Carbohydrates: The Powerhouse of Life

Carbohydrates are the most abundant compounds in living plants, serving as a principal repository of photosynthetic energy. They are found in above-ground and below-ground plant parts, constituting 50-80% of the dry matter in leaves, fruits, and seeds. Carbohydrates also furnish a significant portion of the metabolizable energy in the diets of most primates, including humans and animals.

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Carbohydrate Classification and Characteristics

Monosaccharides

Monosaccharides are single carbohydrate units containing three to seven carbon atoms. The six-carbon monosaccharides (hexoses) that are particularly important in animal nutrition are glucose, fructose, and galactose.

Disaccharides

Disaccharides consist of two monosaccharide units linked together, such as sucrose (glucose + fructose), lactose (glucose + galactose), and maltose (glucose + glucose).

Oligosaccharides

Oligosaccharides are polymers of three or more monosaccharide units, including raffinose, stachyose, and verbascose.

Starch and Starch-like Polysaccharides

Starch Structure

Starch, a polymer of glucose, consists of amylose (a straight-chain polymer) and amylopectin (a branched-chain polymer).

1

Starch Digestion

Starch digestion involves salivary and pancreatic α-amylases, yielding maltose, maltotriose, some glucose, and limit dextrin. Further digestion to glucose is accomplished by intestinal maltase.

2

Resistant Starch

Resistant starch that escapes enzymatic digestion or foregut fermentation may undergo microbial fermentation in the hindgut, potentially leading to digestive issues.

3

Non-Starch Polysaccharides

1 Insoluble Fiber

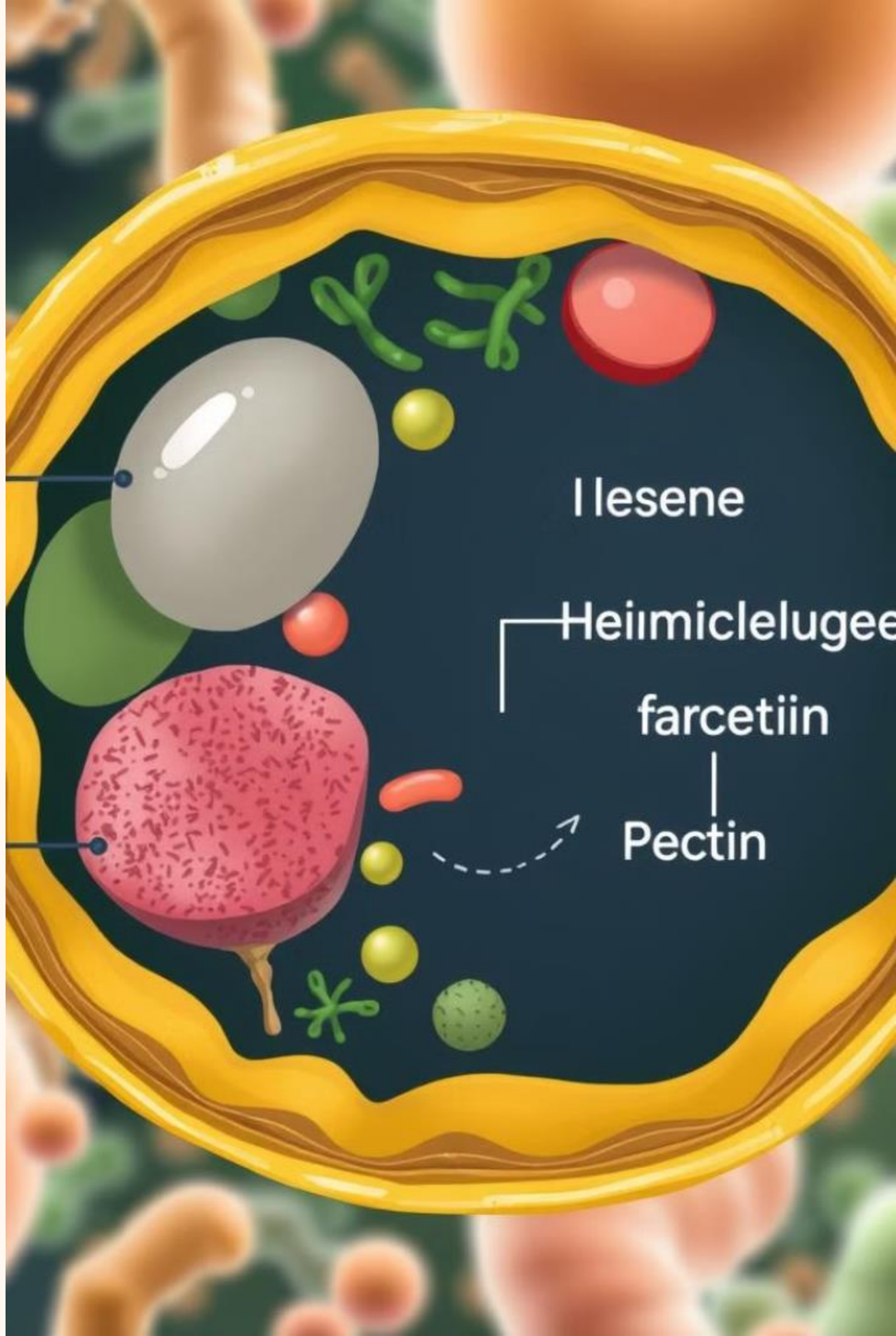
Cellulose and hemicelluloses are structural polysaccharides that make up the bulk of plant cell walls and are referred to as insoluble fiber.

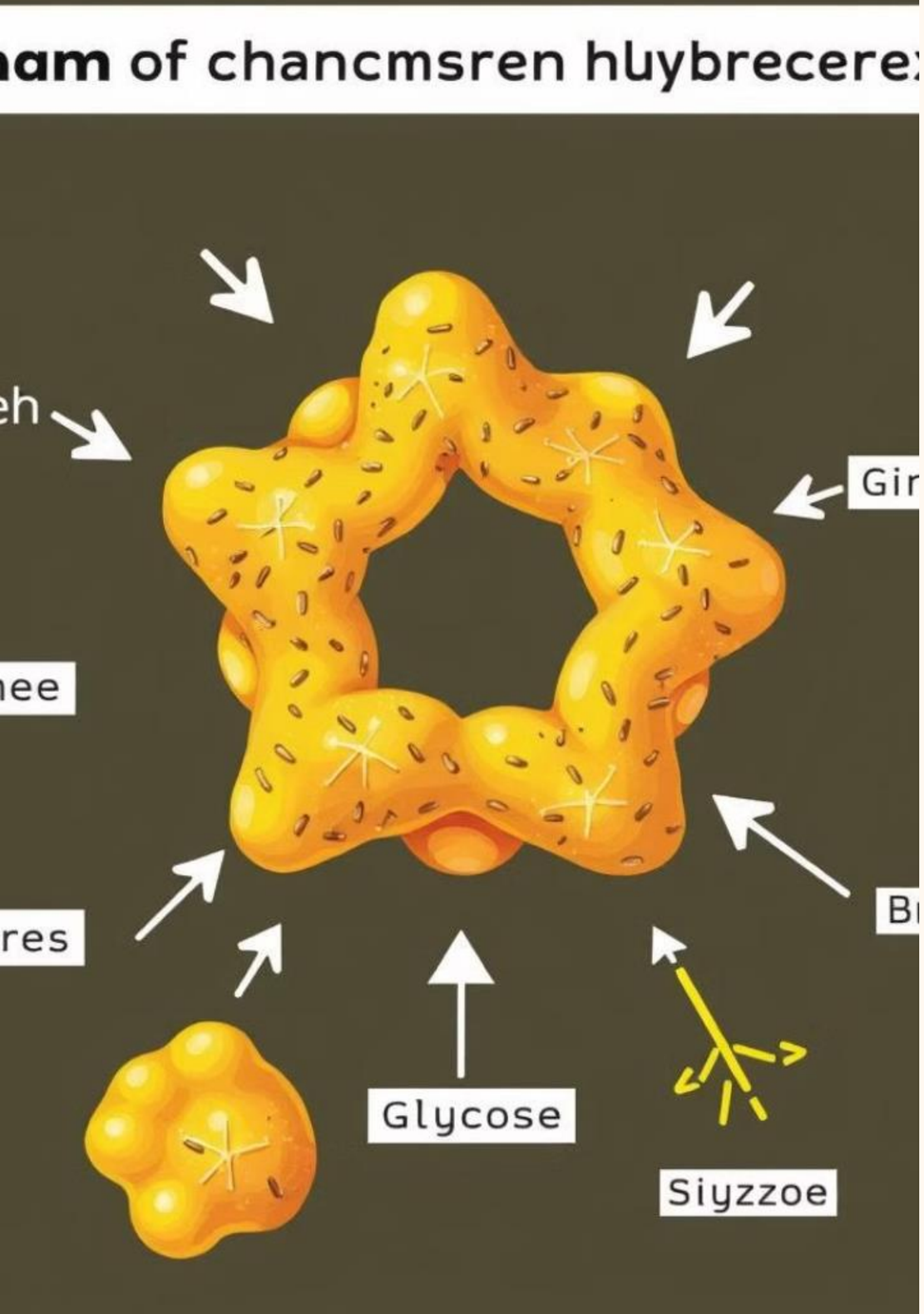
2 Soluble Fiber

Soluble non-starch polysaccharides, such as fructans, mannans, and galactans, swell to form a gel or gummy solution and are fermented by gut bacteria.

3 Pectic Substances

Pectic substances are associated with the plant cell wall and are included among the soluble non-starch polysaccharides.





Carbohydrate Digestion and Metabolism

1

Amylose and Amylopectin

Starch (amylose and amylopectin) is converted to dextrins by salivary and pancreatic α-amylases.

2

Dextrins to Maltose

Dextrins are further broken down into maltose by α-amylases.

3

Maltose to Glucose

Maltose is finally converted to many α-D-glucose units by intestinal maltase.

Carbohydrate Fermentation

Cellulose and Hemicelluloses

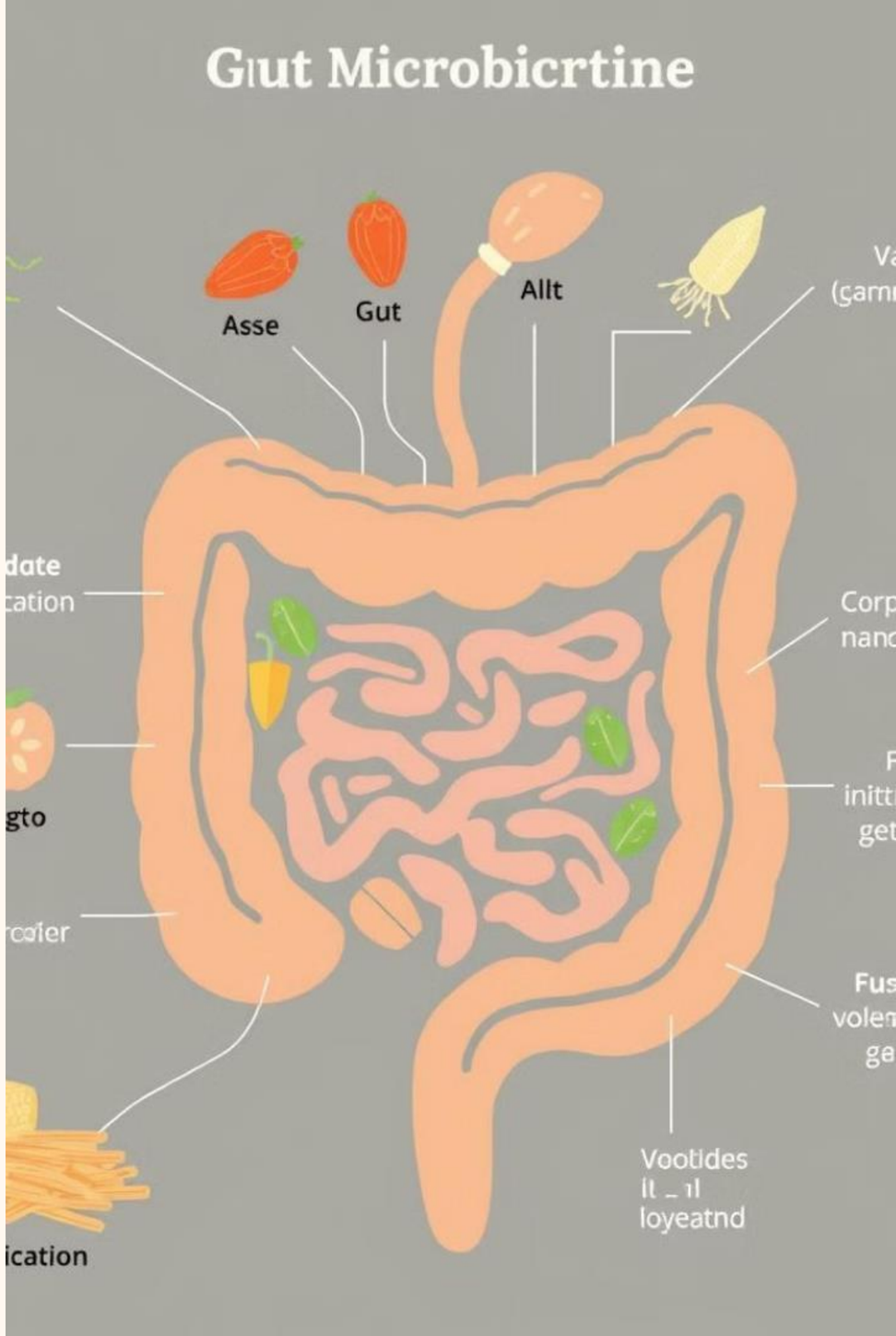
Cellulose and hemicelluloses cannot be digested by endogenous mammalian enzymes but can be fermented by gut microbes, producing volatile fatty acids.

Soluble Fiber

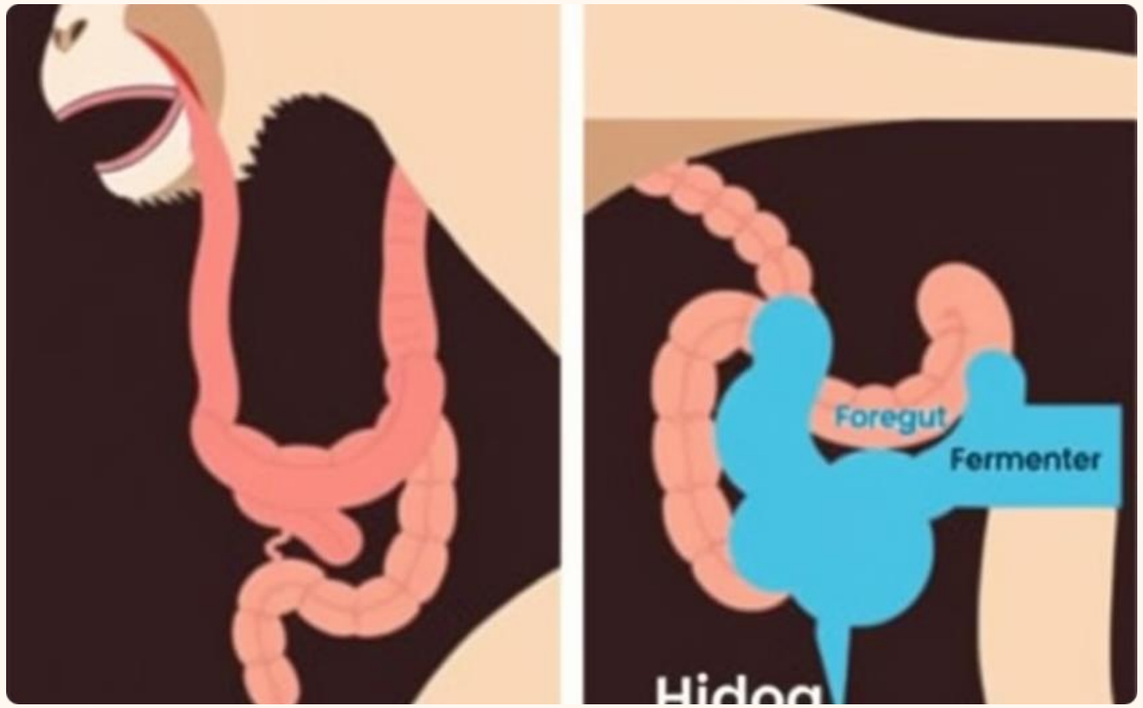
Soluble non-starch polysaccharides, such as fructans, mannans, and galactans, are fermented quite completely by gut bacteria.

Pectic Substances

Pectic substances are also fermented, and the microbial degradation of these substances is often quite complete.



Carbohydrate Digestion in Primates



Foregut vs. Hindgut Fermentation

Primates with pregastric digestive compartments, such as macaques, rely more on fermentative digestion of carbohydrates in the foregut. Primates without pregastric compartments, like humans and chimpanzees, ferment carbohydrates in the hindgut.

Dietary Carbohydrate Sources

Primates, including humans, obtain carbohydrates from a diverse range of plant-based foods, such as fruits, vegetables, grains, and legumes.

Carbohydrate Intolerance in Primates

Lactose Intolerance

Some adult primates, including humans and captive macaques, exhibit lactose intolerance due to limited intestinal lactase activity.

Digestive Upsets

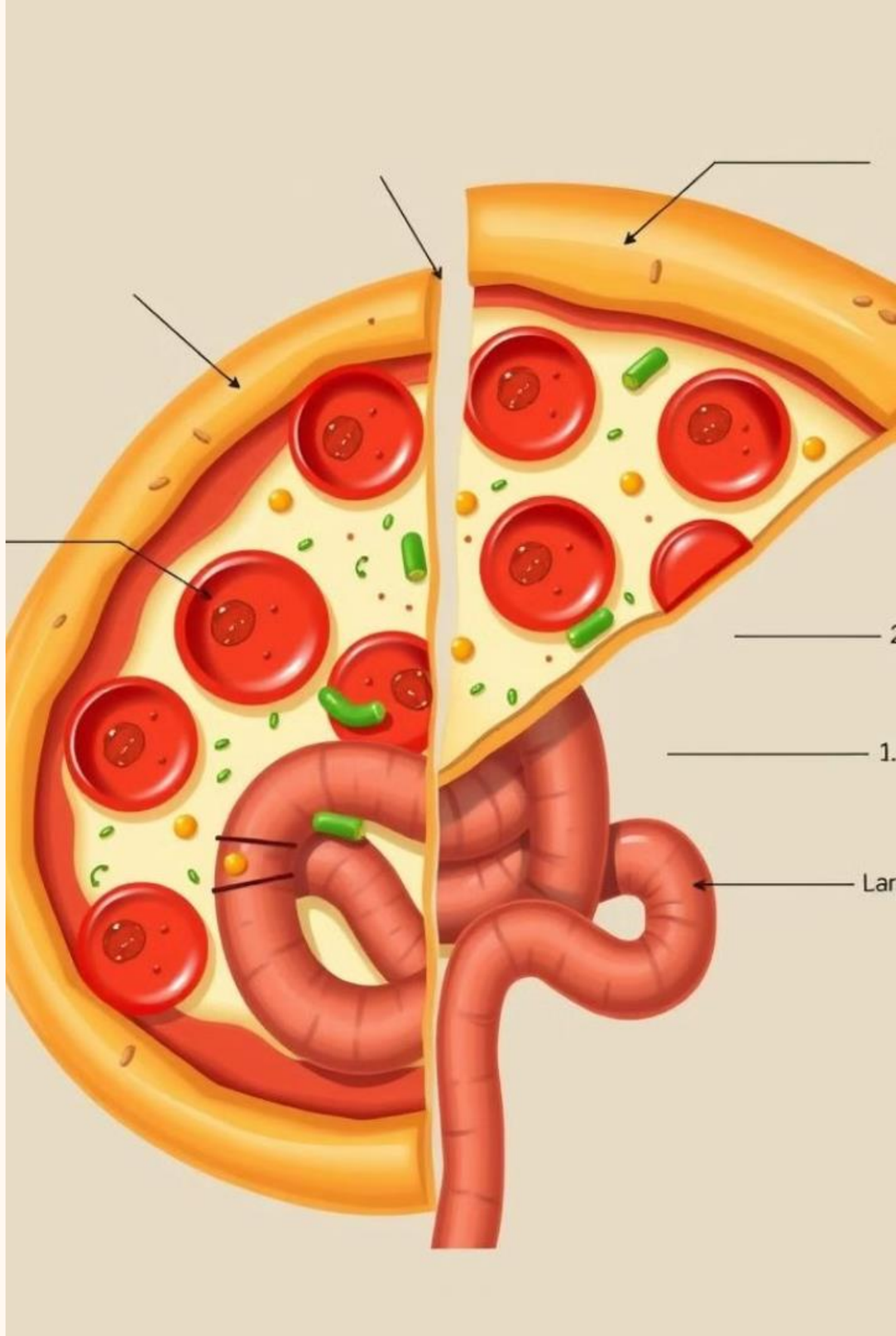
Excessive fermentation of rapidly digested carbohydrates, such as high-starch, low-fiber diets, can lead to digestive issues in foregut fermenting primates.

Potential Consequences

Severe digestive upsets from rapid carbohydrate fermentation can result in abdominal discomfort and even death in some primate species.

Carbohydrate Digestion and Absorption

Carbohydrate	Simple-Sugar Components	Digestion	Digestive Products
Maltose	Glucose	Maltase	Glucose
Sucrose	Glucose, Fructose	Sucrase	Glucose, Fructose
Lactose	Glucose, Galactose	Lactase	Glucose, Galactose
Starch	Glucose	Amylases	Glucose
Fructans	Fructose	Gastric Acid	Fructose
Galactans	Galactose	Fermentative	Volatile Fatty Acids
Cellulose	Glucose	Fermentative	Volatile Fatty Acids



Carbohydrates and Primate Nutrition

Dietary Importance

Carbohydrates, along with protein and fat, are essential macronutrients in the diets of primates, including humans. They provide a significant portion of the metabolizable energy required for optimal health and metabolic efficiency.

Adaptations and Limitations

Primates have evolved various adaptations for carbohydrate digestion and metabolism, but they also face limitations, such as lactose intolerance and the potential for digestive issues from rapid fermentation of certain carbohydrates.

Balancing Carbohydrates

Achieving the right balance of carbohydrates, along with other essential nutrients, is crucial for maintaining the overall health and well-being of primates in both natural and captive settings.