MODULE 5

BLOOD SUGAR REGULATION

STUDENT GUIDE

NTA Nutritional Therapy Association

CONTENTS

MODULE OVERVIEW

WHAT YOU WILL LEARN IN THIS MODULE & HOW TO USE THIS GUIDE

LEARNING OUTCOMES

- Recognize and state a client soundbite for each of the four Big Ideas in Blood Sugar Regulation.
- Discuss the interaction of the pancreas, adrenals, adipose tissue, liver and skeletal muscle (PAALS), including influential hormones and physiological processes for blood sugar regulation and energy production.
- Explain the role of the HPA axis in blood sugar regulation.
- Explain the metabolic processes the body uses to convert each of the macronutrients into energy and recommend different fuel sources for different activities and situations.
- Explain how dietary and lifestyle choices, environmental toxicity, physiology and other factors can negatively impact blood sugar regulation.
- Analyze an individual's energy cycles and symptoms as indicators of blood sugar dysregulation.
- Recommend dietary and lifestyle changes based on bioindividuality that positively impact metabolic flexibility.

SEE **VIDEO 1: INTRODUCTION TO BLOOD SUGAR REGULATION** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR CATHY EASON.

LEARNING ACTIVITIES

- **Diagram:** Draw a diagram of the PAALS and CNS, with associated organs and glands, physiological processes, and hormones.
- **Practical Application:** Connect your personal Food and Mood Journal with energy levels and note suggestions for improvement.
- **Journal:** Implement a suggestion from the "Practical Application" assignment and share your findings.

REQUIRED READING

- **Student Guide:** All
- **Introduction to the Human Body:** Chapter 13, The Endocrine System
- **Signs and Symptoms:** Blood Sugar Dysregulation - pages 275-286
- **Adrenal Fatigue:** All
- **Staying Healthy with Nutrition:** Chapter 5, B Vitamins - pages 109-126; Chapter 5, Other B Vitamins - pages 127-138; Chapter 6, Chromium - pages 177-180

HOW TO USE THIS STUDENT GUIDE

Purpose

This guide acts the primary resource for the Blood Sugar Regulation module. It is written to complement the video lectures, and can either be read before or after viewing the videos depending on your learning style.

Navigation

This guide is divided into 7 main sections (which you can quickly jump to using the interactive page numbers in the table of contents above):

- **Module Overview:** What You Will Learn in this Module & How to Use This Guide
- **Anatomy Basics:** The Primary Organs & Hormones Involved in Blood Sugar Regulation
- **Energy & Fuel:** How Cellular Energy is Produced in the Body
- **Dysglycemia:** How Blood Sugar Becomes Dysregulated
- **Diet & Lifestyle:** How to Eat, Relax, and Move Your Way Back to Balance
- **Glossary:** Definitions of Key Words
- **References:** Additional Resources & Citations

Key Words & Glossary

Key words are shown in **bolded blue font** and are defined in the Glossary section.

Citations

Citations are marked with interactive superscript links that take you directly to the the Reference section. Each citation includes links to easily access the studies online. Click the citation number to return to your previous location in the guide.

Learning Tips

Learning tips, language lessons, and notes of interest are shown as follows:

LEARNING TIPS LOOK LIKE THIS

Related Resources, Modules & Videos

Related resources are shown as follows, with different icons depending on the resource type (e.g. a bookmark icon for resources & a play button for videos):

RELATED RESOURCES LOOK LIKE THIS

Big Ideas

Big Ideas provide a useful summary of key concepts and "educational soundbites" you can share with clients. They are shown as follows:

BIG IDEAS LOOK LIKE THIS

ANATOMY BASICS

THE PRIMARY ORGANS & HORMONES INVOLVED IN BLOOD SUGAR REGULATION

THE IMPORTANCE OF BLOOD SUGAR REGULATION

Blood sugar regulation is one of the NTA's "Foundations" because it affects all aspects of human physiology:

- Energy production and balance
- The tissue integrity of every organ and blood vessel
- Hormonal balance (including hormones of digestion, stress, and sexual function)
- Brain health, mood, memory, and cognitive function
- If blood sugar regulation is not working efficiently, overall health cannot be achieved, leading to oxidative stress, glycation, and erratic energy output.

Optimization of the blood sugar regulation system and the primary blood sugar regulation organs is a top priority in every health challenge.

SEE **VIDEO 2: THE BIG IDEAS OF BLOOD SUGAR REGULATION** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR VICTORIA LAFONT.

GLUCOSE & GLYCOGEN

Glucose is the technical name for "blood sugar." It is an important source of energy which, along with fatty acids and proteins, can be converted into **ATP** (adenosine triphosphate), the fuel used in every cell in your body.

The Glucose Sweet Spot

A small amount of glucose is found in the blood stream at all times (an average of approximately 4 grams [1]), a precise amount which is tightly regulated by the **CNS** (central nervous system) in an optimal range of 70 to 90 mg/dL (3.9 to 5.0 mmol/L). If serum glucose levels move out of this tightly regulated range, the brain immediately triggers the release of hormones that work to return glucose levels to normal.

Most doctors are trained that "normal" means any **fasting blood glucose** (FBG) level under 100 mg/dL (5.6 mmol/L) and **postprandial blood glucose** (PPG) Levels less than 140 mg/dL (7.8 mmol/L). However, what constitutes truly "normal" or "healthy" FBG and PPG levels is a controversial topic. For example, in one study, individuals with FBG levels above 95 mg/dL (5.3 mmol/L) had more than 3 times the risk of developing Type 2 Diabetes than those with FBG levels below 90. [2] Another study showed progressively increasing risks of heart disease in individuals with FBG levels above 85 mg/dL (4.7 mmol/L) compared to those with FBG levels below 81 mg/dL (4.5 mmol/L).[3]

Storage of Excess Glucose

STORAGE AS GLYCOGEN

Excess glucose beyond what is needed to maintain this range in the blood is stored first as glycogen in the liver and skeletal muscles in a process called **glycogenesis**.

"GLYCO–" IS A LATIN ROOT MEANING "SUGAR" OR "GLUCOSE."

"–GENESIS" IS A LATIN ROOT MEANING "GENERATION" OR "CREATION."

Glycogen is a polysaccharide which can be easily converted back into glucose as needed to fuel bodily processed in a process called **glycogenolysis**.

"–LYSIS" IS A LATIN ROOT MEANING "BREAK DOWN."

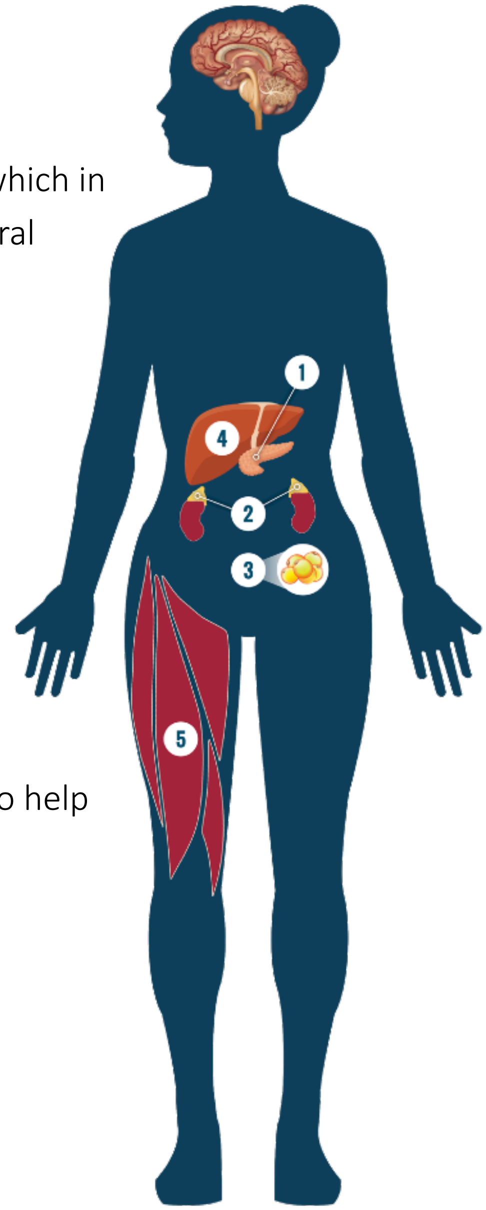
Depending on one's size, the human body can store approximately 100 grams of glycogen in the liver (400 calories) and 400 grams in the muscles (1,400 to 2,000 calories). Though the total ***quantity*** of glycogen stored in the muscles is higher than in the liver, the ***concentration*** of glycogen is much higher in the liver (10% by weight) than in the muscles (2% by weight).[4]

"STARCH" IS THE FORM OF GLYCOGEN FOUND IN PLANTS.

STORAGE AS TRIGLYCERIDES

Once one's glycogen stores are full, any additional glucose is stored as **triglycerides** in the **adipose tissue** in a process called **lipogenesis**.[5]

KEY ORGANS & HORMONES



The brain is the primary organ of blood sugar regulation, which in turn directs the activity of the following 5 primary peripheral organs and tissues (the "**PAALS**") via the CNS:[6]

- **P**ancreas ①
- **A**drenal glands ②
- **A**dipose tissue ③
- **L**iver ④
- **S**keletal muscle ⑤

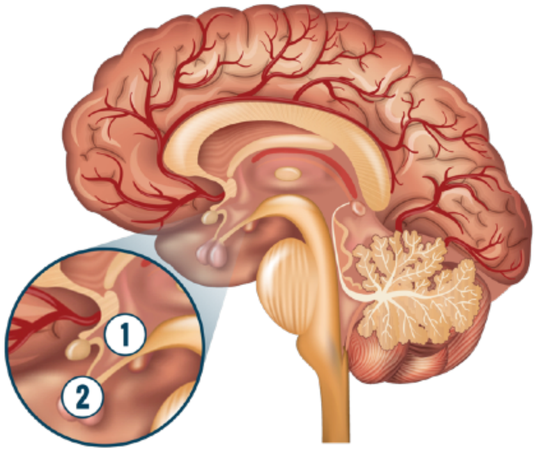
Also, the CNS works in tandem with 5 primary hormones to help regulate blood sugar levels:

- Insulin
- Glucagon
- Epinephrine & Norepinephrine
- Cortisol

BIG IDEA 1: BLOOD SUGAR REGULATION IS CONTROLLED BY THE CENTRAL NERVOUS SYSTEM'S COMMUNICATION WITH THE "PAALS": THE PANCREAS, THE ADRENAL GLANDS, ADIPOSE TISSUE, THE LIVER, AND SKELETAL MUSCLE.

SEE **VIDEO 3: THE PAALS & G-WORDS** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR VICTORIA LAFONT.

The Brain & CNS



The CNS is comprised of the brain and the spinal cord. There are many different areas within the brain, but the **hypothalamus** ① and **pituitary** ② are of key importance in regulating blood sugar levels.

It was once believed that blood sugar levels are primarily regulated by hormones released by the pancreas, adrenals, and liver, but decades of research now show that blood sugar is controlled first and foremost by the CNS, which in turn coordinates with the peripheral organs to regulate blood sugar levels. [7 8]

IF BLOOD SUGAR REGULATION WERE AN ORCHESTRA, THE CNS WOULD BE THE CONDUCTOR, WHILE THE "PAALS" WOULD BE THE INSTRUMENTS.

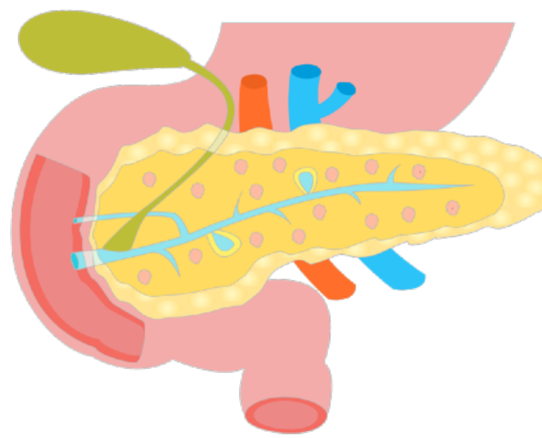
The hypothalamus and pituitary direct changes in glucose output from the liver and glucose uptake as follows:

- Glucose levels are monitored closely by glucose-sensing neurons in the hypothalamus.
- These signals are integrated with other information collected from afferent neurons (neurons that transmit signals from peripheral organs or body parts to the CNS), circulating hormone levels (e.g. insulin), and the quantity of postprandial (post-meal) nutrients.
- If glucose levels are deemed too high or too low, the hypothalamus communicates needed changes in blood sugar levels to the pituitary gland.

- The pituitary then directs the "PAALS" (via hormonal signals and efferent neurons) to either increase conversion of glycogen to glucose (output), or glucose to glycogen (uptake).[9]

HYPOTHALAMUS → PITUITARY → PAALS

The Pancreas



The pancreas is located just behind the stomach, stretching about 6 inches (15 cm) along the back of the abdomen. The organ is known as a **mixed gland** since it serves both **endocrine** and **exocrine** functions.[10 11]

ENDOCRINE FUNCTIONS OF THE PANCREAS

As an endocrine gland, the pancreas produces a number of important hormones within a small cluster of cells called the **Islets of Langerhans**, which make up about 1% of the total pancreas mass. These cells produce two particularly important hormones for blood sugar regulation:

- **Insulin**, a hormone produced in the **beta cells** of the pancreas which helps store excess blood sugar away in our liver, muscles, and fat tissue. Think of insulin as a key that unlocks our cellular "gates" to let glucose and fat *into* our cells.

"INSULIN" IS FROM THE LATIN WORD "INSULA", MEANING "ISLAND"

- **Glucagon**, a hormone produced in the **alpha cells** of the pancreas which helps release stored energy for use in the body. Think of glucagon as a key that unlocks our cellular "gates" to let glucose and fat ***out of*** our cells.

"GLUCAGON" IS A COINED TERM FROM "GLUCOSE AGONIST"

EXOCRINE FUNCTIONS OF THE PANCREAS

As an exocrine gland, the pancreas produces and secretes two important substances into the duodenum to aid in healthy digestion:

- pancreatic juice
- digestive enzymes

The pancreatic juice contains a substance called **bicarbonate**, which helps neutralize the highly acidic **chyme** entering the duodenum from the stomach. The digestive enzymes include:

- **pancreatic proteases**, which help break down proteins
- **pancreatic amylase**, which helps break down carbohydrates and sugars
- **pancreatic lipase**, which helps break down dietary fats

INSULIN = ENERGY STORAGE

When blood sugar levels get too high, the pancreas releases the hormone insulin, which helps store away excess energy in three key ways:[12]

- The liver converts glucose to glycogen via a process called **glycogenesis**, and stores it for future use. The average adult can store approximately 100 grams of glycogen in the liver, accounting for about 10% of the organ's weight.

- Like the liver, skeletal muscle cells also convert excess blood glucose to glycogen via glycogenesis, and store it locally for future use. The average adult can store approximately 400 grams of glycogen in their skeletal muscles, accounting for 1 to 2% of muscle mass. Note that the more muscle mass we have, the more glycogen we can store.
- When the liver and muscle glycogen stores are full, the liver then converts any remaining glucose to triglycerides, which are then stored in fat cells.

IN ADDITION TO HELPING REGULATE ENERGY STORAGE, INSULIN IS HIGHLY "ANABOLIC" AND IS VERY IMPORTANT IN THE BUILDING OF MUSCLE TISSUE.

GLUCAGON = ENERGY RELEASE

When blood sugar gets too low, the pancreas releases the hormone glucagon, which increases the pool of available fuel in the blood stream in four key ways:[13]

- The liver converts glycogen back to glucose in a process called **glycogenolysis** (the opposite of **glycogenesis**), and releases glucose into the bloodstream.
- Muscle cells convert glycogen back to glucose, but unlike in the liver, this freed glucose is used locally in skeletal muscles instead of being released into the bloodstream.
- Fat cells release free fatty acids into the blood in a process called **lipolysis**.[14]
- Protein is converted to glucose within the liver in a process called **gluconeogenesis**.

INSULIN VS. GLUCAGON CYCLES

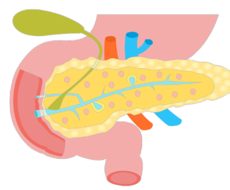
Insulin
Increases glycogenesis
Increases lipogenesis
Decreases lipolysis

Glucagon
Increases glycogenolysis
Increases gluconeogenesis
Increases lipolysis

When blood glucose levels get too **high**...

When blood glucose levels get too **low**...

...the pancreas releases **insulin** into the blood...



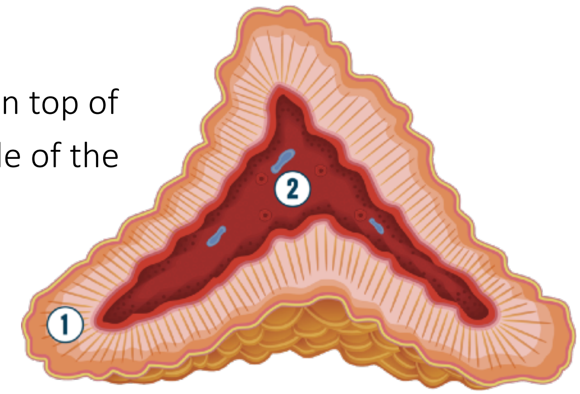
...the pancreas releases **glucagon** into the blood...

...which triggers glucose to be converted to **glycogen** in the liver.

...which triggers glycogen to be converted to **glucose** in the liver.

The Adrenal Glands

The adrenal glands are **endocrine glands** that sit on top of the kidneys. There are two glands, one on each side of the body. Each gland has two main parts:



- **adrenal cortex ①**
- **adrenal medulla ②**

"**ADRENAL**" IS FROM LATIN ROOTS: **AD**– = UPON + **RĒNĒS** (KIDNEY) + –**AL** (PERTAINING TO). "ADRENALINE" ADDS THE SUFFIX –**INE** (MADE OF)

"**CORTEX**" IS LATIN FOR "BARK," "RIND," "SHELL," OR "HUSK"

"**MEDULLA**" IS LATIN FOR"MARROW" OR "PITH"

ADRENAL CORTEX

The adrenal cortex has three zones, each of which produces distinct hormones:

- The glomerulosa, the outermost layer, produces aldosterone
- The fasciculata, the middle layer, produces cortisol
- The reticularis, the innermost layer, produces sex hormones

ADRENAL MEDULLA

The inner part of the adrenal gland, called the adrenal medulla, produces:

- The catecholamines **epinephrine** (a.k.a. adrenaline) and **norepinephrine** (a.k.a. noradrenaline)

"EPINEPHRINE" IS FROM GREEK ROOTS: **EPI–** (UPON) + **NEPHRÓS** (KIDNEY) + **–INE**

"EPINEPHRINE" AND "NOREPINEPHRINE" ARE THE STANDARD TERMS USED IN SCIENCE.

- The peptides somatostatin and Substance P

EPINEPHRINE

Epinephrine is a hormone produced by the adrenal medulla after receiving the signal from the CNS that a stressful situation has presented itself (whether an external threat like a bear or an internal threat like dangerously low blood sugar levels).[15] It prepares you to fight or flee by increasing:

- Heart rate
- Pupil and bronchial dilation
- Blood glucose and lipids

Epinephrine increases the quantity of available fuel in three key ways:

- Stimulating glycogenolysis in the liver, which converts glycogen to glucose
- Stimulating lipolysis, which releases fatty acids from triglycerides stored in body fat

- Stimulating gluconeogenesis, which converts lactate, glycerol, and amino acids to glucose in the liver

NOREPINEPHRINE

Norepinephrine is the main neurotransmitter used in the sympathetic nervous system (SNS). It is created in the adrenal medulla and postganglionic neurons. Like epinephrine, it's also involved in the fight-or-flight response and also binds to Alpha and Beta Receptors. Unlike epinephrine, norepinephrine also increases blood pressure through vasoconstriction.

CORTISOL

Cortisol is a steroid hormone released when stress levels are high or blood sugar levels are too low.[16] It increases the fuel available to the heart and skeletal muscles in the same basic ways as epinephrine:

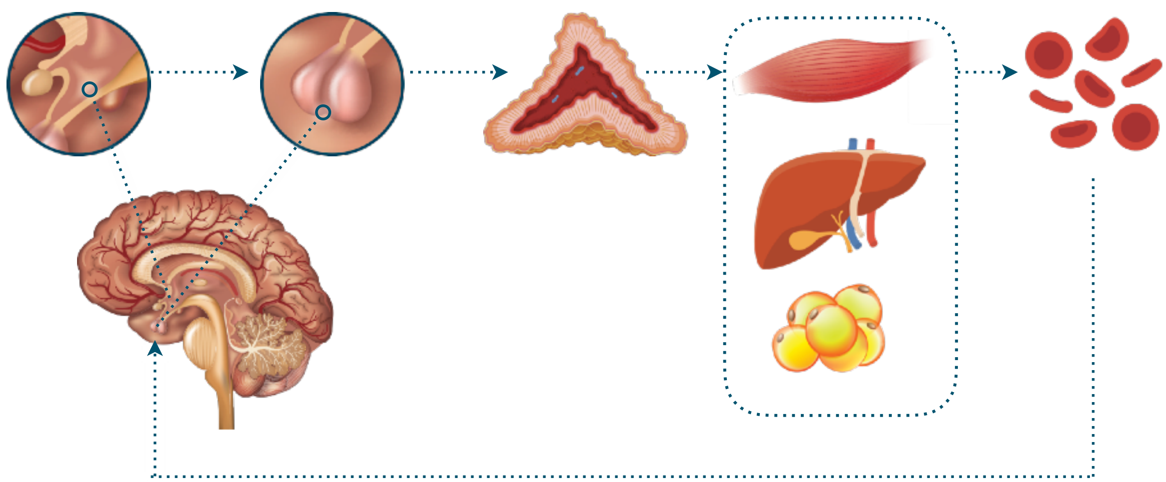
- Stimulating glycogenolysis
- Stimulating lipolysis
- Stimulating gluconeogenesis[17]

Cortisol, however, takes more time to respond to stressors (minutes rather than seconds), since it relies on a more complex process called the the **HPA Axis** (hypothalamic-pituitary-adrenal axis).

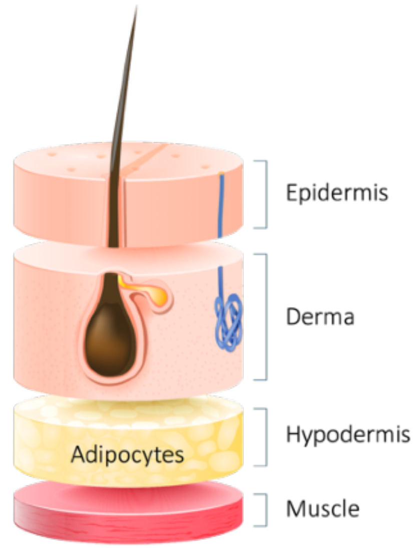
SEE VIDEO **VIDEO 4: THE HPA AXIS** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR VICTORIA LAFONT.

THE HPA AXIS

Step 1	Step 2	Step 3	Step 4	Step 5
Corticotropin-releasing hormone (**CRH**) is released from the **hypothalamus**.	Adrenocorticotropic hormone (**ACTH**) is released into the bloodstream from the **pituitary**.	Cortisol is released into the bloodstream from the adrenals.	Cortisol triggers **glycogenolysis**, **gluconeogenesis**, and **lipolysis**.	Blood sugar rises. CRH & ACTH are suppressed via a **negative feedback loop**.



Adipose Tissue



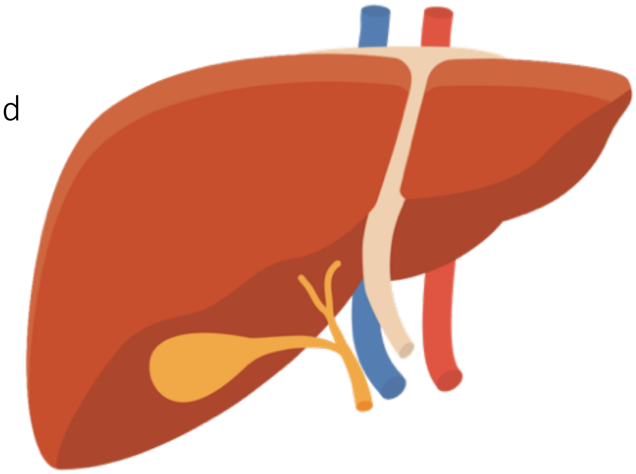
Body fat, technically called **adipose tissue**, is a form of loose connective tissue composed primarily of **adipocytes** (fat cells), which store energy in the form of **triglycerides** [18]when certain conditions are met (e.g. full glycogen stores, high blood sugar levels, high insulin levels, etc.).[19]

When the opposite conditions are met (e.g. depleted glycogen stores, low blood sugar levels, and low insulin levels), this stored energy can be freed from adipocytes, shuttled to cells in our muscles, brain, heart, etc., and converted into **ATP** (cellular energy). Gram for gram, triglycerides contain more energy than glycogen, and can be stored "anhydrously" (without water).

Contrary to popular belief, adipose tissue is ***not*** an inert tissue that simply stores extra energy for later use. In reality, the tissue can act as an endocrine gland, which synthesizes and secretes a number of hormones,[20] including:

- **leptin**, a hormone which ***inhibits*** hunger signals
- **ghrelin**, a hormone which ***triggers*** hunger signals

The Liver



The liver is a large, triangle-shaped organ located in the upper right quadrant of the abdomen under the ribs, with four lobes of varying sizes. With an average weight of 3.2 to 3.7 pounds (1.44 to 1.66 kg), the liver is the heaviest internal organ and the largest gland in the body. It performs more than 500 functions in the human body, including:

- Converting glucose into glycogen via glycogenesis for storage.[21]

GLUCOSE → GLYCOGEN = GLYCOGENESIS

- Converting glycogen back into glucose via glycogenolysis for use as energy around the body

GLYCOGEN → GLUCOSE = GLYCOGENOLYSIS

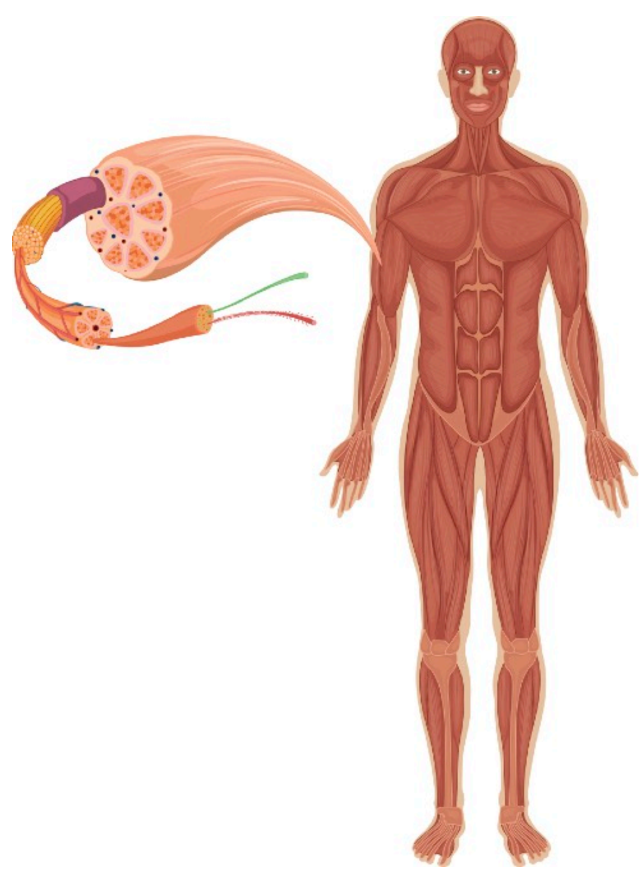
- Converting protein into glucose via gluconeogenesis
- Converting fatty acids into **ketones** via ketogenesis
- Producing triglycerides
- Producing cholesterol (about 1,000 milligrams per day), which is then used to create hormones, Vitamin D, and bile

- Producing **bile**, which helps digest dietary fats and eliminate toxins from the body
- Producing various proteins used in blood clotting, nutrient transport, and immune function
- Filtering and processing the nutrient-rich blood coming from the digestive tract before it circulates to the rest of the body
- Storing nutrients such as Vitamin B_{12}, iron, copper, and the fat-soluble vitamins A, D, E, and K
- Processing toxins (e.g. xenobiotics) and metabolizing alcohol, drugs, etc.

The Skeletal Muscles

The skeletal muscles play three keys roles in blood sugar regulation:[22]

- Helping normalize blood sugar levels by taking in excess glucose
- Storing excess glucose as glycogen
- Providing protein for gluconeogenesis



TAKING IN GLUCOSE

When blood sugar levels are too high, the pancreas releases insulin, which signals skeletal and cardiac muscles (as well as cells in the liver, fat tissue, and kidneys) to take in glucose. The diffusion of glucose across cell membranes is accomplished via the **GLUT-4** transporter and facilitated diffusion. When insulin binds with receptor sites on the surface of a cell, GLUT-4 transporters are moved to the plasma membrane, where they link together with glucose molecules via endocytosis.

GLUT-4 ACTIVITY IS PRIMARILY REGULATED BY INSULIN, BUT CAN ALSO BE INCREASED THROUGH HIGH-INTENSITY PHYSICAL ACTIVITY.

STORING GLUCOSE AS GLYCOGEN

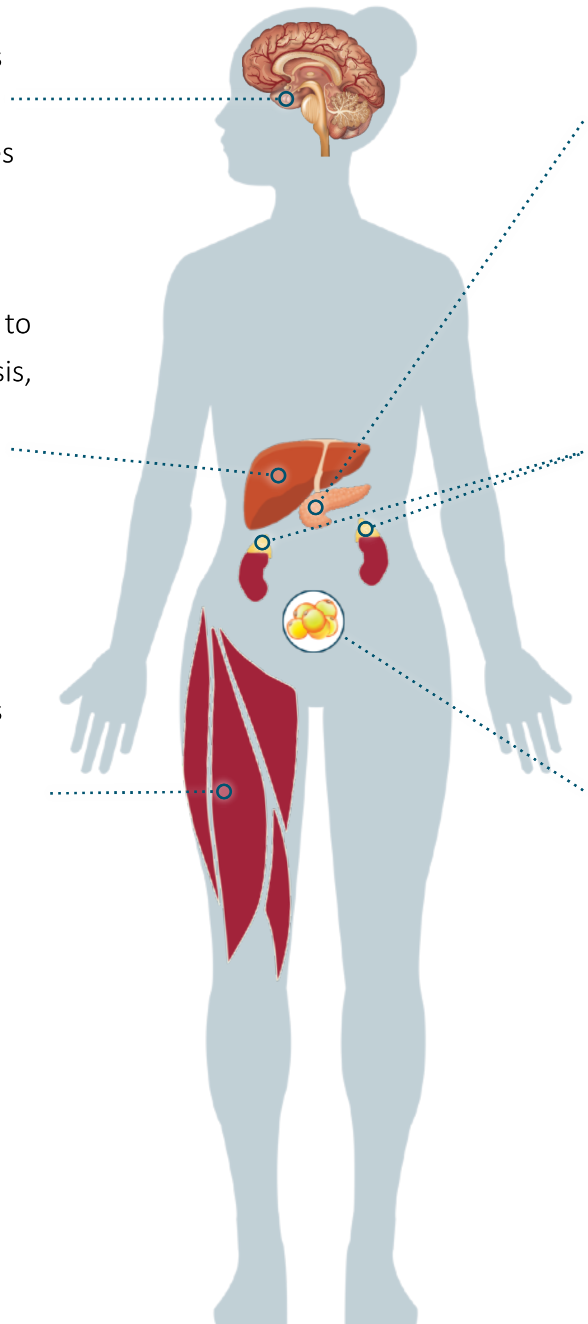
As discussed earlier, approximately 350 to 500 grams of glucose (1,400 to 2,000 calories) can be stored in our muscles as glycogen. To review, the process of creating glycogen is called glycogenesis, while the process of converting glycogen back to glucose is called glycogenolysis.

Note: The glycogen stored in the skeletal muscles can only be used locally to fuel the muscles themselves, while that stored in the liver can be used to create serum glucose that can be used anywhere in the body. This is because muscle cells lack the enzyme glucose-6-phophatase, which is needed to create free glucose which can be transported out of the cells.

PROTEIN SUBSTRATE FOR GLUCONEOGENESIS

Skeletal muscle can also act as a source of potential fuel. When blood sugar gets dangerously low, protein from our muscles can be broken down via a process called **proteolysis**, and converted into glucose within our liver via **gluconeogenesis**.

SUMMARY: GLUCOSE HOMEOSTASIS VIA THE CNS & PAALS



ENERGY & FUEL

HOW CELLULAR ENERGY IS PRODUCED IN THE BODY

OUR 3 ENERGY SYSTEMS

Human beings need energy to think, move, digest, rest, rebuild, stay warm, and detoxify. But where does this energy come from? The answer is cellular respiration, a set of various metabolic reactions and processes that convert the biochemical energy from the macronutrients we eat into a form of cellular energy called **ATP** (adenosine triphosphate). Our cells convert carbohydrates, fats, and proteins into ATP via the following three systems:

- The creatine phosphate system
- The anaerobic glycolysis system
- The aerobic system

The three systems operate somewhat like dimmer switches: all three are "on" all the time, but one of the systems might get "turned up" more than the other two depending on the duration and intensity of physical activity.

SEE VIDEO **VIDEO 5: FUELING FOR FUNCTION** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR VICTORIA LAFONT.

The Creatine Phosphate System

The **creatine phosphate system**, also known as the ***phosphagen system*** or ***ATP-CP system***, dominates during extremely short, intense activity. Though it's the fastest way to produce ATP in the body, this system also burns out the fastest, providing energy for less than 10 seconds of all-out effort.

Small amounts of creatine phosphate (CP) is stored in your skeletal muscles, ready to donate a phosphate to convert adenosine ***di***phosphate (A**D**P) into adenosine ***tri***phosphate (A**T**P).

This Creatine Phosphate System is used for extremely short and intense activities like a 1-rep max effort in weightlifting.

THIS CREATINE PHOSPHATE SYSTEM IS USED FOR EXTREMELY SHORT AND INTENSE ACTIVITIES LIKE A 1-REP MAX EFFORT IN WEIGHTLIFTING.

The Anaerobic Glycolysis System

The **anaerobic glycolysis system** dominates during relatively short periods of activity, specifically from about 10 seconds to 2 minutes. As the name implies, this process does not require oxygen, and was likely one of the earliest forms of energy production to evolve when oxygen was less concentrated in the atmosphere than today.

Anaerobic glycolysis produces ATP about 100 times faster than the oxidative phosphorylation system we will discuss next, but this speed comes with a cost: each molecule of glucose produces only 2 ATP molecules in this process, out of a potential 38 ATP molecules per glucose molecule.

THE ANAEROBIC GLYCOLYSIS SYSTEM IS USED FOR RELATIVELY SHORT ACTIVITY LIKE THE 200-METER DASH.

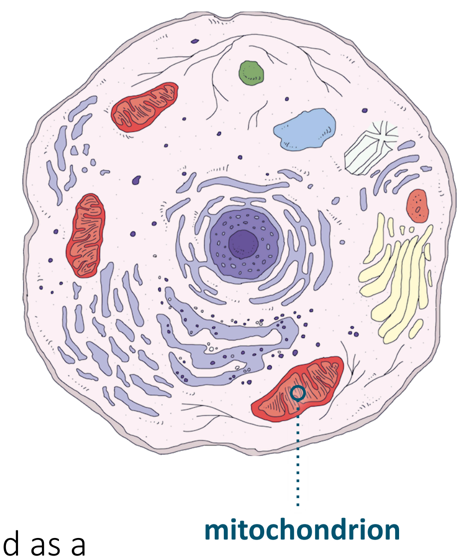
The Aerobic System

The **aerobic system** dominates during longer durations of activity, and is the slowest but most efficient form of cellular energy production. It relies on oxygen and a series of complex chemical reactions to convert carbohydrates, fat, and protein into ATP. The aerobic system produces ATP in two ways:

- the citric acid cycle
- the electron support chain

THE CITRIC ACID CYCLE

The **citric acid cycle** (CAC), also known as the ***Krebs cycle*** or ***tricarboxylic acid cycle*** (TCA cycle), converts a compound called **Acetyl-CoA** (acetyl coenzyme A) into ATP inside of our **mitochondria**, which are cellular organelles that act as the powerhouses of our cells.



THE ELECTRON TRANSPORT CHAIN

The **electron transport chain** uses the electrons produced as a byproduct of the citric acid cycle to produce ATP in a process called *oxidative phosphorylation* (OXPHOS).

THE AEROBIC SYSTEM IS USED IN WALKING AND SPORTS LIKE LONG DISTANCE RUNNING, CYCLING, AND CROSS-COUNTRY SKIING.

FEED YOUR MITOCHONDRIA

When it comes to energy production, humans are extremely adaptable, flexible omnivores, capable of producing ATP from all three macronutrients:[23]

- Carbohydrates
- Fat
- Protein

All three can fuel our cells, but all three also help create cellular structures. This is one of the many reasons why balance and nutrient-density is so important.

There are pros and cons of each fuel source depending on the context and one's unique bioindividual needs. Certain ratios of macronutrients work better for certain individuals based on their ancestry, activity levels, stress levels, insulin sensitivity, and metabolic flexibility.

SEE **VIDEO 4: FUELING FOR FUNCTION** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR VICTORIA LAFONT.

MACRONUTRIENT RATIOS ARE DISCUSSED IN MORE DETAIL IN THE **BASICS OF NUTRITION** MODULE.

Carbohydrates

CARBS = "KINDLING"

When it comes to fueling our metabolic fire, you can think of carbohydrates as "kindling." They burn fast and hot (perfect for short, intense activity), but need to be replenished frequently if used as the primary fuel source.

CARBS → ATP

Carbohydrates are converted to cellular in a process called **glycolysis**, which converts glucose into **pyruvate**, which can enter the CAC. [24]

CARB QUANTITY, QUALITY, AND SOURCING

Dietary carbohydrates come from many different sources, including vegetables, fruits, starches, grains, dairy, and simple sugars. When our body breaks down carbohydrates for storage, they are stored as glycogen in the liver and skeletal muscles as discussed earlier, and then in adipose tissue when our glycogen stores are full.

Depending on your activity levels, body composition goals, and efficiency burning carbs and fat for fuel, you may need more or less carbohydrates. Regardless of the quantity, try to eat the most nutrient-dense, unrefined carbs you can. As luck would have it, many whole foods contain the very nutrients you need to properly digest and metabolize them. Sweet potatoes, for example, are rich in manganese, a mineral that plays a key role in fat and carbohydrate metabolism.

Fats

FATS = "LOGS"

Continuing the fire analogy, you can think of fats as "logs," which burn more slowly than kindling and require less constant "stoking" of the metabolic fire (perfect for long, low intensity activity).

Once digested, fats are stored in the body as **triglycerides**. Unlike our limited storage of glycogen in the liver and muscles, our body has a vast capacity to store fat. Even the leanest person typically stores 20 times more energy from fat than from carbohydrates. The issue is whether or not one can actually utilize this stored fat for fuel, which requires sufficiently low levels of circulating insulin.

FAT → ATP

Lipolysis (breaking down fat and using it as energy for the body) produces more ATP than **glycolysis**, but it takes much more time and requires the presence of oxygen. It is therefore more ideal for slow, steady activity, and less ideal for short, intense activity. Unlike glucose, which must first be converted to pyruvate before being converted to Acetyl-CoA (which can enter the citric acid cycle), fatty acids can skip this step and be converted directly into Acetyl-CoA through beta-oxidation.

FAT QUANTITY, QUALITY, AND SOURCING

Like with carbohydrates, the quantity of fat you need to fuel function and structure will depend on numerous bioindividual factors. In general, many people don't eat enough healthy fats, thanks in large part to an unfounded fear of dietary fats based on an unproven link with heart disease.

Food quality is important with all macronutrients, but it is especially important when it comes to fats. Toxins bioaccumulate (build up) in fat tissue, so try to get fats from clean sources like 100% grass-fed animals, pasture-raised eggs, organic coconut oil, cold-pressed olive oil, organic avocados, etc.

SEE THE **FATTY ACID BALANCE** MODULE FOR MORE INFORMATION.

Proteins

Like carbohydrates and fats, proteins also act as both a cellular fuel and a building material. They are used to create muscles, ligaments, tendons, red blood cells, enzymes, and hormones, and can be converted into ATP.

PROTEIN → ATP

Protein can also be converted into ATP in two ways:

- It can be converted into glucose via gluconeogenesis, which can then enter glycolysis
- Or it can be oxidized into alpha-keto acids, which can enter the CAC

PROTEIN QUANTITY, QUALITY, AND SOURCING

Some people don't get enough protein, while others get too much. How much is enough?

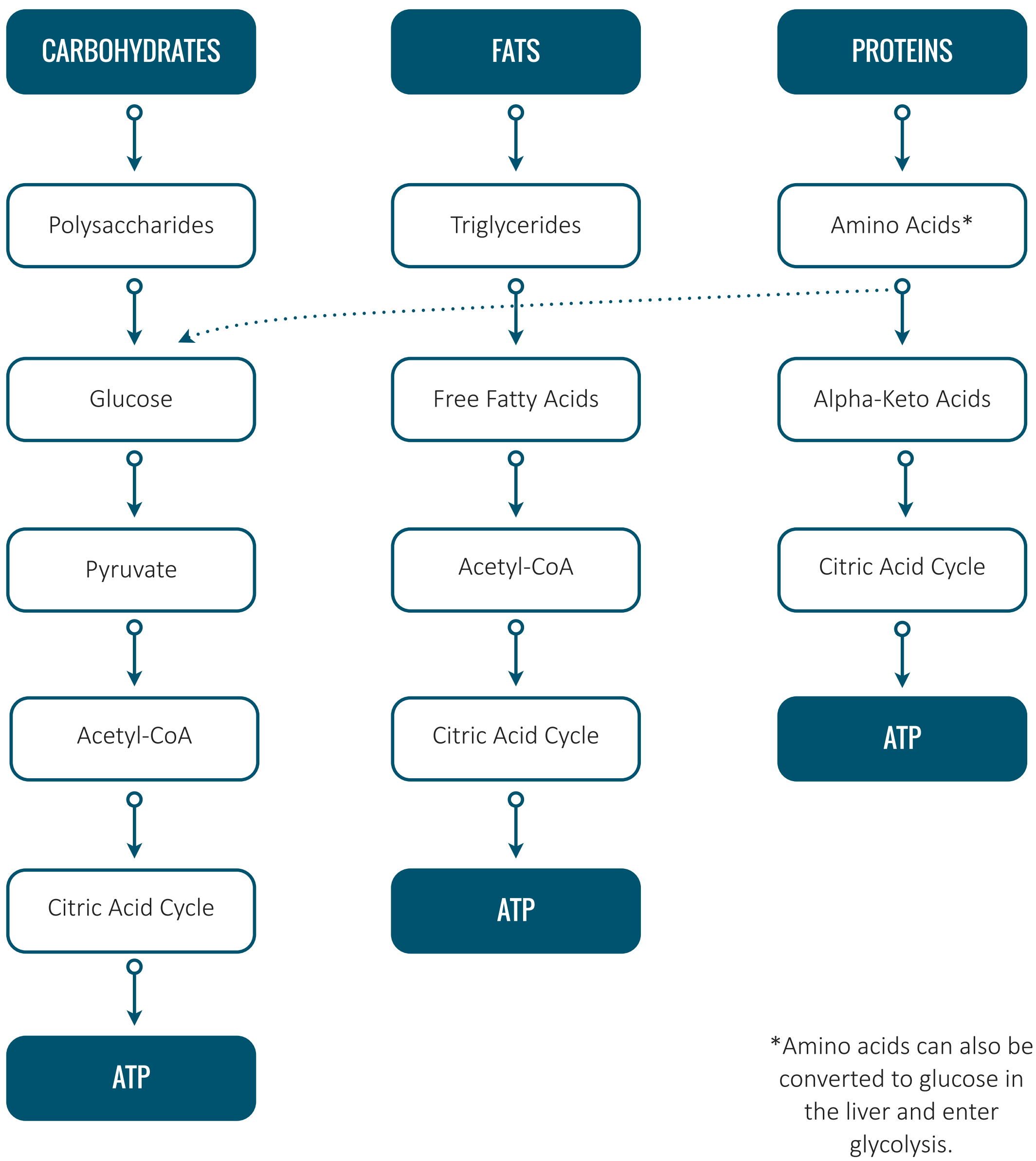
- In general, the upper limit for protein is 35 percent of total calories
- For athletes, it's recommended to aim for 0.6 to 1 gram of protein per pound of lean body mass (or 1.3 to 2.2 grams per kilogram)

Like with carbohydrates and fat, however, bioindividuality is key, and each person will have unique protein needs depending on a variety of factors.

The good news is that the brain and gut both have innate mechanisms that carefully regulate our desire for protein, so when in doubt, people should listen to their body and not force themselves to eat more protein when they feel full.

When possible, protein should come from 100% grass-fed animals, pasture-raised poultry and eggs, and wild-caught fish.

CONVERSION OF MACRONUTRIENTS TO ATP



METABOLIC FLEXIBILITY

Throughout most of human evolutionary history, food availability was sporadic and unpredictable. When food was plentiful, we ate as much as we could, storing excess energy not needed for immediate physiological functions for later use in our livers, muscles, and adipose tissue. When food was scarce, we easily tapped into this stored energy, maintaining the high level of focus and performance needed to survive. This **metabolic flexibility**, coupled with our varied, omnivorous diet, allowed homo sapiens to survive and thrive in a wide range of climates and conditions. [25]

TECHNICALLY SPEAKING, "METABOLIC FLEXIBILITY" IS THE CAPACITY FOR THE ORGANISM TO ADAPT FUEL OXIDATION TO FUEL AVAILABILITY. THE INABILITY TO MODIFY FUEL OXIDATION IN RESPONSE TO CHANGES IN NUTRIENT AVAILABILITY HAS BEEN IMPLICATED IN THE ACCUMULATION OF INTRAMYOCELLULAR LIPIDS AND INSULIN RESISTANCE. [26]

Favored Metabolic Pathways During Absorptive State

When consuming ample quantities of carbohydrates, proteins, and fats (called an **absorptive state**), the following metabolic pathways are favored:

LIVER

Glucose is used as energy, with excess stored as glycogen and converted to free fatty acids for storage in adipose tissue. Amino acids are also metabolized.

MUSCLES

Like in the liver, glucose is used as energy or stored as glycogen.

ADIPOSE TISSUE

Fatty acids are stored as triglycerides.

CNS

Glucose from food sources is used for energy.

Favored Metabolic Pathways During Postabsorptive State

Between meals (called the **postabsorptive state**), the following metabolic pathways are favored:

LIVER

Glycogen, glycerol, lactate, and alanine are converted to glucose as needed.

MUSCLES

Glucose and free fatty acids are used as a fuel. Lactate and alanine are sent to the liver to be converted to glucose as needed.

ADIPOSE TISSUE

Triglycerides are converted to free fatty acids and glycerol. The former are used to fuel muscles and other tissues, while the latter is converted to glucose in the liver.

CNS

Glucose (converted mostly from liver glycogen) is the primary fuel source.

Favored Metabolic Pathways During Short Fasts

During short fasts (18-48 hours without food intake), the following metabolic pathways are favored:

LIVER

Once liver glycogen is depleted, glucose is created from lactate, amino acids, and glycerol. Lactate is provided mostly by muscle tissue, but a small amount can also come from red blood cells.

MUSCLES

Protein from muscle tissue is catabolized to provide amino acids for gluconeogenesis (conversion to glucose) in the liver.

ADIPOSE TISSUE

As with the postabsorptive state, triglycerides are converted to free fatty acids and glycerol.

CNS

Glucose remains the primary fuel, but it’s converted instead from lactate and amino acids instead once liver glycogen is depleted.

Favored Metabolic Pathways During Extended Fasts

During extended fasts (greater than 48 hours), the following metabolic pathways are favored:

LIVER

Glucose is created predominantly from glycerol (from adipose tissue), sparing continued muscle catabolism. **Ketones** are produced from fatty acids, which fuel the CNS and muscles.

MUSCLES

Ketones and fatty acids are used for fuel.

ADIPOSE TISSUE

Triglycerides are converted to free fatty acids and glycerol.

CNS

Ketones produced in the liver become the primary source of fuel instead of glucose.

SUMMARY: METABOLIC PATHWAYS, FUELS & FLEXIBILITY

	Liver	Muscle	Adipose	CNS
Absorptive State	Used: Glucose Stored: Glycogen	Used: Glucose Stored: Glycogen	Stored: Triglycerides	Used: Glucose
Postabsorptive State	Used: Glucose (From Glycogen, Lactate, Amino Acids & Glycerol)	Used: Glucose Stored: Glycogen	Freed: Fatty Acids & Glycerol	Used: Glucose (From Liver Glycogen)
Fasted State	Used: Glucose (From Lactate, Amino Acids & Glycerol)	Used: Glucose (from Liver) Freed: Lactate & Amino Acids	Freed: Fatty Acids & Glycerol	Used: Glucose (From Lactate & Amino Acids Converted in Liver)
Extended Fasting	Used: Glucose (Primarily From Glycerol)	Used: Ketones & Fatty Acids	Freed: Fatty Acids & Glycerol	Used: Ketones (From Liver)

DYSGLYCEMIA

HOW BLOOD SUGAR BECOMES DYSREGULATED

GENES & ENVIRONMENT

Ancient Genes & Environment

The metabolic flexibility discussed in the last section made our species well-suited to the unpredictable, inconsistent food supplies that defined the vast majority of human evolution. Our ability to store excess energy and raise low blood sugar levels were essential for our survival when food was scarce. What food we did find tended to be rich in life sustaining vitamins and minerals, and packed with filling fats, proteins, and fiber. Food constituents like simple carbohydrates were rare and only available during limited parts of the year, and our genes therefore guided us to eat all we could when we came upon precious commodities like honey or fruit.

Modern Mismatch

Today, the very genetic adaptations that once served us so well (especially the ability to quickly raise blood sugar when food is scarce) often lead to metabolic issues and undesirable health outcomes.

Simple carbohydrates are now ubiquitous, low-cost, and widely marketed. These highly processed and hyper-palatable foods activate the brain's reward center and bypass normal satiety hormones, which leads us to eat past the point of physical satiation.

These large influxes of simple carbohydrates cause a rapid rise in blood sugar levels, which our bodies see as an emergency that must be dealt with immediately:

- The pancreas releases insulin to help bring down blood sugar levels by storing away excess glucose as glycogen and triglycerides.
- But insulin can overcorrect, causing blood glucose levels to drop too low (called **reactive hypoglycemia**), which the body also sees as an emergency.
- The CNS then signals the release of epinephrine, followed by cortisol, to bring up blood sugar levels by converting glycogen and amino acids to glucose.

When we over-consume simple carbohydrates—which is very easy to do given our genetic programming and access to hyper-palatable processed foods—this same cycle can repeat over and over again throughout the day, eventually leading to blood sugar dysregulation.

BIG IDEA 2: NEVER BEFORE HAVE WE HAD THE EMERGENCY NEED TO LOWER BLOOD SUGAR. THE INCREASED CONSUMPTION OF PROCESSED AND REFINED FOODS, ENVIRONMENTAL TOXICITY, AND STRESS CREATE THIS UNIQUE AND CRITICAL NEED.

STRESS & BLOOD SUGAR

In addition to the metabolic stress caused by frequent consumption of simple carbohydrates and refined foods, modern humans are also exposed to far more chronic environmental toxins and stressors than our ancestors.

While neither toxins nor stressors are new experiences for humans (we certainly dealt with our fair share of food-borne toxins, predators, natural disasters, etc. during our span on this planet), the quantity and quality of both today is a far cry from what our genes evolved to handle.

Environmental Toxins

Modern humans are exposed to more toxins than ever before thanks to industrial waste and industrial farming. According to the U.S. Environmental Protection Agency, over 85,000 new synthetic chemical compounds have been introduced since World War II, many of which are in the air, our water, and our food. Not all of these are necessarily considered harmful to human health, but even if a given chemical is considered "safe" on its own or in small doses, the total body burden can be significant when exposure is long-term and combined with multiple compounding factors:

- Xenobiotics like pesticides, herbicides, drugs, solvents, metals, etc.
- Infections, including parasites
- Food-borne toxins and molds like aflatoxin, fusarium, etc.
- Electromagnetic fields and radiation
- Alcohol consumption, smoking, etc.
- Structural and mechanical imbalances, nasal or intestinal obstructions, etc.
- Hormonal imbalances
- Psycho-social factors like emotional trauma, stress, loneliness, etc.

When it comes to toxic load, what we put on our bodies can actually be a bigger deal than what we put in them. That's because our gut lining has evolved to be exceptionally good at blocking toxins, at least when it's healthy. Moreover, cosmetics and personal care products are poorly regulated, and they can contain numerous untested chemical compounds that could pose serious risks to human health, especially when added up with other environmental toxins over longer periods of time.

Just like cosmetics, many of the most common household cleaning products harbor compounds that do not do your body any favors.

After reviewing over 2,000 cleaning products, the Environmental Working Group (EWG) determined that 25% included potentially carcinogenic ingredients, 50% included ingredients not listed on the label, and 75% included ingredients that can negatively affect respiration.

Environmental Stress

Over the vast majority of human history, we lived in what researchers call an **Immediate Return Environment**. Threats and decisions had an immediate impact on our well-being or survival. When we were hungry, we ate. When another animal was hungry and wanted to eat us, we fought or ran. Every decision we made had an immediate impact on our lives (for better or worse). Stressors were acute, and sometimes literally a matter of life or death, but they were short-lived and the right decision was usually instinctual and obvious. Our innate stress response was a powerful, effective way to keep us alive.

Most humans now live in a very different world. Industrialized societies, unlike the hunter-gatherer bands our ancestors adapted to, are **Delayed Return Environments** where stress tends to be chronic, may it be overflowing freeways, overflowing inboxes, overflowing calendars, or overflowing highly processed food. Ambiguity and uncertainty are now the norm, and most choices don't have an immediate impact on our survival or wellbeing.

The problem is that we as a species have had very little time to adapt to the extremely new environment in which we now live. To the brain, an urgent email from your boss can cause the same stress response as a sabertooth tiger threatening your life! ***We*** may know consciously that an email isn't going to kill us, but ***our CNS*** doesn't.[27]

PROCESSED FOOD & DYSGLYCEMIA

Rising Epidemics

Metabolic diseases such as **Type 2 Diabetes**, once rare conditions, are now widespread in industrialized societies:

- The U.S. has witnessed an 800% increase in diabetes rates since 1960. According to the 2017 National Diabetes Statistics Report,[28] 30.3 million Americans have diabetes (9.4% of the population).
- It's estimated that 1.2 million Australians (5.1% of the population) have diabetes.
- In China, 110 million people (11.6% of the population) are estimated to have diabetes.

Similarly rapid rises can also be seen in many other metabolic conditions, including:

- **Hyperinsulinemia**
- **Insulin Resistance**
- **Metabolic Syndrome**
- **Nonalcoholic Fatty Liver Disease**
- **Cardiovascular Disease**

The Role of Processed Foods

While all of these conditions are multifactorial and each are influenced by important genetic, epigenetic, lifestyle, and environmental components, there are plausible biological mechanisms and research evidence suggesting that overconsumption of processed food is one primary contributor.

For example, there is mounting evidence that simple sugars like sucrose ("table sugar") and high-fructose corn syrup (HFCS) may be of particular concern given their unique metabolic effects.[29] [30] [31]

MORE THAN "EMPTY CALORIES"

Contrary to widespread belief, outdated science, and food industry arguments, this cluster of metabolic diseases is not simply the result of sedentary lifestyles and overeating all sources of calories.

This overly simplistic "calories in, calories out" view ignores the important differences that various macronutrients (and specific forms of sugar) have on insulin, leptin, and other key metabolic hormones.

A WORD OF CAUTION

While the connection between simple sugars, insulin resistance, and disease are compelling, there are other plausible dietary and lifestyle factors to consider, too, and it's prudent not to make the same well-intentioned (but ultimately misguided) "leaps of faith" taken by health organizations when they maligned dietary fat and cholesterol without sufficient, conclusive evidence. Keep in mind, for example, that many of the studies to date:

- Can only show correlation, not causation
- Have been conducted using animal studies, meaning that the results may not translate accurately to humans
- Have been short and small in scale, making it difficult to determine long-term implications

As we continue to learn more, it is essential to view scientific literature with a critical (yet open) mind, respect the bioindividuality of each client, and appreciate the multifactorial nature of metabolic imbalances.

Sugar, Sugar, Everywhere

BIG IDEA 3: THE YEARLY CONSUMPTION OF OVER 174,000 METRIC TONS OF PROCESSED SUGAR WORLDWIDE-AND THE AVERAGE OF 160 LBS. PER PERSON PER YEAR IN THE AMERICAN POPULATION-IS DRASTICALLY AFFECTING OUR HEALTH.

HIDDEN SUGAR

Refined sugar can now be found in a dizzying array of modern foods and consumer goods, including the obvious sweet treats (soda, candy, etc.), but also less obvious items like:

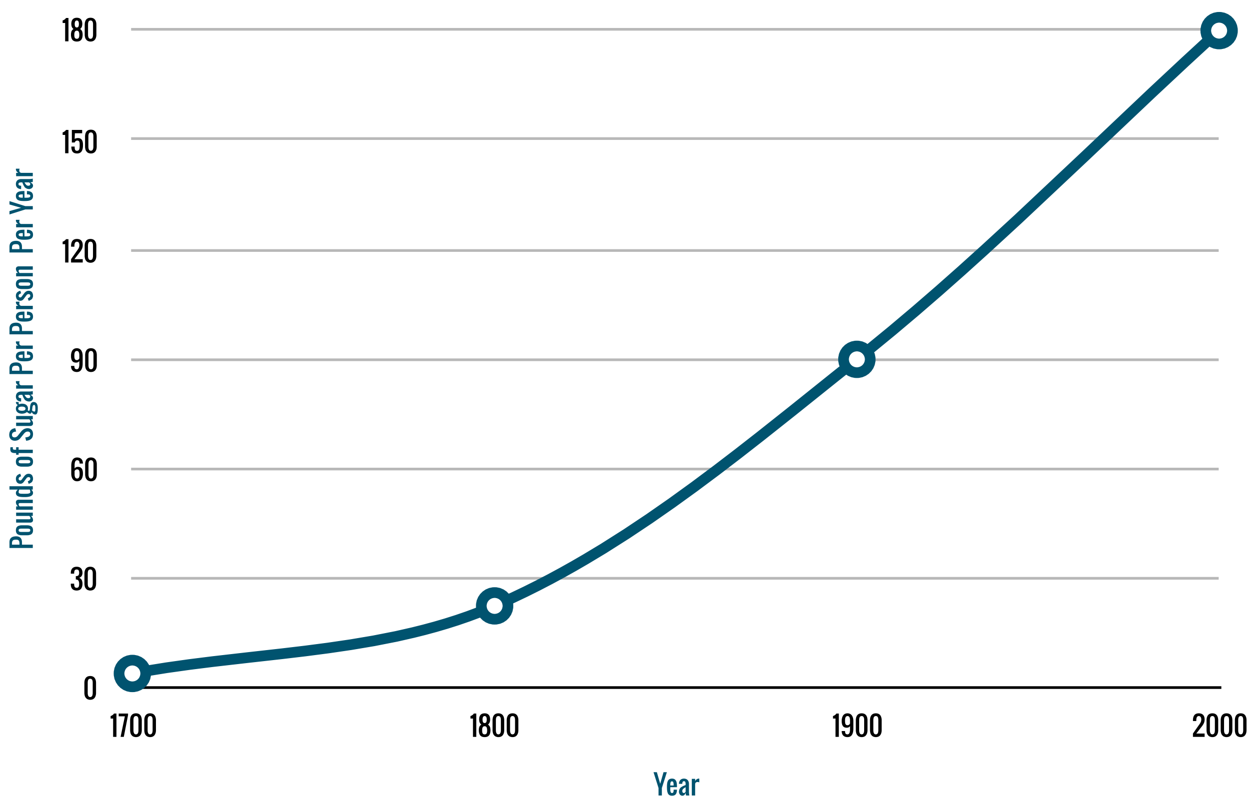
- bread (e.g. Wonder Bread, which contains up to 10% sugar)
- salad dressings (e.g. Kraft Creamy French Salad Dressing, which contains 6 grams/serving)
- cigarettes (sugar makes otherwise alkaline tobacco smoke more acidic, which makes it easier to breathe more deeply into the lungs and increase the action of nicotine)

AVERAGE CONSUMPTION

Since the dawn of refined sugar production in the 1600s, consumption has rapidly increased across the globe, spurred on by the Industrial Revolution in the 1800s, the Rise of Big Food in the early 1900s, and the demonization of dietary fat in the last half of the 20th century (more sugar was added to food to maintain palatability as fat was removed).[32]

- 1700: 4.9 grams per day or 3.99 lbs (1.81 kg) per year
- 1800: 22.4 grams per day or 22.49 lbs (10.2 kg) per year

- 1900: 112 grams per day or 89.95 lbs (40.8 kg) per year
- 2000: 227 grams per day or 179.89 lbs (81.6 kg) per year



IT'S DIFFICULT TO ESTIMATE CHANGES IN SUGAR CONSUMPTION OVER TIME SINCE MOST AVAILABLE DATA IS BASED ON "DELIVERIES" (THE AMOUNT MADE AVAILABLE BY INDUSTRY), NOT ACTUAL CONSUMPTION.

COMMON SOURCES OF ADDED SUGAR

So where is all this extra sugar coming from? The answer is sweetened beverages and processed foods. Consider the grams of sugar per serving of the following popular foods:

- Coca-Cola = 39 grams
- Frappuccino = 31 grams
- Apple Juice = 26 grams
- Yoplait Yogurt = 27 grams
- Bagel with Jelly = 20 grams
- 1 cup Raisin Bran = 19 grams
- 3 Oreos = 13 grams
- Protein Bar = 11-18 grams

THE TYPICAL ADOLESCENT TODAY CONSUMES 73 GRAMS OF SUGAR PER DAY FROM SWEETENED DRINKS ALONE! [33]

DECODING LABELS: SUGAR CAN GO BY MANY NAMES ON INGREDIENT LABELS. SEE THE **NAMES OF REFINED SUGAR** HANDOUT FOR A LIST OF THE MOST COMMON NAMES YOU'LL ENCOUNTER.

A DAY IN THE LIFE...

The body works continuously to maintain normal glucose levels in the blood throughout the day. But when we eat too often, eat too much, and eat too many refined carbohydrates, our bodies can get stuck in a self-perpetuating vicious cycle. Here is a day-in-the-life example of how this dysfunctional cycle can look, following a client we shall call ***Sally Sweettooth***:

- Sally is startled out of bed by her blaring 6 am alarm, and scrambles to get herself ready for work and her daughter ready for school.
- They both quickly eat a high-carb, low-fat breakfast of cereal, orange juice, and coffee with sugar before rushing off to work.
- This puts extremely high amounts of glucose into the bloodstream in a short amount of time. The pancreas tries to compensate by pumping out insulin to handle the influx of glucose.
- The insulin rapidly lowers the blood sugar levels to normal, but it overshoots the mark. Blood sugar levels rapidly drop to a level below the normal range.
- Sally's pancreas pumps out glucagon to raise blood sugar levels. But when this is not enough to bring blood sugar levels to normal, her body enters a "fight-or-flight" mode as the adrenals release epinephrine and cortisol to bring up blood sugar further.
- Feeling this drop in blood sugar as low energy, Sally pops over to the coffee shop to get a donut and large non-fat vanilla latte.
- The surge of sugar then starts the cycle all over again, with a blood sugar spike, overcompensating insulin surge, and a rapid drop in blood sugar well below normal levels.
- Despite just snacking, Sally's hormones and appetite urge her to have lunch again only an hour and a half later. She has a sub-sandwich and a soda,

triggering the same surge-spike-drop cycle repeats yet again, urging her to have an afternoon snack just 2 hours later.

- She then gets a call from her daughter's volleyball coach saying she is late to pick her up from practice.

- Epinephrine and cortisol surge through her veins as she races through traffic, which raises blood sugar, triggers the release of insulin, and causes her blood sugar to drop too low.

- She reaches for a Snickers bar in her purse, which she quickly gobbles down. This combination of psychological, physiological, and dietary stressors keeps her body in a heightened state, greatly taxing the HPA axis.

- Finally at home, she has 3 glasses of wine to help calm her nerves, which further stresses her liver, HPA axis, and cardiovascular system, and further dehydrates her already water-starved body.

- With her daughter finally in bed, Sally finds herself utterly exhausted and has little energy left to prepare a proper meal. At 9 pm, she pours a bowl of cereal and sits down to watch TV.

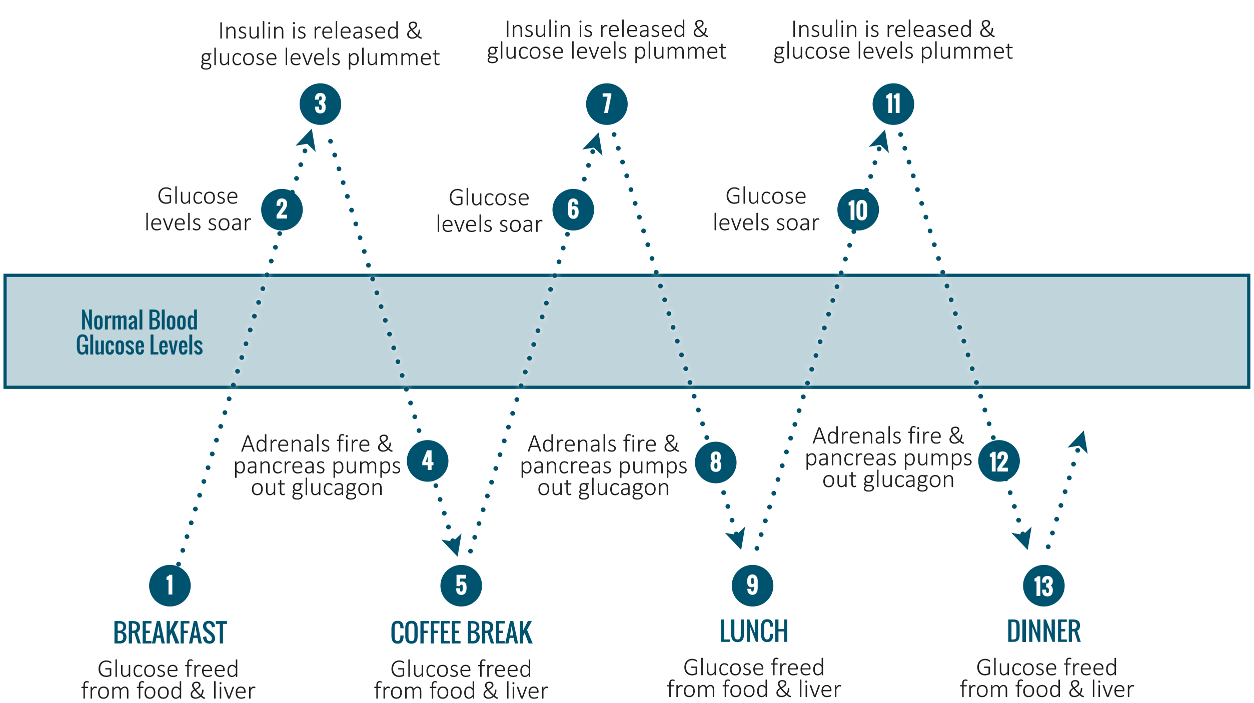
- Her head hits the pillow at 11 pm, and she falls asleep immediately given how tired she is from her busy day.

- As she sleeps, her body works to keep her blood glucose levels in a normal range. For a while, glucagon triggers the conversion of stored glycogen to glucose and protein to glucose via gluconeogenesis, and her blood glucose levels remain the normal range.

- Given Sally's high-stress lifestyle, chronic sleep deprivation, and frequent consumption of refined sugars, however, her severely dysregulated blood sugar system struggles to keep glucose levels high enough with glucagon alone. Her blood sugar begins to drop too low, leading to the release of epinephrine and cortisol. These stress hormones help increase glucose levels immediately, but the life-saving emergency response comes at a cost: it wakes Sally up.

- She is now wide-awake at 3 am, and is unable to fall back to sleep until 5, getting just one more hour of precious sleep before having to force herself out of bed when the 6 am alarm blares, starting the whole cycle over again.
- Not only can sleep deprivation contribute to dysglycemia, but it can also affect hunger hormones, and increase appetite for sweets, which further dysregulates the blood sugar regulation system and HPA axis.

IMPACT OF THE MODERN DIET & LIFESTYLE



STAGES OF DYSGLYCEMIA

REMEMBER: NTPS AND NTCS DO NOT DIAGNOSE OR TREAT DISEASE. THE FOLLOWING IS PROVIDED FOR EDUCATIONAL PURPOSES ONLY.

Dysglycemia can be divided into five basic stages:

- Phase 1: Compromised Blood Sugar Regulation
- Phase 2: Hyperinsulinemia & Reactive Hypoglycemia
- Phase 3: Insulin Resistance
- Phase 4: Metabolic Syndrome
- Phase 5: Type 2 Diabetes

Healthy Function

Healthy blood sugar regulation and metabolic flexibility provide:

- Efficient metabolization of all three macronutrients
- Consistent energy levels and reduced cravings throughout the day
- The ability to tap into stored energy in glycogen and adipose tissue to fuel function

Phase 1: Compromised Blood Sugar Regulation

Common signs and symptoms of compromised blood sugar regulation include:

- Increased cravings for sugar and refined carbohydrates

- Increased hunger and reduced satiation from meals
- Weight gain
- Increased blood pressure
- Impaired beta-oxidation of fat
- Difficulty burning fat for weight loss

Phase 2: Hyperinsulinemia & Reactive Hypoglycemia

Common signs and symptoms of Hyperinsulinemia and Reactive Hypoglycemia include:

- Fatigue and low energy levels
- Strong cravings for sweets and caffeine
- Ravenous hunger
- Irritability, anxiety, nervousness, and feeling light headed if meals are missed
- Feeling jittery or shaky between meals
- Skin tingling (especially around mouth)
- Sweating
- Rapid or irregular heartbeat
- Headaches
- Memory issues
- Difficulty concentrating or thinking clearly
- Blurred Vision

- Insomnia
- Crying out during sleep

Phase 3: Insulin Resistance

Common signs and symptoms of Insulin Resistance include:

- Increased hunger
- Increased lethargy
- Increased brain fog and difficulty focusing
- Increased weight gain, especially in abdomen
- Increased blood sugar and cholesterol levels
- Increased blood pressure
- Hyperpigmentation of the skin, especially around the neck and in the armpits
- Depression and mood disorders
- Endocrine imbalances, including thyroid and fertility issues
- Slow healing
- Premature aging

Phase 4: Metabolic Syndrome

Common signs and symptoms of Metabolic Syndrome (also called “Syndrome X”) include:

- Abdominal obesity

- Systemic inflammation
- High blood glucose levels (fasting levels above 100 mg/dL or 5.55 mmol/L)
- Hemoglobin A1c (Hb1Ac) above 5.5
- Dyslipidemia (low HDL, high LDL, and high triglycerides)
- High blood pressure

Phase 5: Type 2 Diabetes

NOTE: TYPE 1 DIABETES IS CAUSED BY DESTRUCTION OF BETA CELLS IN THE PANCREAS BY A VIRUS OR AUTOIMMUNE REACTION, NOT CHRONIC DYSGLYCEMIA LIKE TYPE 2 DIABETES.

Common signs and symptoms of Type 2 Diabetes include:

- Extreme hunger or thirst
- Persistent hunger, even after a meal
- Frequent or increased urination
- Tingling sensations in the hands or feet
- Chronic, persistent fatigue
- Frequent infections
- Extremely high blood glucose levels (at least one reading above 200 mg/dl or 11.1 mmol/L in a 24-hour period)
- Hemoglobin A1c (Hb1Ac) above 6.4

Glycation & AGEs

Glycation and the production of **AGEs** (advanced glycation end products) occurs when glucose reacts with amino acids via the Maillard reaction.

In the kitchen, this chemical reaction is what gives browned food its distinctive flavor (e.g. it's turns bread into toast). When produced in vivo (within the body), however, glycation can cause a number of problems as proteins and sugars form cross-links:[34]

- Narrowing of the microvasculature in the eyes, kidneys, feet, brain, etc.[35]
- Damage to arterial walls, joints, and cellular membranes
- Impaired communication between—and within—cells
- Disrupted cellular metabolism and reduced ATP production
- Increased oxidative stress
- Premature skin aging [36]

SUMMARY: EVALUATING DAILY FUNCTION

	Balanced Blood Sugar	Hyperinsulinemia & Hypoglycemia	Insulin Resistance
Morning Energy	Arise in the morning with energy and a feeling of being rested	Difficulty waking up	Arise in the morning not feeling rested or recovered
Morning Appetite	Arise with an appetite	Arise wanting to consume sugar or caffeine	Arise with sugar cravings, leading to a high-sugar and high-starch breakfast
Appetite Between Meals	Experience moderate hunger between meals but without strong cravings for sugar or refined carbs	Low energy between meals, especially a dip between 3 and 5 pm, with cravings for sugar, salt, and caffeine	On-going sugar cravings, an energy drop after lunch & reliance on stimulants after meals
Energy After Meals	No fatigue or changes in energy levels after eating	Sense of relief & increase in energy after meals	Fatigue after meals
During Sleep	Sleep soundly throughout night	Difficulty staying asleep through the night (often waking up between 2 and 3 am)	Difficulty falling asleep

DIET & LIFESTYLE

HOW TO EAT, RELAX & MOVE YOUR WAY BACK TO BALANCE

WHAT'S THE SOLUTION?

Fortunately, there are three key dietary and lifestyle adjustments that can help support the body's natural ability to regulate blood sugar, increase insulin sensitivity, and improve metabolic flexibility:

- Eating a balanced, nutrient-dense, properly prepared, whole foods diet, and adjusting macronutrient ratios as needed to reduce spikes in blood sugar and insulin.
- Reducing stress levels and changing one's relationship to psychological stressors through mindfulness and meditation.
- Increasing daily physical activity and movement.

BIG IDEA 4: THROUGH ADJUSTMENT OF MACRONUTRIENT RATIOS, AN INDIVIDUAL CAN CREATE BALANCED HORMONAL RELEASE AND UTILIZE ALL MACRONUTRIENTS-FATS, CARBOHYDRATES, AND PROTEINS-FOR ENERGY.

SEE **VIDEO 6: LIFESTYLE CHOICES** FOR AN OVERVIEW FROM NTA LEAD INSTRUCTOR VICTORIA LAFONT.

NUTRITION

Macronutrient Balance

Our metabolisms were designed to be energized by fats, glucose, and proteins. A balance of all whole food macronutrients is the normal and preferred fuel for the human body. Our culture is primarily living off the energy of processed sugars. We need a balance of energy from all macronutrients. Primarily using any one macronutrient for energy production can create issues with how well the body can use a balance of all macronutrients for energy production.

Glycemic Index & Load

The **Glycemic Index** (GI) is a numerical indicator that measures the blood glucose response after consuming 50 grams of available carbohydrates in food.

The rating is based on a reference food (pure glucose or white bread), which is given an arbitrary value of 100. The GI value of a specific food is expressed as a percentage of that arbitrary rating. The higher the percentage, the greater the supposed surge in blood sugar. However, GI values have two key limitations:

- GI values don't tell you how many grams of carbohydrate are found in a given serving
- GI can wrongly malign otherwise healthy foods, especially those which involve comically large servings to reach 50 grams of carbohydrates

FOR EXAMPLE, YOU'D HAVE TO EAT 1.5 POUNDS (0.7 KG) OF CARROTS TO REACH 50 GRAMS OF CARBOHYDRATES!

Glycemic Load, which refers to the glucose effect produced by a standard serving of food rather than a fixed amount of carbohydrate, overcomes many of these issues. It's determined by multiplying a given food's GI by the number of non-fiber carbohydrates (in grams) contained in a single serving size.

CARROTS, FOR EXAMPLE, HAVE A RELATIVELY HIGH GI OF 71, BUT A GL OF ONLY 6.

Keep in mind, however, that *both* GI and GL have limitations:

- Response to carbohydrates is highly bioindividual.
- When eaten together with fat, carbohydrates tend to be digested and absorbed more slowly.

GLYCEMIC INDEX VS. LOAD

	Low	Medium	High
Glycemic Index	< 55	56 – 69	> 70
Glycemic Load	< 10	10 – 20	> 20

Food (1 Serving)	Carbohydrates (Grams)	Glycemic Index	Glycemic Load
Potato (1 baked)	37	121	45
Grape Nuts (½ cup)	47	96	45
Corn Flakes (1 cup)	26	119	31
Pasta (1 cup cooked)	40	71	28
White Rice (½ cup cooked)	35	81	28
Cheerios (1 cup)	22	106	23
White Bread (2 slices)	24	100	22

Food (1 Serving)	Carbohydrates (Grams)	Glycemic Index	Glycemic Load
Corn Chips (1 oz.)	15	105	16
Beans (½ cup cooked)	27	60	16
Bread (whole grain, 2 slices)	24	64	15
Wild Rice (½ cup cooked)	18	78	14
All-Bran (1 cup)	24	60	14
Lentils (½ cup cooked)	20	41	8
Popcorn (1 cup air-popped)	5	79	4

Client Considerations

When conducting an Initial Interview and reviewing a client's NAQ and Food & Mood Journal, pay particular attention to the following criteria. When properly addressed through nutritional therapy, they can greatly increase metabolic flexibility and blood sugar balance.

FREQUENCY OF MEALS & SNACKS

- Is the client able to utilize stored energy (i.e. glycogen and adipose tissue) throughout day?
- Is the client reliant on dietary energy from meals and snacks?
- Is the client able to maintain energy levels when going 3 to 5 hours without a snack or meal?
- Does the client ever skip meals?

MACRONUTRIENT BALANCE & DIGESTION

- Does the client eat a healthy balance of fat, protein, and carbohydrates appropriate for their bioindividual needs and activity level?
- Is the client able to properly digest, absorb, and utilize all three macronutrients?
- Does the client rely on quick energy sources like refined sugar?
- Does the client crave sugar and sweets after meals?
- Does the client feel the need for stimulants such as coffee after meals?
- Does the client get fatigued after consuming carbohydrates?
- Is the percentage of carbohydrates too high, causing a blood sugar spike and insulin-induced drop?
- Do you experience an energy drop after lunch?

SLEEP

- Does the client have trouble falling asleep?
- Does the client have trouble staying asleep?
- Does the client have trouble waking up?
- Do you experience on-going sugar cravings?

SEE THE **METABOLIC BALANCE DIET** CLIENT HANDOUT FOR A SHORT-TERM EATING PLAN DESIGNED TO HELP BRING CLIENT BLOOD SUGAR BACK INTO BALANCE AND RECALIBRATE THE BODY'S NATURAL ABILITY TO REGULATE ENERGY AND FUEL LEVELS.

Nutrients that Support Blood Sugar Regulation

The body requires a wide diversity of nutrients to properly balance blood sugar levels, but the following compounds, co-enzymes, vitamins, minerals, and molecules are of particular importance:

APDS

APDS (allyl propyl disulfide) has been shown to lower blood sugar by competing with insulin for breakdown sites in the liver.

ARGININE

Arginine plays an important role in the promoting of the secretion of insulin.

VITAMIN A

Vitamin A plays a key role in the production and activity of adrenal hormones. Note that there are two primary forms: retinol (found in animal foods) and carotenoids (the precursor form found in plant foods)

VITAMIN B_1

Vitamin B_1 (thiamin) is used to create the enzyme TPP (thiamine pyrophosphate), which is necessary for carbohydrate metabolism, energy production, and nerve function.

VITAMIN B_2

Vitamin B_2 (riboflavin) is needed to secrete insulin from the pancreas. It also helps improve metabolic activity, boosts the immune system, and supports the nervous system.

VITAMIN B_3

Vitamin B_3 (niacin) is a component of the coenzymes NADP (nicotinamide adenine dinucleotide phosphate) and NAD (nicotinamide adenine dinucleotide), which play a role in carbohydrate metabolism, energy production, and the manufacture of adrenal hormones. It's also been shown to naturally improve cardiovascular health markers such as blood pressure.

VITAMIN B_5

Vitamin B_5 (pantothenic acid) is an important component of coenzyme A, involved in the manufacture of adrenal hormones and the utilization of fats and carbohydrates as fuel.

VITAMIN B_6

Vitamin B_6 (pyridoxine) helps maintain hormonal balance and is used in the creation of proteins and transmitters.

VITAMIN B_7

Vitamin B_7 (biotin) enhances glucose utilization and can help reduce hypoglycemia symptoms and sugar cravings. It is primarily synthesized by friendly gut bacteria, but can also be found in some foods.

CHROMIUM

The body uses chromium to create GTF (glucose tolerance factor), which enhances insulin activity. Low chromium levels may lead to insulin resistance.

MANGANESE

Manganese functions in enzymes that regulate blood sugar.

MHCP

MHCP (methylhydroxychalcone polymer) is a water-soluble compound found in cinnamon that helps improve insulin sensitivity. Like insulin, it increases the uptake of glucose by cells and stimulates glycogenesis.

POTASSIUM

Potassium is essential for the conversion of blood sugar into glycogen.

VANADIUM

Deficiency in vanadium may contribute to faulty blood sugar control, contributing to hypoglycemia or diabetes.

SEE THE **THERAPEUTIC FOODS FOR BLOOD SUGAR** HANDOUT FOR A CLIENT-FRIENDLY SUMMARY OF THIS INFORMATION & A TABLE OF FOODS THAT CONTAIN THESE NUTRIENTS.

OTHER LIFESTYLE FACTORS

Helping clients transition to a nutrient-dense, whole foods diet is the primary task of nutritional therapy and one of the most effective ways to regulate blood sugar levels. However, there are three key lifestyle factors that can make nutritional therapy even more effective:

- reducing stress levels
- increasing movement
- getting sufficient sleep

The 3 Ms: Mindfulness, Meditation, and Movement

MINDFULNESS

Mindfulness is a fancy word for a very simple concept: being aware of what's happening in the present moment. Because of the environmental-biological mismatch we just discussed, our minds constantly worry about decisions we'll make in the future and regret decisions we already made in the past. This present-focus can help reduce anxiety, lower cortisol levels, and improve overall health and happiness. One of the best ways to increase mindfulness, reduce stress levels, and change one's relationship with stressors that cannot be avoided is maintaining a daily meditation practice.

MEDITATION

Meditation is arguably the most powerful tool you have to increase mindfulness and your resilience to stress. Contrary to popular belief, meditation is not about "having an empty mind." At first, thoughts will come into your head. You will get momentarily distracted. The actual "practice" part is continually coming back to your breath each time you catch yourself following thoughts. A good analogy is that one should observe thoughts as if they are "clouds in the sky" or "cars passing on the road." Don't chase them or judge them as either good or bad, right or wrong. Just watch them go by and then come back to the breath. Just like with lifting weights, each repetition strengthens your "mindfulness muscles" and makes it that much easier to stay focused on what matters most throughout your day.

MOVEMENT

When animals (including humans) experience stress in nature, it almost always comes hand in hand with some kind of movement, whether it's fighting or fleeing. In modern environments, on the other hand, we rarely engage in physical movement after experiencing stress (e.g. a near collision on the road, reading an angry email, etc.), which allows the cortisol released into our blood streams to keep circulating longer than it should. Next time you experience something stressful, try engaging in some kind of physical movement, may it be a brisk walk, doing some air squats in the bathroom, playing tag with your kids, etc. Not only will this help process out stress hormones more quickly, but physical movement can also use up excess blood sugar and increase insulin sensitivity.

Sleep

Poor sleep is associated with poor blood sugar regulation. Not only can sleep deprivation affect metabolism,[37] but it can also decrease insulin sensitivity.[38] To help clients improve sleep quantity and quality, you can suggest:

- Avoiding caffeine consumption after noon
- Avoiding blue light exposure 2 hours before bed
- Engaging in daily physical activity
- Meditating before bed
- Using blackout curtains, eye masks, ear plugs, etc.

GLOSSARY

Absorptive State	The period in which the gastrointestinal tract is full of food and glucose is used as the primary fuel.
Acetyl-CoA (Acetyl Coenzyme A)	A molecule derived from macronutrients that is converted to ATP in the citric acid cycle.
ACTH (Adrenocorticotropic Hormone)	A polypeptide hormone secreted by the anterior pituitary gland involved in the HPA Axis.
Adipocytes	A specialized cell found in adipose tissue that stores triglycerides.
Adipose Tissue	A form of connective tissue composed mostly of adipocytes (also known generally as “body fat”).
Adrenal Cortex	The outer portion of the adrenal glands which produces a number of hormones, including aldosterone, cortisol, and sex hormones.
Adrenal Medulla	The inner portion of the adrenal glands which produces epinephrine (adrenaline) and norepinephrine (noradrenaline).
Advanced Glycation End Products (AGEs)	Proteins or lipids that become glycated as a result of exposure to sugars. May contribute to degenerative diseases such as diabetes, atherosclerosis, kidney disease, and Alzheimer's disease.
Aerobic System	A metabolic system that converts macronutrients to ATP in the presence of oxygen. Used for longer, less-intense activity.
Alpha Cells (α-cells)	Cells found in the pancreas which produce and excrete glucagon.

Anaerobic Glycolysis System	A metabolic system that creates ATP from glucose without the need of oxygen. Used during relatively short, intense efforts of 10–30 seconds.
ATP	Adenosine triphosphate is an energy carrier used in cells
Beta Cells (β-cells)	Cells found in the pancreas which produce and excrete insulin.
Bicarbonate	A substance released by the pancreas to help neutralize acidic chyme entering the duodenum. Chemical Formula: $NaHCO_3$
Bile	A substance produced in the liver to aid in the digestion of fats in the small intestine.
Cardiovascular Disease (CVD)	A class of diseases that affect the heart muscle or blood vessels, including angina, myocardial infarction (a.k.a. heart attack), stroke, heart failure, etc.
Chyme	The semi-fluid, partially digested form of food that enters the duodenum from the stomach.
Citric Acid Cycle	A series of chemical reactions that converts acetyl-CoA (derived from carbohydrates, fats, and proteins) into ATP. Also known as the Krebs cycle or tricarboxylic acid cycle.
CNS	The part of the nervous system which includes the brain and spinal cord.
Creatine Phosphate System	A metabolic system that rapidly creates ATP using creatine phosphate (CP). Used during short, intense efforts less than 10 seconds.
CRH (Corticotropin-Releasing Hormone)	A polypeptide hormone and neurotransmitter secreted by the hypothalamus involved in the HPA Axis.

Delayed Return Environment	An environment in which actions have delayed results.
Endocrine Gland	A gland which produces and secretes hormones directly into the blood.
Epinephrine (Adrenaline)	A hormone and neurotransmitter that plays an important role in the fight-or-flight response by increasing blood flow to muscles, heart rate, and blood sugar levels.
Exocrine Gland	A gland which produces various substances and excretes them through a series of ducts.
FBG	The amount of glucose found in the blood after at least 12 hours of not eating.
Ghrelin	A peptide hormone produced in the gastrointestinal tract which helps increase appetite and regulate the use of energy.
Glucagon	A hormone produced in the pancreas which increases the quantity of glucose and fatty acids in the blood by freeing store energy from cells. Primary catabolic hormone of the body.
Gluconeogenesis (GNG)	A metabolic pathway that converts amino acids, lactate, and glycerol into glucose.
Glucose	A simple sugar that circulates in the body as blood sugar. Chemical Formula: $C_6H_{12}O_6$
GLUT-4	The insulin-regulated glucose transporter that moves glucose into adipocytes and muscle cells.
Glycation	The non-enzymatic bonding of a sugar molecule (e.g. glucose or fructose) to a protein or lipid molecule.

Glycemic Index	A value assigned to foods based on how quickly the food causes increases in blood glucose levels. A value of 100, based on pure glucose, is used as the scale standard.
Glycemic Load	A glycemic value based on the quantity of carbohydrates per serving of food.
Glycogenesis	The process of converting glucose to glycogen for storage in the liver or skeletal muscles.
Glycogenolysis	The process of converting glycogen back into to glucose.
Glycolysis	The metabolic pathway that prepares converts glucose into pyruvate, which can then enter the Citric Acid Cycle.
HPA Axis (Hypothalamic-Pituitary-Adrenal Axis)	A complex set of interactions between the hypothalamus, the pituitary gland, and the adrenal glands.
Hyperinsulinemia	A condition involving excess levels of insulin in the blood relative to the level of glucose.
Hypothalamus	An important part of the brain that links the nervous system to the endocrine system via the pituitary gland.
Immediate Return Environment	An environment in which actions have immediate results.
Insulin	A hormone produced in the pancreas which decreases the quantity of glucose in the blood by encouraging uptake by cells. The primary anabolic hormone of the body.
Insulin Resistance (IR)	A pathological condition in which cells no longer respond normally to the action of insulin.

Islets of Langerhans	Structures in the pancreas that contain the endocrine cells that produce glucagon (α-cells) and insulin (β-cells). Also known as "pancreatic islets." Discovered by Paul Langerhans in 1869.
Ketone Bodies	Molecules produced by the liver from fatty acids during extended periods of fasting, carbohydrate restrictive diets, etc.
Leptin	A hormone produced in adipocytes that helps inhibit hunger.
Lipogenesis	The process of converting simple sugars to fatty acids, which can then be stored as triglycerides.
Lipolysis	The breakdown of triglycerides into glycerol and free fatty acids.
Metabolic Flexibility	The ability to modify fuel oxidation in response to changes in macronutrient and metabolic fuel availability.
Metabolic Syndrome	A clustering of three or more of the following conditions: abdominal obesity, high blood pressure, high blood sugar, high serum triglycerides, and HDL levels.
Mitochondrion	A cellular organelle that produces ATP via the citric acid cycle. Plural: mitochondria
Mixed Gland	A gland such as the pancreas that functions as both an exocrine and endocrine gland.
Negative Feedback Loop	A balancing feedback system that tends toward equilibrium.
Nonalcoholic Fatty Liver Disease (NAFLD)	A condition in which fat is deposited in the liver due to causes other than chronic overconsumption of alcohol.

Norepinephrine	The main neurotransmitter used in the sympathetic nervous system (SNS). Involved in the fight-or-flight response. Increases blood pressure through vasoconstriction.
PAALS	An acronym to remember the key peripheral organs involved in blood sugar regulation: the pancreas, the adrenal glands, adipose tissue, the liver, and skeletal muscles.
Pancreatic Amylase	An enzyme secreted by the pancreas into the small intestine to help break down carbohydrates.
Pancreatic Lipase	An enzyme secreted by the pancreas into the small intestine to help break down fats.
Pancreatic Protease	An enzyme secreted by the pancreas into the small intestine to help break down proteins.
Pituitary Gland	A pea-sized gland attached to the base of the brain next to the hypothalamus which controls the function of other endocrine glands in the body (e.g. the pancreas, the adrenal glands, etc.).
Postabsorptive State	The period in which the gastrointestinal tract is empty and stored fuel is used for energy.
Post-Prandial Glucose (PPG)	The quantity of glucose in the blood after a meal (as opposed to fasting blood glucose levels).
Proteolysis	The breakdown of proteins into polypeptides or amino acids.
Pyruvate	A key intermediate compound in many metabolic pathways, including glycolysis (glucose is converted to pyruvate before entering the citric acid cycle). Chemical Formula: CH_3COCOO^-
Reactive Hypoglycemia	Dangerously low blood levels caused by a rapid rise and subsequent insulin-induced fall (a.k.a. postprandial hypoglycemia).

Triglycerides	The storage form of fat in the body, created by joining glycerol with three fatty acid molecules.
Type 1 Diabetes	A form of diabetes mellitus in which insufficient quantities of insulin are produced. Also known as Diabetes Mellitus Type 1.
Type 2 Diabetes	A metabolic disorder characterized by high blood sugar levels and insulin resistance. Also known as Diabetes Mellitus Type 2.

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ADDITIONAL RESOURCES

Crash Course

- Metabolism & Nutrition, Part 1
- Metabolism & Nutrition, Part 2

Khan Academy

- Glucose & Glucagon
- Regulation of Glycolysis & Gluconeogenesis
- The Hypothalamus & Pituitary Gland
- Hormone Concentration Metabolism & Negative Feedback

Other

- Insulin vs Glucagon: The Relevance of Dietary Protein - Dr Benjamin Bikman
- Mastering Nutrition with Chris Masterjohn, PhD

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