# Macronutrients, Calories, and Blood Glucose

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# Issues for Discussion

- Optimal macronutrient distribution in diet
- Role of carbohydrates
- Role of protein
- Role of fat
- Glycemic effects of foods
- Role of macronutrients in exercise

# Goals of MNT for Diabetes

- **Promote healthful eating patterns**, emphasizing a variety of nutrient-dense foods in appropriate portions to improve overall health and specifically to:
  - Achieve and maintain body weight goals
  - *Attain glycemic*, blood pressure, and lipid *goals*
  - Delay or prevent complications of diabetes
- **Address individual nutrition needs** based on personal and cultural preferences, health literacy and numeracy, access to healthful foods, willingness and ability to make behavioral changes, and barriers to change

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# Goals of MNT for Diabetes

- **Maintain the pleasure of eating** by providing nonjudgmental messages about food choices
- **Provide practical tools for healthy eating** rather than focus on individual macronutrients, micronutrients, or single foods

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# Macronutrient Distribution

# Eating Patterns

- **No single ideal dietary distribution of calories among carbohydrates, fat, and protein for people with diabetes**
- Macronutrient distribution should be individualized

- A variety of eating patterns acceptable for the management of type 2 diabetes and prediabetes including Mediterranean, DASH, and plant-based diets

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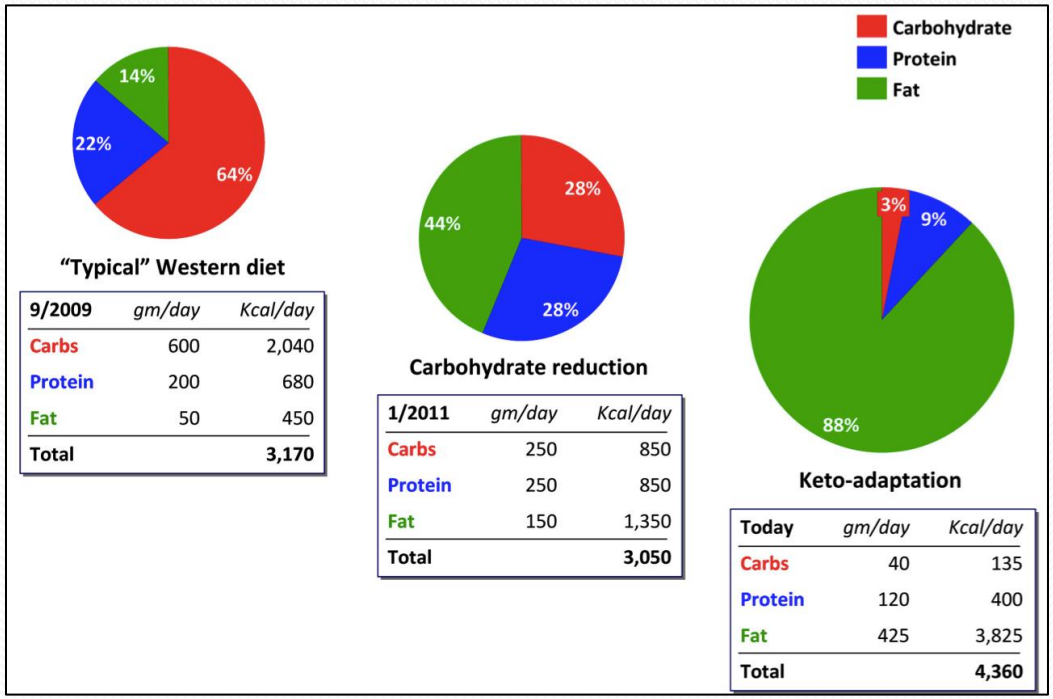
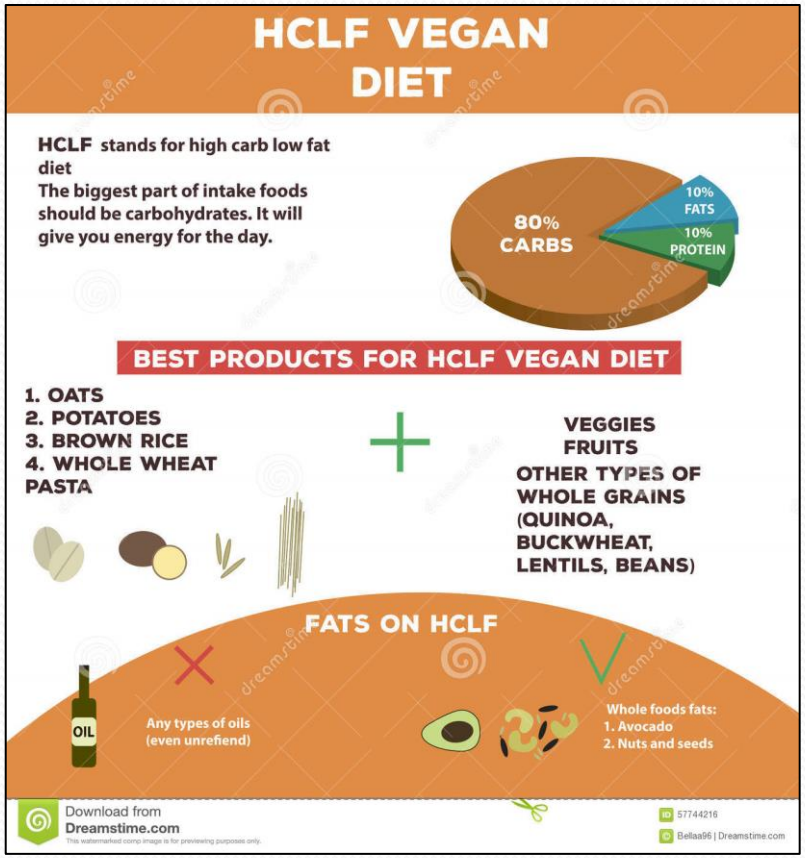
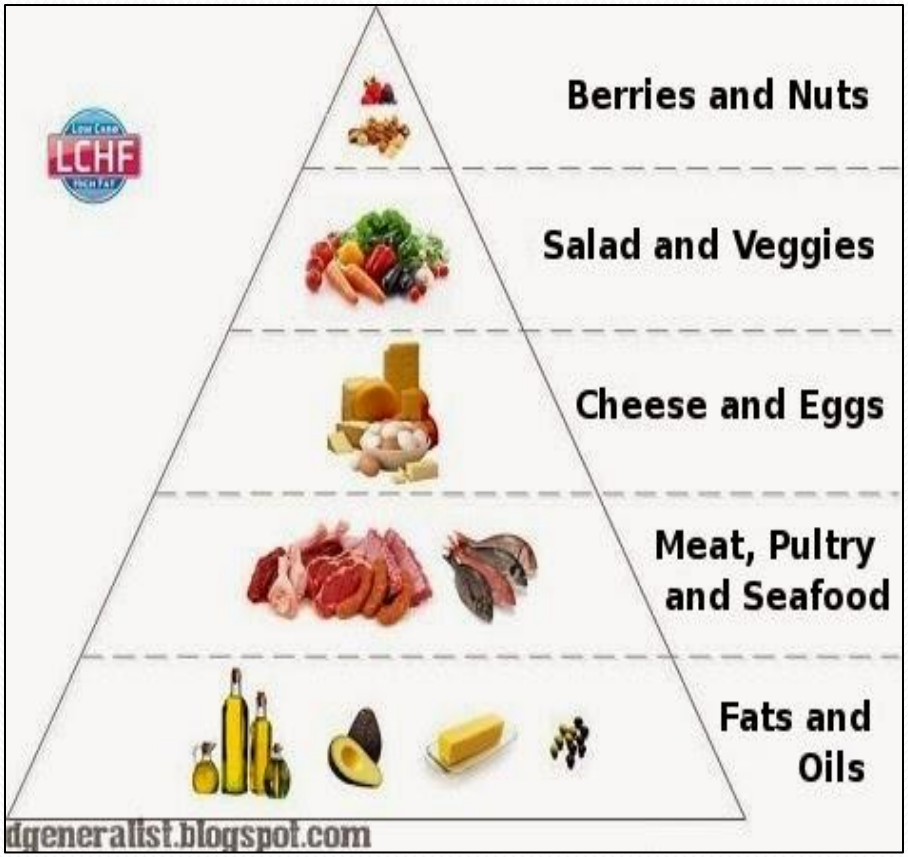
# Macronutrient Distribution

- Macronutrients distribution should be based on individual assessment of current eating patterns, preferences, and metabolic goals

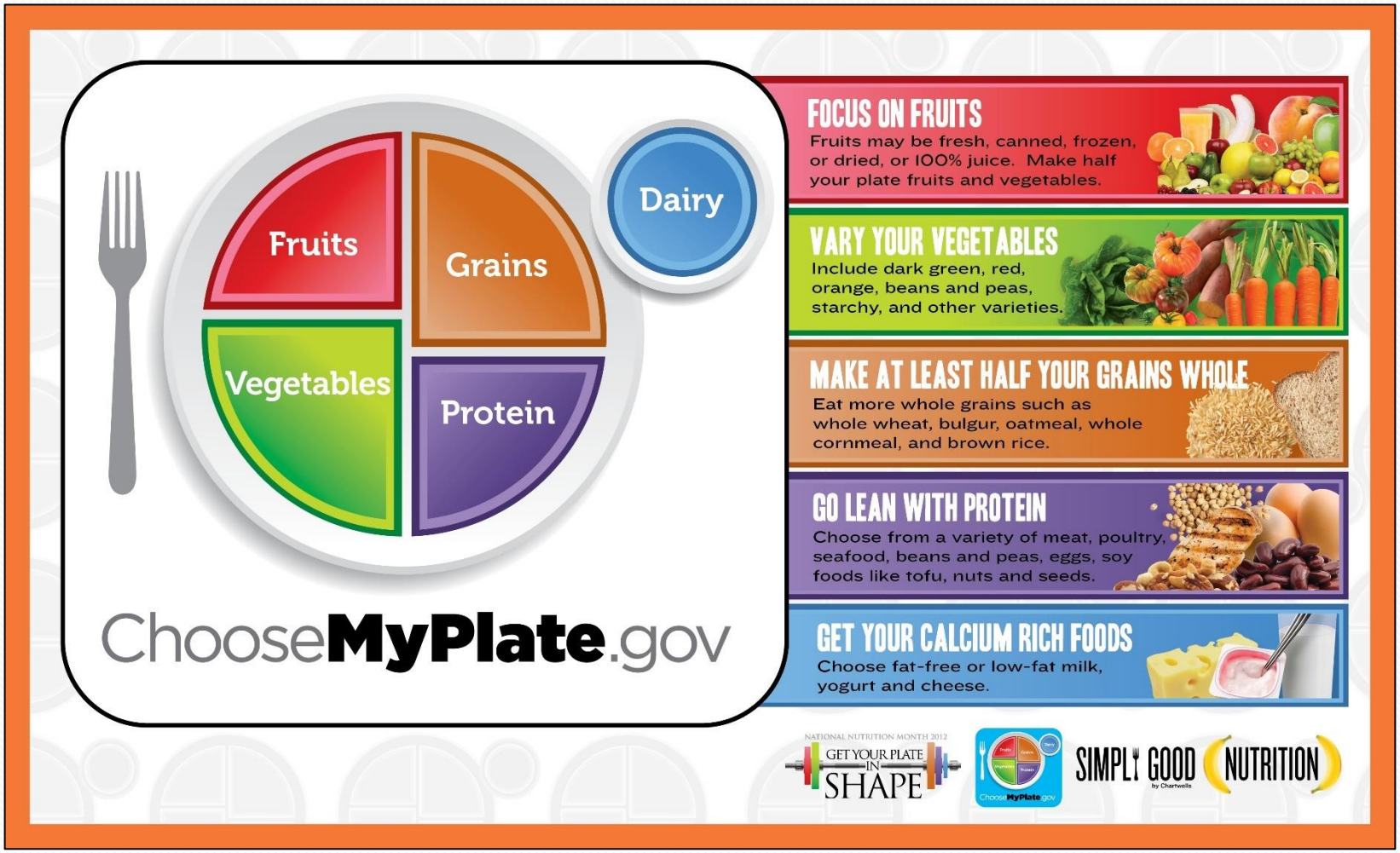


# From One Extreme to the Other

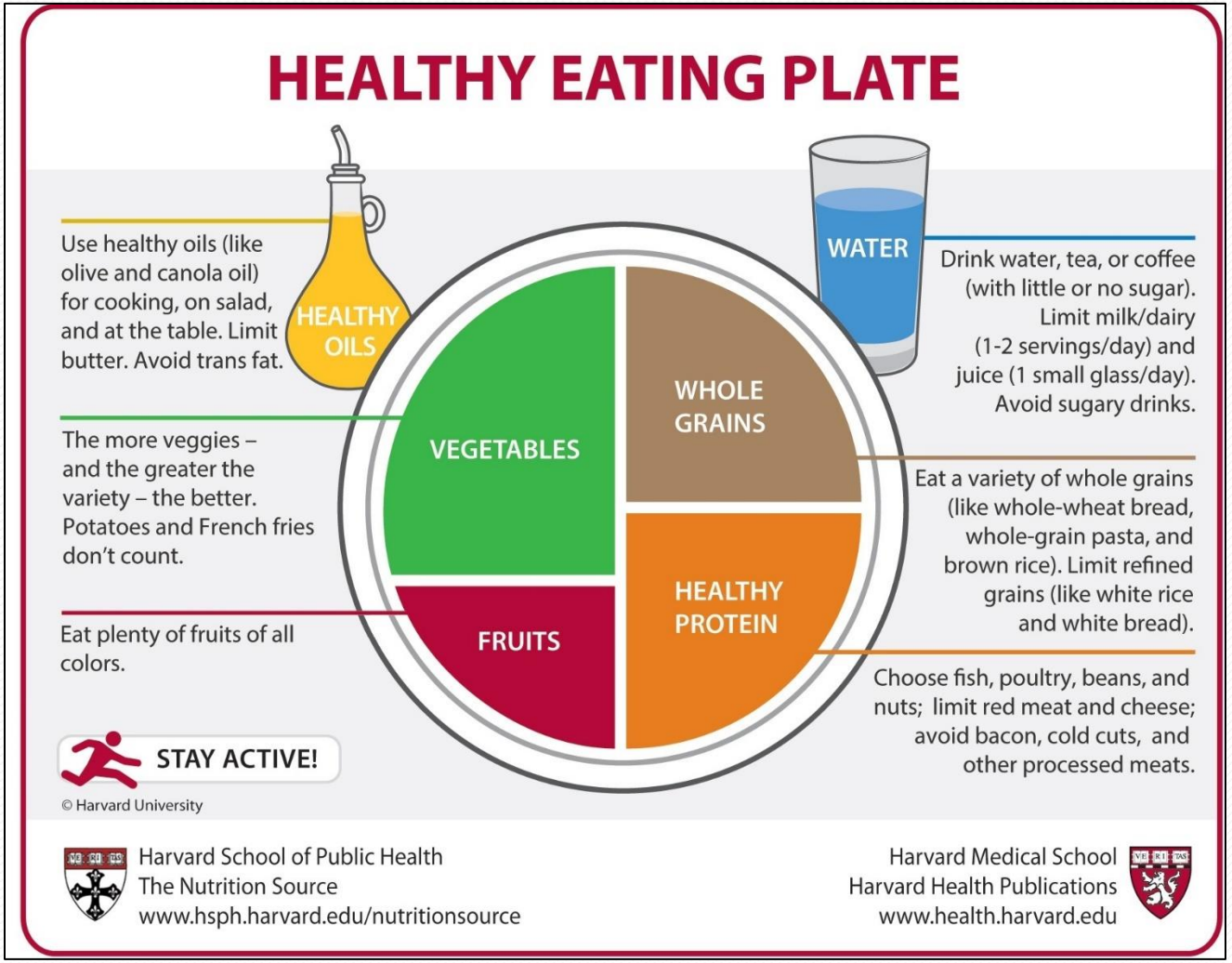


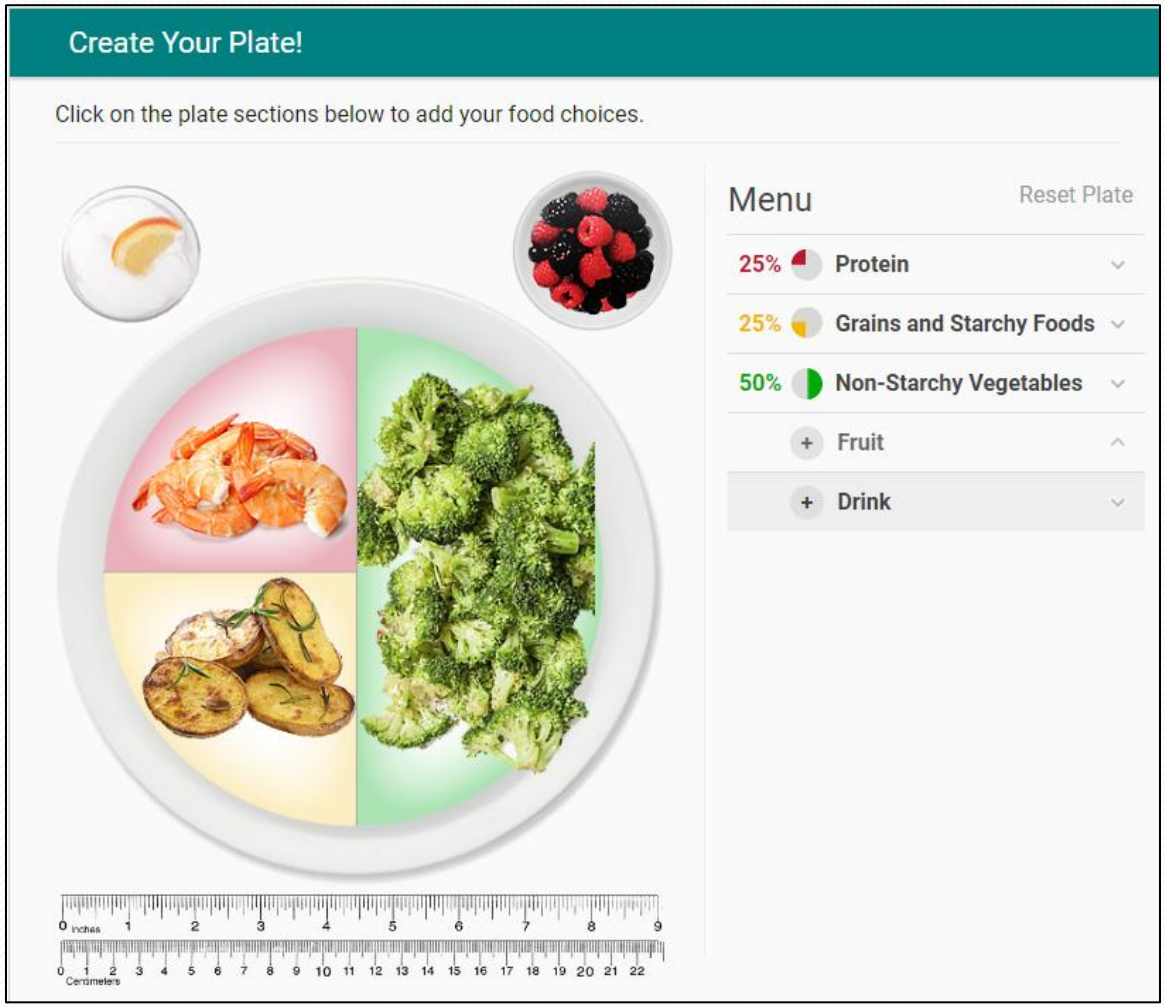
# MyPlate Recommendations



# Healthy Eating Plate Recs



# Diabetes Meal Plate




http://www.diabetes.org/food-and-fitness/food/planning-meals/create-your-plate

# AMDR (% of Total Daily Diet)

## Acceptable Macronutrient Distribution Ranges (AMDR)

| Males & Females | Total Carbs | Total Protein | Total Fat |
|---|---|---|---|
| | % of Energy | % of Energy | % of Energy |
| 1-3 years | 45-65% | 5-20% | 30-40% |
| 4-18 years | 45-65% | 10-30% | 25-35% |
| 19 + years | 45-65% | 10-35% | 20-35% |

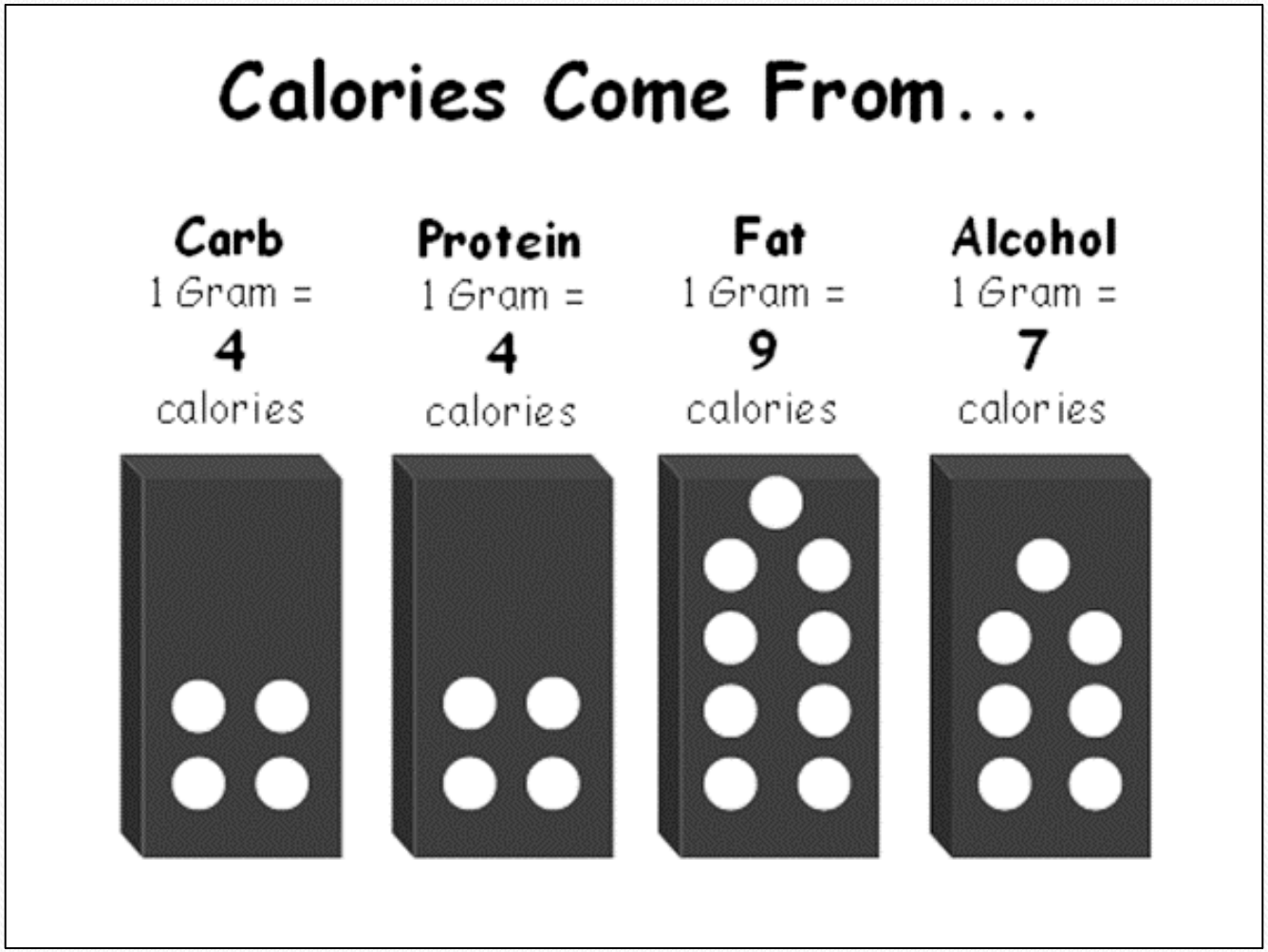
# Macronutrient Ranges (AMDR)

| | All Adults | Diabetes* |
|---|---|---|
| • Carbohydrates: | **45**-65% | 40-**45**% |
| • Fat: | 20-35% | **30**-35% |
| • Protein: | 10-35% | **20**-**30**% |

- *ADA does not take a definitive stance on macronutrient distribution ranges for adults with diabetes

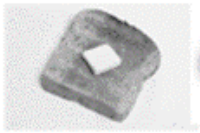
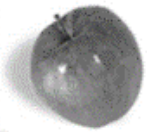
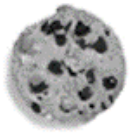
http://www.nationalacademies.org

# Calorie Equivalents



# Macronutrient Servings

## What is One Carb Serving?

| Breads/Grains | Fruit | Milk | Other Carbs |
|---|---|---|---|
|  |  |  |  |
| 1 slice whole grain bread | 1 small fresh fruit | 8 oz. low fat milk | 1 medium choc. chip cookie |

## What is One Serving of a Meat/Protein/Meat Alternative?

| Lean meats, fish, poultry, low fat cheese | Tuna fish, cottage cheese | Beans, peas, lentils (15 grams carb) | Peanut** butter |
|---|---|---|---|
| 1 ounce = | 1/4 cup = | 1/2 cup = | 2 Tbsp. |

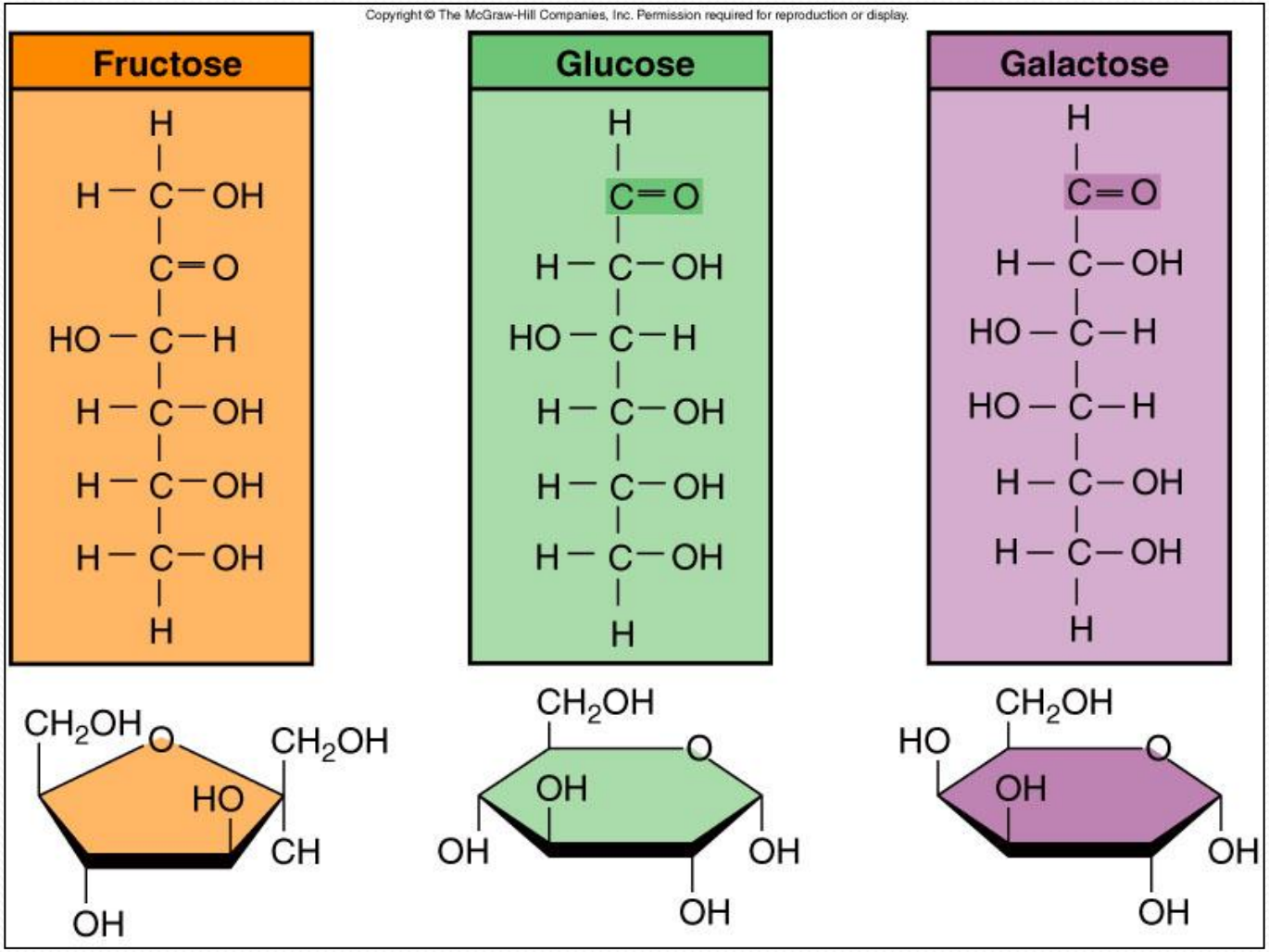
1 serving lean meat = 3 grams fat, 0 carb
1 serving medium fat meat = 5 grams fat
**1 serving = 2 extra fat servings

## What is One Fat Serving?

| | | | |
|---|---|---|---|
| Margarine | Salad dressing, Reduced fat mayo or marg. | Bacon* | Reduced calorie salad dressing |
| Oil | | | |
| Butter* | | | |
| Mayonnaise* | Cream cheese | | |
| 1 tsp. = | 1 Tbsp. = | 1 strip = | 2 Tbsp. |

1 serving fat = 5 grams fat, 0 grams carb
* = saturated fat

# Role of Carbohydrates



# Types of Dietary Carbohydrates

**TABLE 4.1** Types of dietary carbohydrates***

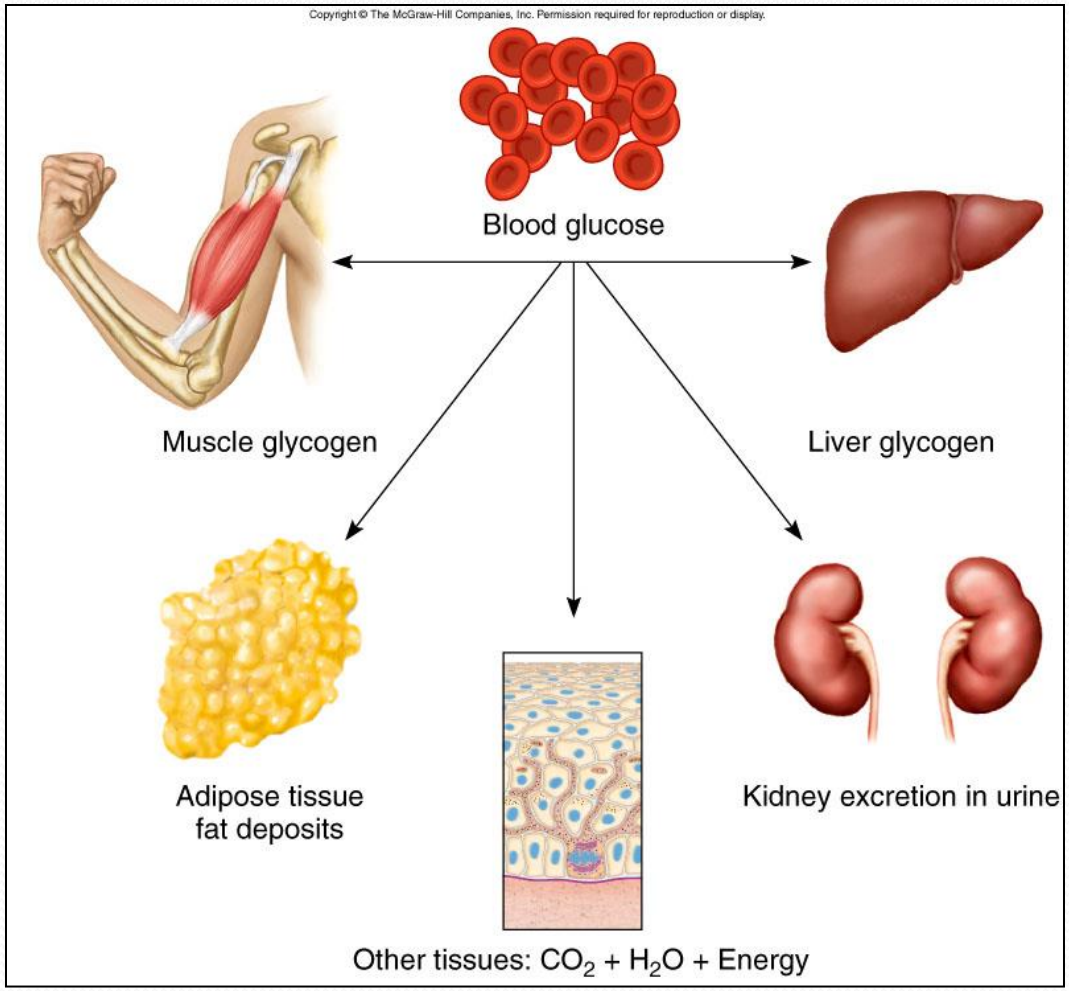
| Monosaccharides | Disaccharides | Polysaccharides | Other carbohydrates |
|---|---|---|---|
| Glucose<br>Fructose<br>Galactose | Sucrose<br>Maltose<br>Lactose | Plant starch<br>Amylose<br>Amylopectin<br>Resistant starch | Sorbitol (sugar alcohol)<br>Ribose (a five-carbon sugar) |
| | | Animal starch<br>Glycogen | |
| **Dietary fiber** | **Functional fiber** | **Dietary/ Functional fiber**** | |
| Hemicellulose<br>Resistant starch* | Polydextrin<br>Psyllium<br>Resistant starch* | Beta-glucans<br>Cellulose<br>Gums<br>Pectins | |

*Certain forms

**Dietary fiber if found intact in food; Functional fiber if extracted and added to foods.

***See text for food sources of the types of dietary carbohydrates.

# Fates of Blood Glucose



# What Is Fiber?

- **Dietary** fiber (intact foods)
  - Water soluble and water insoluble
- **Functional** fiber (isolated, extracted, or synthetic)
  - Pectin, gums, resistant starch
- **Total** fiber
  - Sum of all types
- Recommended total: (gm per day)
  - Adults <50 years: **38 g M, 25 g F**
  - Adults >50: **30 g M, 21 g F**

# ADA Carbohydrate Recs

- **Emphasize carbs in whole grains, vegetables, fruits, legumes, and dairy products**
  - Emphasis on foods higher in fiber and lower in glycemic load advised, especially over those with sugars
- Avoid sugar-sweetened beverages to control weight and reduce risk for CVD and fatty liver
- Minimize consumption of foods with added sugar that displace healthier, more nutrient-dense food choices

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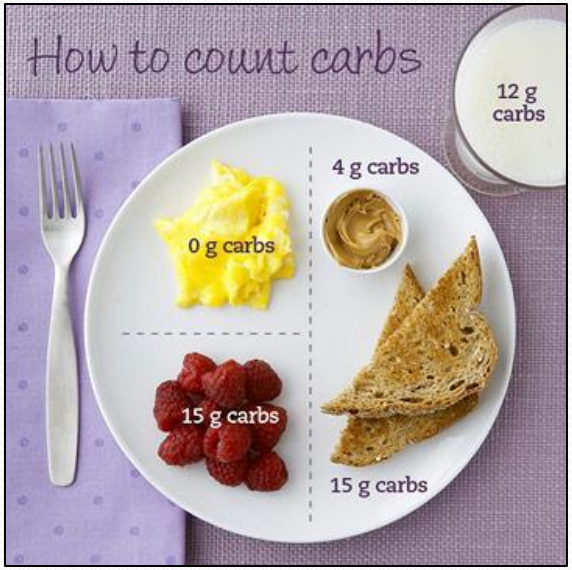
# ADA Stance on Carb Counting

- Individuals with T1D or T2D taking insulin for meals should be educated on counting carbs
- Modify insulin dosing from meal to meal based on carb intake to improve glycemic control

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# Nonnutritive Sweeteners

- Nonnutritive sweeteners may reduce overall calorie and carbohydrate intake
  - If substituted for caloric ones and without compensating with calories from other sources
- Generally safe to use within acceptable daily intake levels


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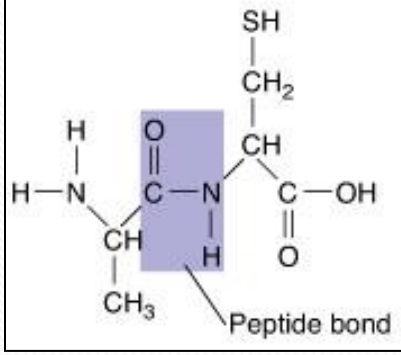
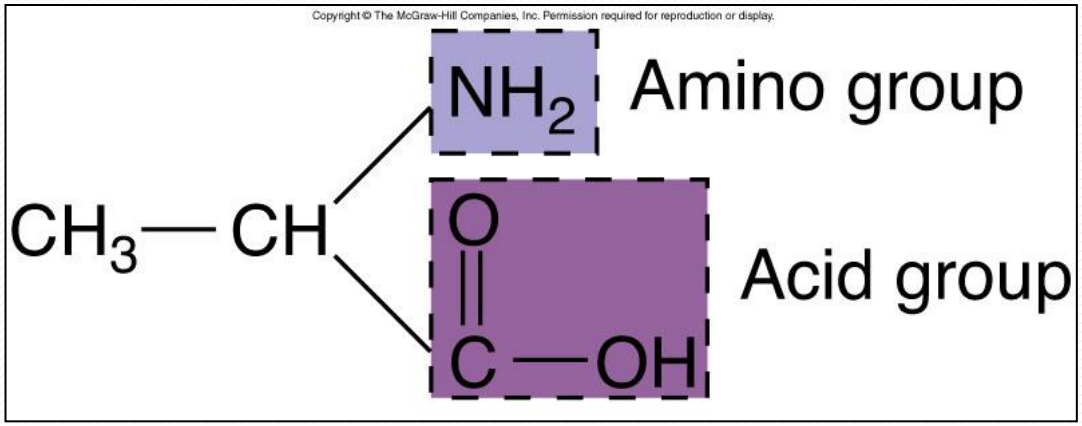
# Role of Protein






| | |
|---|---|
| AA | Amino acid |
| AA—AA | Dipeptide |
| AA—AA—AA | Tripeptide |
| AA—AA—AA—AA—AA—AA—…—AA | Polypeptide (50–100 AA) |
| AA—AA—AA—AA—AA—AA—AA—AA—AA—AA—AA—…—AA | Protein (>100 AA) |





# Animal vs. Plant Proteins

- Animal proteins generally regarded as “better” since complete (all essential amino acids)
- High quality plant proteins, but only soy complete

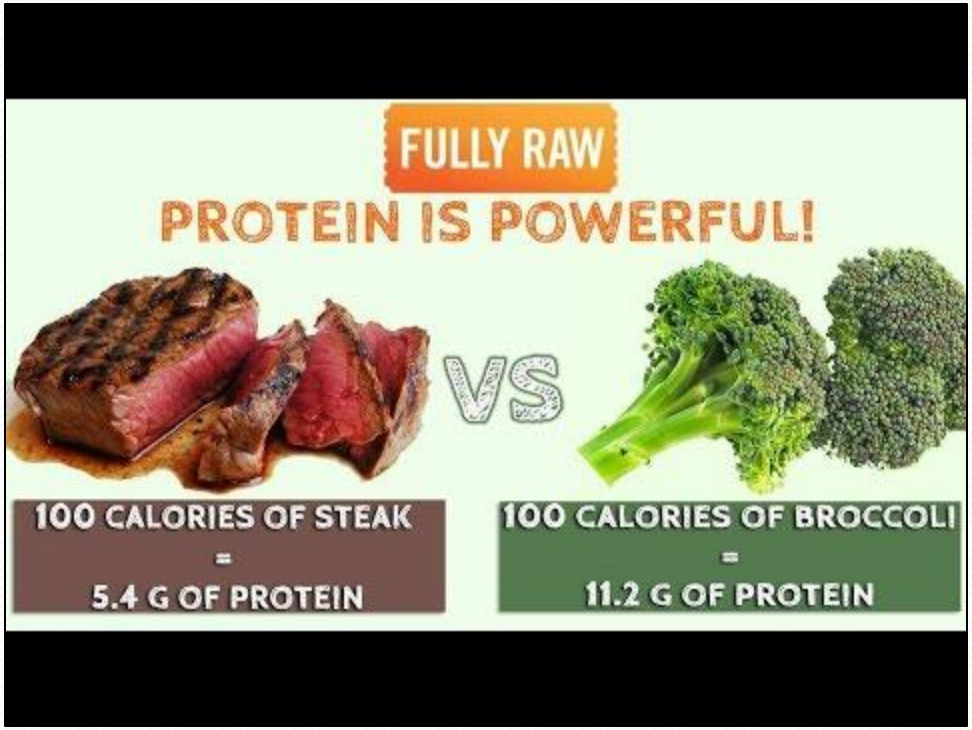


**TABLE 6.1** The dietary amino acids

| Essential amino acids | Nonessential amino acids |
|---|---|
| Histidine | Alanine |
| Isoleucine* | Arginine** |
| Leucine* | Asparagine |
| Lysine | Aspartic acid |
| Methionine | Cysteine** |
| Phenylalanine | Glutamic acid |
| Threonine | Glutamine** |
| Tryptophan | Glycine** |
| Valine* | Proline** |
| | Serine |
| | Tyrosine** |

* BCAAs; **Conditionally essential

# ADA Protein Recs

- Lowering daily protein intake (from 1–1.5 g/kg or 15–20% total calories) does not necessarily improve health
- **Ideal amount of dietary protein to optimize either glycemic control or CVD risk unknown**
- Higher protein may increase satiety

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# ADA Protein Recs

- In T2D, ingested protein increases insulin response without increasing blood glucose
  - *More insulin released to cover protein*
- In T1D, higher protein intake may raise mealtime insulin needs to cover delayed postprandial rise in blood glucose
  - *More insulin needed to cover protein*

- Carbohydrate sources high in protein should not be used to treat or prevent hypoglycemia

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# Protein and Kidney Disease

- Dietary protein should be at recommended daily allowance of 0.8 g/kg body weight/day, but not lower

- Lower protein intake does not alter glycemic measures, CVD risk, or rate of decline of glomerular filtration rate

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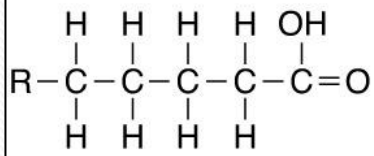
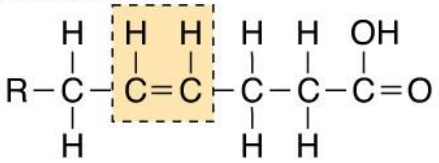
# Role of Fat

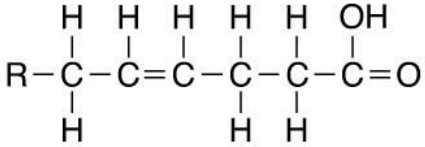




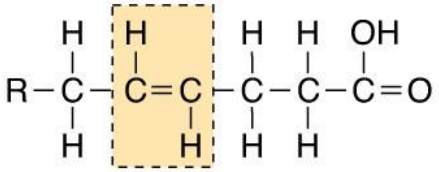
Saturated fatty acid



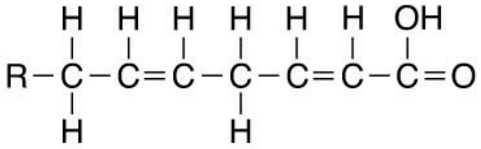
Unsaturated fatty acid (*cis*)



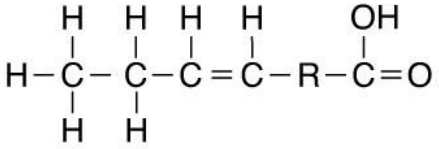
Monounsaturated fatty acid



Unsaturated fatty acid (*trans*)



Polyunsaturated fatty acid



Omega-3 fatty acid

# ADA Fat Recs

- **Ideal total dietary fat content for PWD not identified**
- Mediterranean-style diet (rich in monounsaturated fats) may improve glucose metabolism and lower CVD risk
  - Effective alternative to a diet low in total fat but relatively high in carbohydrates

- Eating foods rich in **ω-3 fatty acids**, such as fatty fish (EPA and DHA) and nuts and seeds (ALA), recommended to prevent or treat CVD (but not ω-3 dietary supplements)

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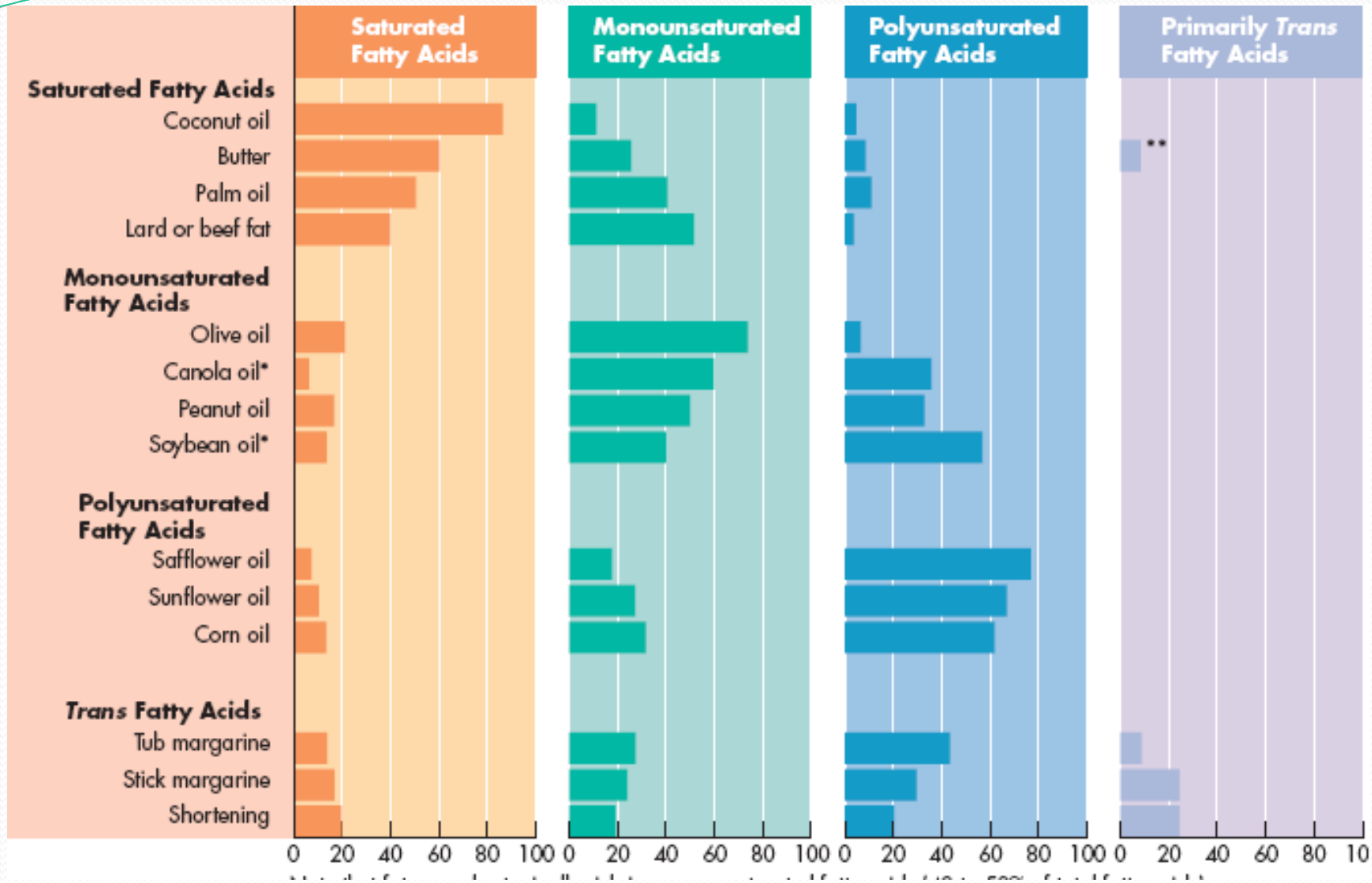
Saturated Fatty Acids
Monounsaturated Fatty Acids
Polyunsaturated Fatty Acids
Primarily Trans Fatty Acids
Saturated Fatty Acids
Coconut oil
Butter
Palm oil
Lard or beef fat
Monounsaturated Fatty Acids
Olive oil
Canola oil*
Peanut oil
Soybean oil*
Polyunsaturated Fatty Acids
Safflower oil
Sunflower oil
Corn oil
Trans Fatty Acids
Tub margarine
Stick margarine
Shortening
**
0 20 40 60 80 100
0 20 40 60 80 100
0 20 40 60 80 100
0 20 40 60 80 10

# Type of Fats vs. Total Fat

- Type of fats consumed more important than total amount of fat when looking at metabolic goals and CVD risk

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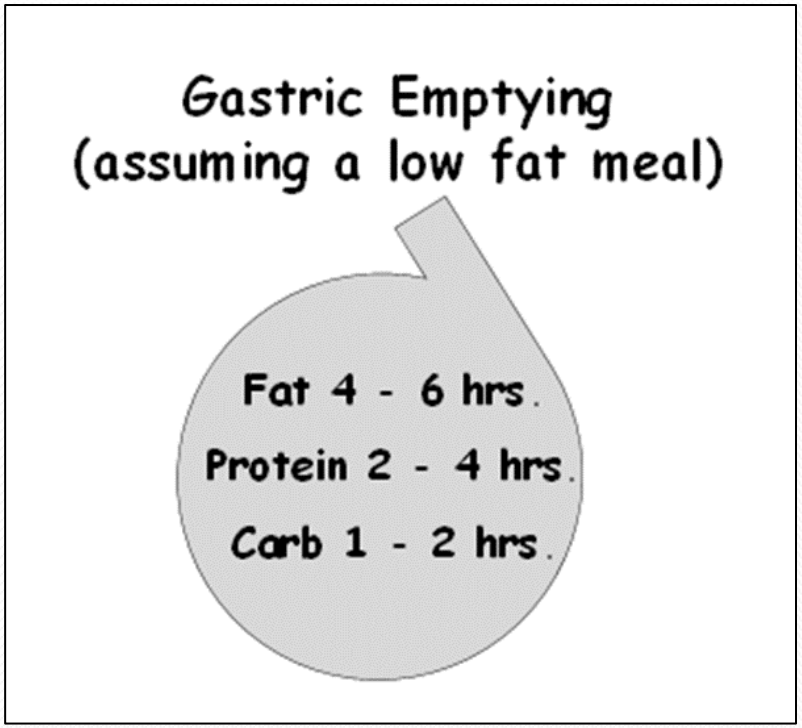
# Delayed Effects of Fats

- Higher fat intake may require mealtime insulin dose adjustments to compensate for delayed postprandial glycemic excursions



# Glycemic Effects of Foods

# Glycemic Effects of Carbs

- Affected by relative carbohydrate, protein, and fat
- **Foods with little or no carbohydrate do not have much of an immediate impact on the rise in blood glucose** (i.e., they have a low or no effect)
  - Examples: meat, fish, eggs, avocado, wine, beer, spirits, *most* non-starchy vegetables
- Harder to test the effects of mixed meals and foods
  - Also, test subjects do not have diabetes
  - Intersubject and intrasubject variability

# What Is Glycemic Index?

- Relative to the effect of **50 grams** of a specific carbohydrate on the rate of rise in blood glucose
- 50 grams of glucose ranked at 100

- GI rating scale:
  - **70 or more – High**
  - **56 to 69 – Medium**
  - **55 or less – Low**

# Typical Glycemic Index Values

## GLYCEMIC INDEX CHART

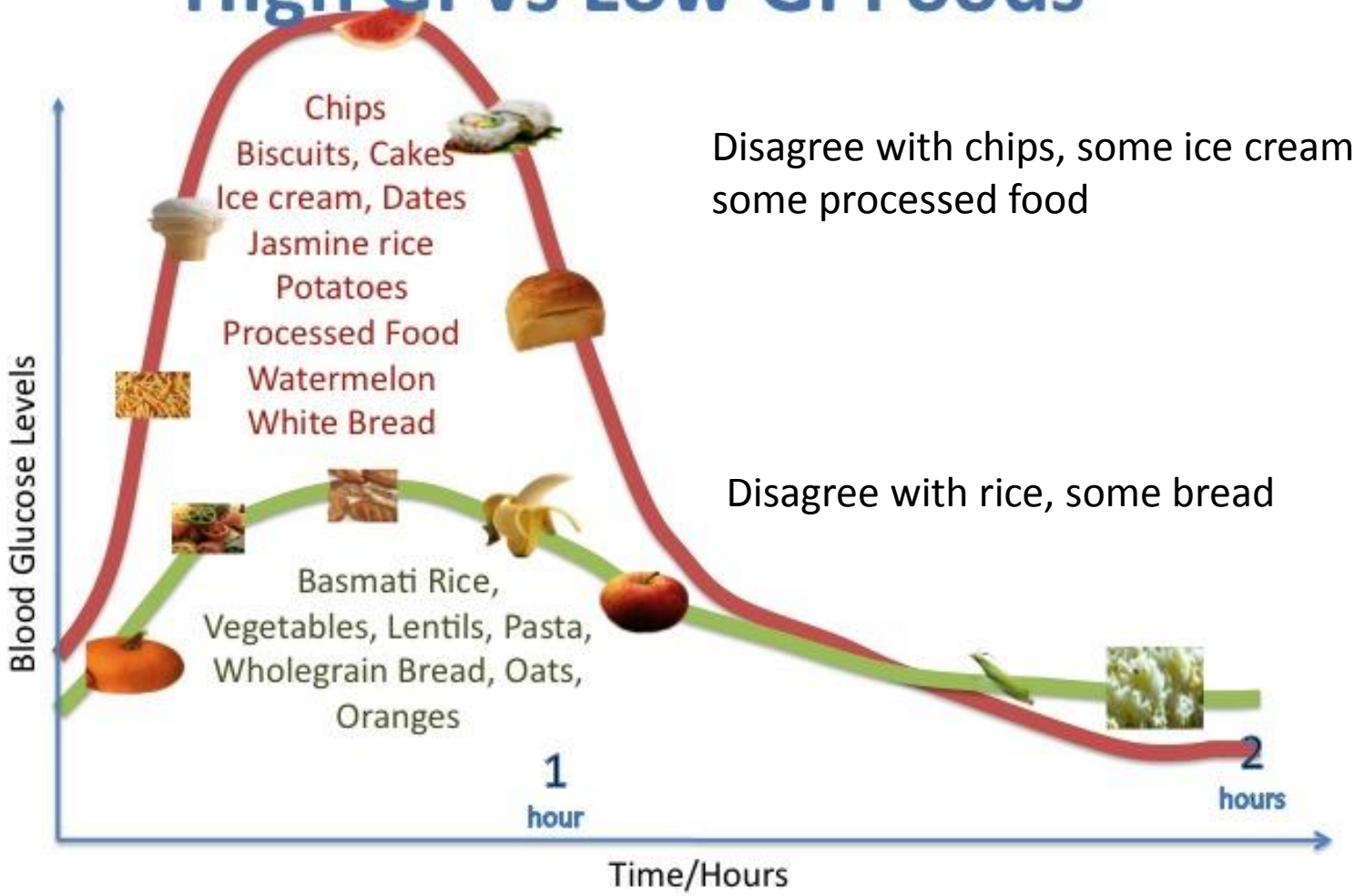
Low Glycemic (55 or Below) High Glycemic (70 or Higher)

| SNACKS | G.I. | STARCH | G.I. | VEGETABLES | G.I. | FRUITS | G.I. | DAIRY | G.I. |
|---|---|---|---|---|---|---|---|---|---|
| Pizza | 33 | Bagel, Plain | 33 | Broccoli | 10 | Cherries | 22 | Yogurt, Plain | 14 |
| Chocolate Bar | 49 | White Rice | 38 | Pepper | 10 | Apple | 38 | Yogurt, Low Fat | 14 |
| Pound Cake | 54 | White Spaghetti | 38 | Lettuce | 10 | Orange | 43 | Whole Milk | 30 |
| Popcorn | 55 | Sweet Potato | 44 | Mushrooms | 10 | Grapes | 46 | Soy Milk | 31 |
| Energy Bar | 58 | White Bread | 49 | Onions | 10 | Kiwi | 52 | Skim Milk | 32 |
| Soda | 72 | Brown Rice | 55 | Green Peas | 48 | Banana | 56 | Chocolate Milk | 35 |
| Doughnut | 76 | Pancakes | 67 | Carrots | 49 | Pineapple | 66 | Yogurt, Fruit | 36 |
| Jelly Beans | 80 | Wheat Bread | 80 | Beets | 64 | Watermelon | 72 | Custard | 43 |
| Pretzels | 83 | Baked Potato | 85 | Onions | 75 | Dates | 103 | Ice Cream | 60 |

Glycemic Index values obtained from www.lowglycemicdiet.com, www.nutritiondata.com and www.diabetesnet.com

Search database at www.glycemicindex.com

# High GI vs Low GI Foods




Disagree with chips, some ice cream, some processed food

Disagree with rice, some bread

Graph adapted from: www.gisymbol.com (University of Sydney). Images from Microsoft Clipart.

# GI Affected By…

- Ripeness/storage of foods (green vs. ripe bananas)
- Processing of foods (highly processed vs. natural)
- Cooking method (al dente pasta)
- Type or variety (converted long-grain vs. short-grain rice)
- Acidity of foods (vinegar)
- Individual differences in response

- Eaten alone or part of mixed meal
- Amount eaten (total carbs, GL)

# Glycemic Load

- Incorporates both **GI** and **portion size**
- **Subtracts out grams of fiber**

$$GL = \frac{(\text{Glycemic index}) \times (\text{grams of non-fiber carbohydrate in one serving})}{100}$$

The following values are used to rank the glycemic load of foods:

- 20 or more—High GL foods
- 19-11—Medium GL foods
- 10 or less—Low GL foods

# Typical Glycemic Load Values

*Some examples of Glycemic Index (GI) and Glycemic Loads (GL) of common foods taken from the international tables [8]*

| Food | GI | Serving size (g) | Available carbs (g) | GL |
|---|---|---|---|---|
| Watermelon | 72 | 120 | 6 | 4 |
| Ice cream, premium (high-fat) | 37 | 50 | 9 | 4 |
| Spaghetti, white, boiled 5 min | 32 | 148 | 48 | 15 |
| Skittles (Mars Confectionery, Australia) | 70 | 50 | 45 | 32 |
| Baked potato Ontario, white, baked in skin (Canada) | 60 | 150 | 30 | 18 |
| Sushi, salmon (I Love Sushi; Australia) | 48 | 100 | 36 | 17 |
| Carrots, NS (Canada) | 92 | 80 | 6 | 5 |
| Rice cracker, plain (Sakada, Japan) | 91 | 30 | 25 | 23 |

Search database at www.glycemicindex.com

# GI/GL of Select Hawaiian Foods

- **Dasheen** (Jap. taro, boiled)—57 g carbs, 1 cup mashed
  - GI 75 (high); GL 43 (high)
- **Mochi** (glutinous rice ball)—28 g carbs, 4 1-in cubes
  - GI 48 (low); GL 13 (medium)
- **Breadfruit** (‘ulu, raw)—27 g carbs (1/2 cup)
  - GI 68 (medium); GL 18 (medium)

# GI/GL of Select Hawaiian Foods

- **Papaya** (paw paw)—30 g carbs, 1 medium
  - **Ripe:** GI 55 (low); GL 17 (medium)
  - **Raw:** GI 60 (medium); ***GL 9 (low)—only 15 g carbs***

- **Bananas**—~25 g carbs, 1 large (8-9”)
  - **Under ripe:** GI 30 (low); ***GL 6 (low)***
  - **Almost ripe:** GI 42 (low); GL 11 (medium)
  - **Ripe:** GI 51 (low); GL 13 (medium)
  - **Over ripe:** GI 48 (low); GL 12 (medium)
  - **All trials:** ***GI 46-62 (low to medium);*** GL 11-16 (medium)

# Use of GI/GL in Diabetes

- Low-GI foods and meals produce lower glycemic responses (studies in T1D)
- Risk of mild hypoglycemia is greater with low-GI than with high-GI foods

- **Low-GI foods more likely to cause early hypoglycemia**
  - Correlation between GI and time to hypoglycemia
  - Each unit increase in GI delaying hypoglycemia by 1 min

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Use of Food Insulin Index (FII)

- FII is based on insulin demand evoked by *1,000-kJ food portions* (calories) in healthy subjects
- **Accounts for all nutritional and metabolic factors affecting insulin demand, not just macronutrients**

- **Improves glycemia in the 3-h postprandial period**, but relatively short postprandial monitoring may not have detected delayed impact of fat and protein

Bell et al. *Eur J Clin Nutr,* 68:1055–1059, 2014

# Impact of Mixed Meals

- Systematic review of 21 studies on glycemic effect of fat (n = 7), protein (n = 7), and GI (n = 7)

- **Fat, protein, and GI all modify postprandial glycemia**
- **Late postprandial hyperglycemia the predominant effect of dietary fat**
- **In some with high fat intake, glucose reduced in the first 2–3 h**, possibly due to delayed gastric emptying

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Impact of Mixed Meals

- 10 studies on insulin bolus dose and delivery patterns required for high-fat and/or high-protein meals
- Results inconsistent regarding optimal bolus delivery pattern (due to study design differences), but…

- **High-fat/protein meals require more insulin than lower-fat/protein meals with identical carbohydrate content**

- **Marked interindividual differences in fat sensitivity**

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Protein with Carbohydrate

- Protein affects postprandial glycemia, but **effects differ when consumed with and without carbohydrates**
- Addition of 35 g protein to 30 g carbohydrates increased blood glucose by 2.6 mmol/L (47 mg/dL) at 5 hours

- **Effect of fat and protein additive**, with blood glucose concentrations increasing by 5.4 mmol/L at 5 hours
  - Sum of individual incremental increases for protein and fat

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Protein *without* Carbohydrate

- **Effect of protein only (with no carbs and fat) less**
- Addition of 12.5–50 g protein with no effect
- **75 and 100 g protein** increases glucose
  - Reached peak at the conclusion of the 5-hour study
  - Increase in similar to that of **20 g carbs** without insulin

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Unanswered Questions (T1D)

- How much fat does there need to be in a meal before a clinically significant glycemic effect becomes apparent?
- Is there a threshold and/or dose response (i.e., more fat requires more insulin)?
- Do all types of fat and protein have similar effects?

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Unanswered Questions (T1D)

- Are there phenotypic characteristics that can be used as markers to identify individuals with diabetes who are more nutrient sensitive and will require more insulin to cover higher-fat/protein meals?

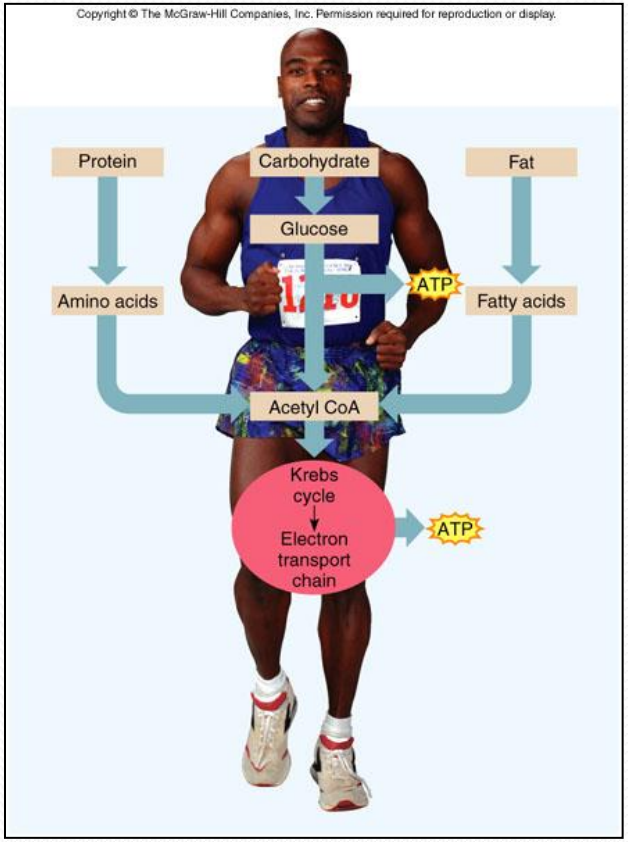
- What are the optimal insulin dose adjustments needed for common meals with varying fat and protein content?

Bell et al. *Diab. Care,* 38(6):1008-1015, 2015

# Role of Macronutrients in Exercise

# Exercise Fuels

- **ATP-PCr System** (Phosphagens)
  - Stored ATP, PCr only (10 seconds)
- **Lactic Acid System** (Glycolysis)
  - Muscle glycogen exclusively (2 min)
- **Oxygen System** (Aerobic)
  - Use of all fuels possible (over 2 min)



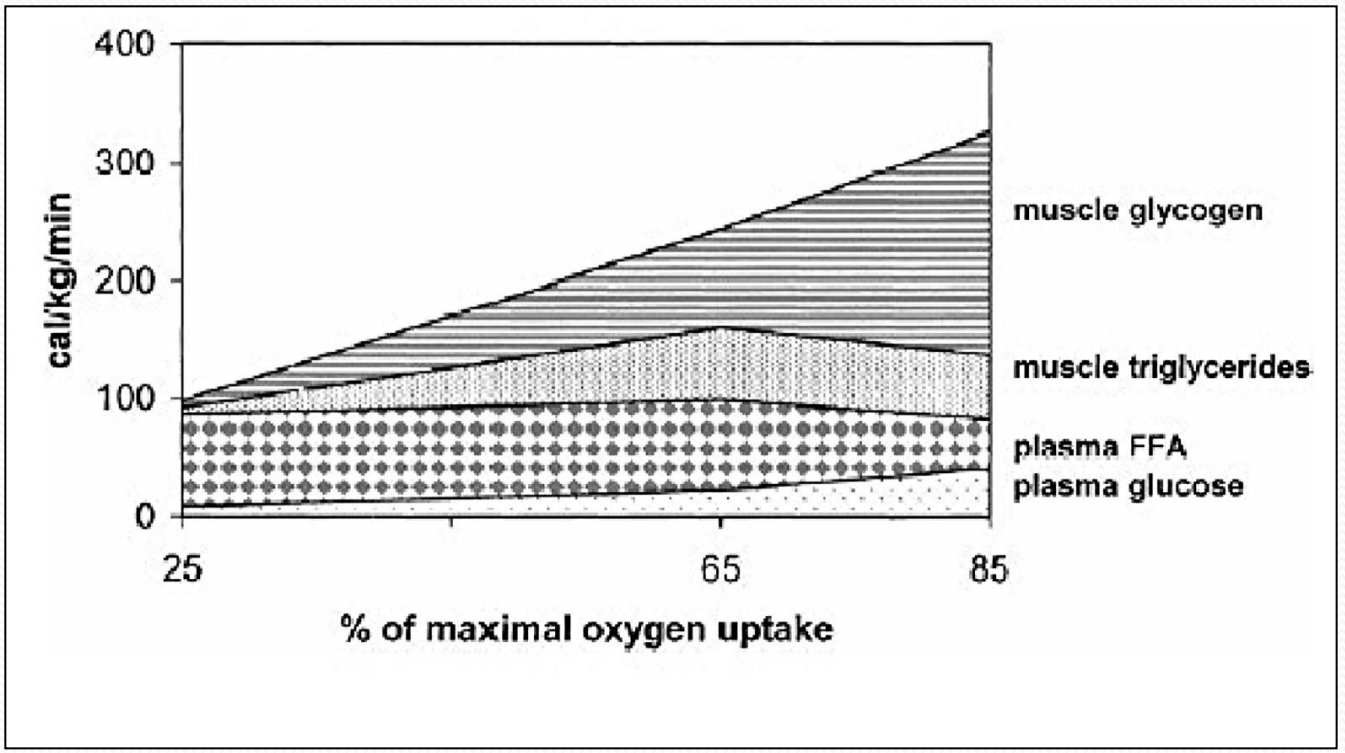
# Exercise Fuel Use by Intensity

- Carb use more “fuel efficient” (more kcals/L oxygen)
- Fat is major energy source for low-intensity ex

- Blood glucose and fat (FFA) use greater during mild exercise (done at < 50% maximal)
- Muscle glycogen and TG used during higher intensity

- Training ↑ ability to use both fuels

# Carbs Used Most for Exercise




- For most exercise (moderate or higher), carbs are main fuel
  - Muscle glycogen (~80%), blood glucose (20%)

Romijn JA et al., *JAP*, 88(5): 1707-1714, 2000

# Limited Carbohydrate Stores

**TABLE 4.5** Approximate carbohydrate stores in the body of a normal, sedentary adult

| Source | Amount in grams | Equivalent amount in calories |
|---|---|---|
| Blood glucose | 5 | 20 |
| Liver glycogen | 75–100 | 300–400 |
| Muscle glycogen | 300–400 | 1,200–1,600 |

# Glucose Use with Exercise

- BG uptake into muscles occurs 2 ways:

  (1) Insulin

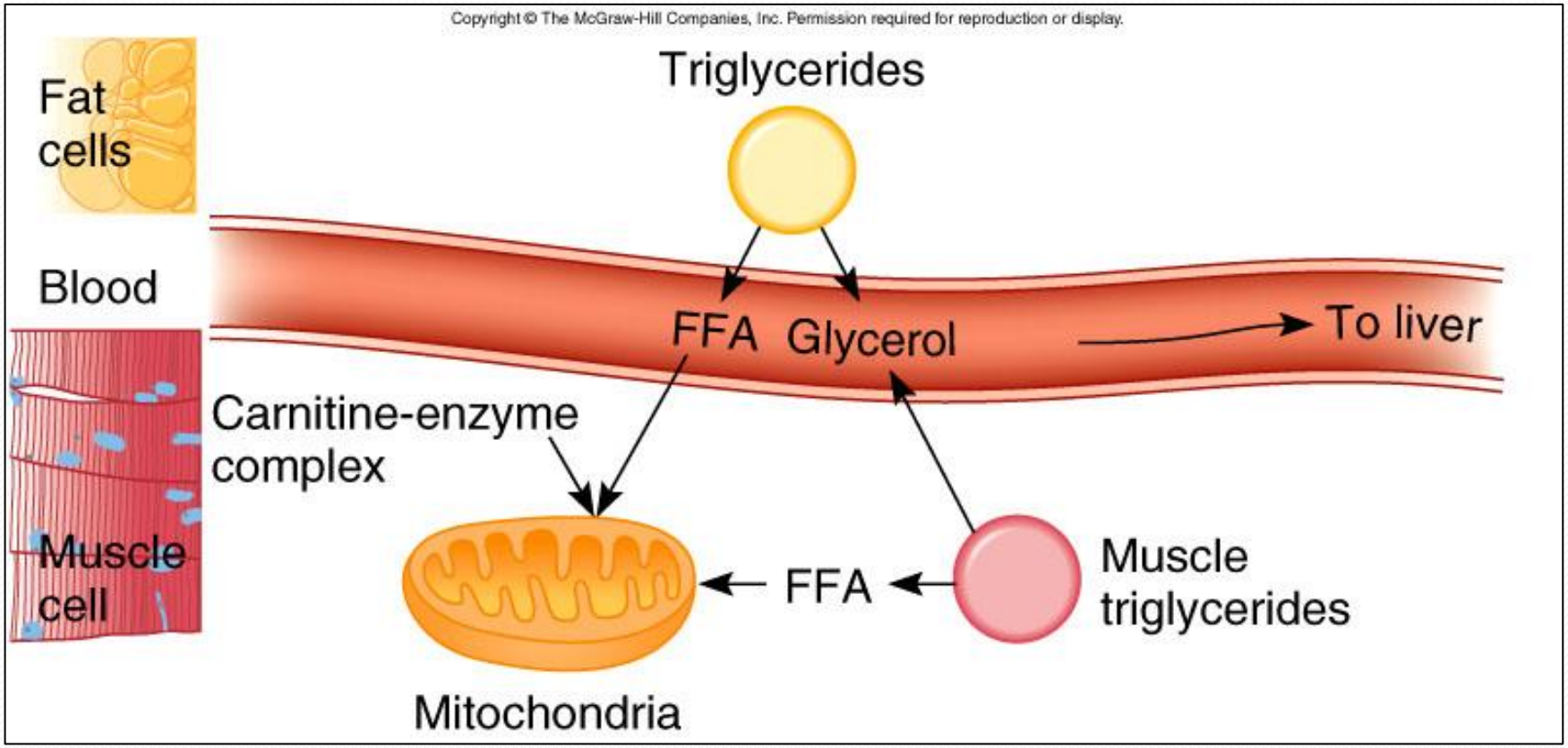
  - Rest
  - Exercise


  (2) Contractions

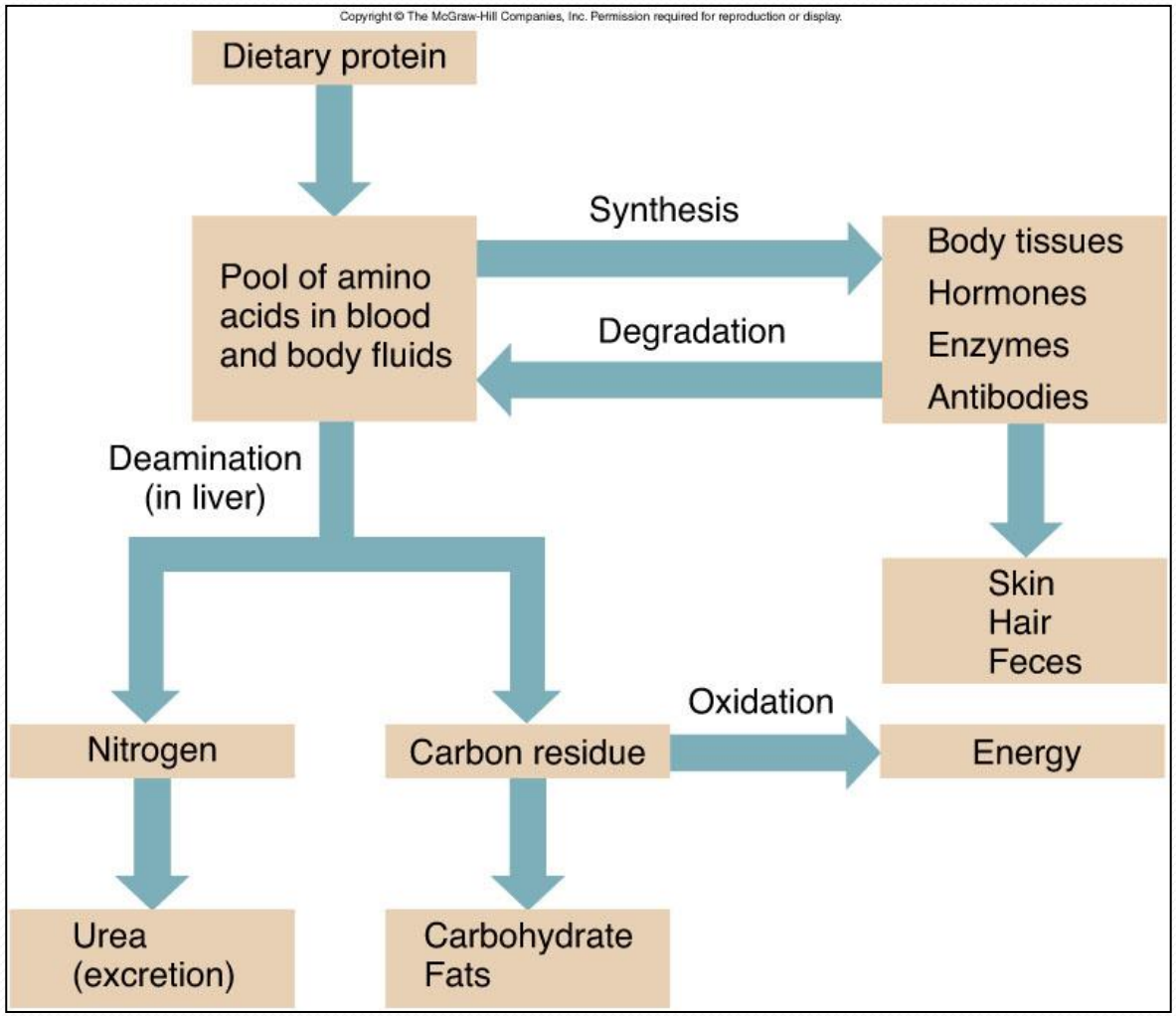
  - Exercise

- Separate, but *additive* mechanisms

# FFA Use During Exercise



# Protein Use for Exercise (<5%)



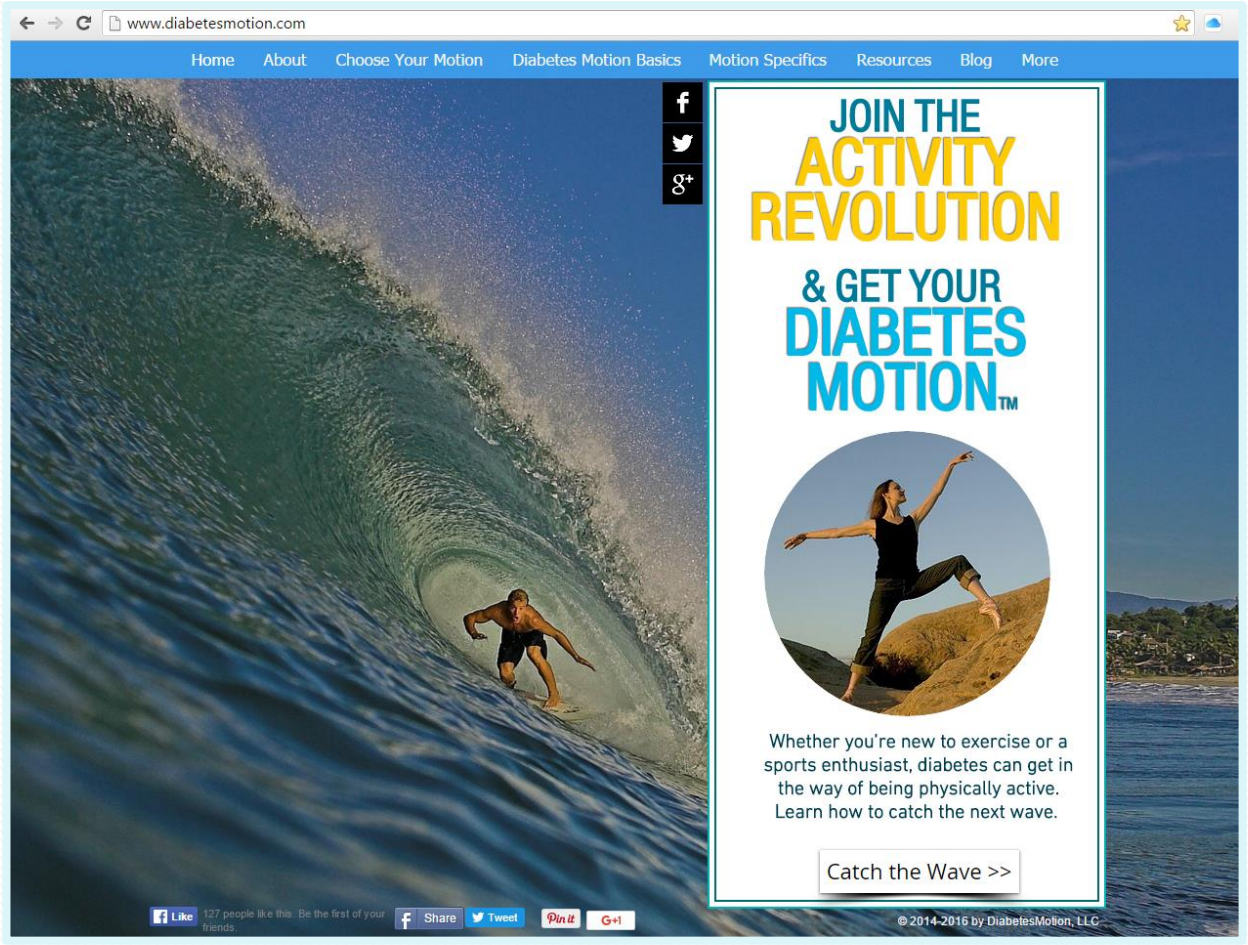
# Protein Intake for Athletes

- Athletes need at least the RDA for protein (0.8-1.0 gm/kg body weight), but likely more
- At 12% of calories, protein intake averages 1.5-1.7 g/kg, so most athletes already consume this
- Increasing calorie intake decreases need for protein

# Final Conclusions

- No single ideal dietary distribution of carbohydrates, fats, and proteins for PWD (but carbs matter)
- Focus on fiber, plant proteins, and type of fat for health
- GI and GL may better predict blood glucose responses
- Protein and fat have delayed effects on glycemia, but how to factors in these effects for all PWD is less clear
- Exercise is primarily fueled by carbs and fat, with carb use greatest during moderate or higher intensity

# Resources




www.DiabetesMotion.com

# QUESTIONS?