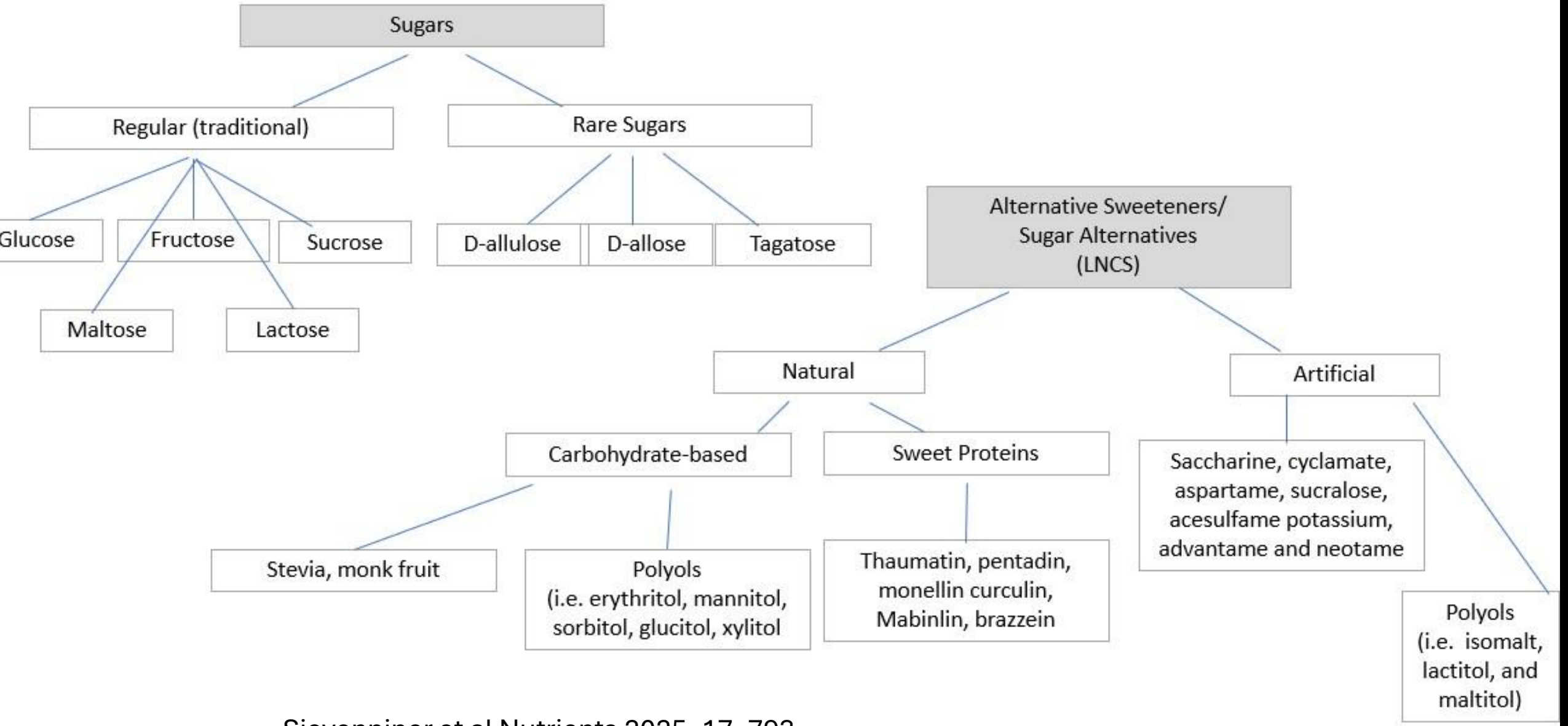
"Understanding the Physiology and Psychology of sweetness - How our body responds to different sweeteners".

Sesikeran Boindala MD, FAMS
Former Director
ICMR NIN
Hyderabad



Sievenpiper et al Nutrients 2025, 17, 793

Sweetness

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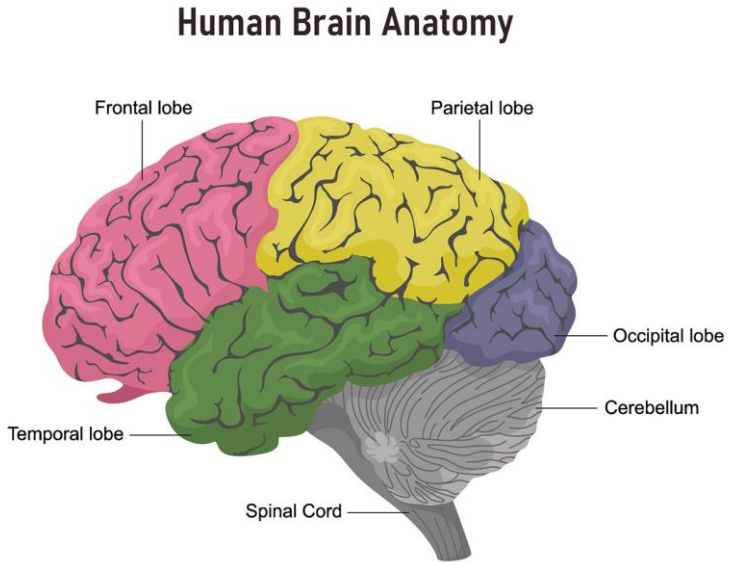
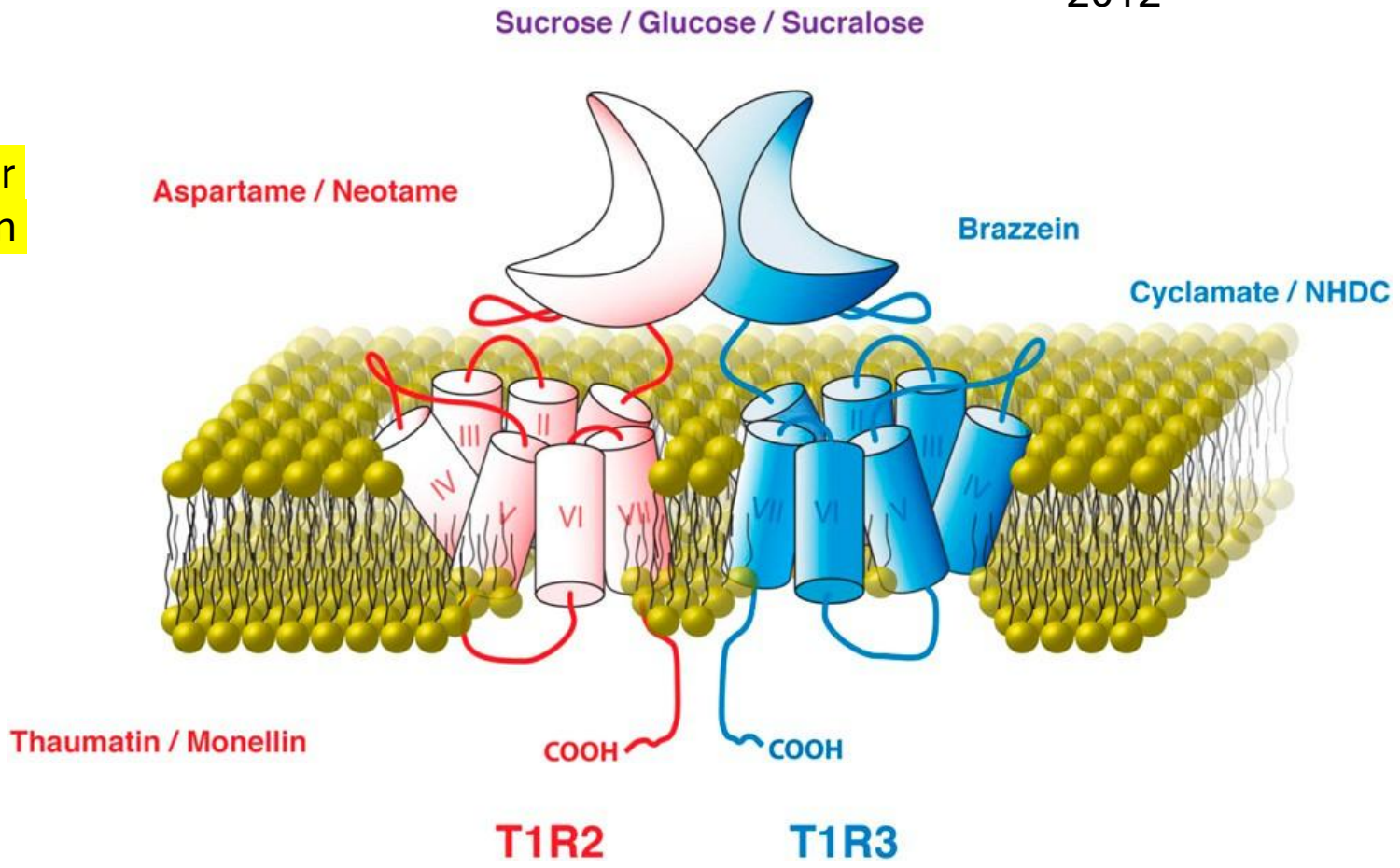

Human Brain Anatomy
Frontal lobe
Parietal lobe
Occipital lobe
Cerebellum
Temporal lobe
Spinal Cord

Taste Receptors (G protein transmembrane)

Vigues S, Dotson CD, Munger SD. The receptor basis of sweet taste in mammals. Results Probl Cell Differ. 2009;47:187–202

Source: Fernstrom et al J Nutr 2012

Inter species and inter individual variations in T1R2.



Cyclamates and Saccharin

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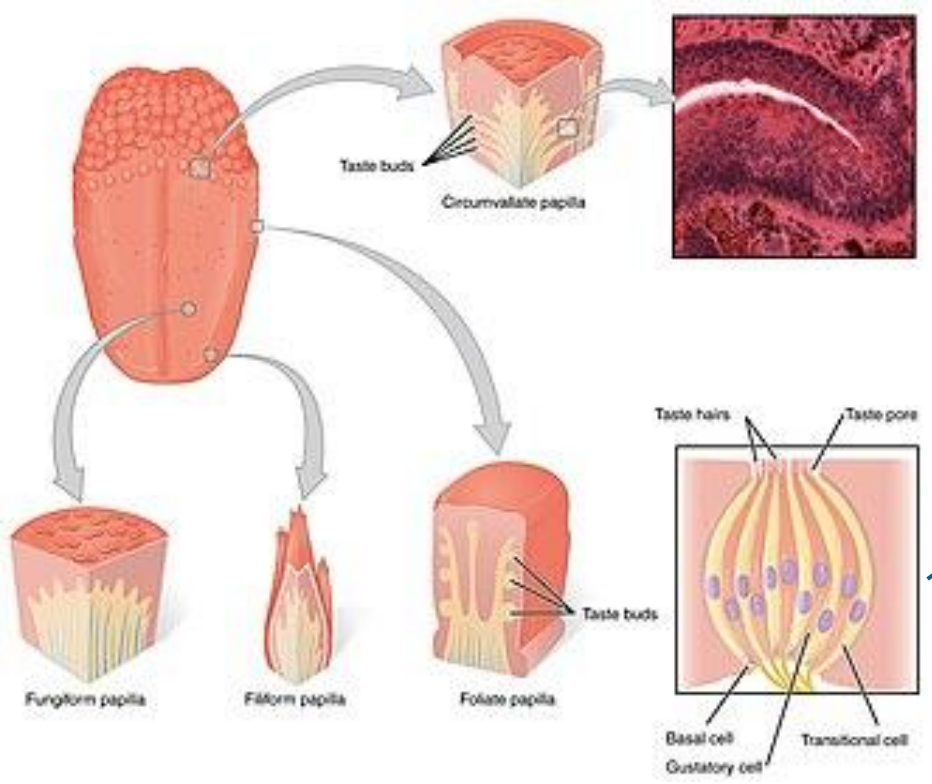
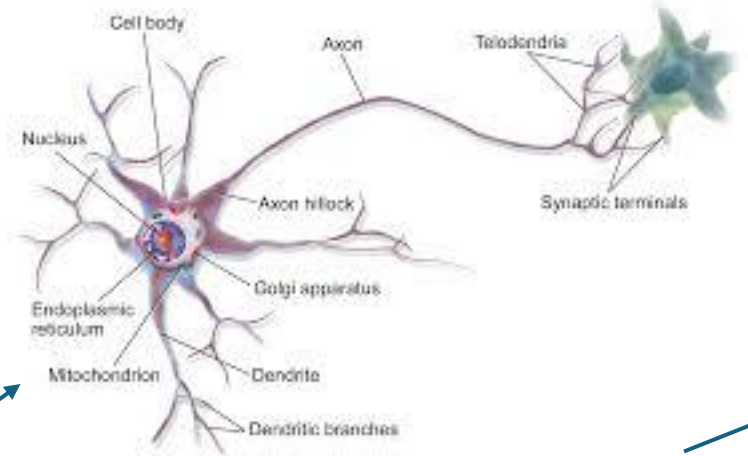
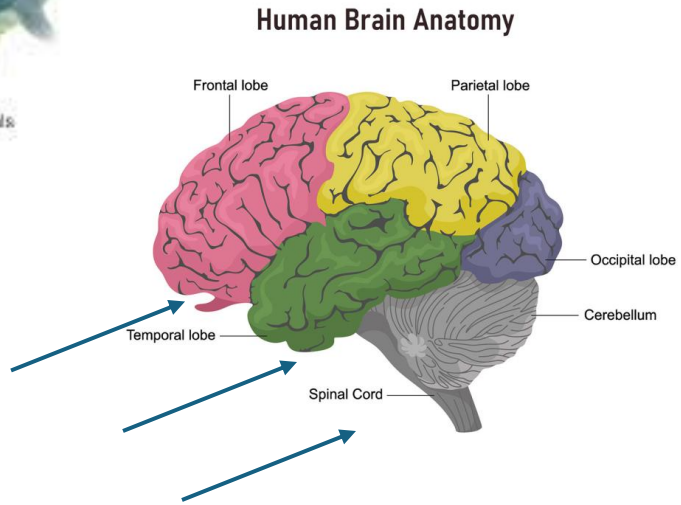
T2R detect bitter taste

Pathways for Sweet Taste perception





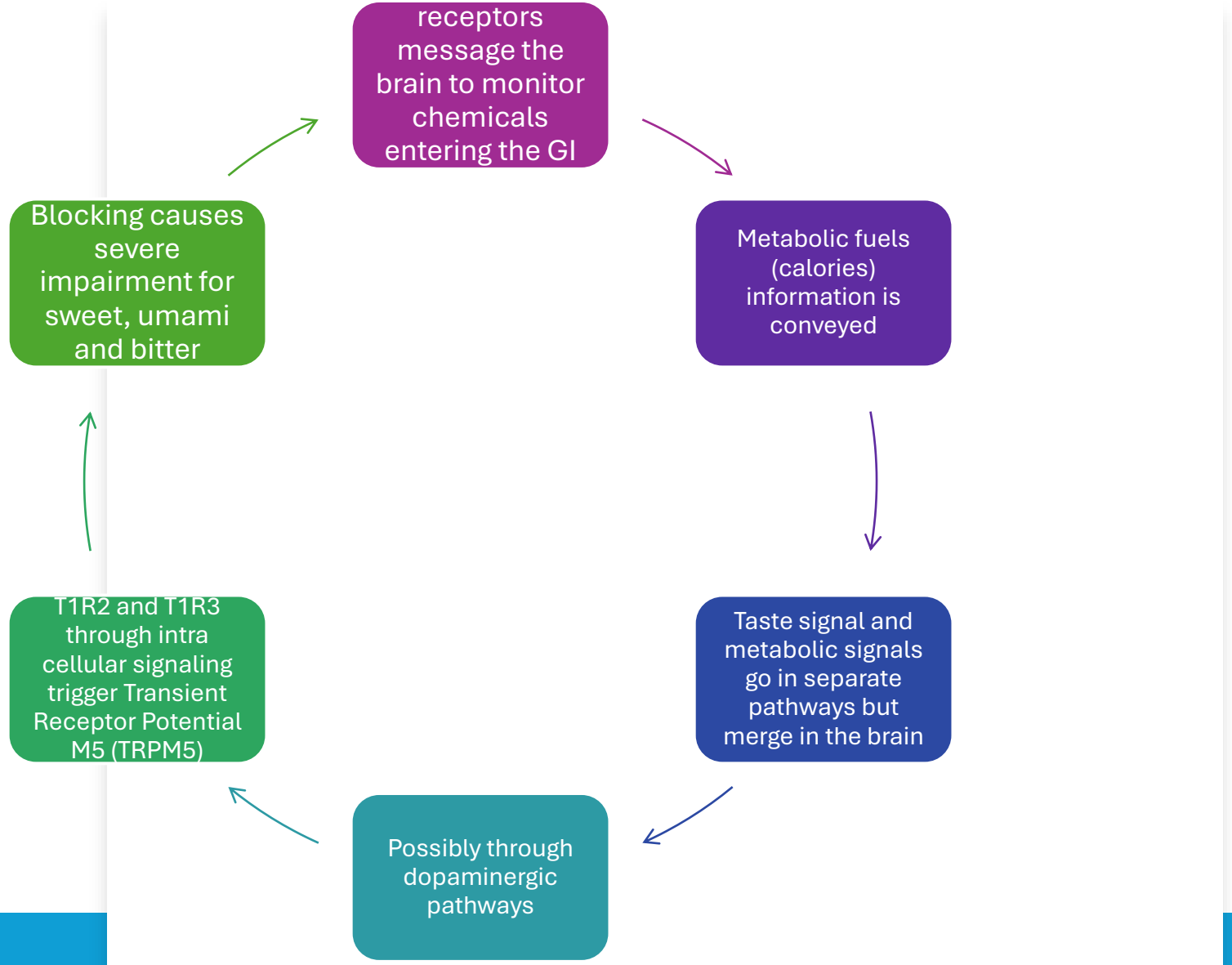
Other stimuli
Smell,
Thermal,Texture



Brain Stem, Thalamus , Cerebral Cortex, Amygdala

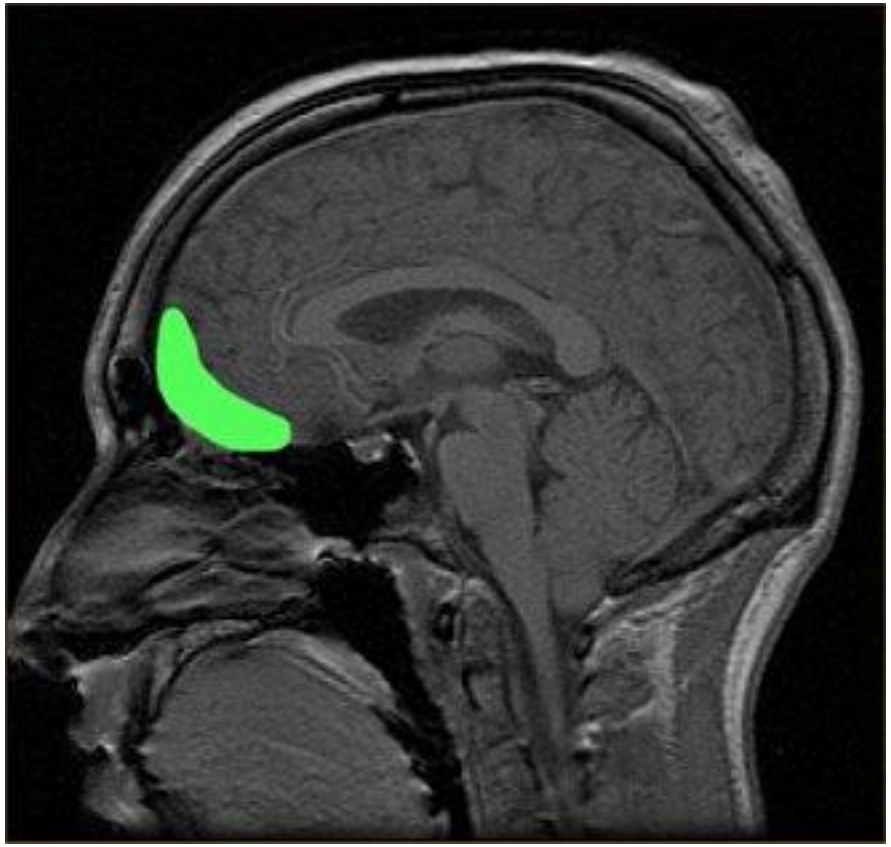
Source: Wikipedia

The Gustatory (taste) System



Gustatory Cortex

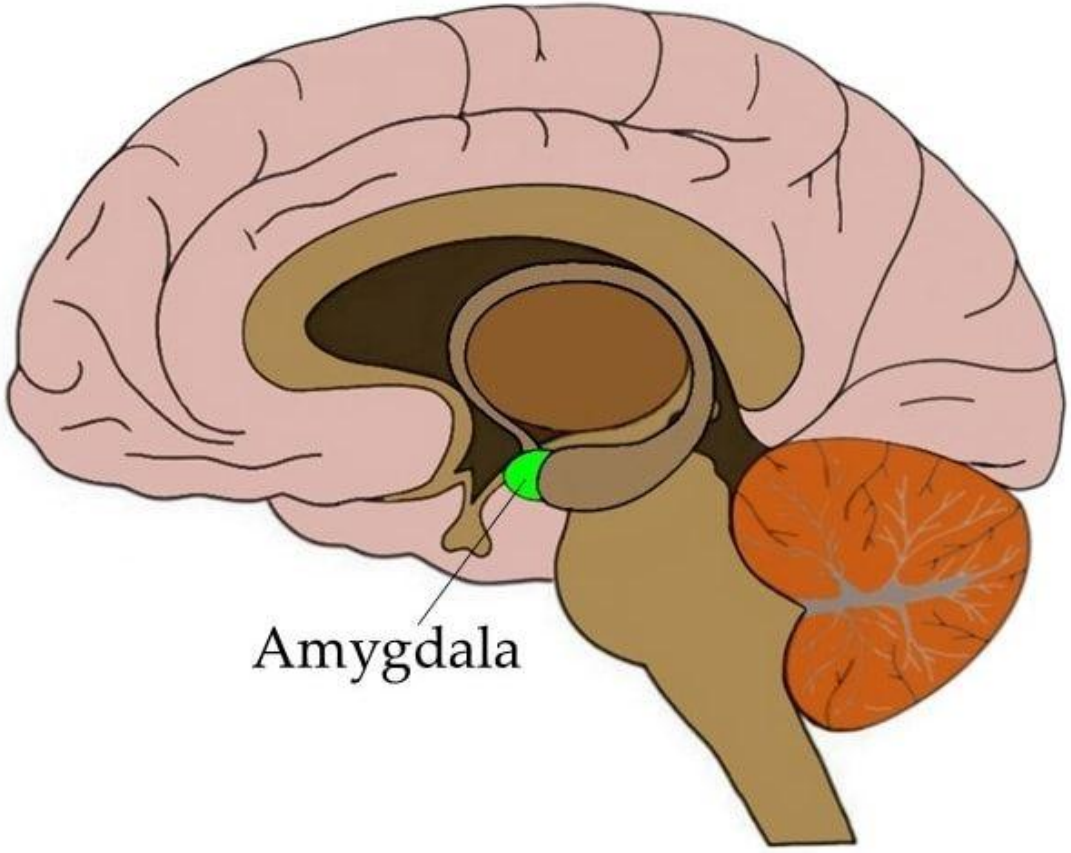
Rolls et al Eu J Neurosc,1989



Stimulated by sweetness and pleasantness of the taste + motivational

Enjoying

Small et al, Neuron,2003



Stimulated by intensity of sweetness

Sweetness without enjoyment

Sweet Taste Preference by the Brain

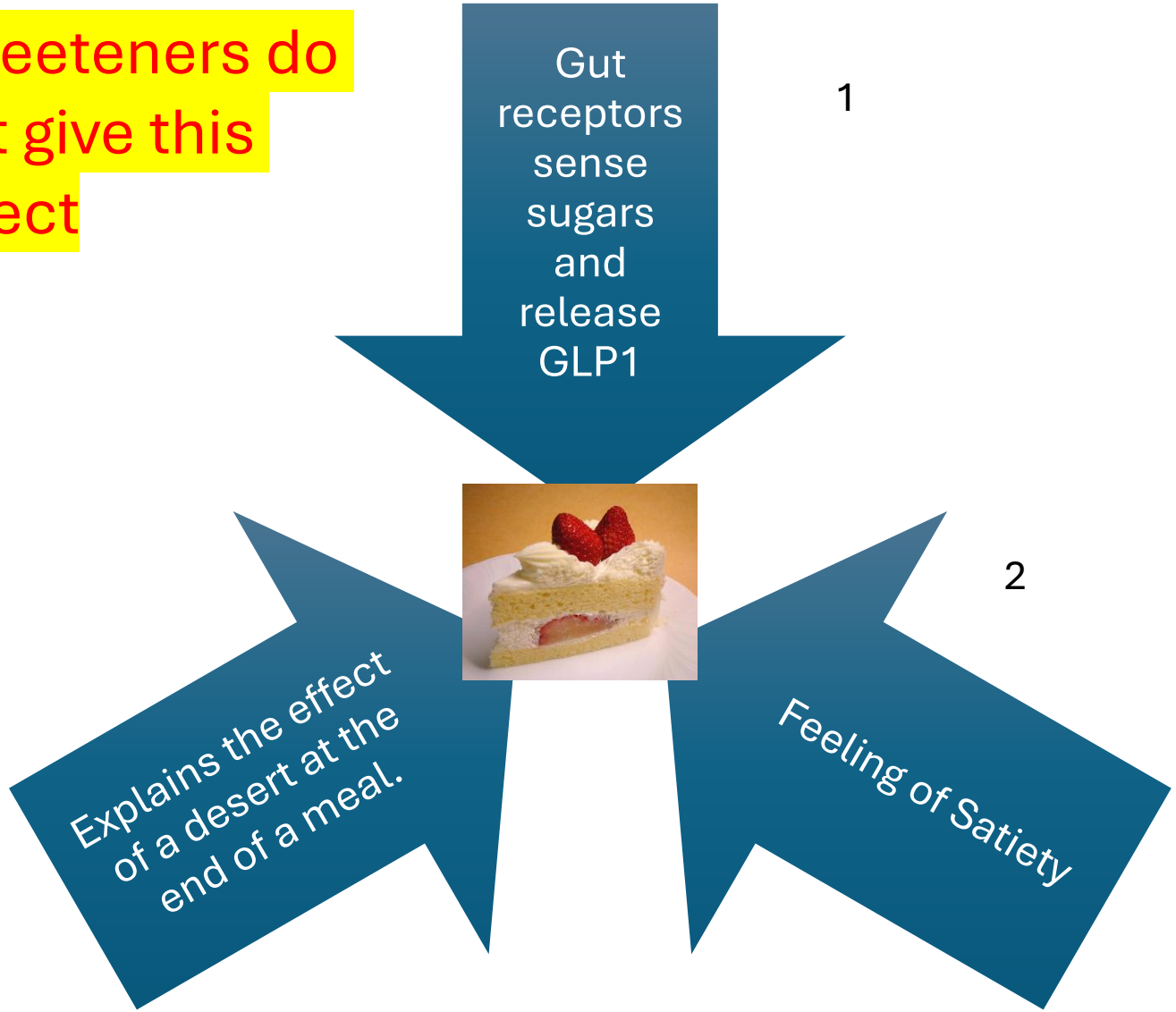
- Evolution linked anything tasting sweet as ENERGY
- Anything bitter as POISON
- Sugar preferences hence acted through pathway independent of sweet taste through Glucose oxidation signals through dopamine signals

Hoffer D et al PNAS,1996

Post Oral effect

A dessert at the end of a meal

Sweeteners do not give this effect



Yeomans et al Physiol Behav ,2008; Mattes and Popkin,Am J Cl Nutr 2009

Preference for sweet products despite satiety

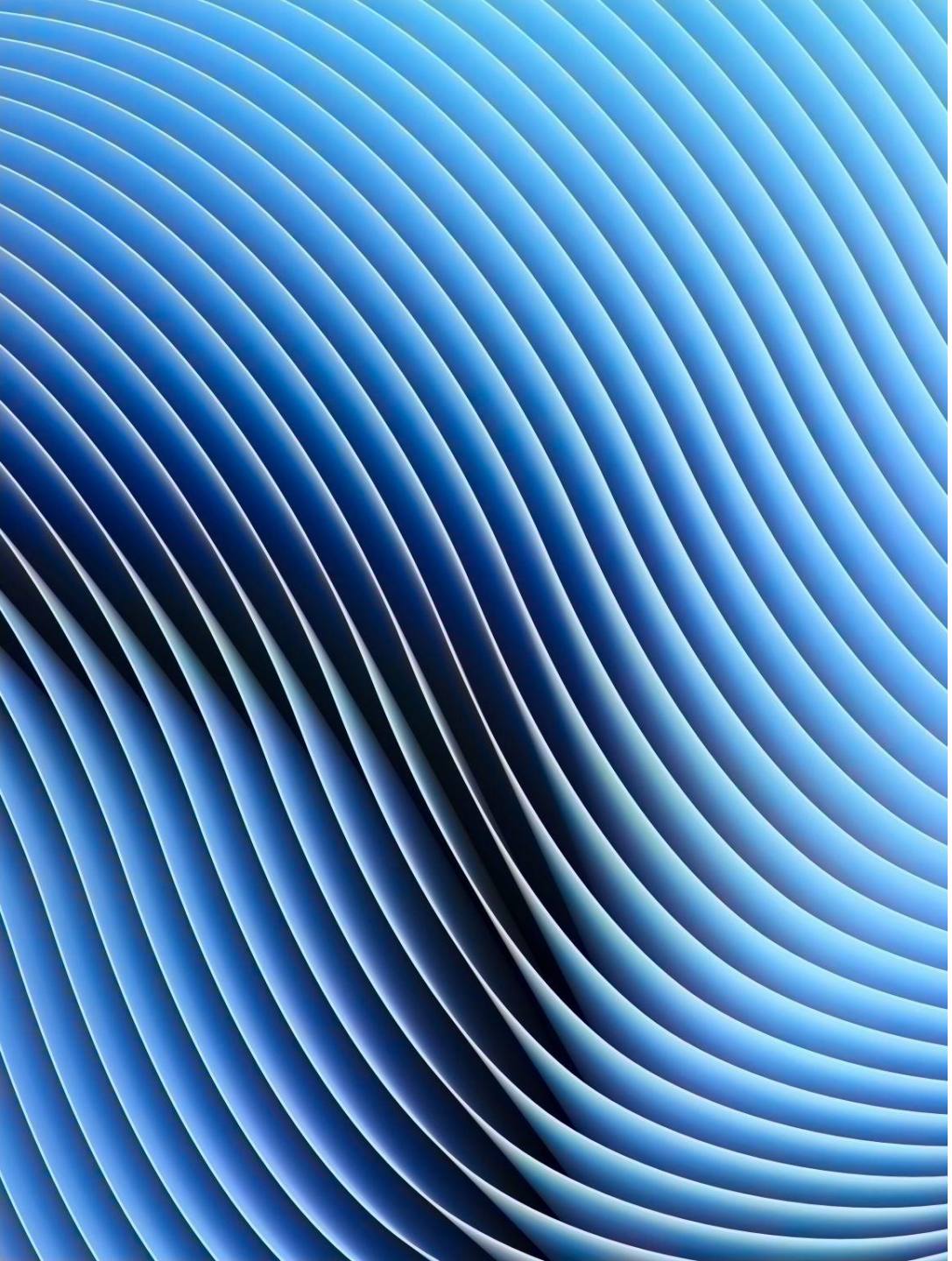
Easy Accessibility

Highly palatable

Other triggers

People who are Obese or a tendency to become obese

(Berridge 2009)



Palatability of sweet products

Desire is more before a meal than after –indicates energy need(Laeng et al 1993)

Ingestion of sweet products causes sensory specific satiety . Desire comes down progressively-Alliesthesia, post ingestion hormonal changes (Brondel et al 2007)

Individual variations are high in response to sweetness (Hetherington et al 1989)

Weight loss also changes desire for sweet substances (Frankham et al 2005)

Role of T1R(R2 and R3 receptors in the gut

Will low calorie sweeteners do the same

Present in	Present in entero endocrine L and K cells
Facilitate	Facilitate glucose absorption and transport
Stimulate	Stimulate production of GLP1 and GIP
Act on	Act on pancreas to reduce Glucagon and Increase Insulin
Reduce	Reduce gastric emptying and decrease appetite (Mace et al 2007,Kokrasvili 2009)

Mueller et al Nature 2005,

Margolskee et al,PNAS, 2005

Dotson etal Curr Op Invest Drugs 2010

LCS and the gut receptors .....

- A single, oral, or i.g.dose of sucralose ,aspartame , or acesulfame-K also did not modify plasma concentrations of GLP-1 and peptide YY (peptide YY is also secreted by L-cells and reduces hunger (Ford HE et al, Eu J Clin Nutr 2011; Steinert RE et al B J Nutr 2011)

Chronic ingestion of sucralose in diabetics did not affect Fasting Glucose. HbA1c or C peptide.(Grotz VL J Am Diet Assoc 2003)

- Similarly, with Rebaudioside A in diabetics and metabolic syndrome (Maki KC et al Food Chem Toxicol,2008)

LCS and the gut receptors

- LCS also bind to same receptors
- Will LCS increase glucose uptake and be insulinogenic
- Will they lower blood glucose and increase appetite

- **Studies showed**
- No change in blood concentrations of GLP1,GIP and Glucose (Fujita et al, Am J Physiol Endocrinol Metab2009)
- Did not influence rise in glucose in GTT
- Sucralose to healthy/diabetic individuals did not elevate C Peptide or Glucose (Mezitis NH et al Diabetes Care 1996)

LCS Non Oral route and the gut receptors

- Intraduodenal infusion of glucose increased plasma concentrations of glucose, GLP-1, insulin, and glucose transport across the gut wall

- But with Sucralose infusion NO EFFECT(Ma J et al , Br J Nutr 2010)

LCS and body weight

Does not Increase food intake or body weight (Fenstrom J Nutr Suppl 2012))

Modest weight reduction

Long term Ingestion not associated with increased food intake or body weight.

Mohan et al Diabetes Ther . 2024 Sep;15(9):2061-2077.

- **Conclusions:**
- In Asian Indians with T2D, replacing about 60 kcal of added sucrose with sucralose in coffee/ tea had no benefit on glycemia but resulted in a small reduction in body weight, body mass index, and waist circumference.
-

- **Table 3. LNCS consumption position guidance for persons with diabetes. (Sievenpiper, Nutrients 2025)**

- **American Diabetes Association (Diabetes Care 2024, 47, S1–S4.)**
-
- “Counsel people with prediabetes and diabetes that water is recommended over nutritive and nonnutritive sweetened beverages.

- However, the use of nonnutritive sweeteners as a replacement of sugar-sweetened products in moderation is acceptable if it reduces overall calorie and carbohydrate intake”.

-

Diabetes Australia. Alternative Sweeteners—Can They Help Manage Diabetes? Available online: https://www.diabetesaustralia.com.au/blog/alternative-sweeteners-diabetes/

"The use of alternative sweeteners could assist in maintaining the palatability of foods and beverages with the absence of sugar and with less energy (kJ)".

"Non-nutritive sweeteners include aspartame, sucralose and stevia. These do not influence blood glucose levels and may be a useful alternative for replacing added sugar".

Diabetes Canada Sugar & Diabetes. Position Statement. Available online: https://www.diabetes.ca/advocacy---policies/our- policy-positions/sugar---diabetes

“Limit intake of free sugars to less than 10% of total daily calorie (energy) intake. This is approximately 50 g (12 teaspoons) of free sugars consumption per day based on a 2000-calorie diet”.

“Limit intake of sugar sweetened beverages (SSB) and drink water in their place”.

“Promote the intake of whole foods and reduce the intake of free sugars throughout life for overall health”.

“Low calorie sweeteners are one tool available for sugar intake reduction efforts”.

Diabetes UK. The Use of Low or No Calorie Sweeteners. Available online: https://www.diabetes.org.uk/about-us/about-the- charity/our-strategy/position-statements/use-of-low-or-no-calorie-sweetners

"LNCS can be used as a 'stepping stone' to reduce intake of sugar in the diet as a part of an overall healthy eating plan".

"LNCS are shown to be safe, and they can be used as part of a strategy for adults and children in the management of weight and diabetes.

LNCS sweetened beverages may be helpful when they are used as a substitute by regular consumers of sugar-sweetened beverages and as long as substitution doesn't lead to later compensation with increased energy intake.

This approach may be helpful for people who are accustomed to a sweet taste and for whom water, at least initially, is an undesirable option".

Effects on NNS on metabolism (Zhang et al,Nutrients 2023)

36 trials involving 472 predominately healthy participants.

No meaningful effect of any NNS alone or as blends on any metabolic or endocrine responses

With similar responses to the standard of care water and no differences across NNSs,

Caloric sweeteners (mainly glucose and sucrose) increased postprandial glucose, insulin, GLP-1, and GIP.

Similar patterns were seen across the coupling and delayed coupling designs with a lack of effect of NNS

Conclusions on NNS, LCS (LNCS) 1

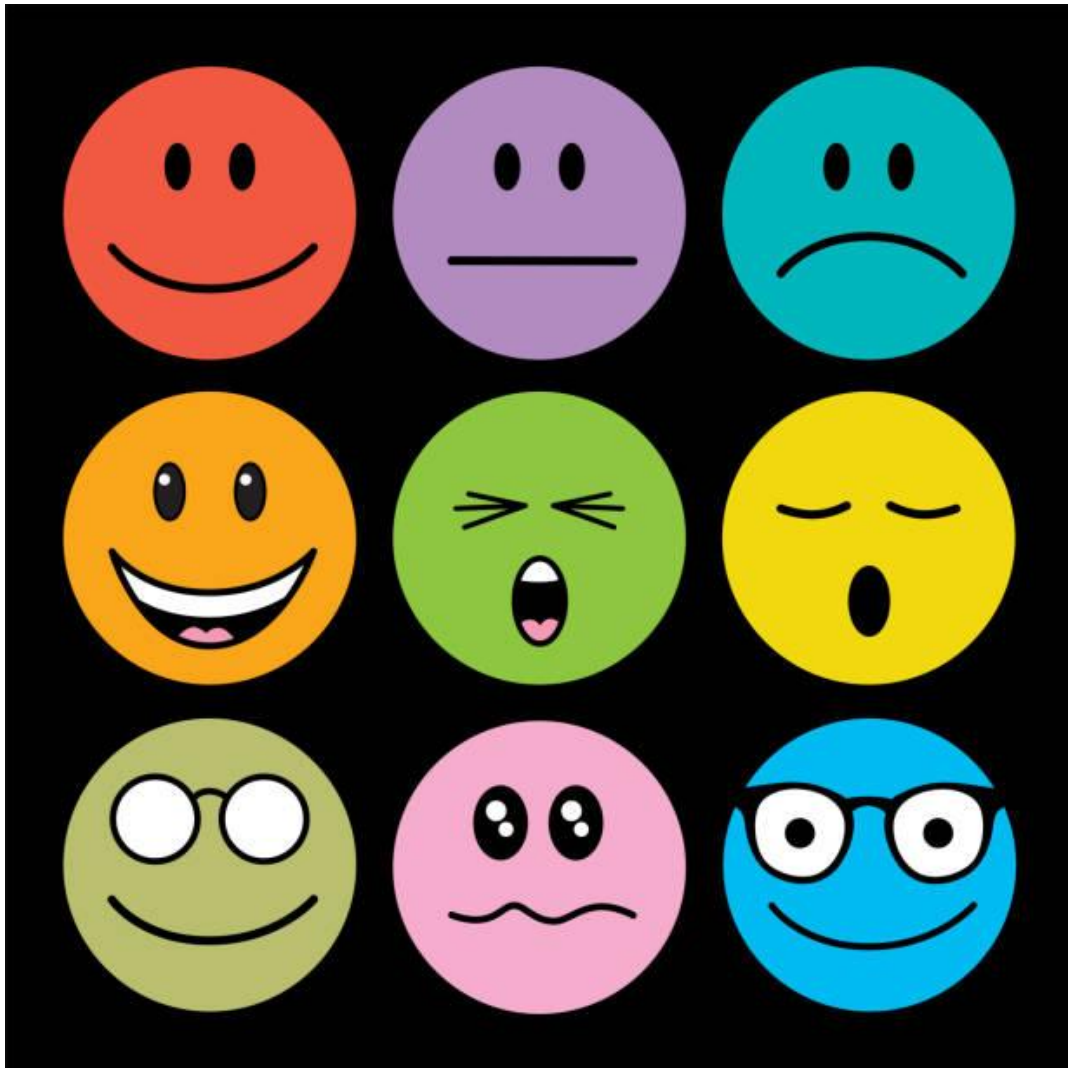
- Systematic reviews and meta-analyses showed that the intended substitution of NNSs for added sugars (especially NNSBs for SSBs) reduces body weight and downstream weight-related cardiometabolic risk factors in randomized controlled trials.

- The substitution is associated with reductions in incident obesity and coronary heart disease, cardiovascular mortality, and total mortality in prospective cohort studies.

Conclusions on NNS, LCS (LNCS) 2

- In addition, a few randomized controlled trials are starting to address the impacts of LNCSs on gut microbiome and has not shown any detrimental effects.
-
- Lastly, emerging evidence from in vitro and a randomized controlled trial have investigated food intake and satiety management and suggests that natural LNCSs may be beneficial.
- (Sievenpiper JL, Nutrients 2025)

Psychology of Sweetness



Liking for sweetness is evolutionary and inborn

Before birth sweet taste detection is functioning and interacting with systems that control suckling (Maone et al ,Dev Psychobiol.1990)

Infants prefer sugar solutions over water

Increasing concentration of sucrose solns on the tongue increase heart rates in newborn

In agitated infants' sucrose decreases heart rates (Ashmead et al 1980, Blass et al, 1999)

Analgesic effect of sweetness in infants and children

- Sweetness has a calming effect
- Signals from the mouth not metabolic
- Safe and effective to reduce anxiety and pain while doing procedures
- Sucrose on the tongue increases pain tolerance
- (Barr et al 1999, Ramenghi et al 1999; Stevens et al 2010)

Preferred concentration of sucrose

Keeps increasing from infancy to adolescence
Adults prefer lesser concentration
About 0.60M sucrose/230 ml water – 12 tsps.
Cola has about 7tsps. / 230 ml or 0.34 M – Adult preference
(Mennella 2011, Desor , 1987)

Bitter(Poison) and Sweet (Pleasure)

- Both bitter and sweet bind to similar receptors
- More types of bitter receptors
- Individual variations and polymorphisms in bitter receptor genes
- Sweetness suppresses bitterness – use of sucrose with caffeine or alcoholic beverages

Bitter(Poison) and Sweet (Pleasure) 2

Bitter medicines given with sweet substances sugar or honey

Bitter receptors are more sensitive in children . LCS bitter after taste may be more in kids (Menella et al 2005, 2010)

“A spoon full of sugar makes the medicine go down” (from Mary Poppins movie)

(Mennela and Bobowski,Physiol Behav,2015)

Cognition, Emotion and Taste

- Bitterness and feelings of moral disgust
- Sweet taste activates pro social behavior, and Romantic feelings
- Individuals with induced romantic feelings perceived plain distilled water as being sweet. (Chan et al; Emotion, 2013)
- Jealousy - Water tasted neither bitter or sweet
- Oxytocin suppresses intake of sweet carbs- Due to effect in the brain and the taste receptors- Site of action is the VMN in hypothalamus a site associated with glucose homeostasis and reproductive behavior (Leng and Sabatier; Tr Endo metab 2017)

Sweetness and Perception

- Pictures of faces appeared attractive when viewed after a sweet snack than a salty one .
- Sweet snacks have reduced stranger anxiety in children
- fMRI and EEG have supported the effect in the brain (Wang et al 2019)
- Sweetness and Pro social behavior started with sweetness of breast milk and infant formula (Barsalou Ann Rev Psychol 2008)

Does reduced sugar exposure from 2 to 11 yrs change the preferred sweetness level

The preference level of sweetness remained heightened even with 10 years of less sugar exposure.

The preference is more biological

n US sugar consumption data showed a decline but intakes still exceed the limits (Slining and Popkin 2013)

Higher sugar preference in growing phase is linked to higher energy needs (Drewnoski, Proc Nutr Soc ,2000)

Early life Sugar exposure

- Children given sugar water as infants preferred more sugar at 2 yrs and up to 10 Yrs (Beauchamp and Moran1984, Pepino and Mennella 2005)
- 4 – 7 yr olds, whose mothers regularly added sugar to their foods only preferred sugar sweetened apple juice and sugared cereal compared to those who did not regularly use sugar (Liem and Mennela 2002)
- Evolution has shaped the child's response to sweetness , but conditioned learning could change this preference (Simmen and Hladik 1998,Beauchamp and Cowart 1985)

Relationship between Sweet preference and Obesity- Too complex 1

150 Children – those who preferred a sweet taste were 2X Obese(Sobek et all 2020)

Hill et al found no relationship between sweet or fatty food preferences and obesity (Hill et al 2009)

Lampure et al 2016 in 24,776 adults over 5 yrs – Obesity more related to fatty food preferences

Relationship between Sweet preference and Obesity- Too complex 2

Consumers of large amounts of sweet or sweet products are often lean (Drewnowski 2007)

Defeliciantonio et al 2018 – fMRI showed combined high fat and High Carb diets were preferred over other isocaloric diets

Triggered reward areas in striatum of brain . Not related to personal preferences

Sweetness –Preference or Addiction

- Sweet stimuli related activation of brain related to Hunger and NOT Fasting or BMI
- Craving and rewarding similar to addictive drugs (Ahmed et al 2013,Olszewski et 2019)
- Non Nutritive sweeteners increased desire for sweet foods promoting overweight and obesity in Rats (Swithers et al 2013)
- fMRI study - Females and Obese have a higher reward stimulation in the brain for Non Nutritive sweeteners (Yunker et al 2021)

Conclusions

- Sweetness is a basic biological and evolutionary need
- Relationship between preference to sweetness and obesity is complex
- LNCS are a good and safe substitute for sugars
- In infancy , childhood and adolescence the desire for sweetness is linked to the energy needs of growth.
- Early childhood exposure seems to play a significant role in adult sweet preference
- Individual variations in genes, receptors, thresholds, neural and endocrine signaling, enabling or restricting environment etc. etc.

Thank

You