive, and social development, as well as changes in eating behavior. Different competencies are developed over time through different learning mechanisms. Relational competencies are the first type of food literacy competency children acquire. These competencies include pleasure from eating healthy and sustainable foods, familiarity with diverse foods, enjoyment of trying new and diverse foods, positive emotional and hedonic associations with healthy and sustainable eating habits, enjoyment of shared meals, appreciation of food culture, as well as mindful eating practices and body image satisfaction. The pleasure experienced from eating healthy and sustainable food is a key food literacy relational competency that starts developing even before children are born. Pleasure is an innate indicator of the satisfaction of the child’s physiological need to eat. In the first 1000 days of life, children learn to associate the pleasure of eating with different foods through familiarization. Exposure to diverse foods from an early age increases food familiarity, which has been identified as a key influencer of children’s willingness to experience new foods. Familiarity with diverse foods and enjoyment of experiencing new and diverse foods can be regarded as relational competencies that contribute to the development of healthy eating habits and also favors good coverage of nutritional needs. Repeated exposure to healthy and sustainable foods from an early age can contribute to increasing familiarity and reducing food neophobia, which has been linked to reduced consumption of vegetables. (Ares et al, 2023)

Children also learn to enjoy foods by observing others’ eating behaviors, most often their parents. From a young age, parents have a crucial impact on how children learn about food, as they shape the so-called home food environment. This includes the food available at home and its accessibility, family food rules, parents’ eating habits, their knowledge about food, and their feeding styles and practices. What, where, when, how much, and in which emotional and social context parents present foods to the child can have an immediate impact on children, but also a longer-term impact in childhood and adulthood. Associative learning or conditioning occurs when an evaluation of a stimulus arises through its association with a second, already liked or

disliked stimulus. Parental use of coercive control feeding practices in early childhood (eg, restriction of certain foods, pressure to eat, the use of rewards and bribes) has mostly counterproductive effects on the child's eating (eg, more dislike of pressured foods, more food fussiness, less enjoyment of eating). These effects can even be long-lasting, as young adults reported that the foods they disliked as adults were those they had been forced to eat as young children. This exemplifies how parents can influence children's relationship with food from early life and the acquisition of relational food literacy competencies like enjoying eating and enjoying experiencing new and diverse foods. (Ares et al, 2023)

Cooking as a family and having family meals can also have an important impact on children's and adolescents' acquisition of relational food literacy competencies, particularly the ability to enjoy shared meals and food preparation. Family meal frequency has been associated with a higher intake of healthy food, child socialization, and decreased overweight and obesity risk in adulthood. Mindful eating practices can be regarded as another relational food literacy competency. These practices can be regarded as a vast range of practices that rely on paying attention to body sensations, thoughts, and feelings about food. They include paying attention to the sensory characteristics of foods while eating, paying attention to feelings of hunger and fullness, noticing cues that elicit eating or the urge to eat, taking nonjudgmental attitudes toward cravings and food-related thoughts, as well as viewing cravings as transient events that are separate from oneself. (Ares et al, 2023)

Body satisfaction is another relevant relational competency, particularly during adolescence, because body dissatisfaction has been associated with eating disorders at that age. Body image and eating patterns begin to develop early in life, and parents are highly influential agents of socialization in these domains by transmitting norms, beliefs, values, knowledge, attitudes, and behaviors related to food, body, and weight to their children. Parental messages about food and weight can have an impact on children's relationship with their body image and body (dis)satisfaction, not only in preadolescent children, but also even those as young as preschoolers. Peers and media also have an important influence on the body image of preadolescents. (Ares et al, 2023)

The adoption of sustainable eating habits requires the establishment of human-nature bonds. Engaging with nature through food gardens, promotes mental well-being as well as a positive outlook and a sense of inclusion and belonging. Gardening programs can also increase children's familiarity with and willingness to try fruits and vegetables, as well as their functional food literacy competencies through knowledge about the origin of vegetables. (Ares et al, 2023)

Functional food-related competencies are the most well-defined components in the food literacy literature. They refer to the basic knowledge of food and nutrition, as well as the skills necessary for food planning, preparation, and disposal. A key functional food competency is the ability to appropriately categorize food. Similarly, evaluatively categorizing food as healthy vs unhealthy helps guide both adults and children toward healthier eating habits. Children's proneness to categorize foods, both in relation to sensory pleasure or nutrition, strongly develops with age and can be a predictor of healthy food choices. Functional food literacy competencies also entail general knowledge about food, including animal sources of food and how foods are grown and produced. Concerning nutritional knowledge, studies show that although 4-year-old children can categorize food as unhealthy, they are unable to comprehend the effects of food healthiness on the body nor use this ability to make informed food choices. Functional competencies also incorporate food preparation skills, which refer to the ability to perform tasks related to the

preparation of food. Food preparation skills are acquired at home with family members, at schools, and in other formal learning environments, as well as through mass media. Although research has shown that children already possess knowledge of food categories and food scripts by 5 years old, mechanical, and technical cooking skills are developed later because they require motor abilities. Food safety knowledge is also part of food preparation skills, as well as a functional food literacy competency. Basic knowledge about food hygiene and safety can encourage safe food-handling behaviors and reduce the incidence of food-borne diseases. (Ares et al, 2023)

To interact with the food environment, children need skills to interpret the information included on food labels and use such information to make healthy and sustainable food choices. Budgetary and financial skills are another functional food literacy competency children and adolescents need to navigate the modern food environment, which becomes increasingly important as they gain independence to make their food purchases. Recent research has suggested that financial skills promote rational decision-making and can reduce the likelihood of engaging in health-damaging behaviors, such as smoking and a lack of physical activity. Critical thinking can be promoted from early childhood by providing opportunities for children to express themselves and to engage actively in food-related decisions. However, only at the age of 8 years do children start to understand the persuasive messages of advertisements, yet they are mostly still unable to criticize them. Broader critical food literacy competencies develop in adolescence when abstract, logical, and counterfactual thinking is developed. (Ares et al, 2023)

Food literacy has emerged as a key individual trait to promote the transformation of food systems toward healthy and sustainable diets. Children's socialization in school offers additional opportunities to promote a healthy food environment and to foster the development of many relational and functional food literacy competencies. School activities that promote familiarity with foods and the acquisition of food-related knowledge should be prioritized, including exposure to diverse foods, sensory games with foods, and gardening programs. It should be stressed that school nutrition education programs should go beyond nutrition knowledge and include practical skills related to food planning, purchase, preparation, and disposal. Research has shown that nutrition education programs delivered at schools are more effective at promoting healthy eating behavior if they address different food literacy competencies instead of focusing on just knowledge transfer. Efforts should be placed on building a healthy food environment and promoting responsive feeding practices to favor the discovery of healthy foods in a responsive way. Parents and caregivers can easily promote familiarity with diverse foods and enjoyment of trying new foods through repeated exposure, social learning, and socialization. These practices can be promoted through behavior-change communication campaigns and nutrition counseling. (Ares et al, 2023)

Beyond biological, social, and environmental factors, emotions have increasingly been recognized for their role in shaping children's eating habits. The importance of emotions in our lives cannot be understated. Emotions shape our experiences, guide our actions, and fundamentally influence our well-being. In the context of eating habits, the theory proposed by psychosomatic pioneer Hilde Bruch has led to an expanded understanding of the role of emotions. Bruch emphasized the crucial role of maternal attitudes during infancy; a mother's inability to respond empathetically to a child's emotional needs profoundly impacts the child's relationship with food. This potentially leads to the child resorting to food as an emotional regulator, thereby blurring the lines between emotional and physical needs. A solid sense of self

and body integrity is essential for healthy emotional development and eating behaviors. The relationship between emotions and eating habits is supported both theoretically and empirically. Research has shown that positive and negative emotions greatly influence food choices and eating behaviors, particularly in children. Moreover, negative emotions like stress, anxiety, and sadness have been associated with unhealthy eating habits, such as emotional eating, binge eating, and consumption of calorie-dense, nutrient-poor foods. Conversely, the influence of positive emotions, like happiness and contentment, has been linked with healthier eating habits, such as increased fruit and vegetable consumption and balanced meal patterns. Understanding the impact of emotions on children's eating habits is crucial for shedding light on the complex interplay between psychological and physical health. This is especially important since children are at an increased risk for eating disorders (EDs). Emotional eating (i.e., eating in response to emotional cues rather than physiological hunger), has been associated with developing obesity and eating disorders in childhood. Food is often used as an emotional regulator, providing comfort in the form of high-calorie, palatable foods during challenging times. Over time, this behavior can reinforce unhealthy eating patterns. Additionally, the emotional experiences of a child can influence their perception of hunger and satiety, disrupting eating patterns and food choices. Research has increasingly focused on understanding the connection between emotions and eating habits in children. (Abdoli et al, 2023)

Growth failure and micronutrient inadequacy during childhood and adolescence can delay growth and create high risk of chronic diseases in adulthood. Puberty is accompanied by a growth spurt that increases the requirements for both macronutrients and micronutrients. These higher requirements are balanced by a more efficient use of protein for development rather than energy. Pubertal timing depends on nutrition during childhood. It also reflects earlier maternal nutrition because appetite control, energy homeostasis, and the pubertal axis are being developed in natal and early postnatal life. Adolescence is a time of transition when habits are formed that persist into adult life. Good habits, such as exercise and a healthy diet, are likely to bring many benefits, including improved performance in school. Nutritional habits are important, with high intake of processed, energy-dense foods, high BMI, and iron deficiency among the top 20 risk factors of disability-adjusted life years (DALYs) worldwide. Such factors pose risks for later-life noncommunicable diseases, which are responsible for two of every three deaths globally. (Lassi et al., 2017)

The available studies suggest that adolescents are becoming more independent in their food choices, more likely to be influenced by their peers, and less likely to pick healthy foods. Other factors that affect their overall nutrition include the kinds of foods available at home, amount of time available to make food, knowledge of food content, and ability to purchase snacks. Sociodemographic, behavioral, and environmental factors are also linked to different patterns of adolescent nutrition. Sociodemographic factors include socioeconomic status, age, sex, location, and degree of urbanization. Behavioral factors include patterns of beverage intake, portion sizes, dieting, family dinners, eating in front of and viewing television, and skipping meals (especially breakfast). Environmental factors include eating or buying food prepared outside the home, maternal education and employment, and parental diet. (Lassi et al., 2017)

Adolescents need more nutrients than adults because they gain at least 40 percent of their adult weight and 15 percent of their adult height during this period. Cognitive growth also depends on micronutrients; B complex vitamins are important in neural communication, and their absence leads to depression. Vitamin B12, folate, and thiamine are important for neural pathways, and

deficiency has been linked to impaired episodic memory and language issues. Iron is required for oligodendrocyte growth and neurotransmitter production, and deficiency affects cognition, memory, and social and motor development. Iodine is involved in structural development, and its absence causes mental retardation. Zinc is found in the forebrain and hippocampus, and its deficiency is linked to impaired attention, learning, and memory, as well as to possible development of neuropsychological diseases. (Lassi et al., 2017)

Many children and adolescents have a micronutrient-deficient diet, and appropriate nutrient supplements are needed. Nutrients can be provided via tablets, powders sprinkled on food or mixed in water, and fortified spreads or snacks. Such foods need to have adequate amounts of energy and micronutrients, taste good, be clean and hygienic. (Lassi et al., 2017)

Sleeping difficulties are increasingly prevalent among adolescents, ranging from 15% to 44%, and have become a globally recognized public health issue. The short-term and long-lasting effects of sleeping difficulties on adolescents' negative developmental outcomes have been highlighted, including a higher risk of cognitive, memory, or academic deficits, increased risk of mental health problems, poorer school performance, behavior problems, and even heart disease or a higher level of all-cause mortality. These adverse consequences may last into adulthood; for example, previous research shows that the level of adolescents' sleep problems predicted their adulthood sleep disturbance. Previous studies have found that lifestyle factors such as consuming excessive amounts of caffeine or prolonged use of screen media in the bedroom at night, environmental factors like excessive lighting in the bedroom, psychosocial problems such as anxiety symptoms, and even medical conditions may contribute to sleeping difficulties among adolescents. Individual eating habits, such as consuming breakfast on weekdays and weekends, consuming fruits, vegetables, sweets, and soft drinks, are essential for living well and can have a strong impact on adolescents' biological clock, circadian rhythm, and physiological hormones like melatonin and serotonin. These factors, in turn, can either facilitate or impair their sleep quality. (Zhao et al, 2023)

A recent exploratory study investigated the relationship between breakfast consumption and subjective sleep quality among university students. The study found that students who skipped breakfast, ate late-night snacks, or replaced meals with snacks were more likely to experience poor overall sleep quality. Only a few studies have found that adolescents with shorter sleep duration report consuming fewer fruits and vegetables than those who sleep for more than 8 h per day. Frequent consumption of vegetables and fruits is significantly associated with fewer sleep difficulties. Fruits and vegetables are rich in fiber, vitamins, and minerals, and high intake of these nutrients has been linked to better sleep quality. Conversely, some studies found that consuming more sweets and soft drinks (except for 5–6 days per week) is associated with more sleep difficulties. These findings contribute to our understanding of the relationships between eating habits and sleep health in children and adolescents. (Zhao et al, 2023)

Aging and Longevity:

Aging is a complex process indicated by low energy levels, declined physiological activity, stress induced loss of homeostasis leading to the risk of diseases and mortality. Recent developments in medical sciences and an increased availability of nutritional requirements have significantly increased the average human lifespan worldwide. Several environmental and physiological factors contribute to the aging process. However, about 40% human life expectancy is inherited

among generations. Aging is a multifaceted, complex process represented by the functional decline of tissues and organs due to changes in molecular composition and physiology of cells. An increase in the human lifespan has been reported for the last many decades. According to the estimates of United Nations, there were more than 63 million people above 90 years of age in 2020. Longevity of human life is heritable from 20% to 40% in the modern human populations. Survival into extremely long ages is a characteristic clustered in families. Better immune systems, metabolic health such as enhanced insulin sensitivity, lipid metabolism leading to healthy levels of plasma lipids, and delay or ability to avoid age related diseases has also been observed in the longevous families. As longevity of life exhibits high heritability, insights into the genetic factors may improve our present understanding of mechanisms responsible to promote health and reduce the risk of diseases. (Bin-Jumah et al, 2022)

Although some of the terms of aging sound interchangeable, it is important to know the exact definition. **Life expectancy** is the amount of time a person is expected to live based on the year they were born, their current age and various demographic factors, including gender. It is always statistically defined as the average number of years of life remaining at a given age. So, life expectancy is basically the average **lifespan** of a population. In contrast, maximum lifespan is the maximum time that one or more members of a population have been observed to survive between birth and death. The oldest woman in the world lived to over 122 years old, so the maximum human lifespan is often given as 120 years. The term **longevity** describes the ability to live a long life beyond the species-specific average age at death. Longevity can be considered as the average lifespan under ideal conditions. The term **healthspan** describes the period of time during which a person is healthy within his or her lifespan. The healthspan is therefore shorter or at most as long as the lifespan, and a person can fall ill early in life but still live for several years. (Max-Planck-Gesellschaft, n.d.)

The ability to define aging and longevity separately has become possible only in recent years. Life expectancies after the age of 70 and especially after the age of 85 have yet to reach a plateau. While life expectancy after the age of 70 continues to increase, so too do the number of individuals living with age-related chronic conditions that affect daily activities. Many believe that age-specific nutritional recommendations for the older population may help to decrease the incidence or severity of debilitating, non-disease disorders that occur with increasing age. Limited research shows a lack of success in establishing age-specific nutritional recommendations for the older population reflects, at least in part, research designs that do not consider the biological differences between aging and longevity. Failure to consider these differences may also lead to difficulty in precisely defining aging or longevity, a prerequisite to efficient experimental designs. Distinguishing human biological aging from longevity can be difficult due to the fact that the rate of aging may affect the length of the life span. Evolutionary theorists have mathematically and empirically demonstrated that longevity is genetically determined from genes that are selected for a reproductive advantage. As such, the principle of genetic determinism provides an appropriate underlying theory for research designs evaluating nutritional factors involved with life span. Investigations evaluating possible gene-nutrient interaction should prove valuable in the search for nutrients that affect longevity. On the other hand, aging is not a product of selective evolution. The aging process more closely reflects chance events that affect biological systems during development or during the early reproductively active years. The genetic determinism model by which young (normal, control) are compared to old (abnormal, experimental) groups will not be effective in identifying mechanisms by which nutritional factors affect aging. Aging will be best understood by

evaluating biological systems during development that are most susceptible to time- or event-dependent alteration leading to functional loss and chronic conditions in old age. (McDonald & Ruhe, 2011)

Why should a nutrition researcher know the difference between aging and longevity? In the next decade and a half in economically developed countries, the population of individuals who will be over the age of 70 years will rise from the current 13% to almost 20%. In the United States that percent increase represents an additional 35 million people. Given the disproportionate amount of health care dollars spent on this population, much of which is covered by entitlement programs, we must do all we can to insure a healthy aging population, anything less could be economically catastrophic. Dietary recommendations are a significant part of the overall strategy for improving the health of the aged population. (McDonald & Ruhe, 2011)

It has been a universal goal to understand the events and adopt the measures to slow down, stop or reverse the aging process. Telomeres are the protective caps at the termini of human and other eukaryotic chromosomes. Their length decreases with age, though it is dependent on many internal and environmental factors. According to reports based on experimental models, the overall length or rate of telomere shortening has been reported to have a link with age expectancy. The shortening of telomere length is rapid in men as compared to women, leading to a comparatively high longevity in women. Shortening of telomeres stops the cell division and production of lymphocytes leading to subsequent loss of cellular ability in immune response. The most important DNA modification associated with aging is DNA methylation. DNA methylation-based biomarkers have answered many of the questions about the aging process and have described the role of epigenetics. As epigenetic changes in the human body are reversible, these biomarkers are therefore useful for the identification and validation of anti-aging interventions. DNA methylation has been linked with human age and the aging process in man and other species. An accelerated DNA methylation age significantly increases the risk of cancer, stroke, and cardiovascular diseases. The second genetic factor associated with aging is histone modifications. Alterations (decrease/increase) in the methylation of histones have been reported to regulate the aging process. Histone methylations have been linked with cellular pathways regulating the age and lifespan. The process of autophagy slows down with age, due to decrease in the ratio of cellular functional mitochondria and subsequent increase in the reactive oxygen species (ROS), aggregation of insoluble or exhausted proteins in the cells. Another consequence of the aging process is accumulation of damaged DNA (mutated, irreparable, double stranded breaks) due to decreased efficiency of damaged DNA repair system (DDR system) in the old cells. Histone methylation promotes the DDR of cells and improve the life activity. (Bin-Jumah, 2022)

Autophagy is a self-degradative process that is important for balancing sources of energy at critical times in development and in response to nutrient stress. Autophagy also plays a housekeeping role in removing misfolded or aggregated proteins, clearing damaged organelles, such as mitochondria. Autophagy allows your body to break down and reuse old cell parts so your cells can operate more efficiently. It's a natural cleaning out process that begins when your cells are stressed or deprived of nutrients. Researchers are studying autophagy's role in fighting disease and the aging process. (Glick et al., 2010)

Methylation is a chemical modification of DNA and other molecules that may be retained as cells divide to make more cells. When found in DNA, methylation can alter gene expression. In this process, chemical tags called methyl groups attach to a particular location within DNA where

they turn a gene on or off, thereby regulating the production of proteins that the gene encodes. DNA methylation is one of several epigenetic mechanisms that cells use to control gene expression. Histone methylation is part of the most common epigenetic regulations that play important roles in developmental processes and diseases. (Segre, 2024)

The word “**epigenetic**” literally means “in addition to changes in genetic sequence.” The term has evolved to include any process that alters gene activity without changing the DNA sequence. a wide variety of illnesses, behaviors, and other health indicators already have some level of evidence linking them with epigenetic mechanisms, including cancers of almost all types, cognitive dysfunction, and respiratory, cardiovascular, reproductive, autoimmune, and neurobehavioral illnesses. Known or suspected drivers behind epigenetic processes include many agents, including heavy metals, pesticides, diesel exhaust, tobacco smoke, polycyclic aromatic hydrocarbons, hormones, radioactivity, viruses, bacteria, and basic nutrients. (Weinhold, 2006)

DNA methylation can be influenced by environmental factors such as diet, hormones, stress, drugs, or exposure to environmental chemicals, suggesting that environmental factors may contribute to adverse health outcomes. (Keil & Lein, 2016)

Nutrition is a strong player not only for its influence on gene expression, but more importantly, because early nutrition alterations could be responsible for the later development of chronic diseases through epigenetic mechanisms. (Kadayifci et al., 2018)

Damaged or mutated DNA accumulation in the multicellular organisms often leads to the onset of cancer or triggers the aging process. Oxidative stress typically caused by reactive oxygen species (ROS), ultra-violet and ionizing radiations can damage cellular components, especially the lipids, proteins, and DNA, is known as a hallmark of cancer initiation and age-related neurodegenerative diseases. Circadian rhythms also play important role in the mammalian cell biochemistry and physiology. Almost each cell has a mechanism to respond to the day night cycles which are mainly regulated by hypothalamus area of brain which is a master pacemaker to modulate cell signaling according to the photoperiods. The circadian desynchrony may lead to the neurodegenerative disorders and metabolic pathologies that ultimately impact the lifespan. The aging process and longevity of lifespan has many well-established risk factors including diabetes, obesity, problems of cardiovascular system due to the lack of physical activity. Several epigenetic factors also contribute to the longevity of lifespan. (Bin-Jumah et al, 2022)

In recent decades, global life expectancies have risen significantly, accompanied by a marked increase in chronic diseases and population aging. Recent findings on the dietary factors influencing chronic diseases and longevity, primarily from large cohort studies, show a few commonalities. First, maintaining a healthy weight throughout life is pivotal for healthy aging and longevity, mirroring the benefits of lifelong, moderate calorie restriction in today's obesogenic food environment. Second, the specific types or food sources of dietary fat, protein, and carbohydrates are more important in influencing chronic disease risk and mortality than their quantity. Third, some traditional diets (e.g., the Mediterranean, Nordic, and Okinawa) and contemporary dietary patterns, such as healthy plant-based diet index, the DASH (dietary approaches to stop hypertension) diet, and alternate healthy eating index, have been associated with lower mortality and healthy longevity. These patterns share many common components (e.g., a predominance of nutrient-rich plant foods; limited red and processed meats; culinary herbs and spices prevalent in global cuisines) while embracing distinct elements from different cultures. Fourth, combining a healthy diet with other lifestyle factors could extend disease-free

life expectancies by 8–10 years. While adhering to core principles of healthy diets, it is crucial to adapt dietary recommendations to individual preferences and cultures as well as nutritional needs of aging populations. (Hu, 2023)

There has been a rapid increase in the prevalence of chronic diseases, including diabetes, cardiovascular diseases (CVDs), cancer, dementia, and other age-related conditions. Many of these diseases are related to suboptimal diet and lifestyles. Poor diet is recognized as a leading contributor to the global burden of diseases, including deaths and disability-adjusted life years (DALYs); it was estimated that worldwide, 11 million premature deaths and 255 million DALYs per year were attributable to unhealthy dietary factors including high sodium and trans fat, and low fruits, vegetables, nuts, and omega-3 fatty acids. The concept of “healthy longevity” has garnered much attention in recent years because it is focused on not only increasing the overall life expectancy or life span of individuals but also on increasing the length of life free from major chronic diseases, often referred to as the “healthspan”. The National Academy of Medicine defined healthy longevity as “years of good health approach the biological life span, with physical, cognitive, and social functioning that enable well-being”. The definition underscores a preventive approach to health and well-being through diet and lifestyle modifications. This concept is also closely linked to healthy aging, which refers to maintenance of physical, mental, and cognitive health as individuals grow older, while delaying the onset of frailty in elderly individuals. (Hu, 2023)

Low-carbohydrate or ketogenic diets have been extensively studied in animal models and humans for their impact on metabolic health outcomes and longevity. Ketogenic diets are extreme low-carbohydrate diets that induce a state of ketosis, in which the body relies primarily on ketone bodies for energy. Animal studies suggest that a ketogenic diet may enhance longevity and health span through influencing multiple metabolic and aging pathways, including improving insulin sensitivity, and inhibiting chronic inflammation. In short-term studies, low-carbohydrate or ketogenic diets have been shown to be more effective in promoting weight loss compared to conventional low-fat high-carbohydrate diets. In addition, carbohydrate restriction lowers blood glucose levels, reduces postprandial glucose spikes, and improves insulin sensitivity in glycemic control among individuals with type 2 diabetes. However, long-term adherence to very low-carbohydrate or ketogenic diets is often challenging due to their restrictive nature. In addition, very low-carbohydrate intake leads to reduced intake of fiber, vitamins, and minerals, which could have negative health consequences. Although low-carbohydrate diets often decrease triglyceride levels and increase HDL levels, such diets have been associated with increased LDL cholesterol levels. The long-term health effects of low-carbohydrate diets appear to depend on the type of fat and protein in the diets. (Hu, 2023)

Replacing 5% of energy from saturated fat with the same amount of energy from monounsaturated fats (MUFAs – olives and avocados) and polyunsaturated fats (PUFAs – nuts, seeds, and fish) was associated with a 27% and 15% reduced risk of mortality, respectively. In another study, replacing 5% of calories from saturated fat with PUFAs, MUFAs, or whole grains was associated with a 25%, 15%, and 9% lower risk of coronary heart disease (CHD), respectively. However, based on the substitution modeling, replacing saturated fat with carbohydrates from refined starches and added sugars did not alter CHD risk. The food source of fat (plant or animal) may also affect health outcomes, even when considering the same type of fat. For example, replacing 5% of energy intake from saturated fat, trans fat, and refined carbohydrates with MUFA intake from plant sources was associated with lower risk of CHD,

whereas the same substitution with MUFA from animal sources did not confer the same beneficial effects. The benefits of polyunsaturated fats (PUFAs), especially linoleic acid, on CVD and total mortality were confirmed in systematic reviews and meta-analysis of cohort studies using biomarkers of linoleic acid intake. (Hu, 2023)

Among individuals aged 50–65-year-old, high protein intake was associated with a 75% increase in overall mortality and a fourfold increase in cancer and diabetes mortality. The association was significant only for animal protein but not for plant protein. On the other hand, in individuals aged 65 or older, higher protein intake was associated with lower mortality. However, the interaction between protein intake and age on mortality has not been observed in other cohorts. Higher animal protein intake was positively associated with cardiovascular mortality, whereas higher plant protein intake was inversely associated with all-cause and cardiovascular mortality with no evidence of effect modification by age. In the substitution analysis, replacing animal protein sources (especially red and processed meats) with plant protein sources was associated with significantly lower risk of all-cause mortality. In a separate analysis, plant protein sources were also associated with lower odds of cognitive decline when compared with animal protein sources, although adequate protein intake appears to be important in the maintenance of cognition in older individuals. (Hu, 2023)

Polyphenols are a diverse group of naturally occurring compounds found in plant-based foods, such as fruits, vegetables, whole grains, nuts, and legumes including soy products, coffee, tea, cocoa, red wine, herbs, and spices. There are thousands of different polyphenols, which can be categorized into subclasses, including flavonoids (found in fruits, vegetables, tea, coffee, cocoa, and soy), lignans (found in seeds, grains, and vegetables), phenolic acids (found in coffee, nuts, and fruits), and resveratrol (found in grapes and wine). Because of their antioxidant, anti-inflammatory, and anticarcinogenic properties, polyphenol-rich foods are considered an important component of healthy dietary patterns that promote overall health and well-being. In addition to their cardiometabolic benefits, such as improved blood lipid profiles and reduced blood pressure, polyphenols have the potential to improve cognitive function and lower the risk of neurodegenerative diseases. Furthermore, they act as prebiotics, promoting the growth of beneficial gut bacteria and maintaining a healthy gut microbiome. Experimental studies indicate that polyphenols exhibit antiaging properties by influencing various hallmarks of aging, including inflammation, oxidative stress, epigenetic alterations, and protein homeostasis plus epidemiologic and clinical trial evidence on the health benefits of several polyphenol-rich foods such as coffee, tea, extra-virgin olive oil, blueberries, avocados, and culinary herbs and spices, show that foods rich in polyphenols also contain beneficial nutrients and compounds such as minerals, vitamins, and carotenoids. (Hu, 2023)

Herbs and spices are widely used in global cuisines, contributing not only to diversity of flavor but also potential health benefits due to their rich content of bioactive compounds, including polyphenols. Notable examples include turmeric in Indian dishes; basil, rosemary, and oregano in Mediterranean cuisine; and ginger, garlic, and cloves in East Asian cuisines. Experimental studies have indicated that many herbs and spices have antimicrobial, antioxidant, and anti-tumorigenic properties. Beyond its culinary use, turmeric has historically been used in Chinese and Indian traditional medicine for addressing various diseases and conditions. Curcumin, a polyphenol, and the active component of turmeric, has been extensively studied in recent decades, demonstrating its potential antioxidant, anti-inflammatory, anti-diabetes, and anticancer effects. (Hu, 2023)

Because individual foods or nutrients are not typically consumed in isolation, it is important to understand health effects of overall dietary patterns, which can provide a more comprehensive view of overall diet, reflecting real-world eating habits. Moreover, evaluating overall dietary patterns can help capture the synergistic or antagonistic effects of different food components consumed concurrently and reduce confounding from intercorrelated dietary components. Moreover, dietary patterns can take into account cultural and regional variations in diet, making dietary recommendations more adaptable and relevant for diverse global populations. The traditional Mediterranean diet (MedDiet) is widely considered a model for healthy eating. The main features of the MedDiet include an abundance of plant foods, such as fruits, vegetables, whole grains, nuts, and legumes; olive oil as the main source of dietary fat; fish and poultry consumed in low-to-moderate amounts; relatively low consumption of red meat; and moderate consumption of wine, typically in conjunction with meals. There is compelling evidence that greater adherence to the MedDiet is associated with reduced risk of obesity, type 2 diabetes, hypertension, dyslipidemia, CHD, stroke, and heart failure. In prospective cohort studies, adherence to the Mediterranean dietary pattern is associated with reduced mortality, especially cardiovascular mortality, thus contributing to increased longevity. In addition, the MedDiet has been associated with slower progression of age-related cognitive decline and lower risk of neurodegenerative disorders such as dementia and Alzheimer's disease.

Similar to the MedDiet, the Nordic diet focuses on plant-based and locally sourced foods that are typically found in the Nordic countries, such as Sweden, Denmark, Norway, Iceland, and Finland. One notable difference between the MedDiet and the Nordic diet is the type of oil used. The MedDiet mainly uses EVOO, whereas in the Nordic diet rapeseed oil is commonly used. Although olive oil is high in oleic acid, rapeseed oil is rich in oleic acid, linoleic acid, and alpha-linolenic acid. The types of whole grains in the Nordic regions are mostly rye, barley, and oats. Among various fruits, berries are featured more prominently in the Nordic diet. Adherence to the Nordic dietary pattern was associated with a small reduction in risk of CVD (7%) and type 2 diabetes (9%). The traditional Okinawa diet has been linked to high concentrations of centenarians on the island of Okinawa. This dietary pattern resembles a vegetarian diet, characterized by its emphasis on root vegetables (mainly purple sweet potatoes), green and yellow vegetables, soybean-based foods, seaweeds and algae, tea, and a variety of medicinal plants (e.g. bitter melon) and spices such as turmeric. Animal food consumption is often limited except for marine fish in coastal regions of the island. In addition to its food composition, a unique feature of the Okinawan diet is the practice of stopping eating when one is 80% full, known as Hara Hachi Bu. This practice is akin to a natural form of mild caloric restriction. Okinawa is one of the five “Blue Zones,” a concept introduced by Buettner. In addition to Okinawa, the other Blue Zones include Sardinia in Italy, Nicoya Peninsula in Costa Rica, Ikaria in Greece, and Loma Linda in California, USA. These regions were recognized for their residents' longevity and high numbers of centenarians. The diets of the Blue Zones are believed to play a crucial role in the exceptional longevity observed in these regions. However, the lifestyles in the Blue Zones also encompass shared features, such as plant-based eating, moderation in consumption, being physically active, and strong familial and social connections. Therefore, it is not possible to attribute the longevity observed in these regions solely to their diets. (Hu, 2023)

Plant-based diets consist of a diverse spectrum of dietary patterns, generally defined by limited consumption of animal foods. Vegetarian diets are a major category of plant-based diets ranging from partial to complete exclusion of animal products, such as vegan diets. Small studies have

shown that compared to participants' usual diets, vegetarian diets significantly reduced blood pressure, total and LDL cholesterol levels, body weight, HbA1c, and other cardiometabolic risk factors. Large cohort studies have shown that vegetarians tended to have lower risk of obesity, type 2 diabetes, and CHD than nonvegetarians. In the Seventh-day Adventist Health Study, participants who followed vegetarian or vegan diets had reduced mortality and longer life expectancies compared to the general population. In addition, participants following vegetarian diets had lower rates of certain cancers particularly colon, breast, and prostate cancers. Moreover, vegetarian diets were associated with better cognitive function and a lower risk of cognitive decline among Adventists. Although the Seventh-day Adventist Health Study has provided valuable insights into the health benefits of vegetarian diets, caution is warranted when applying these findings to the broader population because the participants' other lifestyle practices and religious benefits might have contributed to some of the observed health outcomes. In addition, it is important to pay attention to nutritional adequacy (vitamins B12 and D, iron, calcium, zinc, and long-chain omega-3 fatty acids) of vegetarian diets, particularly vegan diets that entirely exclude animal foods. Traditionally, plant-based diets are quantified by the reduced amount and frequency of animal-based food consumption, often overlooking the quality of the plant-based foods consumed. (Hu, 2023)

Although there is no one-size-fits-all diet for everyone, some traditional diets such as the MedDiet, Nordic, and Okinawa share many common components while embracing distinct elements from diverse cultures. These dietary patterns typically emphasize minimally processed plant foods and healthy fats, coupled with reduced consumption of red and processed meats, and added sugars. The existence of multiple healthy eating patterns across diverse cultures offers the flexibility of combining beneficial elements of various dietary patterns to create personalized diets that enhance long-term enjoyment and adherence. Healthy longevity is influenced not only by diet but also various lifestyle factors, including smoking, physical activity, alcohol consumption, and body weight. findings suggest that most of the extended life expectancies resulting from a healthy diet and lifestyle are free from major chronic diseases. In other words, following a healthy diet and lifestyle not only enhances overall life span but also extends health span, contributing to a longer period of disease-free life expectancy. (Hu, 2023)

2. Toxins and Detoxification

Our Polluted Planet

Environmental pollution is a side effect of industrialization. Money and profits are more important than the health of people and this planet to most big industry. Some of the damage that has been done to this planet is irreversable and only now we are seeing the effects to our health. The health of planet Earth and our own health are aligned. Any kind of chemicals used to pollute Earth in turn pollutes us.

Industry and government seem to believe that exposure to tiny amounts of toxic chemicals pose little to no risk to our health. Chemicals are toxic in small repeated doses, as they can accumulate in the body. A recent study by the Environmental Working Group (EWG) in the U.S. found 232 toxic chemicals in the umbilical cord blood of 10 babies from ethnic minority groups. Since 1995, EWG's body burden testing has found 553 different industrial chemicals, pollutants, and pesticides in 149 Americans across 27 different states.

In Canada, the Environmental Defence released a report in 2013 that involved testing the umbilical cord blood of a small group of newborns for the presence of 310 different synthetic chemicals, which 137 of these chemicals were things such as DDT, PCBs and flame retardant. This report demonstrated that Canadian children are born pre-polluted.

More research in this area needs to happen for the connection between these types of chemicals and serious health issues such as cancer can be made. Cancer is a potential outcome of exposure to these chemicals, as most of these chemicals are carcinogenic. Chemically-induced cancers take many years to develop and because of this, most cancers will not or cannot be linked to chemical exposure.

According to WHO (World Health Organization), in 2003, the global cancer rates were expected to increase 50% by the year 2020, which would mean one in every two people would have some form of this disease.

An update on the global cancer burden using the GLOBOCAN 2020 estimates of cancer incidence and mortality produced by the International Agency for Research on Cancer (IARC). Worldwide, an estimated 19.3 million new cancer cases (18.1 million excluding nonmelanoma skin cancer) and almost 10.0 million cancer deaths (9.9 million excluding nonmelanoma skin cancer) occurred in 2020. Female breast cancer has surpassed lung cancer as the most commonly diagnosed cancer, with an estimated 2.3 million new cases (11.7%), followed by lung (11.4%), colorectal (10.0 %), prostate (7.3%), and stomach (5.6%) cancers. Lung cancer remained the leading cause of cancer death, with an estimated 1.8 million deaths (18%), followed by colorectal (9.4%), liver (8.3%), stomach (7.7%), and female breast (6.9%) cancers. The global cancer burden is expected to be 28.4 million cases in 2040, a 47% rise from 2020, with a larger increase in transitioning (64% to 95%) versus transitioned (32% to 56%) countries due to demographic changes, although this may be further exacerbated by increasing risk factors associated with

globalization and a growing economy (Sung et al, 2021).

Fear of cancer is one of the most motivating factors behind the growth in healthy living these days. All of us are in some way touched by this disease by knowing someone who has this illness.

Cancer was the leading cause of death in Canada in 2021, accounting for over one-quarter (26.6%, or 82,822) of all deaths in 2021, followed by heart disease at 17.7% (55,271). Compared with 2020, these numbers represent an increase of 2.0% in cancer deaths and of 1.6% in deaths attributable to heart disease. Cancer and heart disease were the top two leading causes of death for both women and men in 2021. (Statistics Canada, 2023)

The Environmental Protection Agency (EPA) estimates that there are hundreds of man-made chemicals circulating within the average person. All of these chemicals are poisonous to the body at certain levels. Each of us are bio-chemically unique, so one may feel the negative effects of these chemicals sooner than someone else.

Three Factors That Influence Potential Dangers of Chemicals:

1. Numerous exposures to the same or different chemicals over short or long term.
2. The health of the host that is being attacked such as stress, sleep, refined foods, cigarette smoke, medications, alcohol, and drug usage.
3. Chemicals can interact with each other causing more health problems.

Chemicals are toxic on their own, but what happens when chemicals are mixed together?

They can become 100x more toxic. This can be seen in the formation of trihalomethanes (THMs), which are carcinogenic. The mixture of chlorine to the public water supply and organic compounds form chloroform, which is a trihalomethanes (THM).

Two Ways Chemicals Cause Disease and Damage The Body:

1. Direct irritation
2. Free radicals

Both of which attack the body and suppress the immune system.

Free radicals are atoms or molecules that have unpaired electrons. Free radicals happen through normal body processes such as metabolism. Free radicals are also created from exposure to toxic chemicals. Antioxidants help neutralize free radicals and protect the body from the damaging effects of free radicals. When there is an imbalance between free radicals and antioxidant activity in the body, this is referred to as oxidative stress. Oxidative stress and free radical damage contribute to the etiology of many chronic health problems such as cardiovascular and inflammatory disease, cataract, and cancer. Nutrients such as vitamins A, C, E, and selenium are antioxidant nutrients. Powerful antioxidants that also act as metabolic enzymes are superoxide dismutase (SOD) and glutathione peroxidase. All of these antioxidants help protect the body from the free radical damage created by chemicals in the environment. (Lobo et al, 2010)

Categories of Potential Toxic Chemicals:

- Carcinogenic – increases risk of cancer
- Mutagenic – can alter genetic makeup
- Reproductive Toxins – effects fertility and birth defects
- Developmental Toxins – effect unborn and young children
- Endocrine Disrupters – effects hormone levels
- Nerve Toxins – interferes with the chemical and electrical function of the brain

Two types of chemicals in our food include:

1. Contaminants: fertilizers and pesticides that are sprayed onto the food we eat.
2. Additives: chemicals that are knowingly added to the food we eat.

As of 1983, more than 2,500 chemical substances are intentionally added to foods to modify flavor, color, stability, texture, or cost. In addition, an estimated 12,000 substances are used in such a way that they may unintentionally enter the food supply. These substances include components of food-packaging materials, processing aids, pesticide residues, and drugs given to animals. An unknown number of naturally occurring chemical contaminants also find their way into food. The most notable of these are the products of mold growth called mycotoxins, which include the aflatoxins.

The introduction of a new food additive requires the prior approval of the Food and Drug Administration (FDA) or Health Canada. This approval can be granted only when these government agencies have concluded that the manufacturer has submitted sufficient toxicological data to demonstrate the safety of the additive. Long-term studies to evaluate the carcinogenicity of “direct” additives, i.e., those intentionally added to food, may be required when the intended level of usage is high or when possible carcinogenicity is suspected because of the structure or known biological activity of the additive. This same policy applies to “indirect additives,” which are used in food packaging and as food processing aids. However, these substances are generally present in foods at such low levels that a carcinogenicity test requirement would be imposed only if the indirect additive were suspected of being a carcinogen because of its chemical structure or biological activity.

There has been no requirement to perform tests to determine carcinogenicity for most substances added to food. Substances in this category include those “generally recognized as safe” (GRAS), hundreds of flavoring agents, most additives approved before the 1958 Food Additives Amendment (P.L. 85–929) to the Food, Drug, and Cosmetic Act (U.S. Congress, 1958), and additives used at levels considered low by the FDA, except for suspected carcinogens. Furthermore, very little is known about the tumor-promoting activity of the few food ingredients that have been tested for carcinogenicity (National Research Council, 1982).

Residues of pesticides that can induce tumors may contaminate foods through their application directly on crops or from other sources of environmental contamination. Chemicals that are

intrinsic constituents of foods, such as hydrazines in mushrooms, may also be carcinogenic. Certain unavoidable contaminants in foods, such as aflatoxin B1 and polychlorinated biphenyls, have been found to be carcinogenic in long-term toxicological studies. In addition to known carcinogens that may appear in food as natural constituents, contaminants, or additives, there are a number of chemicals in food whose carcinogenic potential has not been adequately assessed but which are suspected carcinogens because of their known mutagenic activity. (National Research Council (US) Committee on Diet, Nutrition, and Cancer, 2019)

Exposure to pollutants can happen in the home and workplace. Indoor pollutants are an important topic, as in some cases, the air quality outside is better than in our house or workplace.

Indoor environment conditions contribute greatly to human wellbeing, as most people spend around 90% of their time indoors, mainly at home or in the workplace. According to the World Health Organization (WHO), indoor air pollution (IAP) is responsible for the deaths of 3.8 million people annually. IAP can be generated inside homes or buildings through occupants' activities, such as cooking, smoking, use of electronic machines, use of consumer products, or emission from building materials. Harmful pollutants inside buildings include carbon monoxide (CO), volatile organic compounds (VOCs), particulate matter (PM), aerosol, biological pollutants, and others. Therefore, over the past decade, research on air quality control has begun to shift from outdoor to indoor environments, as reflects lifestyle changes linked to increased levels of urbanization. It was indicated that decreased indoor air quality (IAQ) can negatively affect human health. (Tran et al., 2020)

Human daily activities generally cause IAP by the discharge of waste gases, tobacco smoke, pesticides, solvents, cleaning agents, particulates, dust, mold, fibers, and allergens. Humans also create favorable conditions for the development of millions of mold, fungus, pollen, spores, bacteria, viruses, and insects, such as dust mites and roaches. Combustion sources and cooking activates contribute to carbon dioxide (CO₂), sulfur dioxide (SO₂), CO, nitrogen dioxide (NO₂), and particulate matter (PM) emissions into indoor air environments. In addition, equipment, such as computers, photocopy machines, printers, and other office machines, emit ozone (O₃) and volatile compounds. Common building materials, such as poly(vinyl chloride) PVC floor covering, parquet, linoleum, rubber carpet, adhesive, lacquer, paint, sealant, and particle board, can shed toxic compounds (i.e., alkanes, aromatic compounds, 2-ethylhexanol, acetophenone, alkylated aromatic compounds, styrene, toluene, glycols, glycolesters, texanol, ketones, esters, siloxane, and formaldehyde). (Tran et al., 2020)

The respiratory system is frequently the primary target of IAP effects because pollutants often enter into the human body through inhalation. Inhaled air pollutants are associated with allergic diseases and pulmonary diseases, such as asthma, atopic dermatitis, and allergic rhinitis. Lung cancer is usually associated with smoking. Recently, it has been demonstrated that lung cancer is highly linked to IAP exposure in females due to spending long times cooking. (Tran et al., 2020)

The design and operation of ventilation systems also have a significant influence on IAQ. Due to superseding the stale indoor air by the fresh outdoor air, ventilation creates suitable IAQ and a

healthy indoor environment. There are several benefits for the operation of ventilation in a building including: (i) Providing oxygen and fresh air for human respiration; (ii) diluting indoor air pollutants to reach the short-term exposure limits of harmful contaminants as well as odors and vapors; (iii) using outdoor air with a low aerosol concentration to control aerosols inside buildings; (iv) controlling internal humidity; and (v) creating proper air distribution and promoting healthy and comfortable environment. (Tran et al., 2020)

Toxicity in the Food Chain

Toxicity in the food chain happens through the air, water, and soil contamination.

Air pollutants such as car exhaust, mold spores, dust, pollen, particulate matter, carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead can end up in both the food and water supply. Air pollution is of greater concern to general health, as it can contribute to respiratory illnesses, allergies, and cancer. There is a higher level of chemicals in smoggy, heavily populated industrial areas.

Air pollution will affect our immunity. Common themes that emerge are of the capacity of air pollutants to stimulate pro-inflammatory immune responses across multiple classes of immune cell. Air pollution can enhance T helper lymphocyte type 2 (Th2) and T helper lymphocyte type 17 (Th17) adaptive immune responses, as seen in allergy and asthma, and dysregulate anti-viral immune responses. The clinical effects of air pollution, in particular the known association between elevated ambient pollution and exacerbations of asthma and chronic obstructive pulmonary disease (COPD), are consistent with these identified immunological mechanisms. Further to this, as inhaled air pollution deposits primarily on the respiratory mucosa this review focuses on mechanisms of respiratory disease. (Glencross et al, 2020)

Water pollution is also of great concern, as clean water is essential to life and the health of all humans, plants, and animals that share this planet.

According to the 2021 World Water Development Report released by UNESCO, the global use of freshwater has increased six-fold in the past 100 years and has been growing by about 1% per year since the 1980s. With the increase of water consumption, water quality is facing severe challenges. Industrialization, agricultural production, and urban life have resulted in the degradation and pollution of the environment, adversely affecting the water bodies (rivers and oceans) necessary for life, ultimately affecting human health. More than 80% of sewage generated by human activities is discharged into rivers and oceans without any treatment, which results in environmental pollution and more than 50 diseases. 80% of diseases and 50% of child deaths worldwide are related to poor water quality. (Lin et al., 2022)

Water pollution is mainly concentrated in industrialization, agricultural activities, natural factors, and insufficient water supply and sewage treatment facilities. First, industry is the main cause of water pollution, these industries include distillery industry, tannery industry, pulp and paper industry, textile industry, food industry, iron and steel industry, nuclear industry and so on. Various toxic chemicals, organic and inorganic substances, toxic solvents and volatile organic chemicals may be released in industrial production. If these wastes are released into aquatic

ecosystems without adequate treatment, they will cause water pollution. Arsenic, cadmium, and chromium are vital pollutants discharged in wastewater, and the industrial sector is a significant contributor to harmful pollutants. With the acceleration of urbanization, wastewater from industrial production has gradually increased. In addition, water pollution caused by industrialization is also greatly affected by foreign direct investment. Industrial water pollution in less developed countries is positively correlated with foreign direct investment. Second, water pollution is closely related to agriculture. Pesticides, nitrogen fertilizers and organic farm wastes from agriculture are significant causes of water pollution. Agricultural activities will contaminate the water with nitrates, phosphorus, pesticides, soil sediments, salts and pathogens. Furthermore, agriculture has severely damaged all freshwater systems in their pristine state. Untreated or partially treated wastewater is widely used for irrigation in water-scarce regions of developing countries, including China and India, and the presence of pollutants in sewage poses risks to the environment and health. (Lin et al., 2022)

Soil Contamination

Pesticides or insecticides are used to control insects, herbicides kill or inhibit the growth of unwanted plants such as weeds or certain types of grasses, and fungicides are used to control fungal problems such as molds, mildew, and rust. Millions of pounds of these chemicals are used each year, which destroy water ecosystems, wildlife, the soil that grows our food and us. These chemicals are sprayed directly onto the foods, which have the ability to absorb them. The health effects of pesticides depend on the type of pesticide. Some, such as the organophosphates and carbamates, affect the nervous system. Others may irritate the skin or eyes. Some pesticides may be carcinogens. Others may affect the hormone or endocrine system in the body. (US EPA, 2015)

The occurrence of harmful chemicals in the environment has become an issue of great debate in recent decades. Pesticides and other foreign substances in food products and drinking water along with toxic pollutants in the air pose an immediate threat to human health, whereas other contaminants gradually build up in the environment and in the human body, causing disease long after first exposure. It is also well known that many pesticides can accumulate in living species causing long-term and chronic effects, but there are difficulties in defining chronic exposure and disease outcomes, given the existence of a large series of variables of interest, such as lifestyle, occupation, diet preferences, and smoking, all of which must be taken into account to establish a disease-exposure relationship in the epidemiological investigation. (Damalas & Koutroubas, 2016)

Common types of pesticides are organochlorides, which are very toxic and kills by attacking the central nervous system of the pest. These types of chemicals are all carcinogenic, mutagenic, and teratogenic, and stored and accumulate in the body's fatty tissues. Organophosphates (OP) are the most commonly used pesticides today. Approximately 80 million pounds of OP pesticides are used annually in the United States, with 75% of their use in agriculture. Some of these chemicals are the deadly nerve gases developed and used during war. Within the human body, organophosphates act as inhibitors of the enzyme acetylcholinesterase (AChE), leading to excess neurotransmitter acetylcholine (ACh). Acetylcholine (ACh) is a neurotransmitter formed from

acetyl-CoA, which in turn is produced from glucose and choline through the catalytic action of choline acetyltransferase. Individuals may experience memory loss, speech impairment, lack of coordination, and impaired judgment. Chronic exposure to organophosphates can also cause flu-like symptoms, including nausea, vomiting, malaise, and weakness, as well as it has also been associated with peripheral polyneuropathy. Exposure to certain organophosphates has been associated with a potential risk of cancer. Approximately 3 million people globally are exposed to organophosphates, resulting in around 300,000 fatalities. (Adeyinka & Pierre, 2019)

Carbamates are another class of insecticides and bear a chemical resemblance to organophosphate pesticides. Dichlorodiphenyltrichloroethane (DDT) is an insecticide used in agriculture. The United States banned the use of DDT in 1972. Some countries outside the United States still use DDT to control of mosquitoes that spread malaria. DDT is another types of organophosphate pesticide. (CDC, 2021)

Washing fruits and vegetables may not get rid of all these chemicals. Consuming organic or locally grown chemical-free food is one way to avoid agriculture chemicals. Whole foods, consumed in their natural state, also reduces exposure to many additives and preservatives that are found in conventional packaged foods. Certified organic food and drink in the U.S. was estimated at \$59.1 billion in 2010.

The ACNielsen study investigated 33,625 grocery products in conventional retail channels and found:

- 2,281 items were organic grocery products which represented 6.8% of total scanned products.
- Sales value of scanned organic products was \$443.2 million which is equivalent to 1.8% of the sales value of all scanned goods.
- 90.2% of scanned organic items were "certified" organic.
- Organic private label items represented 21% of scanned organic food.

Organic Retail Sales and Trends:

- The value of organic food products sold in Canada through all retail channels was estimated at \$2 billion in 2008.
- Represents a 66% growth over 2006 (\$1.2 billion).

The Clean 15/Dirty Dozen provided by the Environmental Working Group is a guide that shows which fruits and vegetables tested have very low or no traces of pesticides. The Shopper's Guide represents EWG's analysis of the latest fruit and vegetable testing data from the Department of Agriculture and Food and Drug Administration. The 2023 guide includes data from 46,569 samples of 46 fruits and vegetables. The USDA peels or scrubs and washes produce samples before testing, whereas the FDA only removes dirt before testing its samples. Even after these steps, the tests still find traces 251 different pesticides. (Environmental Working Group, 2023)

The 2023 Dirty Dozen:

Of the 46 items included in our analysis, these 12 fruits and vegetables were most contaminated with pesticides:

- Strawberries
- Spinach
- Kale, collard, and mustard greens
- Peaches
- Pears
- Nectarines
- Apples
- Grapes
- Bell and hot peppers
- Cherries
- Blueberries
- Green beans

The 2023 Clean 15:

- Avocados
- Sweet corn
- Pineapple
- Onions
- Papaya
- Sweet peas (frozen)
- Asparagus
- Honeydew melon
- Kiwi
- Cabbage
- Mushrooms
- Mangoes
- Sweet Potatoes
- Watermelon
- Carrots

Food Processing

The majority of food is processed in some way or another before it is consumed. Commercially, there are six main reasons why food is processed.

- To improve shelf-life or storage time
- To make food more available
- To increase the nutritional value
- To improve the flavor of foods

- To make food easier to prepare
- To improve consumer acceptance

Processed foods add chemicals to the food in three ways; by ingredients, contaminants, and silent additives. There are approximately 3,000 food additives that are approved for consumption and deemed safe. These chemicals are on the GRAS list - Generally Recognized As Safe. This list was developed in 1959, which some additives were exempt from the regulation process and some controversy regarding this list.

The law requires food additives to undergo approval by the U.S. Food and Drug Administration (FDA) before they are sold, but GRAS substances are exempted from pre-market approval. In 1997, FDA created a voluntary program for manufacturers to submit their chemical's safety determination in the form of a GRAS notice to the agency. Manufacturers make GRAS determinations regardless of whether they voluntarily submit a notice to FDA for review. They rely on their own employees, the employee of a hired consulting firm or a panel of experts, known as GRAS panel, to review the safety information. Because this process determines whether a chemical is safe for use in food, conflicts of interest and biases need to be avoided or minimized to credibly ensure food is safe. With 403 GRAS notices filed by FDA between 2015 and 2020 and identified whether a GRAS panel was convened and by whom, its members, affiliations, and relationships between panelists and panel conveners. Then, compared FDA's recommendations against the information included in the notices voluntarily submitted by manufacturers. No evidence was found that GRAS panels had adhered to FDA's guidance. Panels are populated from a very small pool of professionals; seven panel members alone occupied almost half of all available panel positions and that they often serve together. Against guidance recommendations, ad-hoc panels have been substituted by panels with recurring members in hired consulting firms' payroll. The widespread persistence of conflicts of interest, appearance of conflict and bias in GRAS determinations continue to put the health of Americans at risk and undermine confidence in the safety of food ingredients in the US market. FDA should require notice for all GRAS determinations including how the financial conflicts of interest of those who make these determinations are minimized. (Matouskova et al., 2023)

Food additives are any substances that are added to food for an intended purpose. Food additives can be from a natural source such as vitamin E as a preservative, citric acid to help foods keep their colour, or fortified to add nutrients such as folate or iron to reduce nutritional deficiencies. Additives can also be artificial or chemical based such as sodium nitrite, aspartame, or artificial colouring agents. Some additives may be natural occurring, but are linked to negative health affects such as trans fats, sulfites, or monosodium glutamate (MSG).

Types of additives include:

- Sweeteners
- Flavoring
- Colouring agents
- Preservatives

- Acids, alkalis, buffers & neutralizers
- Bleaching and maturing agents
- Moisture controls
- Activity controls
- Emulsifiers
- Texturizers
- Clarifying agents
- Nutritional supplements

Artificial food colouring are chemicals made from petroleum and coal-tar products, which can create toxicity and stress of the liver plus some dyes are listed as carcinogenic agents by the World Health Organization. (David et al., 2012)

Research also shows concerns about possible associations between exposure to synthetic food dyes such as FD&C Yellow #5 or tartrazine and the exacerbation of symptoms of Attention Deficit/Hyperactivity Disorder (ADHD) in children. (Miller et al, 2022)

Food Contamination

All foods, no matter how it is stored, has a shelf life, which varies from a few hours to many years. Food can spoil. Food preparation can create a number of problems, which food contamination is the main one. Microorganisms such as mold are the most common, as certain molds produce toxins such as aflatoxins. Certain mushrooms contain toxic chemicals that create symptoms ranging from intestinal upset to fatal neurotoxicity. Bacteria can also produce toxins.

Foodborne illnesses are common in industrialized nations, which certain bacteria are at the root of most foodborne illness cases. Bacteria such as E.coli or salmonella contribute to a large number of cases.

In Canada, foodborne pathogens cause an estimated 4 million cases of gastrointestinal illness annually from known and unspecified agents and serotypes of Campylobacter, Escherichia coli and Salmonella are commonly implicated. Annual cases in Canada were estimated as 447, 122 and 270 per 100 000 people for Campylobacter, E. coli and Salmonella. These cases represent a significant cost to the Canadian economy in terms of lost production and medical treatment estimated at approximately \$325 million per annum. (Smith et al, 2019)

Understanding basic food safety and handling is the best way to reduce foodborne illnesses. Proper food storage is vital to manage food safety. Keep the refrigerator at or below 4 degrees Celsius, which will reduce any bacteria growth. Keep raw meat in sealed containers, away from fresh produce to avoid any type of cross-contamination. Properly wash your hands and surfaces or cutting boards after handling raw meat or have a specific cutting board that is only used for meat and is separate from handling produce helps to reduce cross-contamination. Use an oven safe food thermometer when cooking meat. Most leftover food will last about four days in the refrigerator. For freezing meat or fruits and vegetables, keep the freezer cold, the colder the

better. Ensure that food is properly packed to reduce freezer burn, which can ensure the quality of the food.

Food Irradiation:

Food is irradiated to prolong shelf-life and reduce mold contamination during the shipment of food. This process also reduces microorganisms from being transported across borders. Some of the foods that are irradiated are spices, herbs, pork, grains, beef, fruits and vegetables and frozen foods. The government deems this process completely safe. However, irradiated foods are not labeled. Foods that are irradiated are not radioactive, but may produce a genetic issue such as polyploidy (an abnormal condition in which cells contain more than two sets of chromosomes). This process may also affect the nutritional content of the food.

Quality of Meat:

Contamination between species can happen when animal parts are used in feed for other animals. Another source of food contamination is through the wide use of antibiotics in animal feed, which can create a number of serious health problems if the strain of bacteria becomes bacteria-resistant such as *E. coli*. Hormones in animal feed is not as common as antibiotics, which both are used for the animal to gain weight. In Canada, growth hormones are only approved for use in cows used for beef. Health Canada has approved three natural hormones and three synthetically produced hormones for use in cattle in Canada. Health Canada sets maximum levels of hormones and antibiotics that can be left in food. Growth hormones are not used in cows that produce milk.

GMOs

GMOs or “genetically modified organisms” are organisms whose genetic material has been artificially manipulated in a laboratory through genetic engineering (GE). This relatively new science creates unstable combinations of plant, animal, bacterial and viral genes that do not occur in nature or through traditional crossbreeding methods. About 70% of products on the shelves contain some genetically modified components. Soy, canola, and corn are the highest GMO crops. GMO foods are not labeled and long-term health effects are still being determined. GMO foods can contribute to allergies, immune suppression, and risk of cancer.

GMO crops include:

- Alfalfa (first planting 2011)
- Canola (approx. 90% of U.S. crop)
- Corn (approx. 88% of U.S. crop in 2011)
- Cotton (approx. 90% of U.S. crop in 2011)
- Papaya (most of Hawaiian crop; approximately 988 acres)
- Soy (approx. 94% of U.S. crop in 2011)
- Sugar Beets (approx. 95% of U.S. crop in 2010)
- Zucchini and Yellow Summer Squash (approx. 25,000 acres)

The Institute for Responsible Technology reports that:

- Thousands of sheep, buffalo and goats in India died after grazing on Bt cotton.
- Mice eating GM corn long term had fewer and smaller babies.
- More than half the babies of mother rats fed GM soy died within three weeks.
- Testicle cells of mice and rats on a GM soy change significantly.
- By the third generation, most GM soy-fed hamsters lost the ability to have babies.
- Rodents fed GM corn and soy showed immune system responses and signs of toxicity.
- Cooked GM soy contains as much as 7-times the amount of a known soy allergen.
- Soy allergies skyrocketed by 50% in the UK, soon after GM soy was introduced.
- The stomach lining of rats fed GM potatoes showed excessive cell growth, a condition that may lead to cancer.
- Studies showed organ lesions, altered liver and pancreas cells, and changed enzyme levels.

Before the FDA decided to allow GMOs into food without labeling, FDA scientists had repeatedly warned that GM foods can create unpredictable, hard-to-detect side effects, including allergies, toxins, new diseases, and nutritional problems. Unlike safety evaluations for drugs, there are no human clinical trials of GM foods. Recent health studies provide growing evidence of harm from GMOs such as GM Corn may damage the liver and kidneys, meat raised on GM feed is different, Roundup could cause birth defects, GM Soy linked to sterility, and GM crops do not actually increase yields.

Detoxification

What is Detoxification?

Detoxification is the process of clearing toxins from the body, neutralizing, and transforming toxins in preparation for elimination, and clearing excess mucus and congestion. Detoxification is a relative term for anything that supports elimination can be said to help the body detoxify.

Sources of Toxins:

- External toxins come from diet, drug use, and environmental exposure
- Internal toxins include oxidized fats, free radicals, and other irritating molecules

Poor digestion, slow bowel motility and dysfunction, reduced liver function, and poor elimination through the kidneys, respiratory tract, and skin add to increased toxicity.

Benefits of Detoxification:

- Reduces risk of disease
- Reduces symptoms of toxicity
- Increases energy levels
- Cleanses the body and rests the body's organs

- Purification and rejuvenation
- Clears the skin
- Slows the aging process
- Improves flexibility
- Improves fertility
- Enhances the senses
- Balances hormones and mood

Who, Why, and When Should One Detoxify?

The human body has a natural detoxification process built in given the right nutrients, following a healthy diet and lifestyle, staying hydrated, having proper sleep and exercise. The liver, kidneys, skin, bowels, and lymphatic system all play an important role in helping the body rid itself of toxins. Detoxification is an important process to remove unwanted toxins and materials that the body is exposed to plus that are created in the body by normal metabolic processes. A healthy individual is able to support the detoxification process with good quality, whole foods, exercise, proper sleep, avoiding alcohol, drinking a higher amount of filtered water, and avoiding exposure to chemicals.

The body can become burdened from poor diet, smoking, alcohol consumption, the immune system fighting infections, and general metabolic processes, which can contribute to symptoms of toxicity such as fatigue, headaches, digestive upsets, frequent colds and flus, constipation, mood changes and disorders, sugar cravings, and slower metabolism leading to weight gain and the inability to lose weight. If one is suffering these types of symptoms, it may be time to support the body's detoxification process. Most healthy people will be able to detoxify the body, however, it is not suggested that anyone who is pregnant, dealing with a serious medical condition, children or the elderly follow any type of detoxification program. Detoxification programs can vary and may pose a health risk. Any detoxification or cleansing programs should be outlined by a professional trained in nutrition plus if there is an underlying health condition, the person should also speak to their licenced healthcare provider.

The first step to start any type of cleanse or detoxification is to get the routes of elimination working. This means that bowel motility needs to be addressed first. Proper kidney function is also important, as both feces and urine are modes of removing toxins from the body. These routes of elimination can be improved by increasing both soluble and non-soluble fibre, increasing filtered water consumption, removing any type of processed, packaged foods from the diet, eating whole, natural foods such as fruits and vegetables, and increasing fermented foods or taking a probiotic supplement. This may also mean that any intestinal imbalances such as dysbiosis, candida overgrowth, and intestinal permeability will need to be addressed to support bowel function and motility.

The major percentage of blood being filtered by the liver is from the portal vein, which carries blood from the intestines. The liver can remove a broad spectrum of microorganisms such as bacteria, fungi, viruses, and parasites from the blood. Many of the toxic chemicals that enter the body are fat-soluble, which they dissolve only in fatty or oily solutions and not in water. This makes them difficult for the body to excrete. Fat soluble chemicals have a high affinity for fat tissues and cell membranes, which are composed of fatty acids and proteins. In these fatty tissues

of the body, toxins may be stored for years, being released during times of exercise, weight loss, stress, detoxification, or fasting.

Liver Phases and Detoxification Pathways:

The physiological pathways for detoxification are mainly centered around phase I and phase II enzyme systems of the liver. The liver is the body's most important organ of detoxification, as it continuously processes all forms of substances entering the body from the digestive tract plus the rest of the body such as the skin and respiratory system. The liver deals with all of these compounds, some of which are highly toxic and others which are beneficial and determines what to do with them. The liver does an amazing job of choosing which compounds need to be kept and which need to be removed from the body. It functions like a chemical factory manufacturing certain substances, detoxifying dangerous chemicals and toxins, and directing nutrients all over the body for use, storage, or excretion. The liver makes use of two pathways to detoxification the body, which are known as phase I and phase II pathways. Phase 1 is responsible for breaking down compounds and toxins and sending them to phase 2, which builds new substances from these compounds and toxins by adding molecules to them, which is called conjugation.

The "phases" of detoxification were described as functionalization (or phase I), or the addition of oxygen to form a reactive site on the toxic compound, and conjugation (phase II), or the process of adding a water-soluble group to this now reactive site. (Hodges & Minich, 2015)

During the phase I pathway, toxic chemicals are converted into less harmful chemicals through many chain reactions through the induction of the P450 enzyme. The phase I cytochrome P450 superfamily of enzymes is generally the first defense employed by the body to transform xenobiotics (synthetic chemical), steroid hormones, and pharmaceuticals. The ability of an individual to metabolize 90% of currently used drugs largely depends on the genetic expression of liver enzymes.

Phase I uses many enzymes to break down chemical substances. This phase is known as the 'subtraction' phase of metabolism, where the enzymes subtract molecules from substances and break them down into smaller substances, similar to the digestive system breaking down a complex carbohydrate into glucose. Phase 1 is dependent on all of the different enzymes in the liver for this process. The presence or absence of certain nutrients in the diet can either speed up (induce) or slow down (inhibit) this phase. After the enzymes have broken down some of the substances, some very toxic end products (metabolites) remain, which they must be quickly moved to phase II pathway in order to make them safer for the body to use. Heavy metals can make these important liver enzymes dysfunctional. Various nutrients are required in order for the phase I detoxification system to be carried out efficiently. Cytochrome P450 reactions generate free radicals, which can cause secondary damage to cells, so an adequate supply of antioxidants is essential to reduce tissue damage during this phase. The metabolites from phase I are often potentially more harmful than their original toxic compounds, which it is important for health that these toxic compounds do not build-up. This is where phase II of liver detoxification comes in. (Hodges & Minich, 2015)

After a xenobiotic has gone through the process of becoming hydrophilic (a molecule that can mix and interact with water) through reactions overseen by CYP450 enzymes, its reactive site can be conjugated with an endogenous hydrophilic substance. This reaction is often referred to as "phase II detoxification." (Hodges & Minich, 2015)

In other words, this phase involves converting the fat-soluble toxic chemicals and transforming the toxins into water-soluble chemicals., which make them easier to pass through bodily fluids such as bile or urine. Both phase I and phase II must be in balance. In some cases, the detoxification pathways (Phases I and II) are out of balance, which if phase I is more active than phase II, a build-up of reactive intermediate metabolites can occur, which can lead to tissue damage and disease.

Diet for Detoxification:

The first step in the use of nutritional support to promote detoxification is to remove foods and beverages from the diet that may be contributing to the total body burden of toxicants. Examples include removing (1) foods containing petrochemical residues from farming practices; (2) foods containing polycyclic aromatic hydrocarbons such as charbroiled meat; (3) trans fats; and (4) water contaminated with metals and chemicals. Next, it is important to add foods to the diet that nourish the organs of detoxification, providing substrates and cofactors for optimal detoxification. For the P450 enzymes to be present and conformationally active, an individual must consume high-quality, bioavailable protein as well as a host of phytonutrients, botanicals, minerals, fats, and carbohydrates.

Nutrient cofactors required for phase I cytochrome P450 reactions include riboflavin, niacin, magnesium, iron, and certain phytonutrients such as indoles from cruciferous vegetables, resveratrol, and quercetin support phase I detoxification. (Hodges & Minich, 2015)

Grapefruit juice contains naringenin, a substance which slows down phase 1 enzyme activity. This can also increase the half-life of some drugs, causing them to remain active longer. Curcumin, the compound that gives turmeric its yellow colour, can inhibit phase I while stimulating phase II. Cruciferous vegetables and berries have been suggested as possible modulators of estrogen metabolites. (Hodges & Minich, 2015)

An adequate amount of high-quality, bioavailable protein is important, as a source of amino acids for the production of the phase I CYP enzymes as well as the provision of substrates for phase II enzymes, particularly glycine, L-glutamine, methionine, L-cysteine, and taurine. (Cline, 2015) A low-fat diet can dramatically slow phase II detoxification.

As various nutrients are required for phase II conjugation, which are bound to the toxicants, nutrients can potentially become depleted unless an ongoing dietary supply exists. B vitamins play a major role by acting as cofactors for many enzyme systems including those of liver detoxification. Consume enough of the B complex group of vitamins, as they are needed for optimum detoxification. Vitamin B12 helps to metabolize fats and improves liver health.

After conjugated toxicants exit the liver via the bile, they are excreted into the feces. One component of bile is the variety of bile acids that are necessary to emulsify and solubilize dietary fats. In the distal small bowel, 90% to 95% of the bile acids are reabsorbed and returned to the liver, thus recycling and conserving them. Foods that help increase bile flow are essential for the phase II process and elimination of toxins from the body. (Cline, 2015)

Certain foods that help to protect the liver and detoxify the body include:

- Apples contain pectin which helps to bind and excrete heavy metals in the intestinal tract, which directly helps to reduce the load of filtration on the liver.

- Beets, carrots, red onions, and aubergine (eggplant) contain flavonoids and beta-carotene which are potent antioxidants.
- Lemon is beneficial during a detoxification due to its high amount of vitamins and polyphenols. Lemons are considered master cleansers for general liver health.
- Garlic contains allicin and the mineral selenium, both antioxidants, which assists the removal of heavy metals from the liver.
- Eggs, brown rice and whole grains, broccoli and spinach contain B-complex vitamins, which improve liver function and promote liver decongestion.
- Cruciferous vegetables such as cauliflower, broccoli, cabbage, Brussels sprouts, Bok Choy, kale, radishes, and turnips contain glucosinolates which help the liver produce enzymes for detoxification and aid cytochrome P450 activity. These foods are also rich in the mineral sulphur to enhance phase II detoxification.
- Artichoke leaf promotes regeneration of liver cells and promotes blood flow in that organ, which stimulates bile flow. Artichokes also helps with liver drainage.
- Bitter vegetables such as bitter melon, dandelion greens, mustard greens, and chicory promote the production and flow of bile.
- Dark leafy greens provide folate, which is an essential nutrient for methylation.
- High fibre foods such as whole grains, psyllium, flax or chia seeds, fruit, and vegetables, as fibre binds to toxins and eliminates them through the bowels.

Dandelion root and milk thistle tea help stimulate liver secretions and bile flow. According to research, these herbal extracts protect liver cells by reducing the entry of viral toxins and other toxic compounds into the liver cells. These herbals also promote the regeneration of liver cells.

Chlorella has the potential to inhibit the absorption of certain heavy metals and organic pollutants across the intestinal mucosa, thus decreasing the enterohepatic circulation of these toxicants (Merino et al, 2019).

Alginate is a type of fibre found in seaweed that binds to heavy metals and other toxins to remove them from the body.

Tips for a healthy liver:

- Eat organically or chemical-free produced foods as much as possible to avoid toxic chemical residues.
- Avoid artificial flavorings and preservatives.
- Avoid damaged fats such as hydrogenated fats found in many processed foods.
- Limit or avoid excessive alcohol intake.
- Maintain a healthy weight.
- Exercise regularly.
- Manage stress.
- Use natural home and body care products to reduce chemical exposure.

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