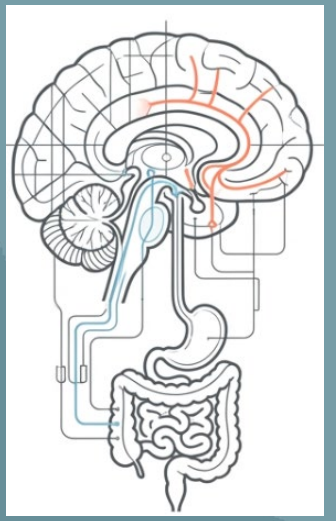


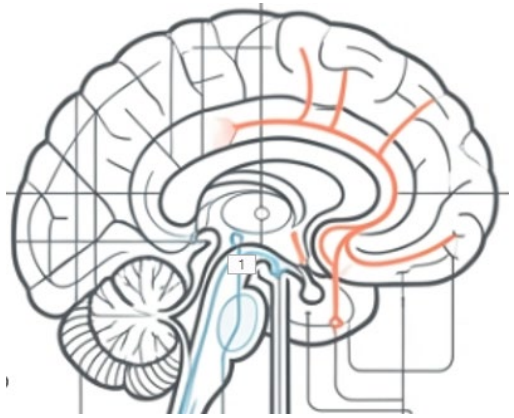
# Targeting the brain: how surgery and medications for obesity reshape the way we eat

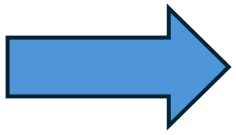
Dr Ruth Price

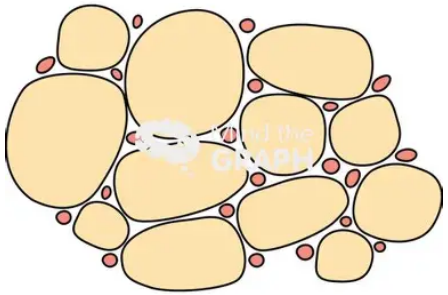
rk.price@ulster.ac.uk

21st April ‘26

# Modern perception of obesity





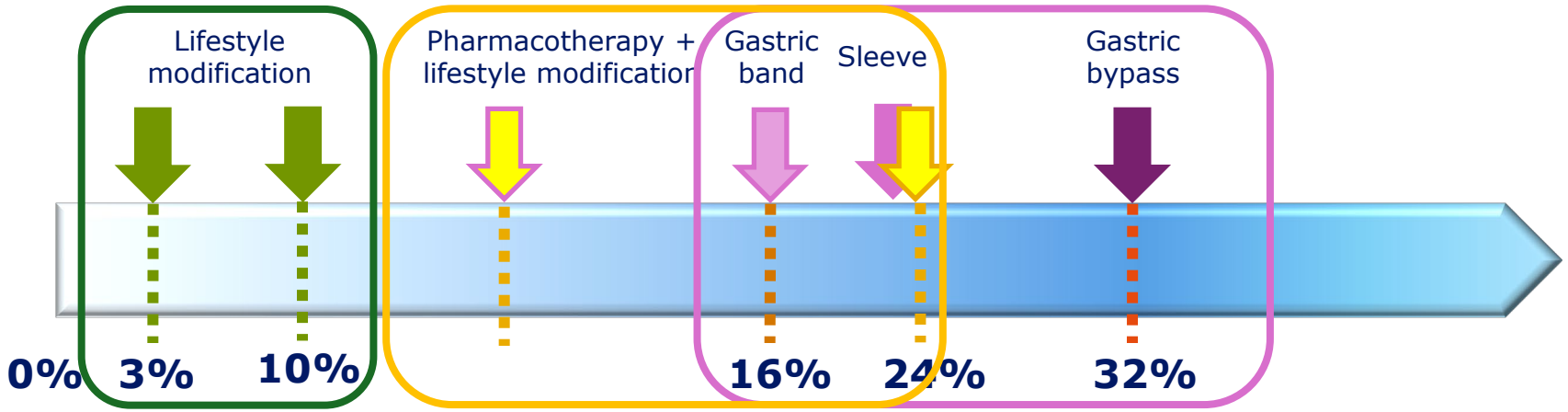


Brain

Eating behaviours

Excess adiposity

# Treatment options for people with obesity

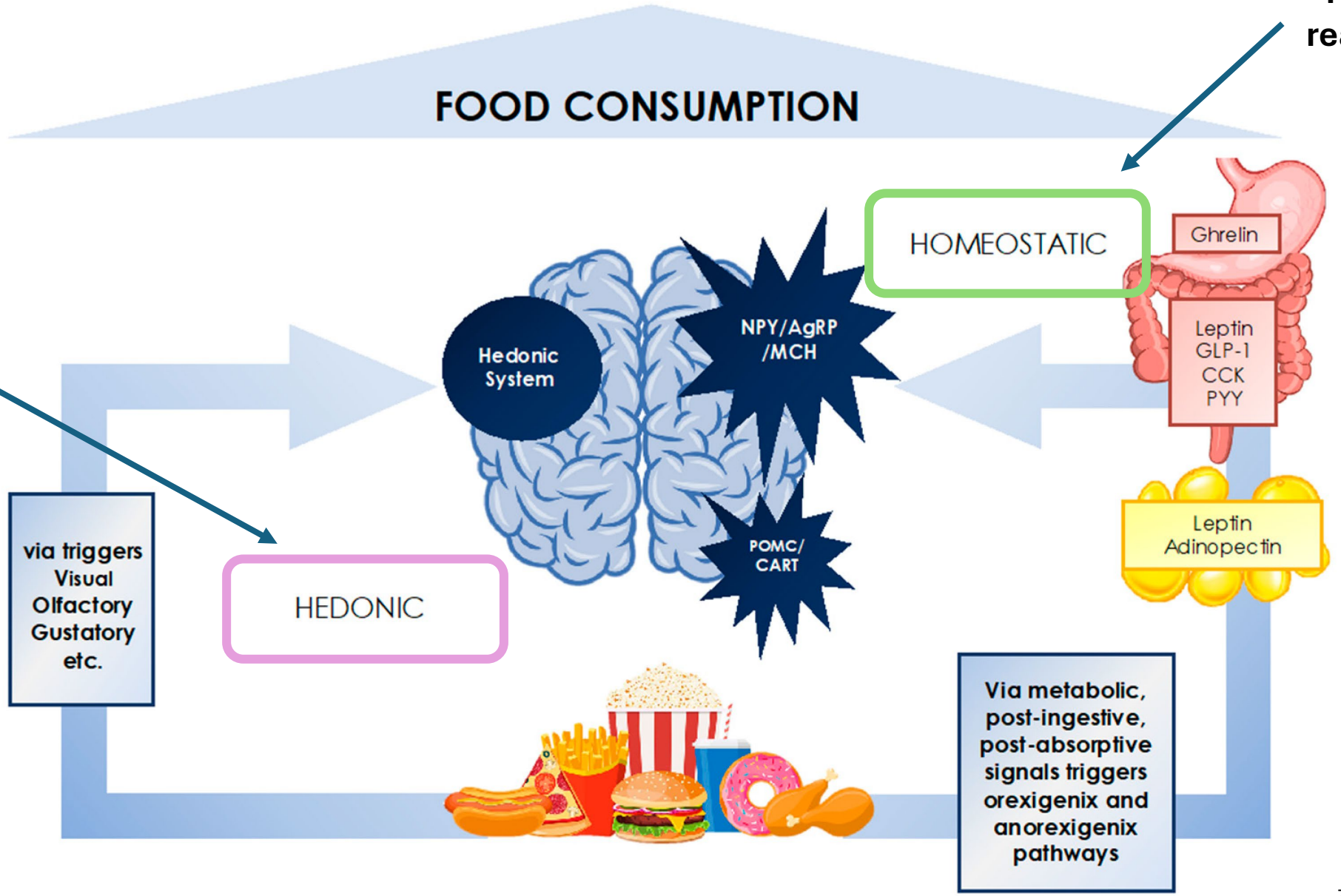



**Eating behaviour:** the patterns, habits, and motives associated with food consumption: ***when, how,*** **and** ***why people eat*****.**

# Regulation of eating behaviour

**Obesity**
**More food to reach satiation**

**Obesity**
**↑ Preference or reward value of energy-dense foods???**




Ziauddeen et al, Nat Rev Neurosci

# Eating behaviour phases; appetitive & consummatory

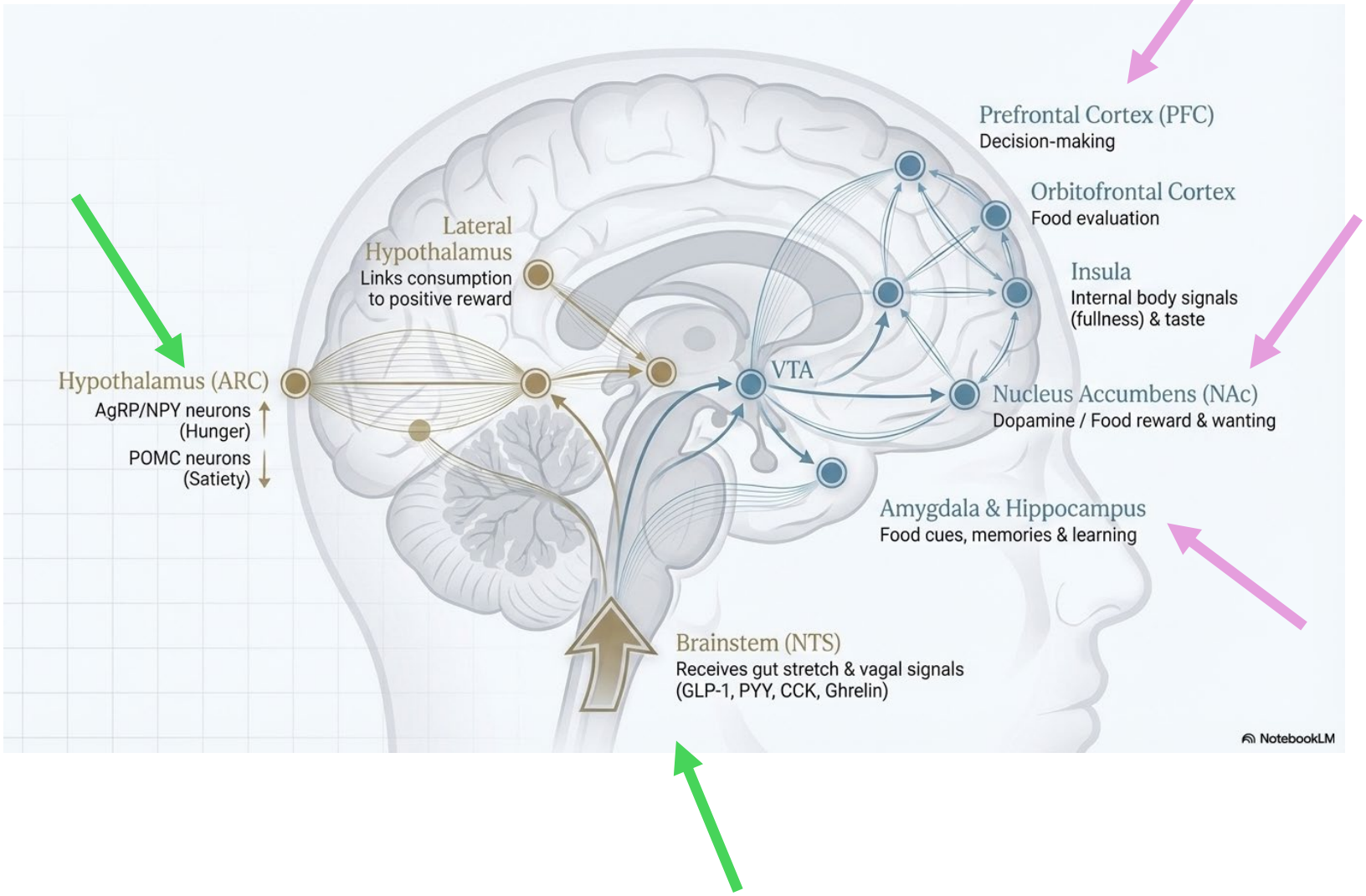
## Appetitive behaviour

**BEFORE a meal**
**Core behaviours**: Hunger, food-seeking, wanting, craving, planning
→ Determines *whether + what* an individual eats

**Homeostatic system :** The 'empty tank' signal

**Hedonic system :** Wanting, even in the absence of need

**Meal initiation**



# Eating behaviour phases; appetitive & consummatory

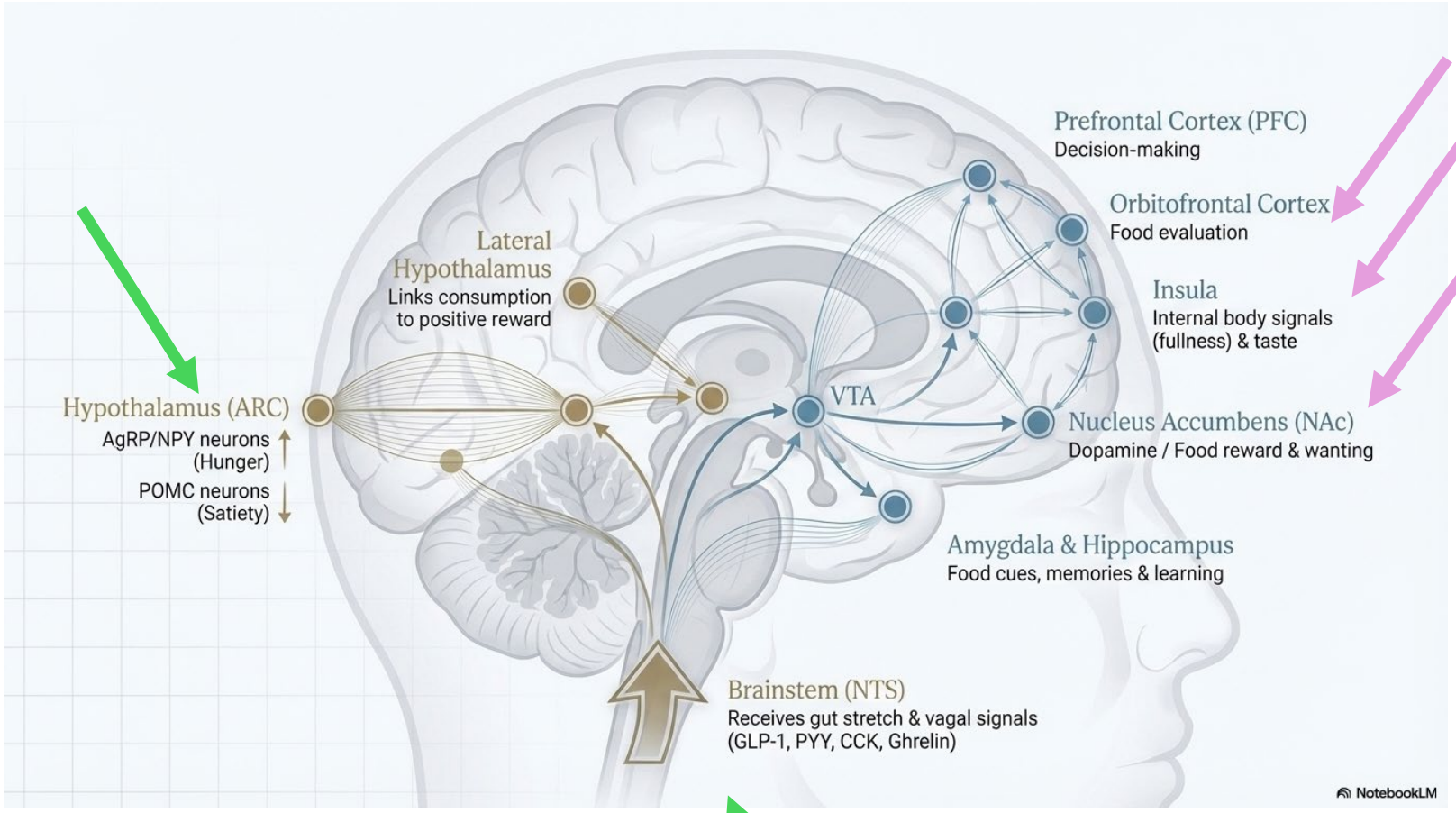
## Consummatory behaviour

**DURING a meal**
**Core behaviours:** Satiety, liking, eating rate,
→ Determines *how much* they eat

**Hedonic system**
Sensory pleasure, reward response

**Homeostatic system**
Satiety, fullness - Aversive break

**Meal termination**



# Behavioural Weight-Loss Interventions

# Behavioural Weight-Loss Interventions Examples

↑ eating frequency

↓ eating rate

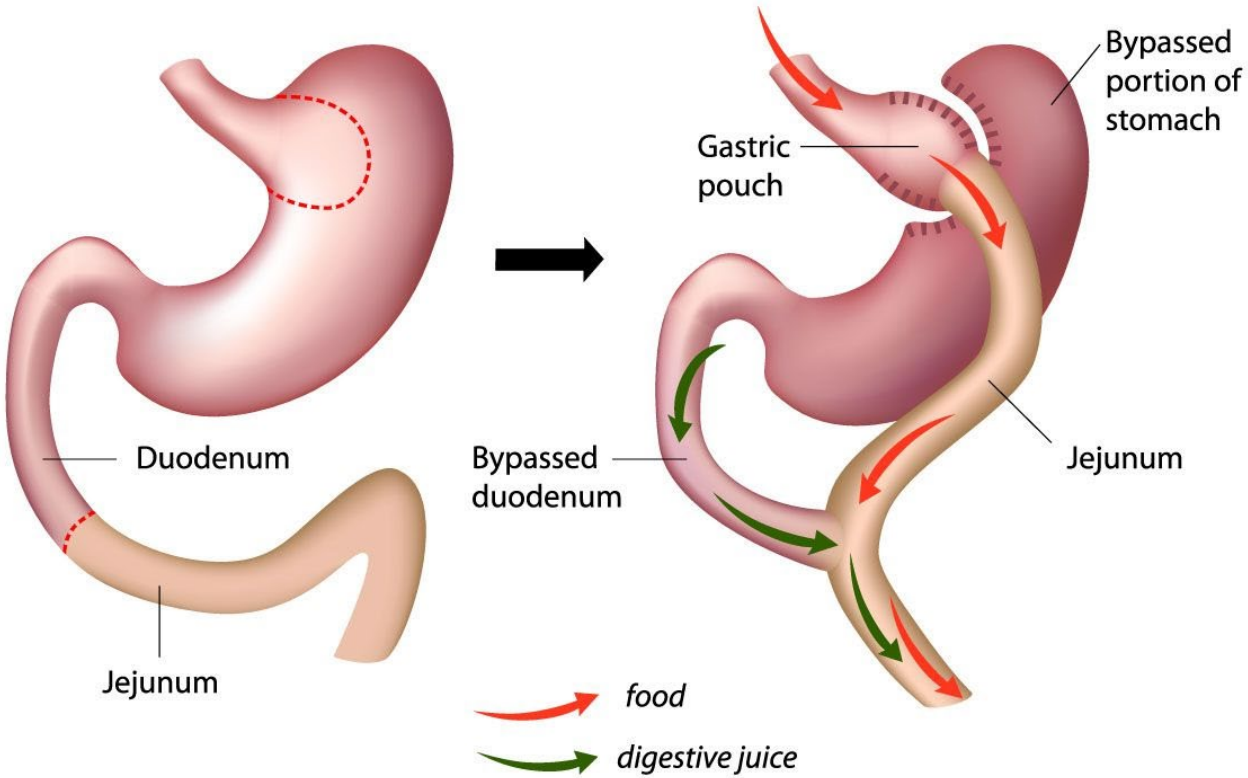
↑ satiety awareness

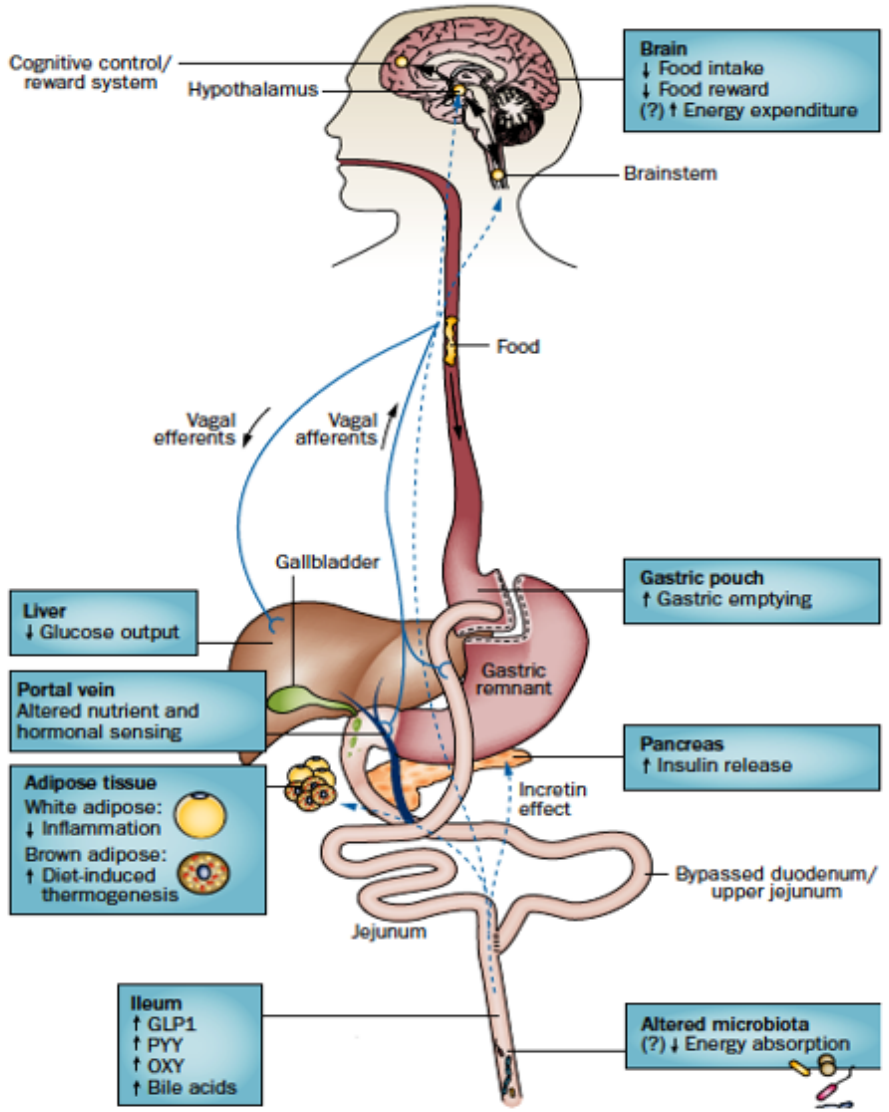
↓ hedonic eating using CBT

↓ energy density

# Roux en Y Gastric Bypass Surgery (RYGB)

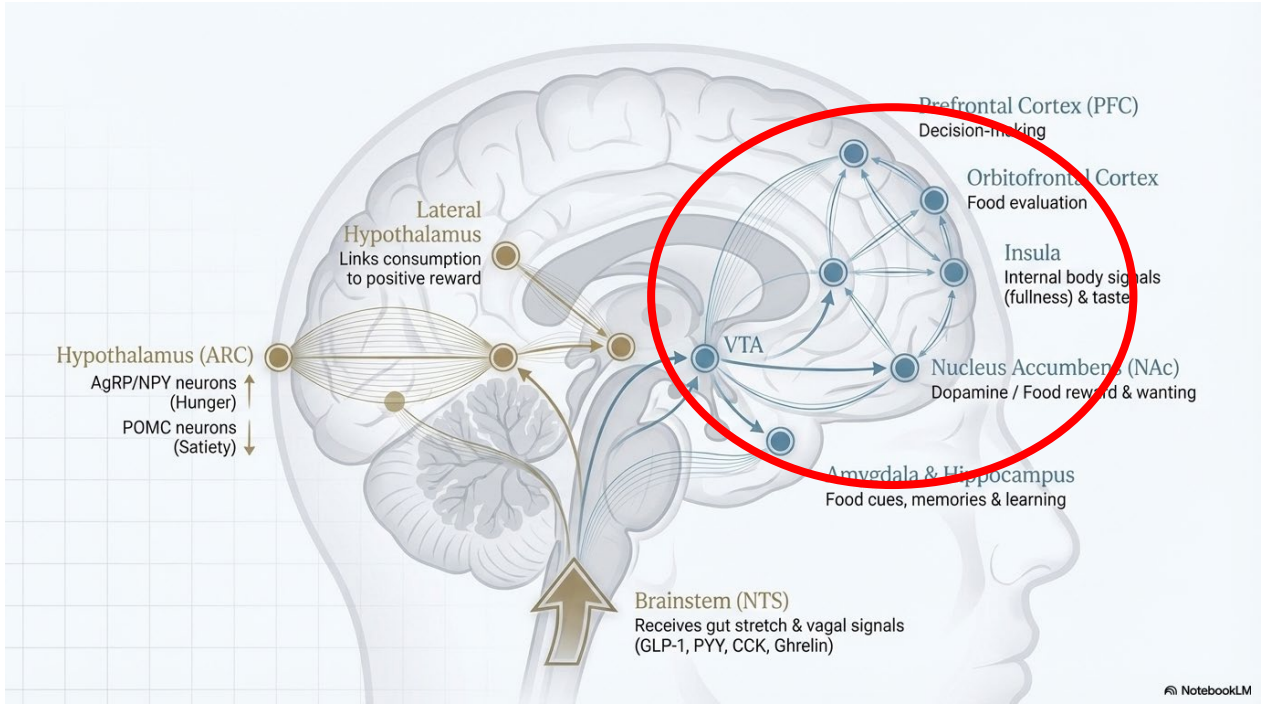
# Roux en Y Gastric Bypass Surgery (RYGB)




Miras A & le Roux CW, Nature Reviews Gastroenterology, *2013*

# Is reduced reward the mechanism?




Pre-operative

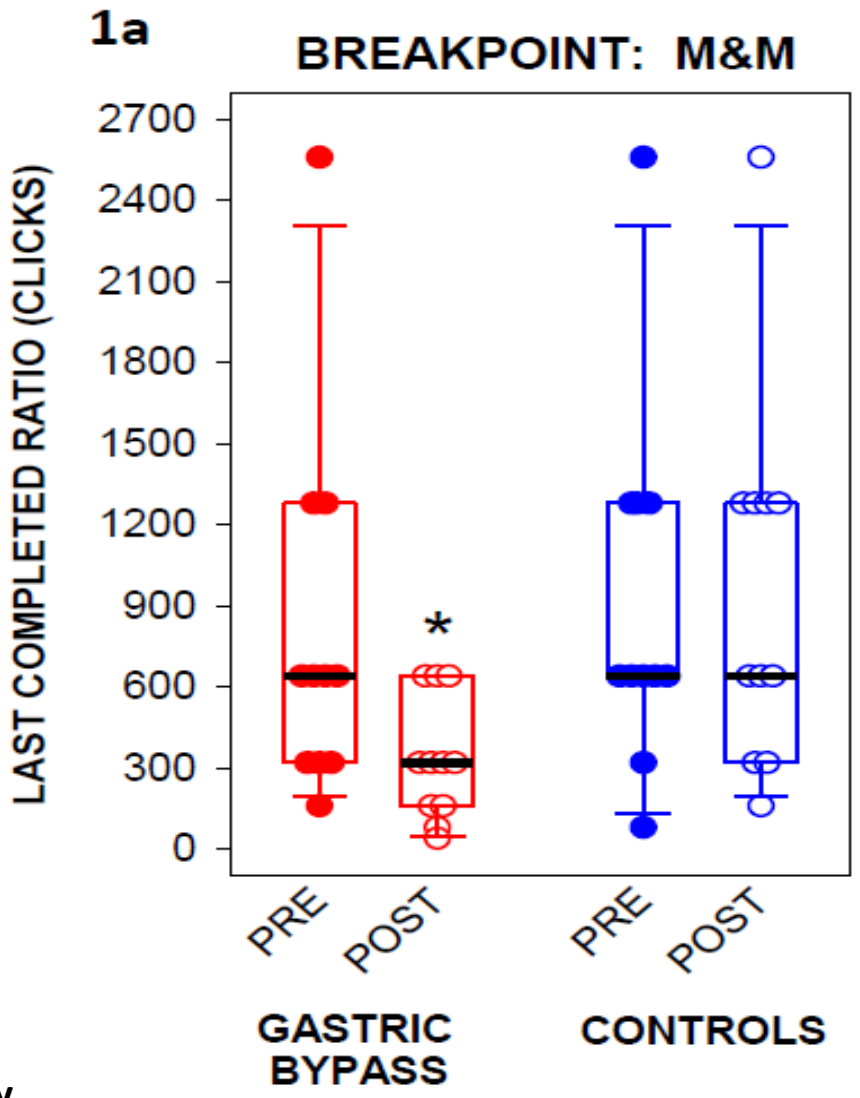
Post-operative

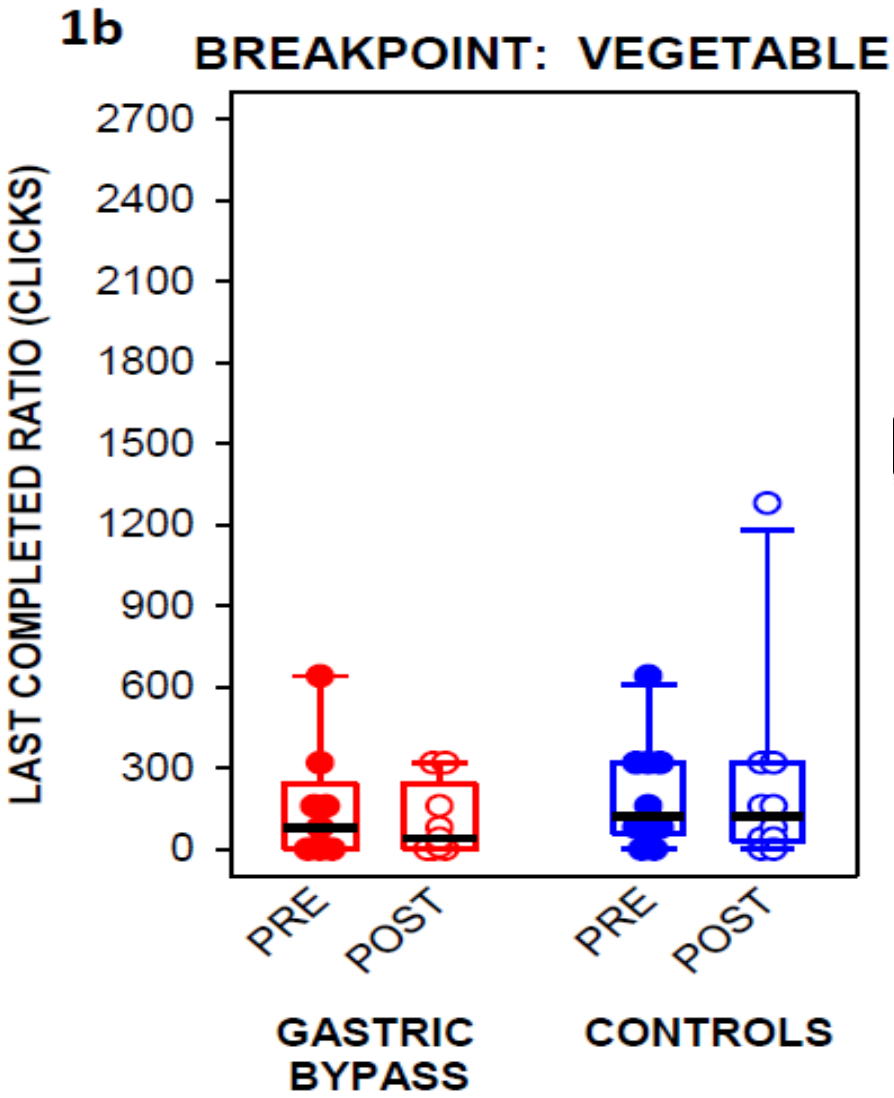
***Hypothesis:*** *Changes in the hedonic system ↓ the reward value of high-fat high-sugar foods after surgery*

# Is reduced reward the mechanism?

**Motivation**: Progressive-ratio schedule.

# Humans work less for sweet/fat taste after gastric bypass



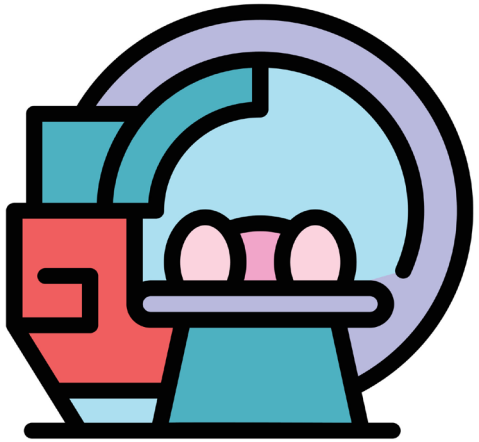




8 weeks post-surgery
Miras et al AJCN 2012

# Is reduced reward the mechanism?

**Motivation**: Progressive-ratio schedule.

**Perceived reward value**: fMRI



↓ motivation for energy dense foods

↓ reward system activation for energy dense foods

# Do these changes impact eating behaviour?

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DOI: 10.1111/obr.13202

BARIATRIC SURGERY/NUTRITION ASSESSMENT

OBESITY Reviews WILEY

## Methodological issues in assessing change in dietary intake and appetite following gastric bypass surgery: A systematic review

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[2]Diabetes Complications Research Centre, University College Dublin, Dublin, Ireland

[3]Department of Psychology and Program in Neuroscience, Florida State University,

**Summary**

Gastric bypass surgery is an effective long-term treatment for individuals with severe obesity. Changes in appetite, dietary intake, and food preferences have all been postulated to contribute to postoperative body weight regulation, however, findings are

**TABLE 2** Summary of methods and outcomes of studies measuring changes in energy and macronutrient intake in patients after gastric bypass from pre- to post-surgery as assessed by dietary records, organized by follow-up duration

| Author (year) | Location | N (baseline) | N (follow-up) | % follow-up | Postoperative follow-up time | Diet record duration | Method notes | Energy intake | Macronutrient intake change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Protein (%EI) | Fat (%EI) | CHO (%EI) |
| Jeffreys et al. (2012)[46] | USA | 27 | 16 | 59 | 2 weeks | 3 days | Dietary record reviewed by dietitian | ↓ | ↑ | ↓ | NS |
| Miller et al. (2014)[52] | USA | 26 | 17 | 65 | 3 weeks | 4 days | Research nutritionist instructed how to complete | ↓ | ↓ | ↓ | NS |
| Aron-Winewsky et al. (2016)[49] | France | 14 | 14 | 100 | 1 month | 3 days | 2 weekdays/1 weekend | ↓ | - | ↑ | ↓ |
| Trostler et al. (1995)[90] | Israel | 19 | 19 | 100 | 1 month | 7 days | Verified w/24-h recall | ↓ | ↓ | ↓ | ↑ |
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**TABLE 3** Summary of methods and outcomes of studies measuring changes in energy and macronutrient intake in patients after gastric bypass from pre- to post surgery as assessed by dietary recall methods, organized by follow-up duration

✓↓ energy intake after RYGB

| Author ( | | | | | | | | Energy intake | Macronutrient intake change | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Protein (%EI) | Fat (% EI) | CHO (%EI) |
| Bavaresc (2010) | | | | | | | | ↓ | ↓ | ↓ | ↑ |
| Laurenius et al. (2013)[24] | Sweden | 43 | 42 | 98 | 6 weeks | Dietary questionnaire | Self-administered | ↓ | - | ↓ | - |
| Anderson et al. (2007)[47] | USA | 50 | 50 | 100 | 3 months | Dietary logs | Reviewed by dietitian | ↓ | ↑ | - | - |
| Bavaresco et al. (2010)[53] | Brazil | 48 | 48 | 100 | 3 months | 24-h recall | - | ↓ | NS | ↓ | ↑ |
| Lima et al. (2014)[58] | Brazil | 29 | - | - | 3 months | 24-h recall | - | ↓ | NS | NS | NS |
| Sarwer et al. (2008)[54] | USA | 200 | 198 | 99 | 20 weeks | Block 98 FFQ | - | ↓ | NS | NS | NS |
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| Brolin et al. (1994)[23] | USA | 108 | 108 | 100 | 6 months | 24-h recall | Obtained by nutritionist | ↓ | NS | ↓ | NS |
| Kenler et al. (1990)[55] | USA | 51 | 48 | 94 | 6 months | 24-h recall | Obtained by nutritionist | ↓ | ↑ | NS | NS |
| Lima et al. (2014)[58] | Brazil | 29 | - | - | 6 months | 24-h recall | - | ↓ | NS | NS | NS |
| Molin-Netto et al. (2017)[93] | Brazil | 41 | 41 | 100 | 6 months | FFQ | Obtained through interview with dietitian | ↓ | NS | ↓ | ↑ |

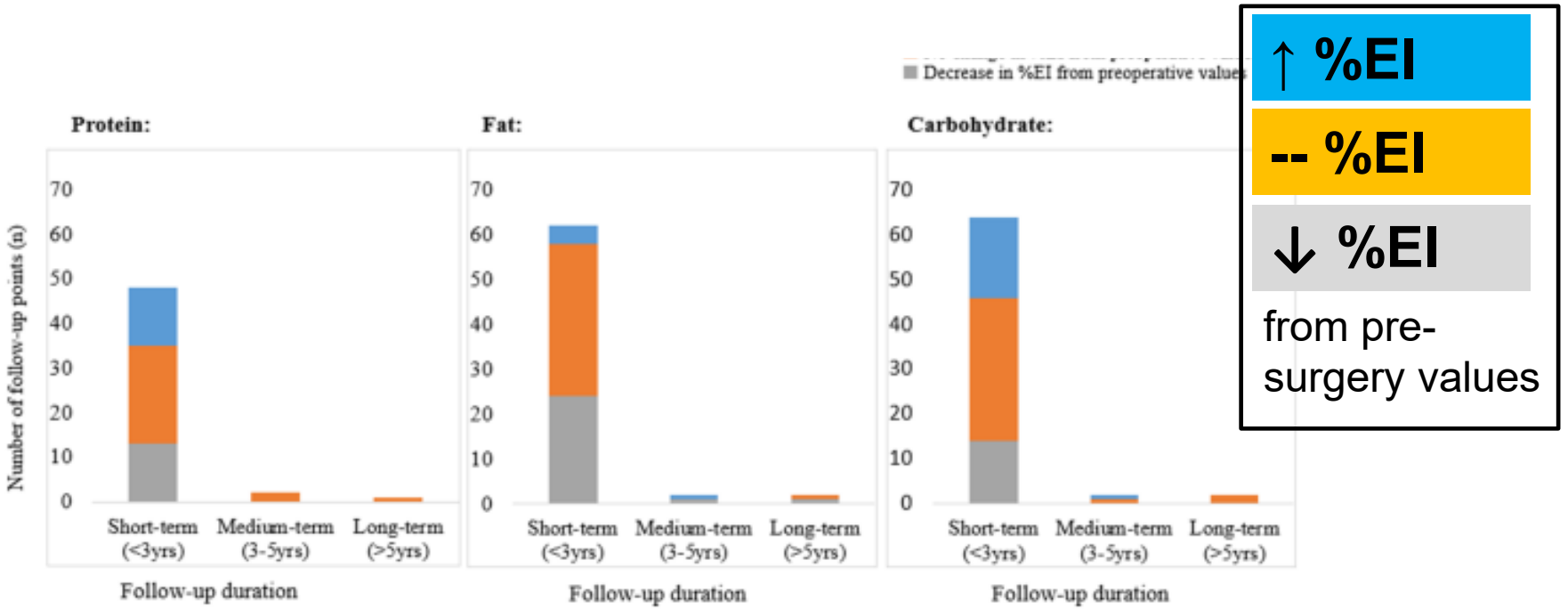


**FIGURE 2** Findings (increase/decrease/no change) from published literature measuring % change in relative macronutrient intake in patients from pre- to post- surgery, organized by follow-up duration. Follow-up durations defined by Brethauer et al. (40-2015)[42]. Data sourced from papers summarized in Table 2

✓/✗=? preference for high-fat high-sugar foods supporting weight loss

# Why?

- Changes in food intake behaviour over time following surgery
- Limited number of follow-up studies with robust methodology (to account for these changes)
- Overwhelming reliance on self-reported changes in food intake post-surgery

**TABLE 2** Summary of methods and outcomes of studies measuring changes in energy and macronutrient intake in patients after gastric bypass from pre- to post-surgery as assessed by dietary records, organized by follow-up duration

| Author (year) | Location | *N* (baseline) | *N* (follow-up) | % follow-up | Postoperative follow-up time | Diet record duration | Method notes | Energy intake | Macronutrient intake change | | |
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| Molin-Netto et al. (2017)[93] | Brazil | 41 | 41 | 100 | 6 months | FFQ | Obtained through interview with dietitian | ↓ | NS | ↓ | ↑ |

# Changes in Eating behaviour after Gastric Bypass


## Aim

- To investigate changes in food intake and eating behaviours within a fully controlled setting.

→ 24-hour period

→ Up to 5 years post-surgery

→ Fully residential conditions

→ Gold standard methods

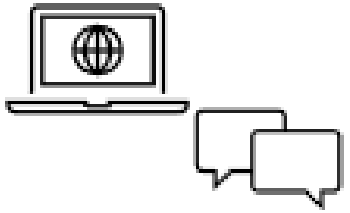
***Primary objective:*** **Is reduced reward the mechanism? (the hedonic system)**

US-IRELAND RESEARCH & DEVELOPMENT PARTNERSHIP

# Study protocol

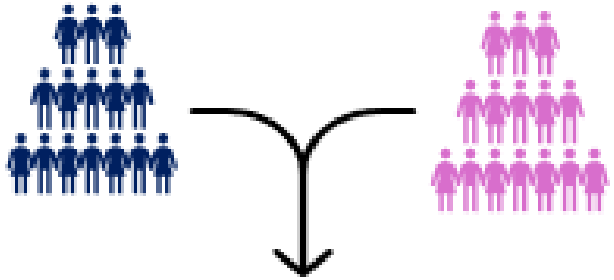
Patients: >18 yrs, eligible for gastric bypass surgery

Controls: >18 yrs, Weight stable



**Patients**
**n = 31**

**Controls**
**n = 32**

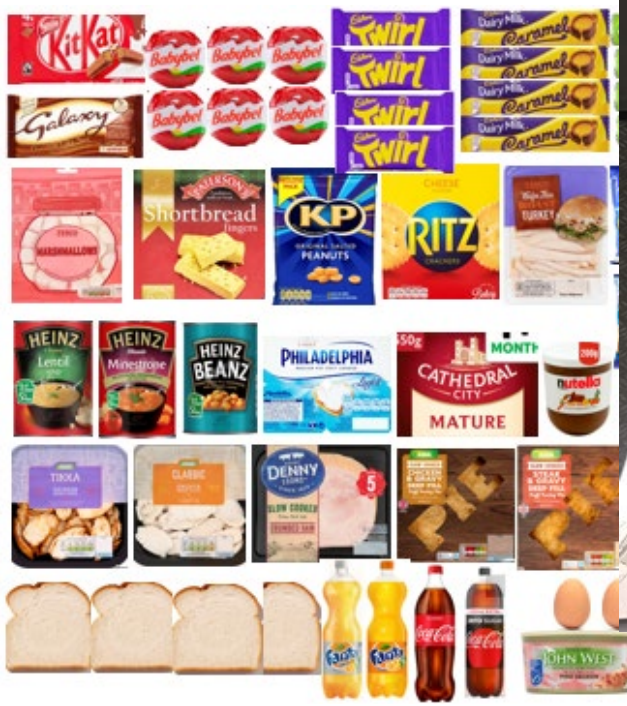


Human Intervention Studies Unit,
Ulster University
(Coleraine Campus)

# Food provision



**54 foods in total**



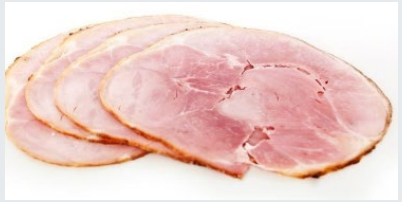

options

Escalope of Turkey

Chicken with Reduced Philadelphia


# Study protocol (Day 2)

## Macronutrient self-selection paradigm.

| | **High simple sugar** ≥30% energy | **High complex carbohydrate** ≥30% energy | **Low carbohydrate/ high protein** >13% energy |
|---|---|---|---|
| **High Fat** ≥40% energy |  |  |  |
| **Low Fat** ≤20% energy |  |  |  |

Geiselman et al, 1998

# Study Protocol (Day 2)

## Covert measurement of self-selected food intake


- Total energy intake (MJ)
- Dietary energy density (kJ/g)
- Macronutrient contribution (%) to energy intake
- Energy contribution (%) from macronutrient groups

# Study Protocol (Day 2)

## CCTV Footage




- Validate intake
- Number of eating occasions (n)
- Size of eating occasions (kJ)
- Eating rate (g/min; kJ/min)

# Study Protocol

## Body Composition

- Dual Energy X-ray Absorptiometry

- Total weight (kg)
- Fat/Lean mass (kg)
- Visceral fat (g)
- Regional (kg)
- Bone Density g/cm$^3$

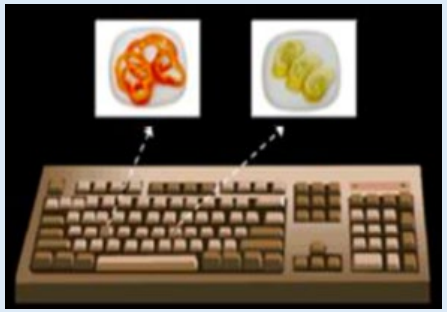
## Gut hormone response

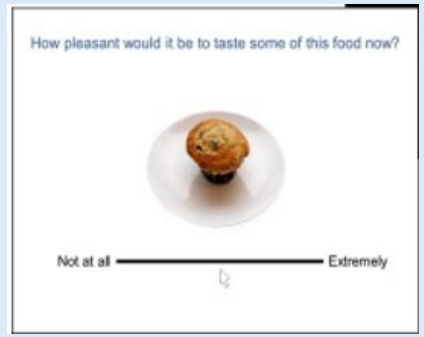
- Blood sample


- Gut hormone & bile acid response

## Reported food preference

- Validated Leeds Food Preference Questionnaire

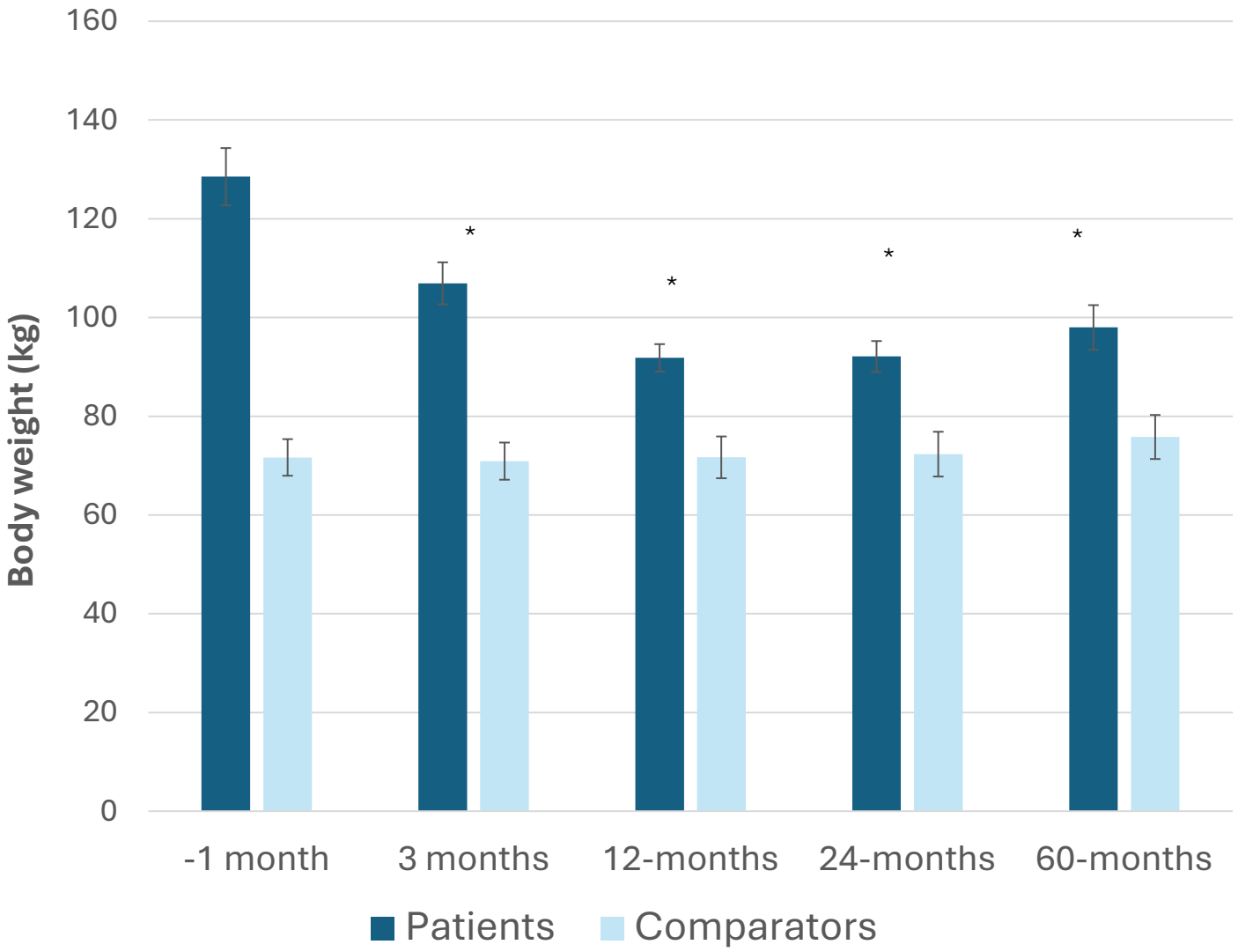





- Food liking and wanting

# Results

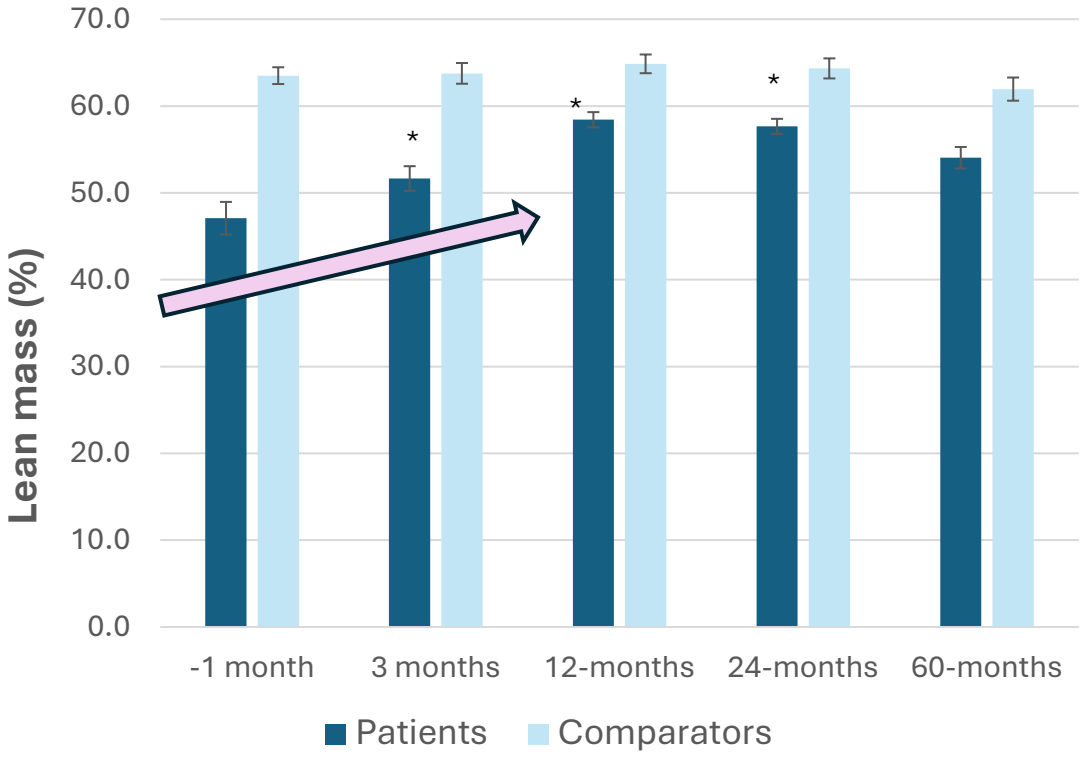
# Change in Weight (kg)

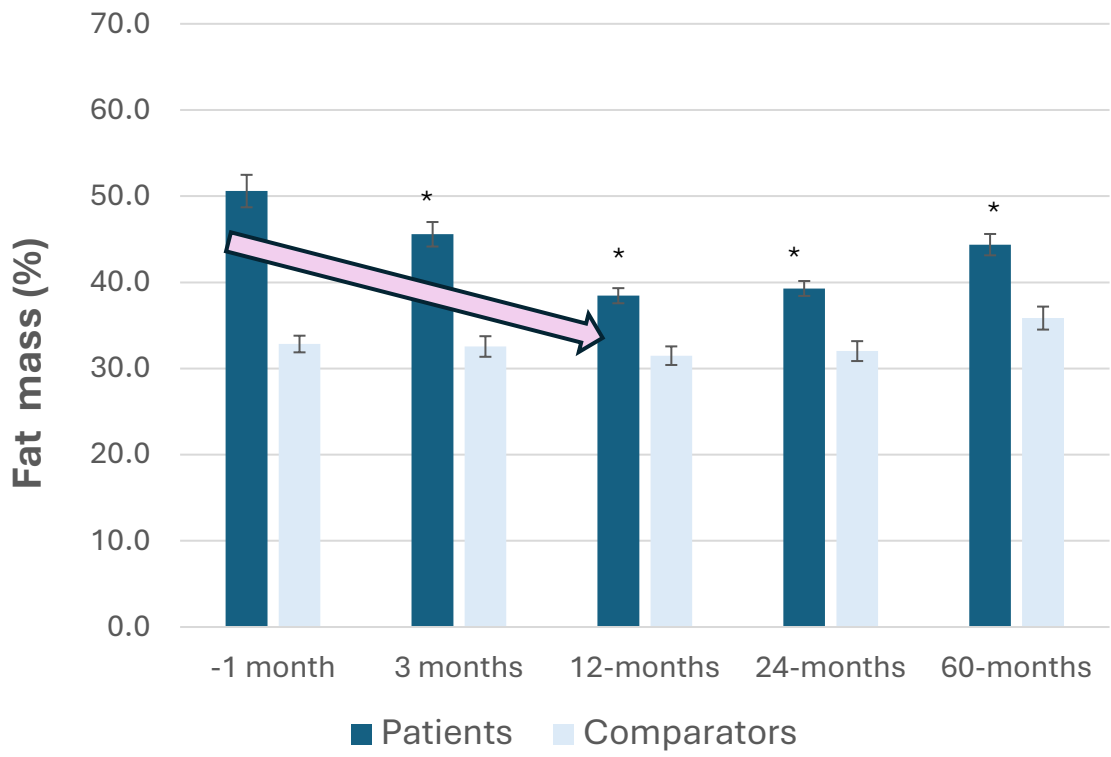



- ↓ 25% of body weight by 12 months

Patients n=18; Comparators n=12
2-way ANOVA $p<0.001$

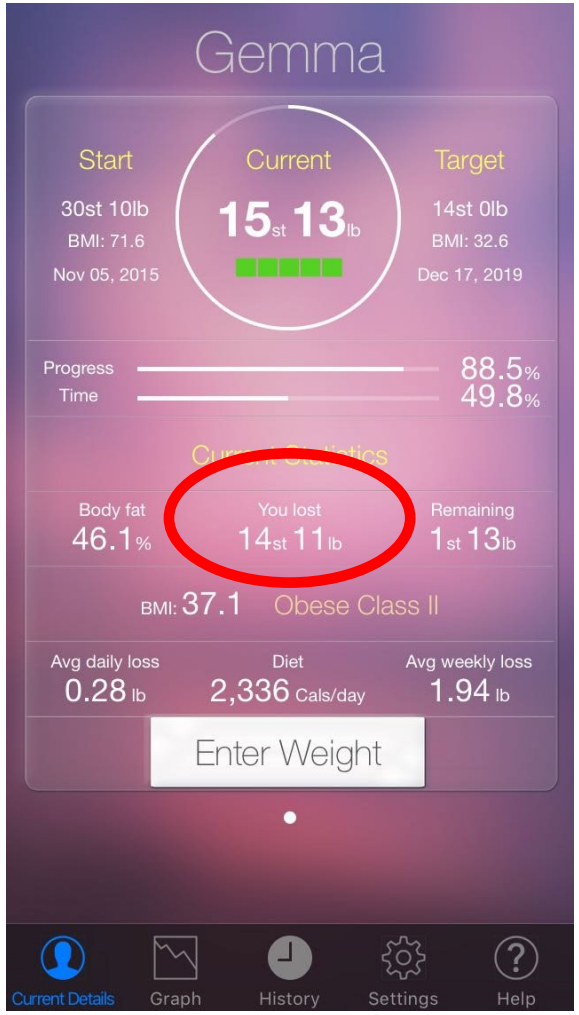
# Change in body composition



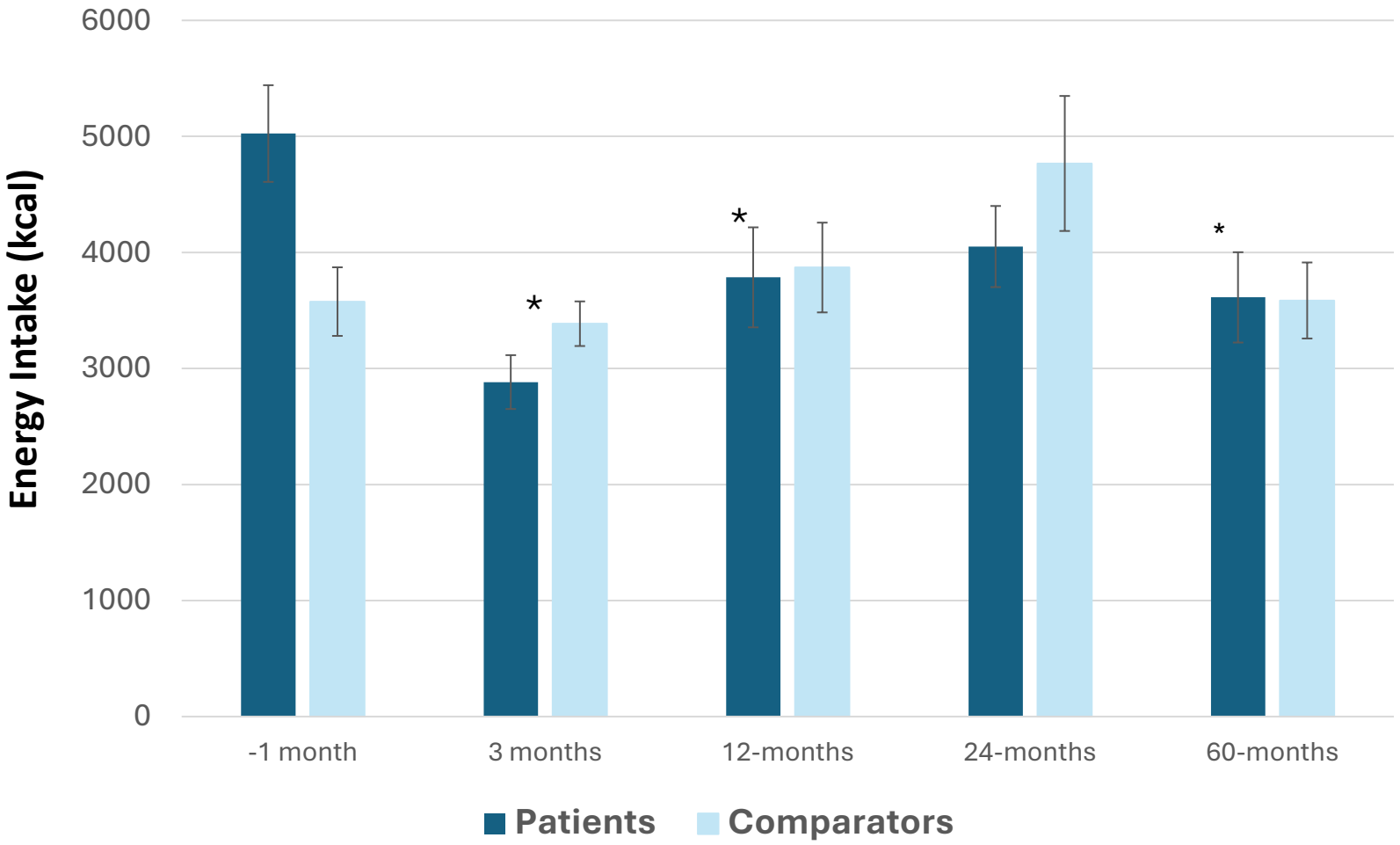

- Improved body composition

- Difference from before surgery
- *n* = 15 patients; *n* = 12 controls; 2-way ANOVA *p* = 0.02




- *Patient experience removed*

# Change in energy intake (kcal) post-surgery

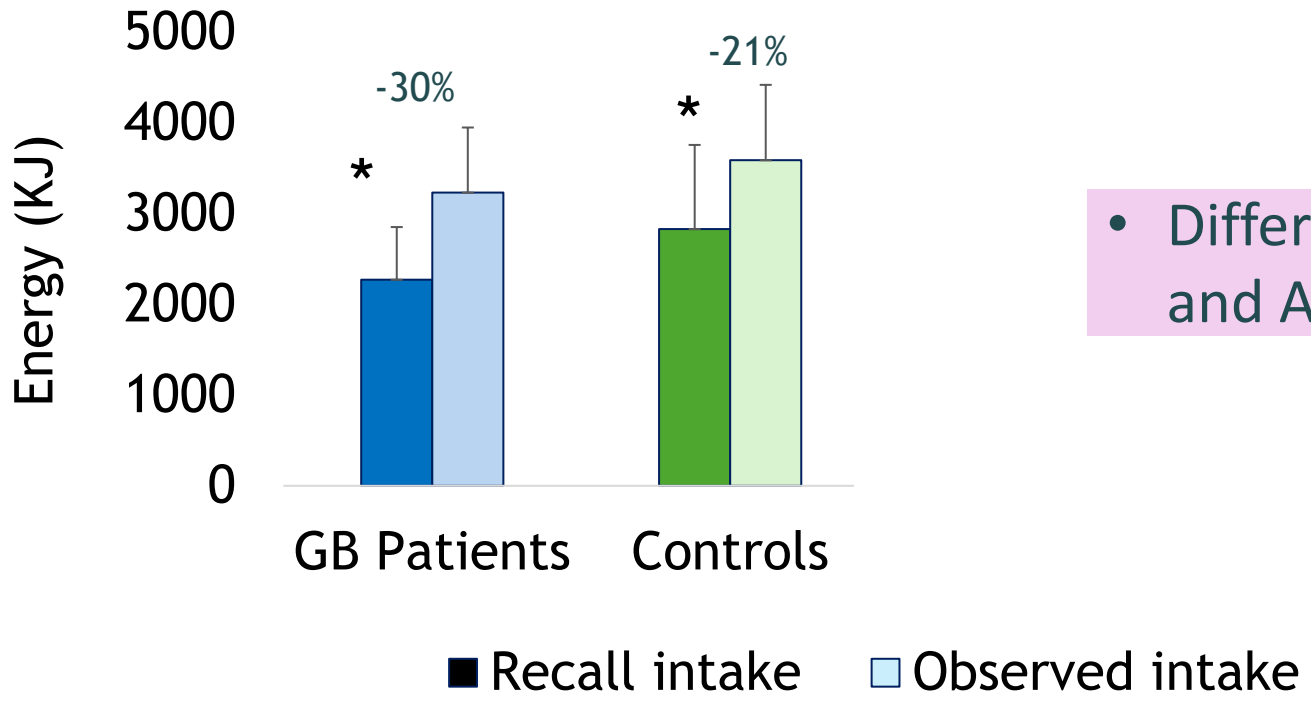



- ↓ energy intake; initially almost 50%, then remains ~25% lower

* Difference from baseline

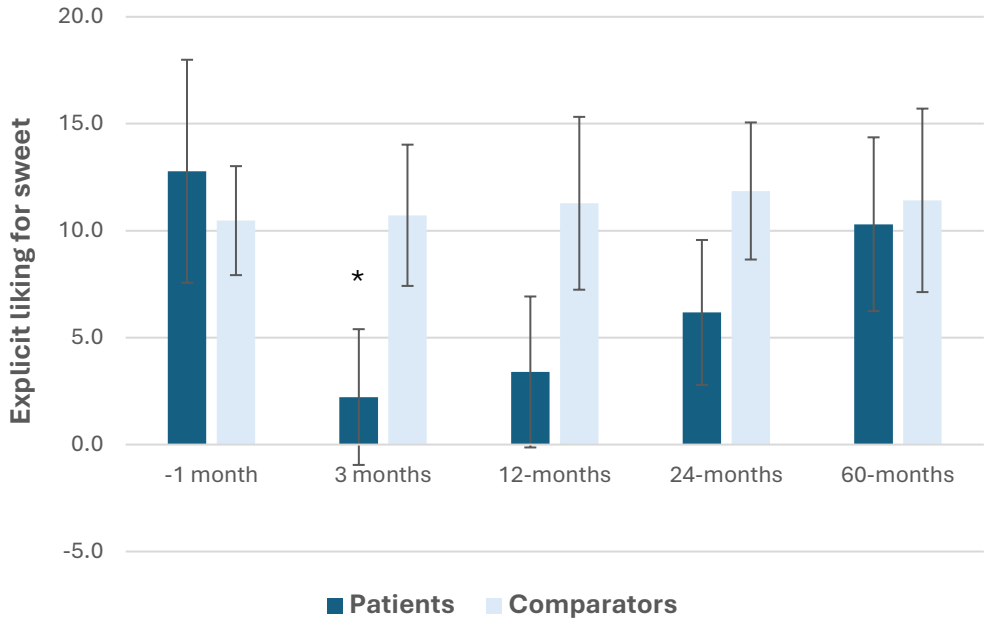
*n* = 15 patients; *n* = 12 controls; 2-way ANOVA *p* = 0.02

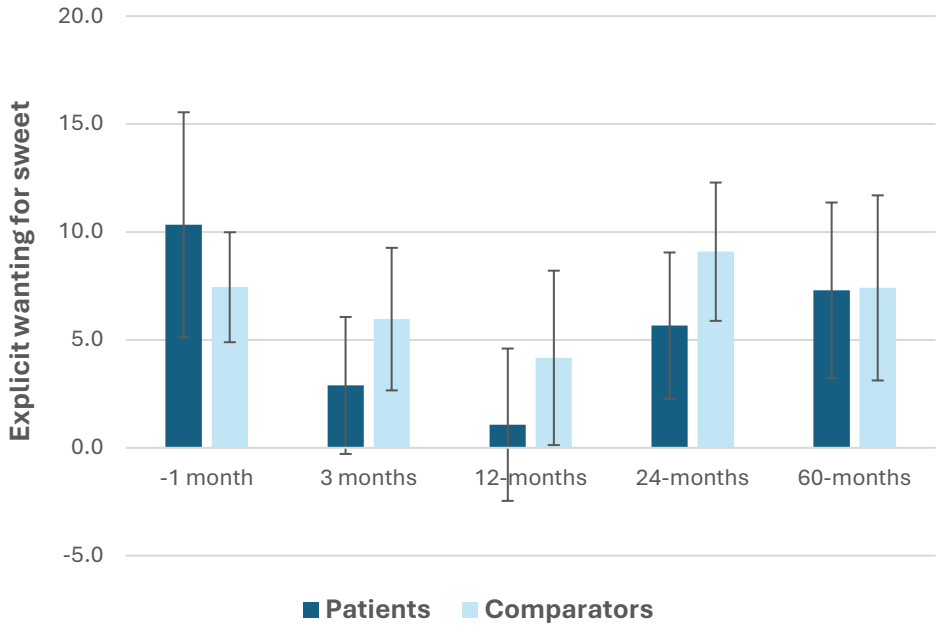
# Energy Intake Misreporting

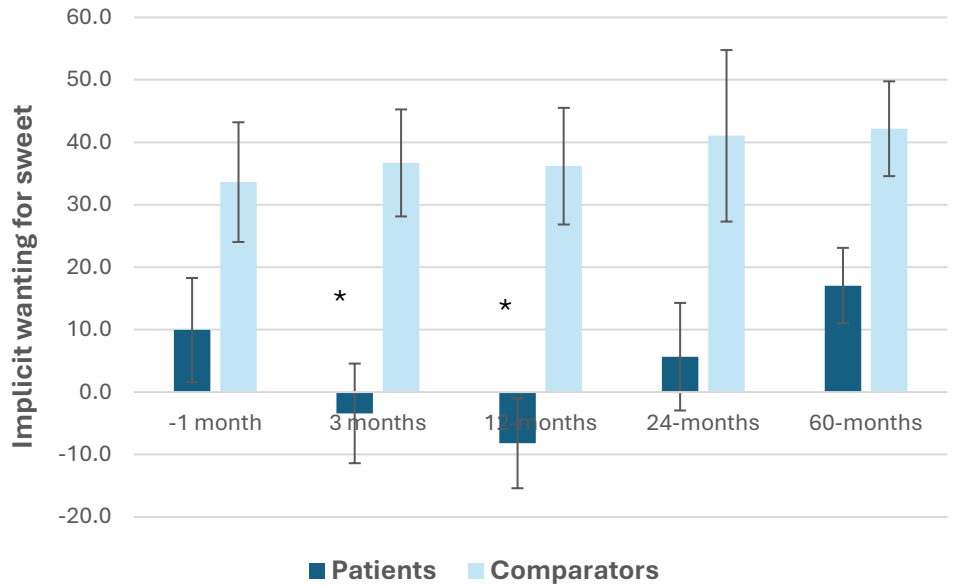



- Difference between REPORTED and ACTUAL food intake

# Change in preferences for sweet foods



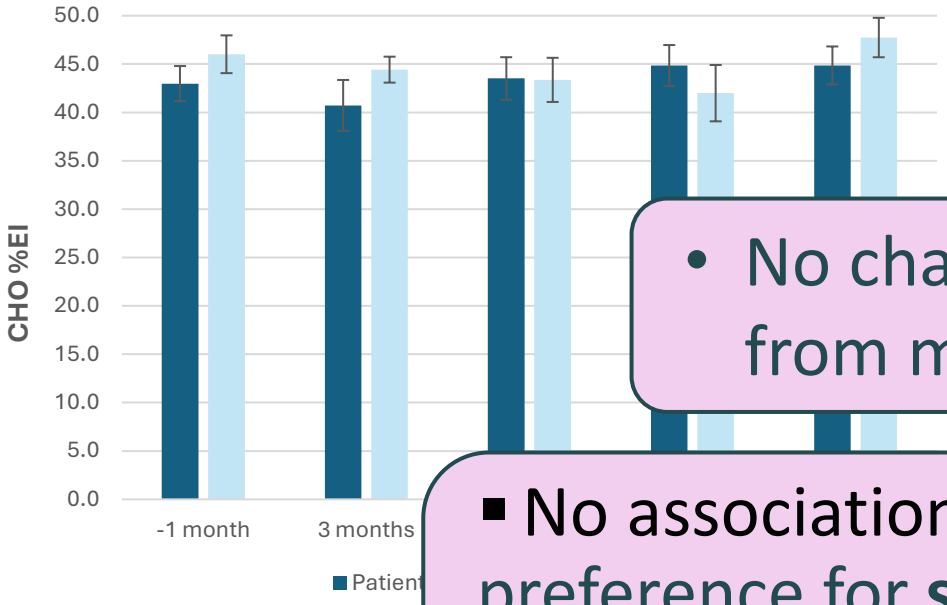




- Early ↓ liking / wanting for sweet foods

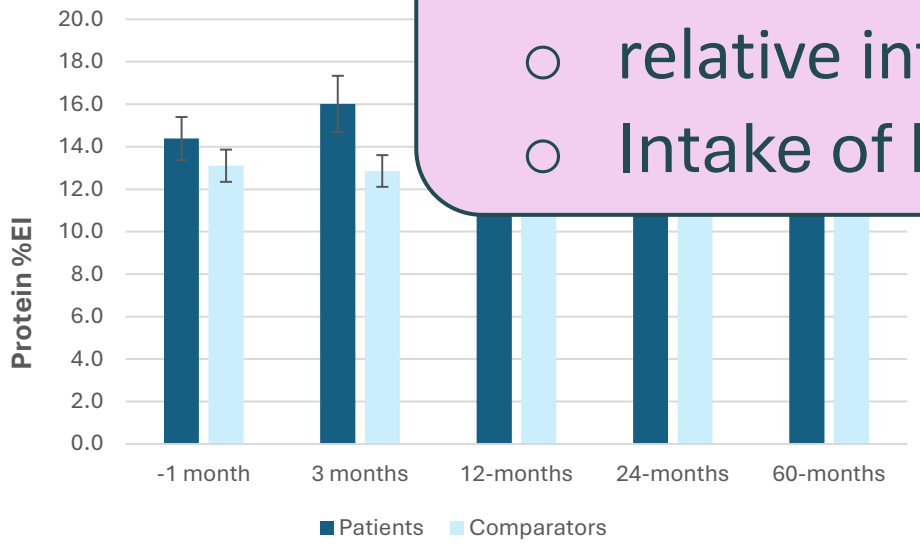
* Difference from baseline

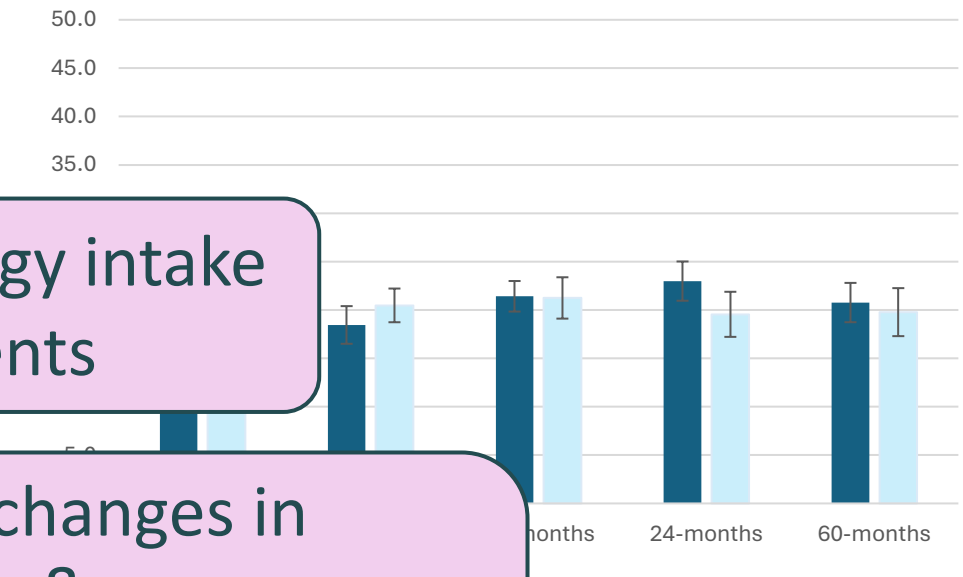
# Change in food choice reflected by macronutrient profile



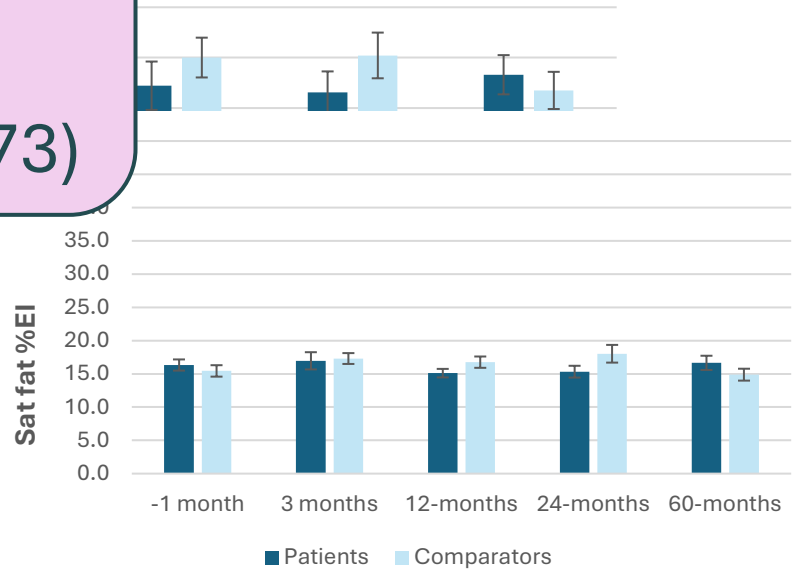

- No change %energy intake from macronutrients

- No association between changes in preference for **sweet foods** &
  - relative intake of sugar (p>0.34)
  - Intake of high-sugar foods (p> 0.73)







# Eating behaviour

| | |
|---|---|
| Timing of eating occasions | ✗ |
| Number of eating occasions | ✗ |
| Duration of eating occasions | ✗ |
| Eating occasion size | ↓ |
| Eating rate | ↓ |

# Summary

Following gastric bypass patients:

- Eat the SAME foods but in SMALLER amounts
- ↓SIZE and RATE in the short-term but not the NUMBER of eating occasions
- ↓ preference for sweet foods but no change in intake

- 30% difference between what patients eat and what they tell you they eat @24 months
- No association between food preference and food intake

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# Evaluation of the impact of gastric bypass surgery on eating behaviour using objective methodologies under residential conditions: Rationale and study protocol

Tamsyn Redpath [a], Fathimath Naseer [a], Ruth Karen Price [a], Adele Boyd [a], Melanie Martin [a], Carel Wynand le Roux [b], Alan C. Spector [c], Margaret Barbara Elizabeth Livingstone [a,*]

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ARTICLE INFO

*Keywords:*
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Study protocol
Objective validation
Food intake

ABSTRACT

Gastric bypass surgery leads to significant and sustained weight loss and a reduction in associated health risks in individuals with severe obesity. While reduced energy intake (EI) is the primary driver of weight loss following surgery, the underlying mechanisms accounting for this energy deficit are not well understood. The evidence base has been constrained by a lack of fit-for-purpose methodology in assessing food intake coupled with follow-up studies that are relatively short-term. This paper describes the underlying rationale and protocol for an observational, fully residential study using covert, objective methodology to evaluate changes in 24-hr food intake in patients (n = 31) at 1 month pre surgery and 3-, 12- and 24 months post surgery, compared to weight-

The Journal of Nutrition
**Obesity and Eating Disorders**

# Food Intake Following Gastric Bypass Surgery: Patients Eat Less but Do Not Eat Differently

M Barbara E Livingstone,[1] Tamsyn Redpath,[1] Fathimath Naseer,[1] Adele Boyd,[1] Melanie Martin,[1] Graham Finlayson,[2] Alex D Miras,[3] Zsolt Bodnar,[4] David Kerrigan,[5] Dimitri J Pournaras,[6] Carel W le Roux,[7] Alan C Spector,[8] and Ruth K Price[1]

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**ABSTRACT**

**Background:** Lack of robust research methodology for assessing ingestive behavior has impeded clarification of the mediators of food intake following gastric bypass (GBP) surgery.

**Objectives:** To evaluate changes in directly measured 24-h energy intake (EI), energy density (ED) (primary outcomes), eating patterns, and food preferences (secondary outcomes) in patients and time-matched weight-stable comparator participants.

**Methods:** Patients [$n = 31$, 77% female, BMI (in kg/m$^2$) 45.5 ± 1.3] and comparators ($n = 32$, 47% female, BMI 27.2 ± 0.8) were assessed for 36 h under fully residential conditions at baseline (1 mo presurgery) and at 3 and 12 mo postsurgery. Participants had ad libitum access to a personalized menu ($n = 54$ foods) based on a 6-macronutrient mix paradigm. Food preferences were assessed by the Leeds Food Preference Questionnaire. Body composition was measured by whole-body DXA



**ARTICLE** OPEN

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**Bariatric Surgery**

# Metabolic adaptation following gastric bypass surgery: results from a 2-year observational study

Fathimath Naseer[1], Shu-Dong Zhang[2], Alexander D. Miras[2], Tamsyn Redpath[1], Melanie Martin[1], Adele Boyd[1], Heather Spence[1], Dimitri J. Pournaras[3], Zsolt Bodnar[4], David Kerrigan[5], Carel W. le Roux[6], M. Barbara E. Livingstone[1] and Ruth K. Price[1]✉



**BACKGROUND/OBJECTIVES:** Metabolic adaptation is the lowering of basal metabolic rate (BMR) beyond what is predicted from changes in fat mass (FM) and fat-free mass (FFM) and may hamper weight-loss progression. It is unclear whether metabolic adaptation occurs following gastric bypass surgery (GBP) and if it persists. The aim of this study was to evaluate the reduction in BMR that is not explained by changes in body composition in patients following GBP compared to a weight-stable comparator group.

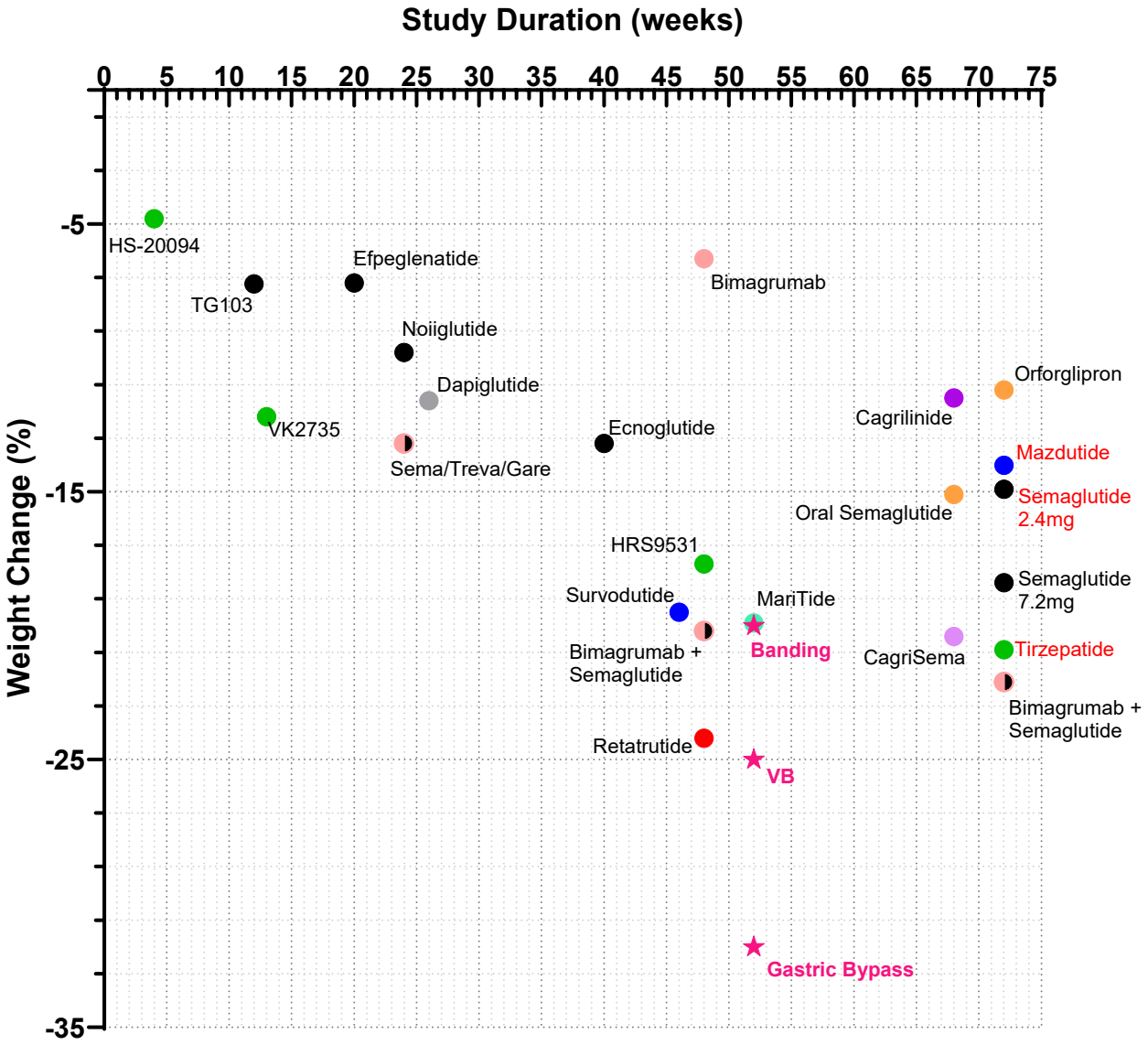
**SUBJECTS:** Thirty-one patients [77.4% female; mean BMI 45.5(SD 7.0) kg/m$^2$; age 47.4(11.6)y] who underwent GBP, and 32 time-matched comparators [50% female; BMI 27.2(4.6) kg/m$^2$; age 41.8(13.6)y) were evaluated at 1-month pre-surgery, 3-, 12- and 24-months post-surgery.

**METHODS:** BMR was measured under standardised residential conditions using indirect calorimetry and body composition using

**Effects of bariatric surgery and obesity medicines on human eating behaviour.** *Annual Review of Nutrition, in press. R K Price*

# Obesity Medications

# Novel Obesity Drugs: percentage weight loss




★ Bariatric Surgery (GBP, VB, Banding)

**Drug Target**

- GLP-1 RA (s.c)
- GLP-1RA (oral)
- GLP-1/GIP RA
- GLP-1/Glucagon RA
- GLP-1/GIP/Glucagon RA
- GLP-1 RA/GIP Antag
- GLP-1/Amylin RA
- Amylin RA
- Myostatin/Activin inhibitor
- Myostatin/Activin inhibitor + GLP-1 RA

Slide credit: Dr Neil Tanday

# What we know about changes in eating behaviour during obesity medication weight loss treatments

*Semaglutide (Ozempic®, Wegovy® & Oral), Liraglutide (*Saxenda®), *Tirzepitide (*Mounjaro®*)*

***Direct (measured)***

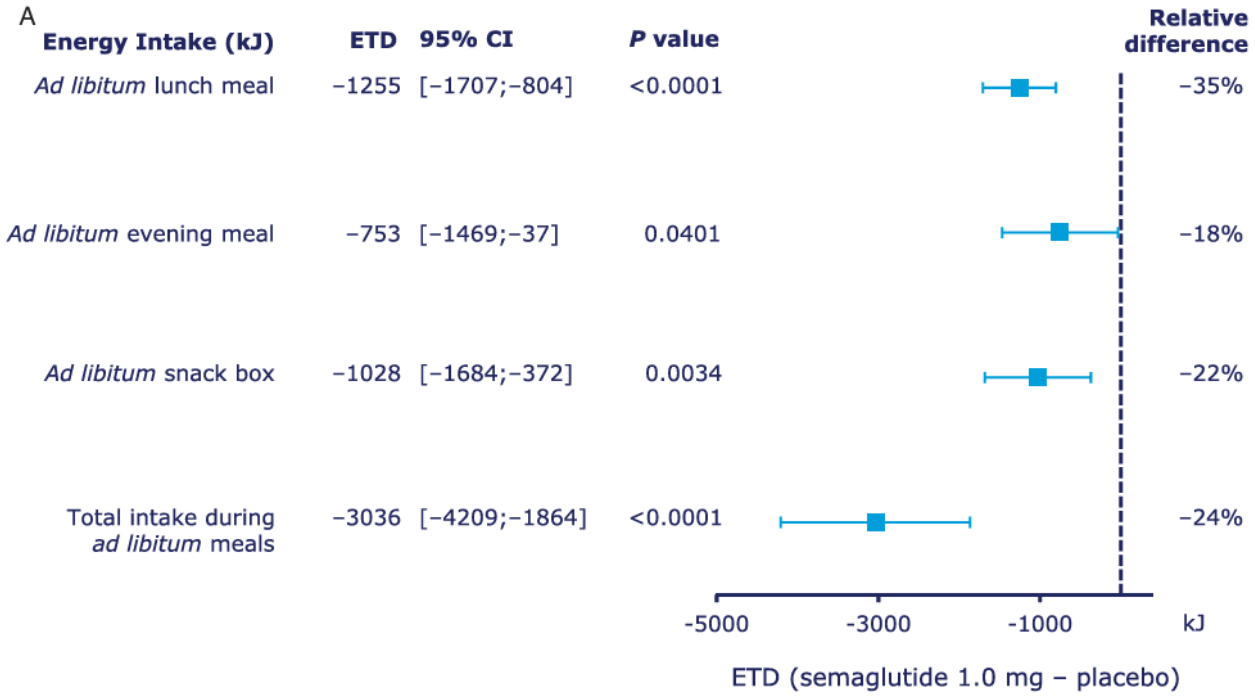
- Energy intake

(1. Martin et al. 2025, 2. Blundell et al., 2017 , 3. Gibbons et al., 2020 , 4. Friedrichsen et al., 2021, 5. van Bloemendaal et al., 2014 (Diabetes), 6. Farr et al., 2016 , 7. Ten Kulve et al., 2016, 8. Martin et al., 2025 , 9. Friedrichsen et al., 2020, 10. Hiramoto et al. 2024, 11. Brindisi et al. 2019, 12. Nicolau et al., 2022 , 13. Kadouh et al. 2020, 14. Brindisi et al. 2019 15. Dalton et al. 2017

# Energy intake during obesity medications using direct methodology

| Intervention duration | Medication | Food provision | Change in energy intake | References |
|---|---|---|---|---|
| 3-weeks<br>6-weeks | Tirzepatide (5mg +10mg) | *ad libitum* lunch | 59% ↓(-315kcal)<br>72% ↓(-658kcal) | Martin et al. 2025 |
| | Liraglutide (1.8mg +3mg) | | 32% ↓(-299kcal)<br>29% ↓(-532kcal) | |
| 12-week | Semaglutide (1.0mg)<br>Oral Semaglutide (14mg) | Standardised breakfast *ad libitum* lunch, dinner + snack-box tests | 24%↓ (-3036kJ)<br>39% ↓(-5096kJ) | Blundell et al., 2017 (with obesity)<br>Gibbons et al., 2020 (with T2DM) |
| 20 weeks | Semaglutide (2.4mg weekly) | *ad libitum* lunch meal | 47%↓ | Friedrichsen et al., 2021 |

# Blundell et al.2017; DOI:10.1111/dom.12932




**Total Daily Reduction: -3036 kJ (-24%)**

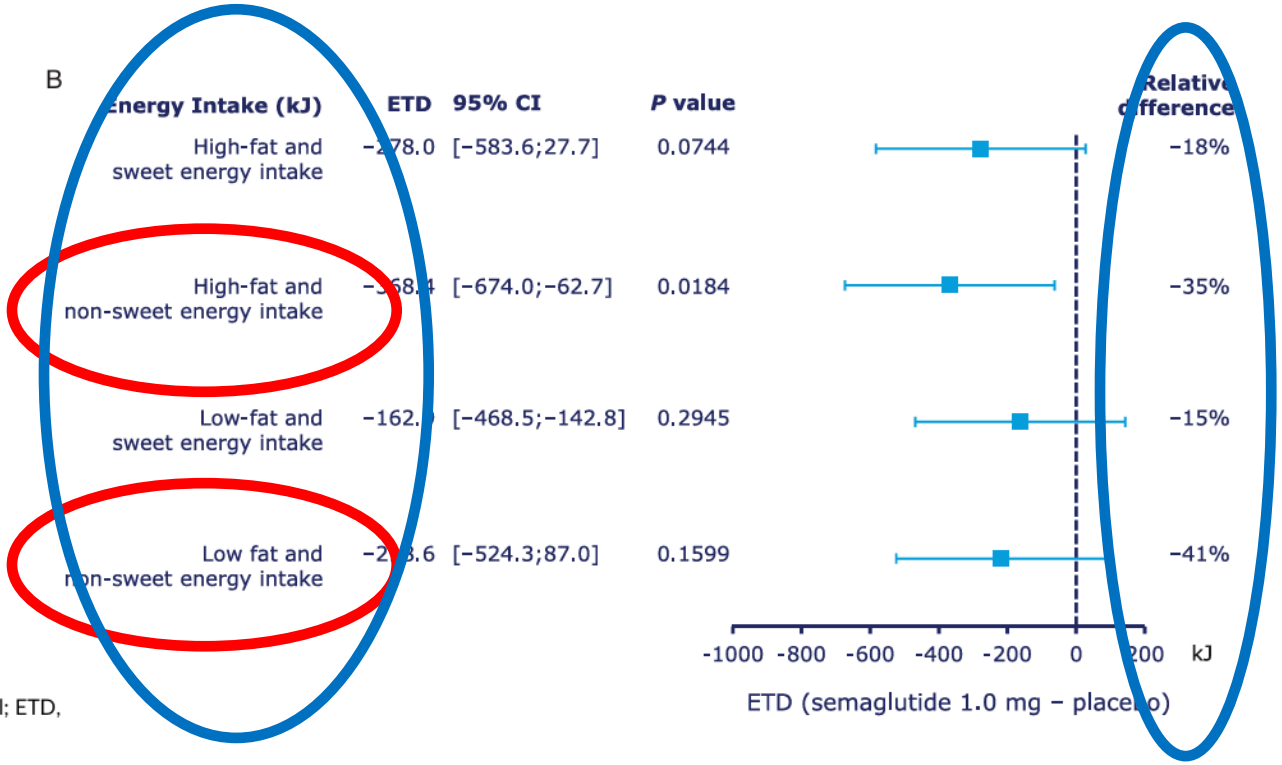



**FIGURE 1** Energy intake during A, *ad libitum meals* and B, *ad libitum* snack box, by food group. Abbreviations: CI, confidence interval; ETD, estimated treatment difference. Relative difference: ETD / estimated mean for placebo × 100%.

# What we know about changes in eating behaviour during obesity medication weight loss treatments

*Semaglutide (Ozempic®, Wegovy® & Oral), Liraglutide (*Saxenda®), *Tirzepitide (*Mounjaro®*)*

***Direct (measured)***

- Energy intake : Energy intake : 24-47.1% (59-72% dual agonists)↓ in energy intake (ad-libitum meal/s) [1-4]
- Reduced reward value, at least in the short-term[5-8]
- Modest delay in gastric emptying, at least in short-term [9, 10]
- Improved detection threshold of sweet flavours [11]

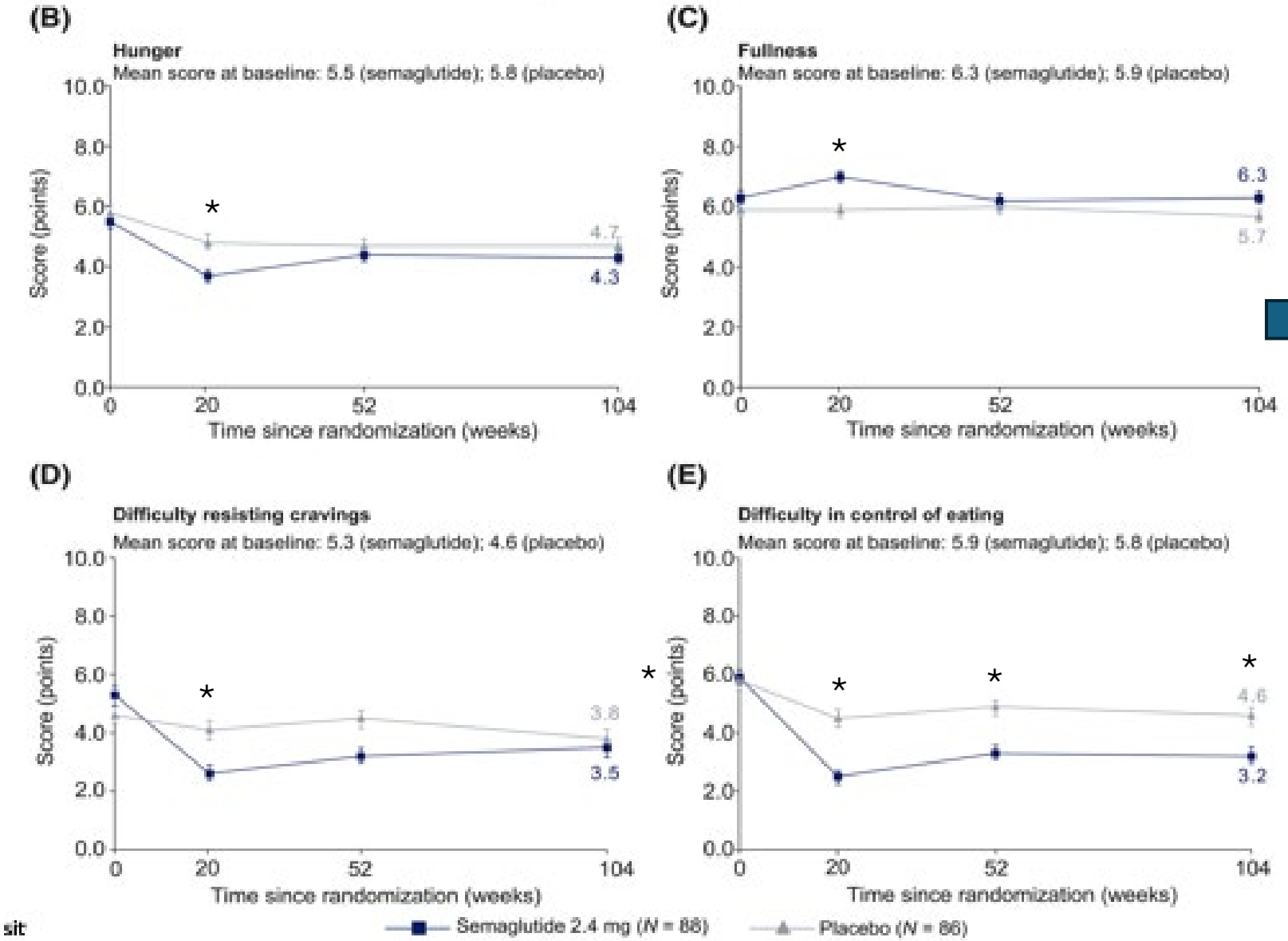
***Subjective (reported)***

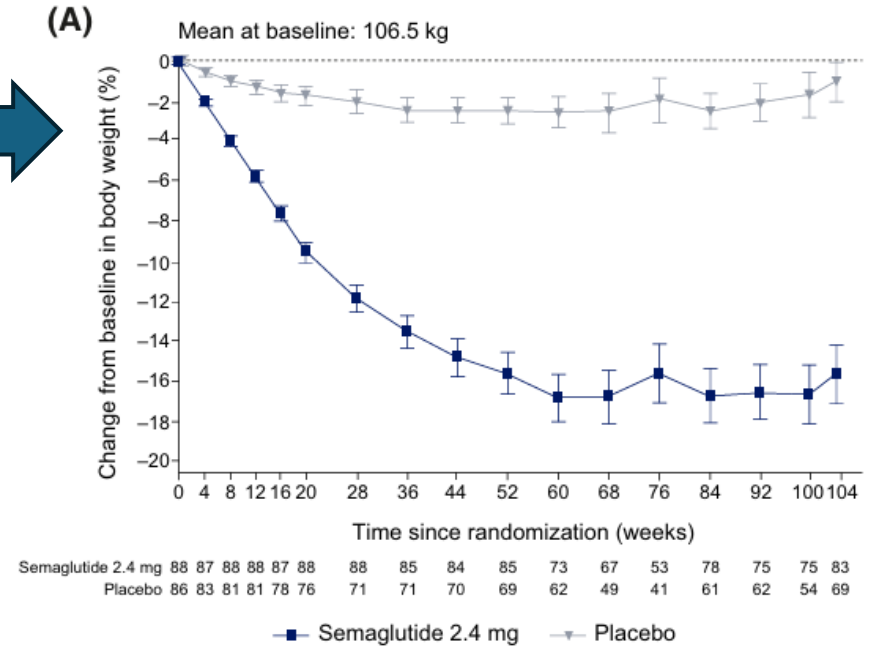
- ↓ hunger & greater satiety [2, 3, 9]
- ↓ hunger, better control, contentment, less food craving and pleasantness [2, 9]
- ↓ in emotional eating & external eating [12]
- ↓ preference for high-fat, non-sweet foods (wanting & liking) [2, 9,] sweet, salty, savoury, and high-fat foods [13] wanting for sweet foods and recalled liking for fatty foods [14].
- Sweet cravings predicted poorer weight loss [12, 15]

**Heavy reliance on short-term self-reported data**

(1. Martin et al. 2025, 2. Blundell et al., 2017 , 3. Gibbons et al., 2020 , 4. Friedrichsen et al., 2021, 5. van Bloemendaal et al., 2014 (Diabetes), 6. Farr et al., 2016 , 7. Ten Kulve et al., 2016, 8. Martin et al., 2025 , 9. Friedrichsen et al., 2020, 10. Hiramoto et al. 2024, 11. Brindisi et al. 2019, 12. Nicolau et al., 2022 , 13. Kadouh et al. 2020, 14. Brindisi et al. 2019 15. Dalton et al. 2017

# Wegovy (semaglutide 2.4mg) clinical trial

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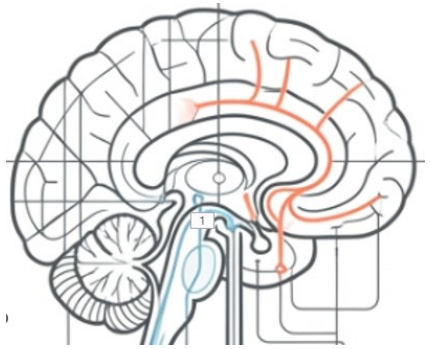
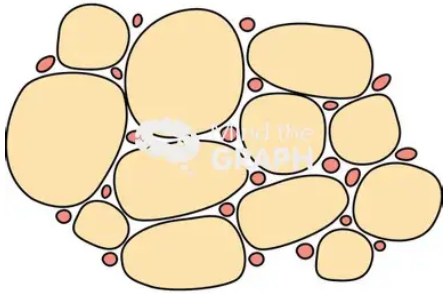
# Summary

## Obesity



Brain

Eating behaviours

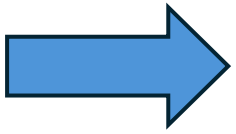


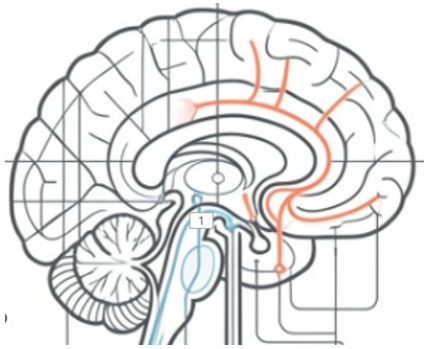
Excess adiposity

# Summary

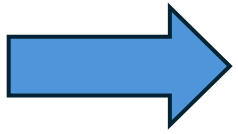
## Obesity treatments

Obesity treatments

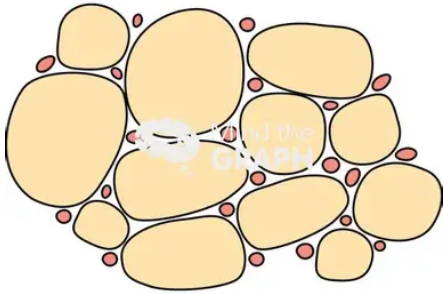




Brain



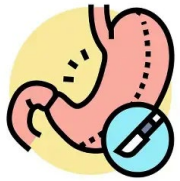
Eating behaviours

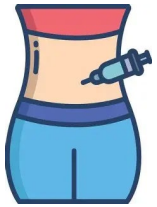


Reduced adiposity

- Obesity treatments work by **biologically reshaping eating behaviour**

# Summary





| Treatment | Homeostatic system | Hedonic system |
|---|---|---|
| **Gastric bypass** | Feeling fuller faster | Changes in reward value doesn't change behaviour |
| **Obesity medications** | Feeling fuller faster ? | ↓ reward value in short-term<br>Behaviour change? |
| **Key behavioural focus** | Mainly *consummatory behaviour:* meal size, fullness, stopping | |

- Obesity treatments work by **biologically reshaping eating behaviour**
- Long-term success depends on how the brain and body adapt over time
- Long-term **direct** measures urgently needed in those using obesity medications

# Impact on Clinical Practice, Patients, and Research

## Clinical Care Mechanisms

Understand the treatment.

Help guide treatment selection, follow-up and manage patient expectations.

## Role of Dietitians

Dietetic care focuses on health gain, rather than weight loss, and managing side effects.

## Patient Understanding and Support

Reduces stigma

Informs patient expectations

## Research and Future Directions

Critical gaps include reliance on self-reported data and limited long-term follow-up.

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## Florida State University

Prof Alan Spector

## University of Leeds

Prof Graham Finlayson

## Bariatric healthcare teams

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Mr Zolt Bodnar

## Participants ☺

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US-IRELAND
RESEARCH & DEVELOPMENT
PARTNERSHIP


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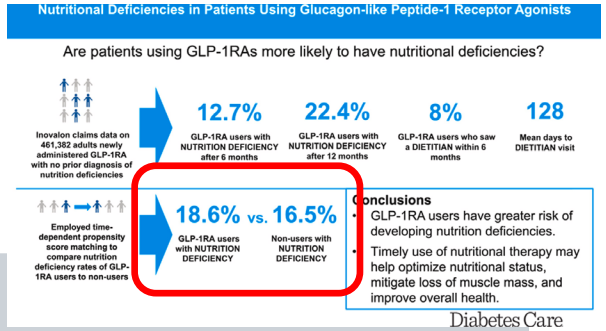
# Nutritional deficiencies?




## Why?

Reduced food volume
Nausea or vomiting
Adversans
Altered absorption + metabolism (e.g. gastric pH ↓ 20%[1])

## Common deficiencies[2]

Vitamin D
Iron, calcium
Vitamin B (thiamin + cobalmin)
Protein


## Context

Baseline diet
Comparison to similar cohorts
Dietetic input
Activity levels

## Guidelines

*"Clinical Practice Guidelines for the Perioperative Nutrition, Metabolic, and Nonsurgical Support of Patients Undergoing Bariatric Procedures—2019 Update"* [3]

([1]https://doi.org/10.2337/dc20-0720https:[2]//doi.org/10.1016/j.obpill.2025.100186 ; [3]https:// doi. org/ 10. 1002/ oby. 22719)