Nutritional consequences of bariatric surgery
Objectives

• **A. Problem of obesity.** Global, India, Kerala

• **B. Surgical management of.**

  I. Physiology of absorption
  II. Gastric hormones
  III. Indications for surgery
  IV. Consequences of:

  a. Restrictive procedures.
  b. Malabsorptive procedures.
  c. Combined bariatric procedures

• **V Nutritional deficiencies:** prevalence, type, prevention, management

  - Laparoscopic adjustable banding.
  - Bilio-pancreatic diversion (BPD)
  - Bilio-pancreatic diversion with a duodenal switch (BPD-DS)
  - Laparoscopic Roux-en-Y bypass
Global problem

Obesity rates in selected countries
2009*, % of adults with BMI† of 30 or over

Mexico
United States
New Zealand
Australia
Britain
Canada
Chile
South Africa
Iceland
Greece
Spain
Russia
Germany
Finland
Turkey
Brazil
Poland
Netherlands
France
Sweden
Italy
South Korea
Japan
China
India

Source: OECD

* Or latest year available  † Body mass index
David visits America

Has David in the US has malnutrition?

After A Short Stay in America, David Returns to Italy
Obesity in India... Kerala’s #2?

<table>
<thead>
<tr>
<th>States</th>
<th>Males (%)</th>
<th>Males rank</th>
<th>Females (%)</th>
<th>Females rank</th>
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<td>Gujarat</td>
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<td>17.6</td>
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<td>Manipur</td>
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<td>17.1</td>
<td>11</td>
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<td>Uttarakhand</td>
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<td>Arunachal Pradesh</td>
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<tr>
<td>Uttar Pradesh</td>
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<td>17</td>
<td>12</td>
<td>18</td>
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<tr>
<td>Jammu and Kashmir</td>
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<td>11.1</td>
<td>5</td>
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<td>Rajasthan</td>
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<td>9</td>
<td>20</td>
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<tr>
<td>Meghalaya</td>
<td>8.2</td>
<td>22</td>
<td>8.9</td>
<td>26</td>
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<tr>
<td>Orissa</td>
<td>6.9</td>
<td>23</td>
<td>8.6</td>
<td>25</td>
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</table>
The number of people undergoing bariatric (weight-loss) surgery in Kerala has doubled in just two years. According to surgeons dealing with obesity cases, at least 60 bariatric surgeries take place every month. Two years ago it was well below 30.

- Dr. Shashi Tharoor (Minister of State for Human Resource Development) inaugurated an awareness programme on Obesity- Bariatric surgery that was hosted by Obesity Solutions. Logo of the clinic during the function.
The goal of Bariatric surgery is to produce Malabsorption. Malnutrition is to be expected.
Diabetes remission after bariatric surgery: 
*Glucose-dependent insulinotropic polypeptide (GIP)* and 
*glucagon-like peptide 1 (GLP-1)*

Gastrointestinal hormones secreted from the duodenal K cells and ileal L cells, respectively.

**Functions:**
1. **insulinotropic.** The two incretins responsible for ~50% of postprandial insulin secretion.
2. **GLP-1 delays gastric emptying,**
3. **decreases appetite and promotes weight loss,**
4. **inhibits glucagon and**
5. **may improve insulin sensitivity**

“The incretin effect” the differential insulin response after oral glucose compared with an equivalent dose of intravenous glucose.

What are the physiological consequences?

[Image showing diagrams of surgical procedures]

**ESTIMATED NUMBER OF BARIATRIC SURGERIES**

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
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<tbody>
<tr>
<td>TOTAL*</td>
<td>158,000</td>
<td>173,000</td>
<td>179,000</td>
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<tr>
<td>Roux-en-Y Gastric Bypass</td>
<td>36.7%</td>
<td>37.5%</td>
<td>34.2%</td>
</tr>
<tr>
<td>Gastric Band</td>
<td>35.4%</td>
<td>20.2%</td>
<td>14.0%</td>
</tr>
<tr>
<td>Sleeve Gastrectomy</td>
<td>17.8%</td>
<td>33.0%</td>
<td>42.1%</td>
</tr>
<tr>
<td>Biliopancreatic Diversion with Duodenal Switch (BPD-DS)</td>
<td>0.9%</td>
<td>1.0%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Revisions</td>
<td>6.0%</td>
<td>6.0%</td>
<td>6.0%</td>
</tr>
<tr>
<td>Other</td>
<td>3.2%</td>
<td>2.3%</td>
<td>2.7%</td>
</tr>
</tbody>
</table>

*Total includes revisions and other procedures.
1. No acid - Iron malabsorption
2. Bacterial overgrowth small bowel.
3. B12 malabsorption
Stomach Empty

↑ Ghrelin = ↑ Appetite
CCK, GLP-1, PYY – all ↓

Stomach Full

↓ Ghrelin = ↓ Appetite
CCK, GLP-1, PYY – all ↑
GIP and GLP-1, the two incretin hormones: Similarities and differences

GIP secretion from K cells is enhanced in response to ingestion of meals or glucose.

GLP-1 secretion from L cells, is enhanced in response to ingestion of meals or glucose.
How many bariatric surgeries are taking place?

The fast growth in weight-loss surgeries has ended. Though numbers are not available beyond 2009, most in the field believe the number of procedures is going down.

Percent change:
- 1992: 4%
- 1993: -4%
- 1994: 12%
- 1995: 13%
- 1996: 13%
- 1997: 12%
- 1998: 12%
- 1999: 27%
- 2000: 29%
- 2001: 34%
- 2002: 64%
- 2003: 36%
- 2004: 22%
- 2005: 4%
- 2006: 15%
- 2007: 7%
- 2008: 0%

Source: American Society for Metabolic & Bariatric Surgery
Gastric Bypass surgeries
Common Problems After Gastric Bypass Surgery

- **Dumping Syndrome**
  - Usually occurs ~30 minutes following a meal. Undigested contents of the stomach are transported or "dumped" into the small intestine too rapidly. Symptoms include nausea, sweating, bloating, abdominal cramps, and diarrhea.
  - Avoid high fat and high sugar foods. For example, instead of 100% fruit juice; dilute 1:1 with water.

- **Diarrhea**
  - Some patients can develop post-operative lactose intolerance. Symptoms could include bloating, abdominal cramps, excessive gas, and diarrhea. Treatment includes following a lactose-free diet.

- **Anatomical complications**
  - There may be reason to suspect a possible surgical complication if a patient has persistent nausea, vomiting, and abdominal pain.
Roux-en-Y

MALABSORPTION OF:
- stomach bypassed
- Glycoprotein (causing Vit B12 malabsorption)
- Copper
- Flouride
- Iodide

doudenum bypass
- Calcium
- Copper
- Folate
- Iron
- Vitamin A, C, D, E, K
- Vitamin B1, B2, B3
- Vitamin B5, B6, B7
- Vitamin B12

portion jejunum bypassed
- Calcium
- Chromium
- Copper
- Folate
- Vitamin A, D, E, K
- Vitamin B1 (Thiamin)
- Vitamin B2 (Riboflavin)
- Vitamin B3 (Niacin)
- Vitamin B5 (Pantotheine)
- Vitamin B6 (Pyridoxine)
- Vitamin B7 or H (Biotin)
- Vitamin C

Duodenal Switch

MALABSORPTION OF:
- stomach is not bypassed
- all nutrients are absorbed

duodenum is partially bypassed,
some nutrients are absorbed

jejunum bypassed (rerouted to digestive limb)
- Calcium
- Iron
- Chromium
- Phosphorous
- Copper
- Selenium
- Folate
- Zinc
- Vitamin A, D, E, K
- Vitamin B1 (Thiamin)
- Vitamin B2 (Riboflavin)
- Vitamin B3 (Niacin)
- Vitamin B5 (Pantotheine)
- Vitamin B6 (Pyridoxine)
- Vitamin B7 or H (Biotin)
- Vitamin C

RNY vs DS
Nutrient Malabsorption
<table>
<thead>
<tr>
<th>Pre-OP deficiency</th>
<th>Post-OP deficiency</th>
<th>Risk factors</th>
<th>Signs and symptoms</th>
<th>Suggested supplementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>3-18%</td>
<td>Low protein (and energy) intakes, intercurrent illness, extreme weight loss (i.e. low food intake) short common channel</td>
<td>Weakness, decreased muscle mass, brittle hair, generalised oedema</td>
<td>Recommended intake: 60-120 g/day (dairy, fish, eggs, meat) or oral protein supplements</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Prevention</td>
</tr>
</tbody>
</table>
Fat digestion & absorption

- **Small bowel**: fat globules get bound by **bile salts**
  - ‘**Emulsification**’, decreases surface tension, easy breakdown by agitation
  - Then, ‘**pancreatic lipase**’ (the main enzyme) digests into fatty acids
  - Finally, 2nd action of bile salts → bind to fatty acids → form ‘**Micelles**’
Common Nutrient Deficiencies

- **Gastric Bypass:**
  - Most common: Iron, Vitamin B-12, Folic acid, Fat soluble Vitamins A, D, & E
  - Thiamin (seen in patients with frequent vomiting)
  - Calcium
  - Protein malnutrition
  - B-12
  - Thiamine deficiency after Bariatric surgery may lead to wernicke encephalopathy, SUDDEN DEATH
B12 deficiency.

- Several factors precipitate deficiency of B12
  - Limited intake
  - Decreased cleavage of the vitamin from R binding protein,
  - Inadequate intrinsic factor.
  - Bacterial overgrowth.
- Manifestations include macrocytic anemia, leucopenia, glossitis, thrombocytopenia, paresthesia, and irreversible neuropathies
Step 1. Dietary B12 combines with R binding protein in Saliva

Intrinsic factor secreted by Parietal cells

Cleaving R Binding protein from B12

B12 combines with IF

Exocrine deficiency

B12 absorbed in ileum

Ileal disease, ilectomy.

Four steps of B12 absorption and three causes of B12 malabsorption

1.) If deficiency
2.) Bacterial overgrowth (blind loop syndrome)
3.) Ileal disease cause B12 deficiency
Short bowel syndrome

Small intestinal bacterial overgrowth (SIBO):

- Oral cavity – 200 species
- Gradient of bacterial concentrations found throughout the gastrointestinal tract
- Stomach $<10^3$ CFU/mL
- Duodenum and proximal jejunum $10^2$–$10^3$ CFU/mL
- Colon $10^{10}$–$10^{11}$ CFU/mL
- Ileum $10^8$ CFU/mL
The number of WE substantially higher than previously reported.

Of 104 reported cases of WE after BS 84 cases were included. Gastric bypass or a restrictive procedure had been performed in 80 (95%).

WE occurred within 6 months of surgery in 79 cases (94%).

Recommended Nutritional Screening and Supplementation After Bariatric Surgery

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Biomarker(s)</th>
<th>Primary symptoms of deficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin B₁</td>
<td>Serum thiamin</td>
<td>Ophthalmoplegia, nystagmus, ataxia, encephalopathy, rapid visual loss (Wernicke encephalopathy)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isolated peripheral neuropathy</td>
</tr>
</tbody>
</table>

Incomplete recovery was observed in 41 cases (49%), memory deficits and gait difficulties were frequent sequela.

Wernicke’s encephalopathy and polyneuropathy associated with vitamin B complex deficiency after a bariatric surgery

- Rapid onset of Wernicke's encephalopathy following gastric restrictive surgery.

- Wernicke-Korsakoff syndrome is a complication of thiamine (vitamin B1) deficiency. Wernicke encephalopathy (WE) is an acute syndrome requiring emergent treatment to prevent death and neurologic morbidity.

- Korsakoff syndrome (KS) refers to a chronic neurologic condition that usually occurs as a consequence of WE.

<table>
<thead>
<tr>
<th>Pre-OP deficiency</th>
<th>Post-OP deficiency</th>
<th>Risk factors</th>
<th>Signs and symptoms</th>
<th>Suggested supplementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin D</td>
<td>Serum 25(OH) vitamin D, calcium, phosphorus, parathyroid hormone</td>
<td>Decreased bone mineral density&lt;br&gt;Secondary hyperparathyroidism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>Serum albumin</td>
<td>Edema, excessive alopecia, poor wound-healing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- SG, RYGB, BPD-DS
- Adults, rickets (in children), arthralgia, depression, fasciculation, myalgia
- 800 U/day [ergocalciferol (vitamin D2) or cholecalciferol (vitamin D3)] or 100 000 U/3–6 months orally
- 50 000–150 000 IU/day; if necessary: calcitriol [1,25 (OH)2D] orally
### Additional annual screening after BPD and BPD-DS

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Plasma test</th>
<th>Clinical consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A</td>
<td>Plasma retinol</td>
<td>Reduced night vision, visual impairment</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>Plasma alpha-tocopherol</td>
<td>Neuropathy, ataxia</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Prothrombin time</td>
<td>Bleeding, easy bruising</td>
</tr>
</tbody>
</table>

### Screen after any bariatric procedure if suggestive symptoms

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Plasma test</th>
<th>Clinical consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>B6 (pyridoxine)</td>
<td>Plasma pyridoxal-5’-phosphate</td>
<td>Anemia, neurological symptoms</td>
</tr>
<tr>
<td>Copper</td>
<td>Serum copper</td>
<td>Anemia, neuropathy</td>
</tr>
<tr>
<td>Zinc</td>
<td>Plasma zinc</td>
<td>Acrodermatitis enteropathica-like rash, taste alterations</td>
</tr>
</tbody>
</table>
Ultraviolet (UV) B radiation with a wavelength of 290-320 nanometers penetrates uncovered skin and converts cutaneous 7-dehydrocholesterol to previtamin D3, which in turn becomes vitamin D3 [1].

Season, time of day, length of day, cloud cover, smog, skin melanin content, and sunscreen are among the factors that affect UV radiation exposure and vitamin D synthesis.

Roughly,
1. 5-30 minutes of sun exposure
2. between 10 AM and 3 PM
3. at least twice a week
4. to the face, arms, legs, or back without sunscreen usually lead to sufficient vitamin D synthesis

Warning: UV radiation is a carcinogen responsible for most of the estimated 1.5 million skin cancers and the 8,000 deaths due to metastatic melanoma that occur annually in the United States.
Deficiency of trace elements.

- Iron; common
- Several factors account
  1. reduced intake.
  2. decreased HCL in the stomach, necessary for dietary Fe in the ferric form to be converted to ferrous state,
  3. reduced absorbing capacity due to bypassing of the primary sites of Fe absorption,
- Management: Fe supplements between meals with food containing vitamin C will enhance absorption.

The stomach serves three functions in iron metabolism:

1. Gastric peptidases and HCL release iron from food.
2. Iron is bound to a high molecular weight chelator that prevents iron from forming large insoluble complexes.
3. Decreased gastric acidity aids in the reduction of iron from its ferric (Fe3+) form to its ferrous (Fe2+) form.
Calcium

<table>
<thead>
<tr>
<th>Pre-OP deficiency</th>
<th>Post-OP deficiency</th>
<th>Risk factors</th>
<th>Signs and symptoms</th>
<th>Suggested supplementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.5–10.5%</td>
<td>Approx. 10%</td>
<td>Pre-existing/deficiency, vitamin D deficiency, RYGB, BPD-DS, LSG, insufficient supplementation with calcium and/or</td>
<td>Low bone density, osteoporosis, muscle contractions, pain, spasms, paresthesia</td>
<td>Oral calcium citrate, 1200–2000 mg/day</td>
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</tbody>
</table>

Aliment Pharmacol Ther. 2014 Sep;40(6):582-609
### Magnesium

*Aliment Pharmacol Ther.* 2014 Sep;40(6):582-609

<table>
<thead>
<tr>
<th>Pre-OP deficiency</th>
<th>Post-OP deficiency</th>
<th>Risk factors</th>
<th>Signs and symptoms</th>
<th>Suggested supplementation</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>35%</td>
<td>32%</td>
<td>Pre-existing deficiency, vitamin D deficiency, RYGB, BPD-DS, insufficient supplementation with magnesium and/or vitamin D</td>
<td>Muscle contractions, pain, spasms, osteoporosis</td>
<td>Oral magnesium citrate, 300 mg/day</td>
<td></td>
</tr>
</tbody>
</table>
Selenium

- deficiency in 14% to 22%
- Se is absorbed in the duodenum and proximal jejunum. Cardiomyopathy is a common manifestation of Se deficiency
- Report of a case of acute heart failure in a patient who lost 100 kg post-BPD and whose cardiac function improved in 3 wk after repletion with Se supplementation.
- Peripheral muscle involvement with myositis, weakness, and muscle cramps are other manifestations of Se deficiency.
- an important role in thyroid hormone production.
Zinc

- absorbed in duodenum and proximal jejunum
- significant hair loss in about one-third of patients after vertical banded gastroplasty,
- reversed by supplementation of 600 mg of zinc sulfate daily.
- deficiency causes diarrhea, emotional disorders, weight loss, intercurrent infection, bullous-pustular dermatitis, and hypogonadism in males.
- acrodermatitis enteropathica like eruption
- Recommendation: of 50 μg of Se and 6.5 mg of Zn per day.
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Ceruloplasmin, Kinky hair, Impaired central nervous</td>
</tr>
<tr>
<td>Zinc</td>
<td>Neutropenia, Anemia, Scorbutic bone lesions, ↓ Ceruloplasmin, Kinky hair</td>
</tr>
<tr>
<td>Chromium</td>
<td>↓ T cell function, ↓ Alkaline phosphatase</td>
</tr>
<tr>
<td>Selenium</td>
<td>Myalgias, Cardiomyopathy, ↓ Glutathione peroxidase and Serum Selenium</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>Night blindness, Impaired dark field adaptation</td>
</tr>
<tr>
<td>Vitamin E</td>
<td>combined degeneration (poster lateral columns) in the presence of a normal serum B₁₂ level</td>
</tr>
<tr>
<td>Thiamine</td>
<td>Wernicke's encephalopathy, Refractory lactic acidosis, Cardiac failure</td>
</tr>
<tr>
<td>Cobalamin (B₁₂)</td>
<td>Weakness, paresthesia, Diarrhea, Dementia, Megaloblastic anemia, Sub acute combined degeneration</td>
</tr>
</tbody>
</table>
Conclusions

2. Risks involved
3. Benefits in the resolution or marked improvement of diabetes, hypertension, and hyperlipidemia far outweigh the risks.
4. Nonetheless, considering the serious consequences of nutritional deficiencies associated with weight loss surgery, it is critically important that early identification, appropriate treatment, and routine prophylactic micronutrient supplementation are recognized as key components in the successful management of the bariatric patient.
Zinc rich food items

- Oysters
- Chicken
- Cheddar Cheese
- Cashews
- Watermelon Seed
- Almonds
- Milk
- Red Meat
- Yoghurt
- Pumpkin Seed
- Salmon
- Cacao/Cocoa Dark Choc
B1 rich foods

Lotus stem  
Capsicum  
Green gram whole  
Soya bean  
Cow pea  
Walnut  
Pistachio  
Wheat  
Red gram pulse  
Cashew nut  
Green gram pulse  
Moth beans
FODMAP diet

- fermentable carbohydrates worsen symptoms of functional gastrointestinal disorders (FGID)
- Symptoms of FGID can result from the malabsorption of fructose and sucrose that occurs when the activity of one of these transporters is altered. Fructose absorption is highly dependent on GLUT 5 activity, and GLUT 5 expression appears to be influenced by dietary fructose and sucrose load.
<table>
<thead>
<tr>
<th>FODMAP</th>
<th>Oligosaccharides</th>
<th>Disaccharides (lactose)</th>
<th>Monosaccharides (fructose)</th>
<th>Polyols</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High FODMAP Content</strong></td>
<td>• Artichokes • Asparagus • Broccoli • Cabbage • Onions • Peas • Wheat &amp; rye • Chickpeas • Watermelon • White peaches</td>
<td>• Cow, sheep, and goat milk • Ricotta and Cottage cheese • Yogurt • Ice Cream</td>
<td>• Apples • Pears • Mango • Peaches • Honey • High fructose corn syrup</td>
<td>• Cherries • Plums • Prunes • Avocado • Mushrooms • Cauliflower • Sorbitol</td>
</tr>
<tr>
<td>Low FODMAP Content</td>
<td>Low FODMAP Content</td>
<td>Low FODMAP Content</td>
<td>Low FODMAP Content</td>
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<td>---------------------------------------------------------</td>
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</tr>
<tr>
<td>• Carrot</td>
<td>• Lactose free and rice milk</td>
<td>• Banana</td>
<td>• Lemon</td>
<td></td>
</tr>
<tr>
<td>• Celery</td>
<td>• Brie cheese</td>
<td>• Blueberry</td>
<td>• Lime</td>
<td></td>
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<tr>
<td>• Eggplant</td>
<td>• Lactose free yogurt</td>
<td>• Grapefruit</td>
<td>• Orange</td>
<td></td>
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<tr>
<td>• Green beans</td>
<td>• Sorbet and gelato</td>
<td>• Grape</td>
<td>• Raspberry</td>
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<tr>
<td>• Lettuce</td>
<td></td>
<td>• Honeydew melon</td>
<td>• Sugar</td>
<td></td>
</tr>
<tr>
<td>• Tomato</td>
<td></td>
<td>• Orange</td>
<td>• Glucose</td>
<td></td>
</tr>
<tr>
<td>• Gluten free cereals/breads</td>
<td></td>
<td>• Strawberry</td>
<td>• sucralose, saccharin, aspartame</td>
<td></td>
</tr>
</tbody>
</table>
Foods suitable on a low-fodmap diet

- **Fruit**: banana, blueberry, boysenberry, cantaloupe, cranberry, dianthus, grape, grapefruit, honeydew melon, kiwi fruit, lemon, lime, mandarin, orange, passion fruit, pawpaw, raspberry, rhubarb, rockmelon, star apple, straw berry, tangerine. Note: Fruit is used in small quantities.

- **Vegetables**: alfalfa, bamboo shoots, bean shoots, bok choy, carrot, celery, chive, choy sum, onion, ginger, green beans, leek, olives, parsnip, potato, pumpkin, red capsicum (bell pepper), silver beet, spinach, squash, swede, sweet potato, turnip, yam, zucchini.

- **Grain foods**: cereals, gluten-free bread or cereal products.

- **Milk products**: milk, lactose-free milk*, oat milk*, rice milk*, soy milk*. 'Check for additives

- **Other**: tofu, sweeteners (sucrose), glucose, artificial sweeteners not ending in 'ul' and 'pull', honey substitutes: golden syrup*, maple syrup*, molasses, treacle (small quantities).

Eliminate foods containing fodmaps

- **Excess fructose**: fruit (apple, mango, nashi, pear, prune fruit, in natural juice, watermelon), sweeteners (fruitase, high fructose corn syrup).

- **Large total fructose dose**: concentrated fruit sources, large served of fruit, dried fruit, fruit juice, honey (corn syrup, fructose).

- **Milk**: milk from cows, goats or sheep, custard, ice cream, yoghurt.

- **Cheese**: soft unpasturised cheese eg cottage, cream, mascarpone, ricotta.

- **Vegetables**: artichoke, asparagus, beetroot, broccoli, brussels sprouts, cabbage, caper, fennel, garlic, leek, okra, onion (all), spinach, spiced onion.

- **Legumes**: beans, peas, lentils, soy beans.

- **Watermelon**: watermelon.

- **Vegetables**: cauliflower, green capsicum (bell pepper), mushroom, sweet corn.

- **Sweeteners**: sorbitol (420), mannitol (421), isomalt (553), maltitol (965), xylitol (667).

- **Fruit**: apple, apricot, avocado, blackberry, berry, cherry, longan, lychee, nashi, nectarine, peach, pear, plum, prune, watermelon.
## Foods for low FODMAP diet

<table>
<thead>
<tr>
<th><strong>fruit</strong></th>
<th><strong>vegetables</strong></th>
<th><strong>grain foods</strong></th>
<th><strong>milk products</strong></th>
<th><strong>other</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>banana, blueberry, boysenberry, cantaloupe, cranberry, durian, grape, grapefruit, honeydew melon, kiwifruit, lemon, lime, mandarin, orange, passionfruit, pawpaw, raspberry, rhubarb, rockmelon, star anise, strawberry, tangelo</td>
<td>alfalfa, bamboo shoots, bean shoots, bok choy, carrot, celery, choko, choy sum, endive, ginger, green beans, lettuce, olives, parsnip, potato, pumpkin, red capsicum (bell pepper), silver beet, spinach, squash, swede, sweet potato, taro, tomato, turnip, yam, zucchini</td>
<td>cereals, gluten-free bread or cereal products</td>
<td>milk: lactose-free milk*, oat milk*, rice milk*, soy milk*</td>
<td>tofu, sweeteners, sugar* (sucrose), glucose, artificial sweeteners not ending in ‘-ol’</td>
</tr>
<tr>
<td>Note: if fruit is dried, eat in small quantities</td>
<td>herbs: basil, chili, coriander, ginger, lemongrass, marjoram, mint, oregano, parsley, rosemary, thyme</td>
<td>bread: 100% spelt bread</td>
<td>*check for additives</td>
<td>honey substitute: golden syrup*, maple syrup*, molasses, treacle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rice</td>
<td>cheeses: hard cheeses, and brie and camembert</td>
<td>*small quantities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>oats</td>
<td>yoghurt: lactose-free varieties</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>polenta</td>
<td>ice-cream substitutes: gelati, sorbet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>other: arrowroot, millet, psyllium, quinoa, sorghum, tapioca</td>
<td>butter substitutes: olive oil</td>
<td></td>
</tr>
</tbody>
</table>
Eliminate foods containing FODMAPs

<table>
<thead>
<tr>
<th>Excess Fructose</th>
<th>Lactose</th>
<th>Fructans</th>
<th>Galactans</th>
<th>Polyols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruit</td>
<td>Milk</td>
<td>Vegetables</td>
<td>Legumes</td>
<td>Fruit</td>
</tr>
<tr>
<td>apple, mango, nashi, pear, tinned fruit in natural juice, watermelon</td>
<td>milk from cows, goats or sheep, custard, ice cream, yoghurt</td>
<td>artichoke, asparagus, beetroot, broccoli, brussels sprouts, cabbage, eggplant, fennel, garlic, leek, okra, onion (all), shallots, spring onion</td>
<td>baked beans, chickpeas, kidney beans, lentils, soy beans</td>
<td>apple, apricot, avocado, blackberry, cherry, longon, lychee, nashi, nectarine, peach, pea, plum, prune, watermelon</td>
</tr>
<tr>
<td>Sweeteners</td>
<td>Cheeses</td>
<td>Cereals</td>
<td></td>
<td>Vegetables</td>
</tr>
<tr>
<td>fructose, high fructose corn syrup</td>
<td>soft unripened cheeses eg. cottage, cream, mascarpone, ricotta</td>
<td>wheat and rye, in large amounts eg. bread, crackers, cookies, couscous, pasta</td>
<td></td>
<td>cauliflower, green capsicum (bell pepper, mushroom, sweet corn</td>
</tr>
<tr>
<td>Large Total Fructose Dose</td>
<td></td>
<td></td>
<td></td>
<td>Sweeteners</td>
</tr>
<tr>
<td>Concentrated fruit sources, large serves of fruit, dried fruit, fruit juice</td>
<td></td>
<td></td>
<td></td>
<td>sorbitol (420), mannitol (421), isomalt (953), maltitol (965), xylitol (967)</td>
</tr>
<tr>
<td>Honey</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>corn syrup, fruisana</td>
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<td></td>
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</tr>
</tbody>
</table>
GIP and GLP-1, the two incretin hormones: Similarities and differences

GIP secretion from K cells is enhanced in response to ingestion of meals or glucose

GLP-1 secretion from L cells, is enhanced in response to ingestion of meals or glucose

Figure 2 | Pancreatic and exopancreatic function of glucose-dependent insulino tropic polypeptide (GIP) and glucagon-like peptide (GLP)-1. GIP acts directly on the endocrine pancreas, bone, fat, gastrointestinal (GI) tract and brain. GLP-1 acts directly on the endocrine pancreas, gastrointestinal tract, heart and brain.
Bile salts in small intestine

- **1st role:** Emulsification of undigested fat - making it more water soluble for digestion
- **2nd role:** Micelle formation - binding with digested fatty acids, facilitating their absorption
- After fat is absorbed, bile salts re-enter intestinal lumen - called ‘ferrying’
- *With the presence of bile in intestine, 97% fat is absorbed, while without its presence, only 40-50% of fat would be absorbed*
- **Play IMP role in absorption of fat and hence, fat soluble vitamins**
- **Enterohepatic circulation:**
  - 94% bile salts get re-absorbed and reach back to liver
    - 47% by ‘Diffusion’ in proximal small bowel
    - 47% by ‘Active transport’ in distal ileum
  - Remaining 6% → lost in feces and replenished by liver