



# Energy Balance

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- Principle of energy balance
- Body energy stores
- Components of intake
  - Energy substrates
  - Energy values
  - Regulation
- Components of expenditure
  - Definitions
  - Predicting expenditure



# Abbreviations & acronyms

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- Ein-energy intake
- TEE-total energy expenditure
- CHO-carbohydrate
- PRO-protein
- EEPA-energy expended in physical activity
- TEM-thermic effect of meals
- FFM-fat-free mass
- CVD-cardiovascular disease
- METS-metabolic equivalents (multiples of RMR)

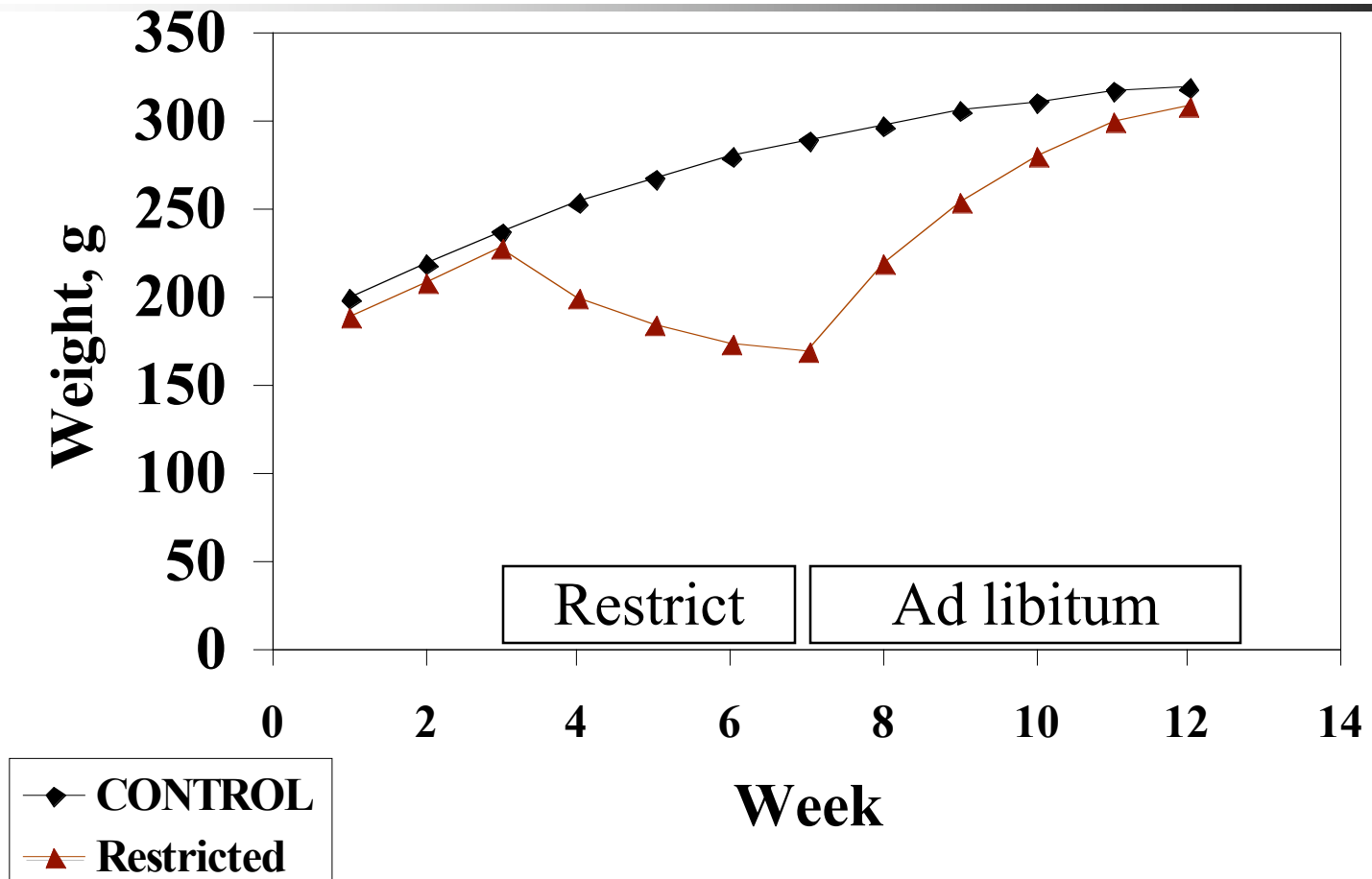
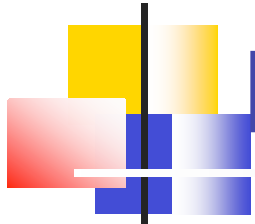


# Energy balance

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- Energy expenditure = energy intake -  $\Delta$  body stores
- Positive balance
  - $E_{in} > TEE$
  - Weight gain (usually)
- Negative balance
  - $TEE > E_{in}$
  - Weight loss (usually)

# Regulation of Energy Metabolism





# Energy value (density) of tissue

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- Adipose tissue

- 80% fat, 15% water, 5% protein
- 7800 kcal/kg (3600 kcal/lb)

- Muscle

- 2% fat, 2% CHO, 73% water, 21% protein
- 1200 kcal/kg (500 kcal/lb)

- Glycogen

- 25% CHO, 75% water
- 1100 kcal/kg (500 kcal/lb)

# Body energy stores – 70 kg

## Male

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- Adipose tissue
  - 15 kg = 12 kg fat      117,000 kcal
- Glycogen
  - 2 kg = 500 g CHO      2,200 kcal
- Skeletal muscle
  - 28 kg = 5.9 kg Pro      (34,000 kcal)
- Viscera
  - 22 kg = 4.6 kg Pro      (26,000 kcal)
- Bone



# Energy intake

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- Macronutrients
  - Fat
  - Protein
  - Carbohydrate



# Atwater Factors – kcal/g

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Gross Energy  
CHO = 4.10  
Fat = 9.47  
PRO = 5.65

Fecal loss

Digestible Energy  
CHO = 4.0  
Fat = 9.0  
PRO = 5.2

Urinary loss

Metabolizable Energy  
CHO = 4.0  
Fat = 9.0  
PRO = 4.0



# Energy Requirement

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- Energy intake that maintains
  - Normal body weight
  - Normal rate of growth
  - Normal activity pattern



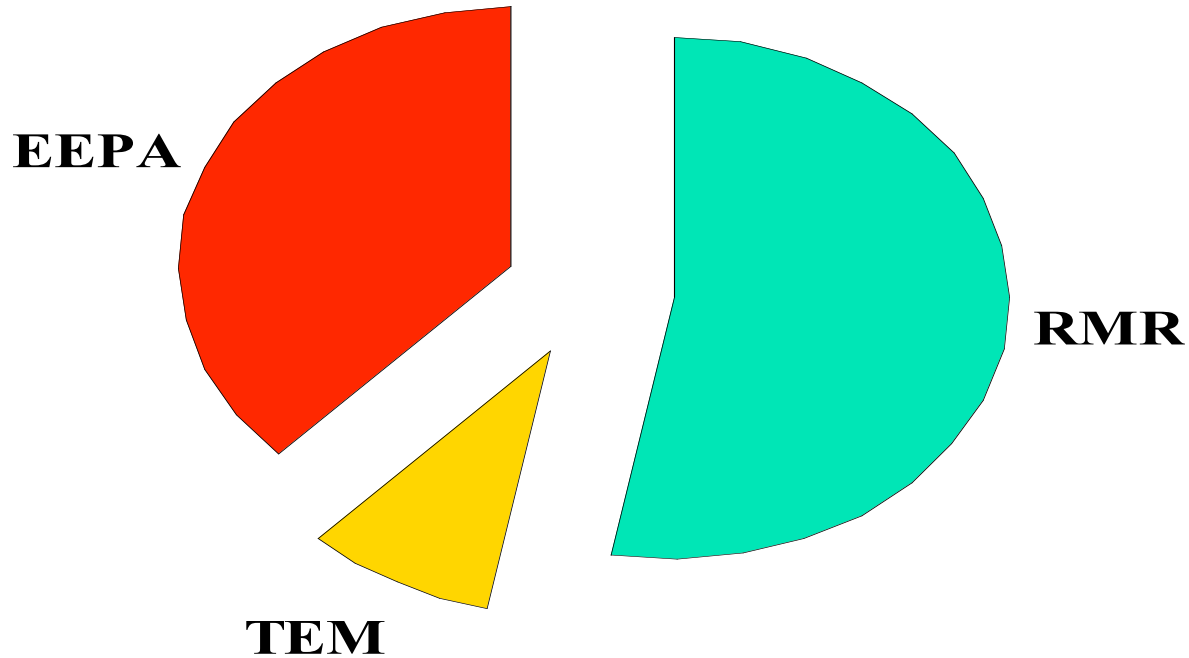
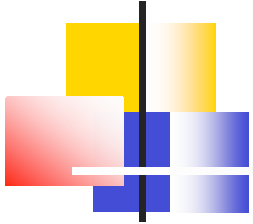
# Energy for growth

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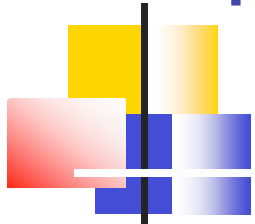
- $\Delta$ body stores is usually small
  - 1 m old infant
    - $5.8\text{g/kg/d} \times 4.1\text{kcal/g} = 100\text{kcal/d}$  (25% of Ein)
  - 6 m old infant
    - $1.8\text{g/kg/d} \times 3.2\text{ kcal/g} = 45\text{kcal/d}$  (7% of Ein)
  - 14 y old male
    - $0.5\text{g/kg/d} \times 2\text{kcal/g} = 50\text{kcal/d}$  (2% of Ein)
  - Pregnant women
    - $1\text{g/kg/d} \times 4.1\text{kcal/g} = 220\text{kcal/d}$  (9% of Ein)
  - Nonpregnant adult
    - $0\text{g/kg/d} = 0\text{kcal/d}$  (0% of Ein)

**Total Energy Expenditure =  
Resting Metabolic Rate  
+ Thermic Effect of Meals  
+ Energy Expenditure of Physical Activity**

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# Resting Metabolic Rate (post absorp)



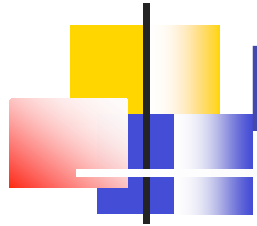
- Defn:

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- RMR: Rate of energy expenditure when subject is lying down at rest, at thermal neutrality, 12-15 h after the last meal.

- Alternate terms:

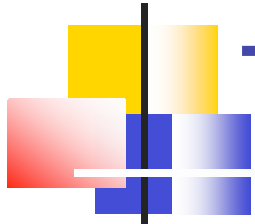
- Basal Metabolic Rate-BMR
- Resting Energy Expenditure- REE
- Sleeping metabolic rate-SMR
  - Lowest sustained MR during sleep
  - $1-5\% < \text{RMR}$



# Resting Metabolic Rate

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- 60 – 70% of TEE
- Function of
  - Body size
    - 0.9 or 1 kcal/kg/h
  - Body composition
    - 21.6 FFM + 370 kcal/d
  - Plane of nutrition (energy balance)
    - $\pm$  200 kcal/d

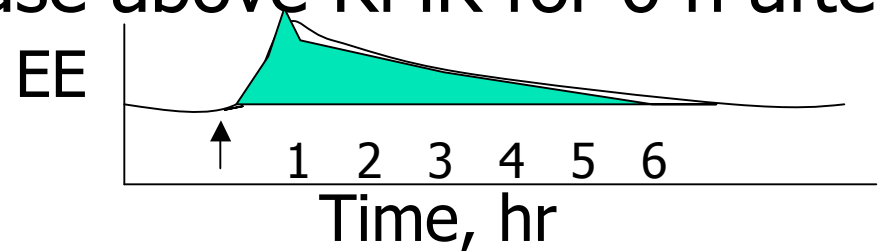


# Thermic Effect of Meals

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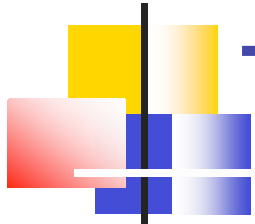
- Defn:

- TEM: The increase above RMR for 6 h after a meal.



- Alternate terms

- Specific Dynamic Action – SDA
- Dietary Induced Thermogenesis-DIT
- Thermic Effect of Food-TEF



# Thermic Effect of Meals

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- 5-10% of food energy
- Function of
  - Meal composition
    - Protein: 20-30%
    - CHO: 5-10%
    - Fat: 3-5%
  - Meal size
    - If E absorption rate < RMR, TEM is small



# Energy Expenditure of Physical Activity

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- Energy expenditure above RMR due to bodily movement produced by the contraction of skeletal muscle
- Alternate terms
  - Physical activity
  - Exercise induced thermogenesis



# Characteristics of Physical Activity

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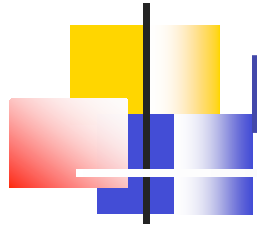
- Duration
- Intensity
- Frequency
  
- Also
  - Type
  - Muscle group involvement
  - purpose



# Physical Activity Tables

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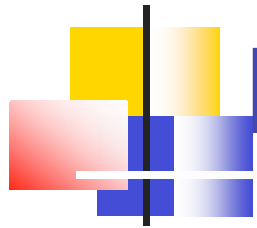
- METS = metabolic equivalents
  - 3 METS = 3 x 1 kcal/kg/h
- Examples
  - Walking, 3 m/h 3.5
  - Running, 7 min mile 14.0
  - Bicycling, light <10 m/h 4.0
  - Computer use 1.5
  - Golf, walk 5.0
  - Shoveling snow 6.0



# Predicting Energy Requirements

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- Three methods
  - Factorial Approach
  - Activity Coefficient
  - Estimated Energy Requirement - DRI



# Factorial Approach

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- Calculate (or measure) RMR
  - Based on body weight
  - Based on body composition
  - Use indirect calorimetry
- Obtain a physical activity record
  - Diary (activity in each time block)
  - Recall (minutes per day spent in PA)
  - Calculate energy expended in PA
- Sum RMR and PA



# Example

- 55kg female

## Activities

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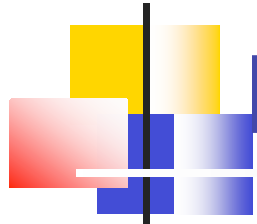
- 1 h/d walking to class, 4 MET
- 30 min run every other day , 0.25h/d at 10 MET
- 6 h/d sitting 1.5 MET
- 7 h 30 min sleep
- 9 h/d light activity *by diff*, 2 MET
- SMR:  $0.9\text{kcal/kg/h} \times 55\text{kg} \times 7.5\text{h} = 371 \text{ kcal}$
- waking:
  - $(4) \times 1 \text{ h} + (10) \times 0.25 + (1.5) \times 6 + (2) \times 9$   
 $= 33.5 \text{ MET hr}$
  - $33.5 \text{ MET h} \times 1 \text{ kcal/kg/hr} \times 55\text{kg} = 1842 \text{ kcal}$
- TEE
  - $(371 \text{ kcal/d} + 1842 \text{ kcal/d}) = 2213 \text{ kcal/d}$
- TEM traditionally assumed part of PA



# Activity Coefficient

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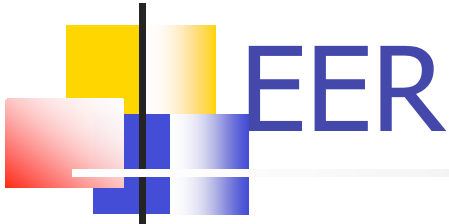
- Predict RMR
- Multiply by estimated activity level
  - Bed rest = 1.15
  - Light = 1.4
  - Moderate = 1.6 (average)
  - Heavy = 2.0
  - Exceptional = 2.3
- Multiply by 1.1 for TEM
- Precision: 15-20%



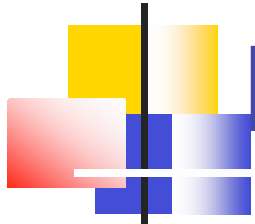
# Estimated Energy Requirements

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- Before 1985 – based on energy intake
- 1985 - World Health Organization Energy Committee recommended expenditure-factorial method  
requirement =  $RMR_{calc} \times \text{Activity factor}$
- 2002 DRI – recommends measured TEE to predict an EER



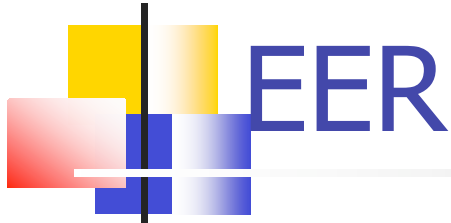
- Differs in concept from RDA
  - Individualized
  - Aims for average
    - No safety factor to include 98% of healthy population
    - similar to EAR
    - Why?
  - Ultimately must be tested against individual weight
    - Why?



# EER

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- For females 19 years and older
- $EER [Kcal/d] = 354 - (6.91 * A[y]) + PA * (9.36 * Wt[kg] + 726 * Ht[m])$ 
  - PA=1.0 if sedentary
  - PA=1.12 if low active
  - PA=1.27 if active
  - PA=1.45 if very active

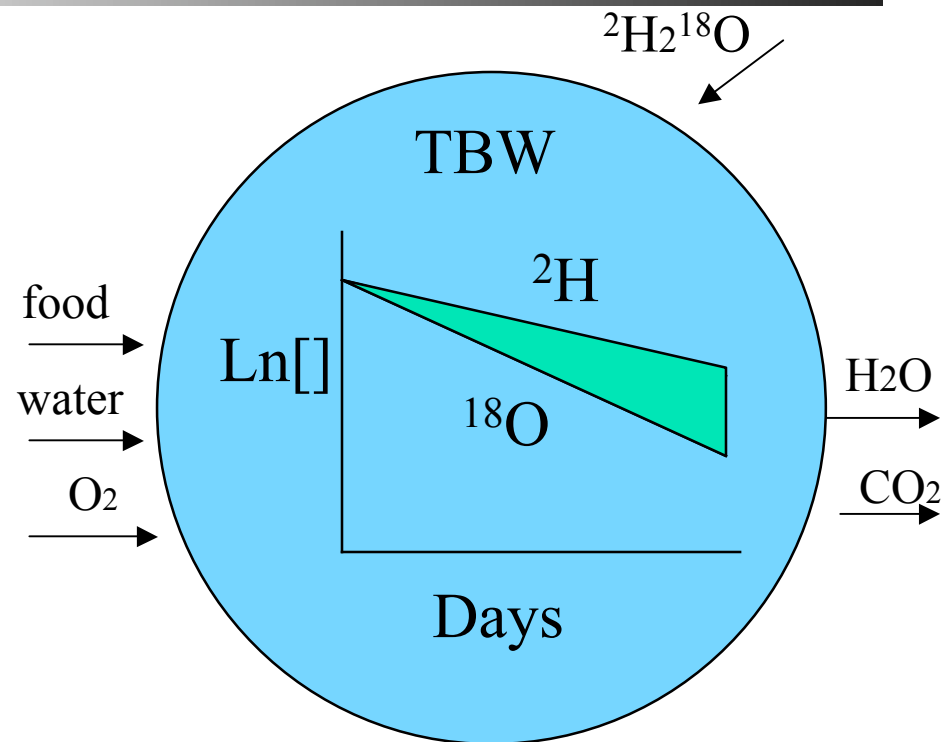


- Measuring TEE using Doubly Labeled Water
- Form of indirect calorimetry
  - Measures CO<sub>2</sub> production
  - Calculate heat production
- Based on differential turnover of H and O in body water
- Uses stable (nonradioactive) isotopes

# Doubly Labeled Water

$$TEE = RMR + TEM + EEPA$$

- Sums RMR+TEM+EEPA
- Uses the dilution principle
  - $C_1V_1=C_2V_2$ , where  $C_2 = TBW$
- Concentration decreases with time due to "turnover"
- Tracers turnover at different rates.
  - $^2H$  lost as water
  - $^{18}O$  lost as water &  $CO_2$
- $rCO_2 = \frac{1}{2} * TBW(k_O - k_D)$





# Problem with DRI

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- DLW - good group TEE data
- Individual CV=15%
  - Physical activity highly variable between individuals
- Individual estimates of energy requirement still require the factorial approach



# Health Benefits of > 4 h/wk Heavy Exercise

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Disease	approx. reduction
CVD-death	50%
Hypertension	25%
Diabetes	25%
Breast cancer	25%
Prostate cancer	50%