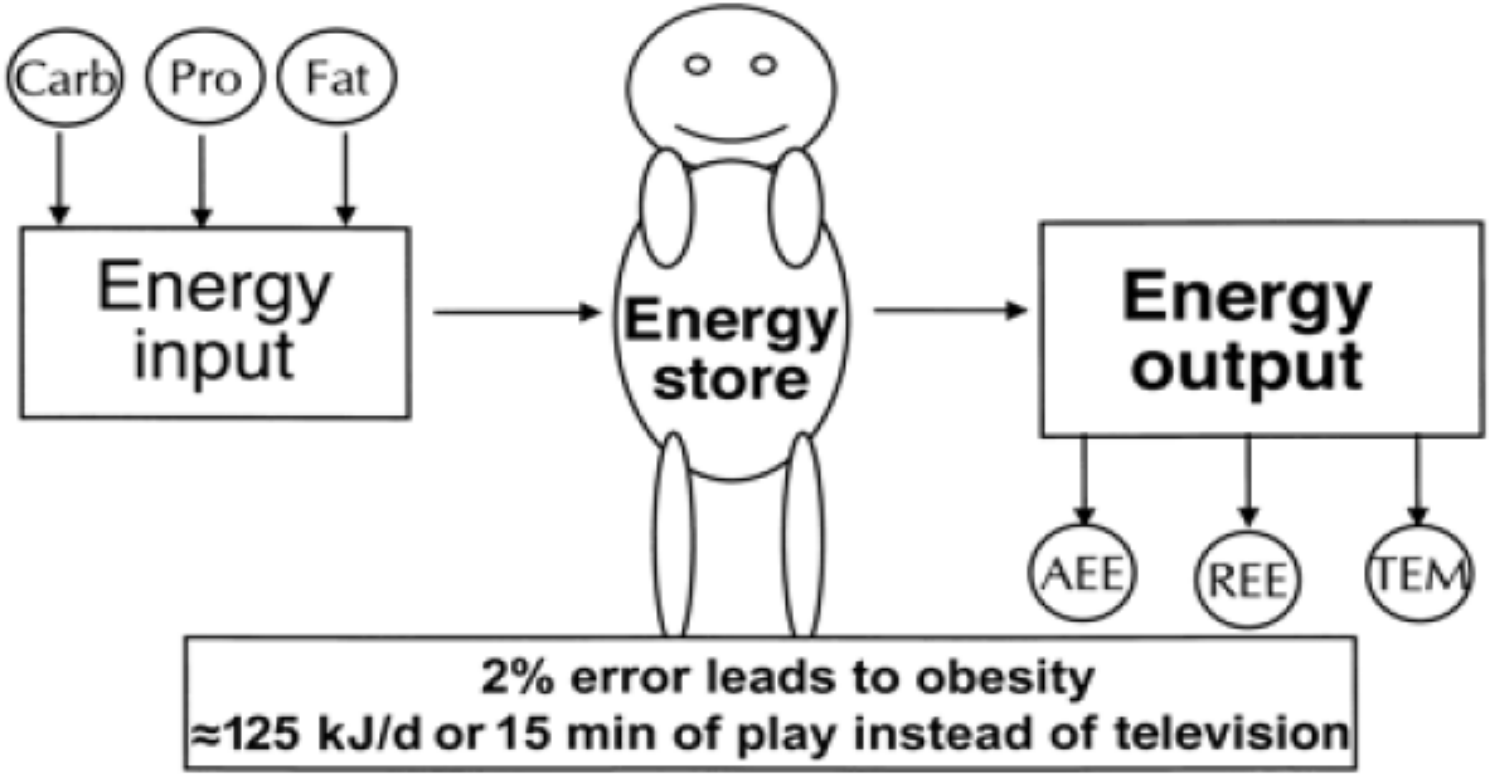
Energy balance and Energy expenditure

Energy balance

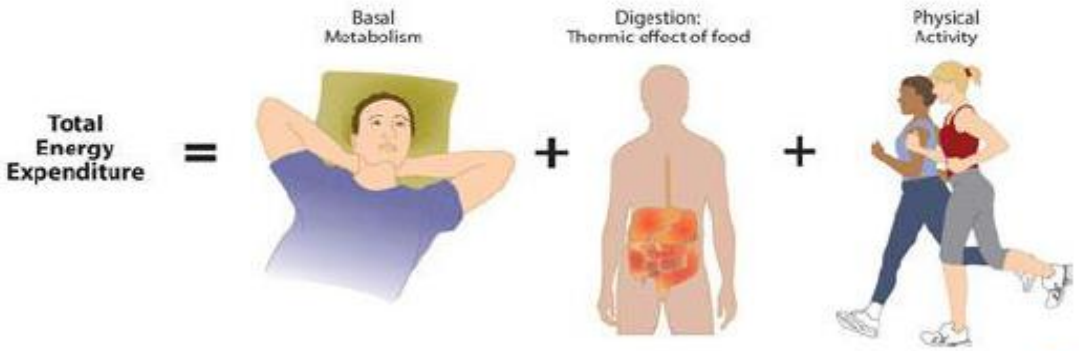


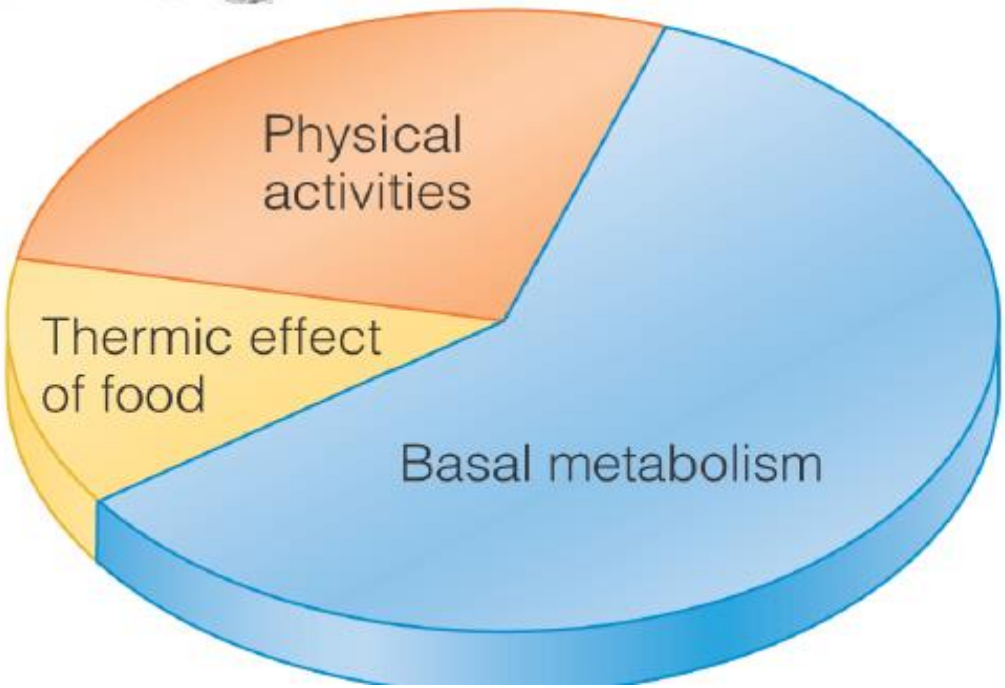
- Total body energy expenditure represents the conversion of oxygen and food (or stored forms of energy such as fat, glycogen and protein) to carbon dioxide, water, heat and

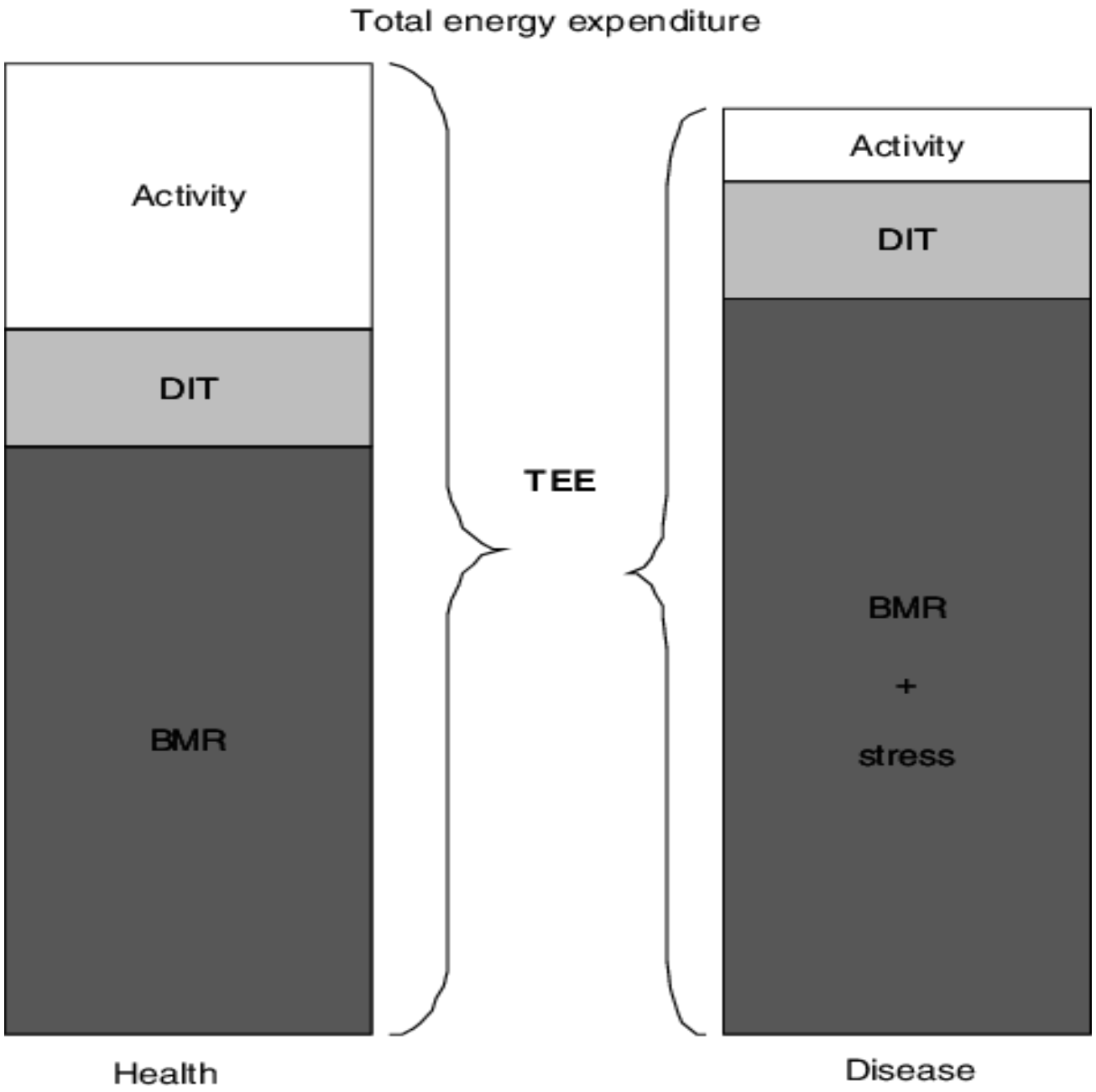
  work on the environment.

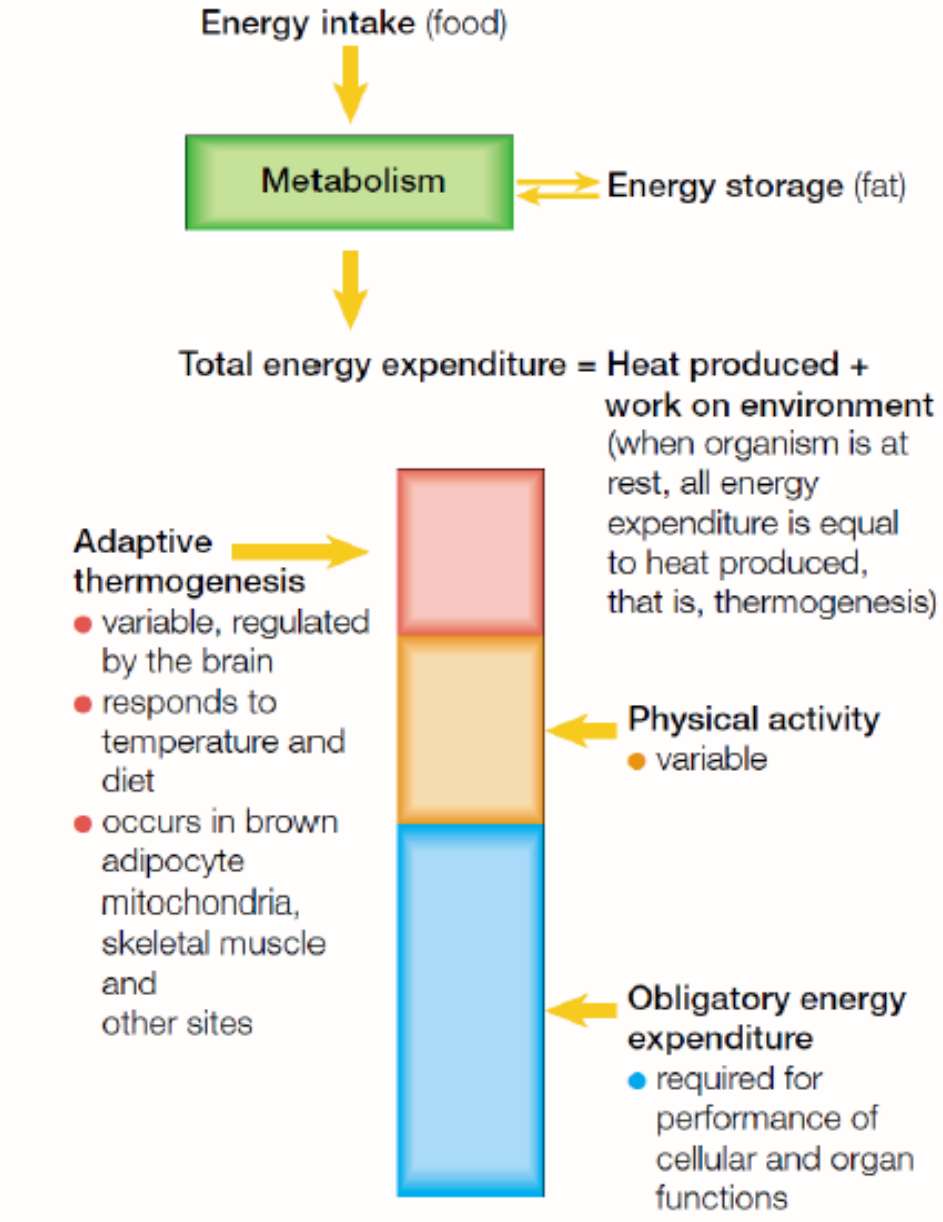
- BasalEnergy Expenditure(BEE)
- PhysicalActivity (PA)
- AdaptiveThermogenesis

Components of Energy Expenditure






Total energy expenditure
Activity
DIT
BMR
TEE
Activity
DIT
BMR
+
stress
Health
Disease



Basal Energy Expenditure
or
Basal Metabolic Rate

Basal energy Expenditure (BEE, BMR)

Represents the minimal energy required for body vital function maintenance.

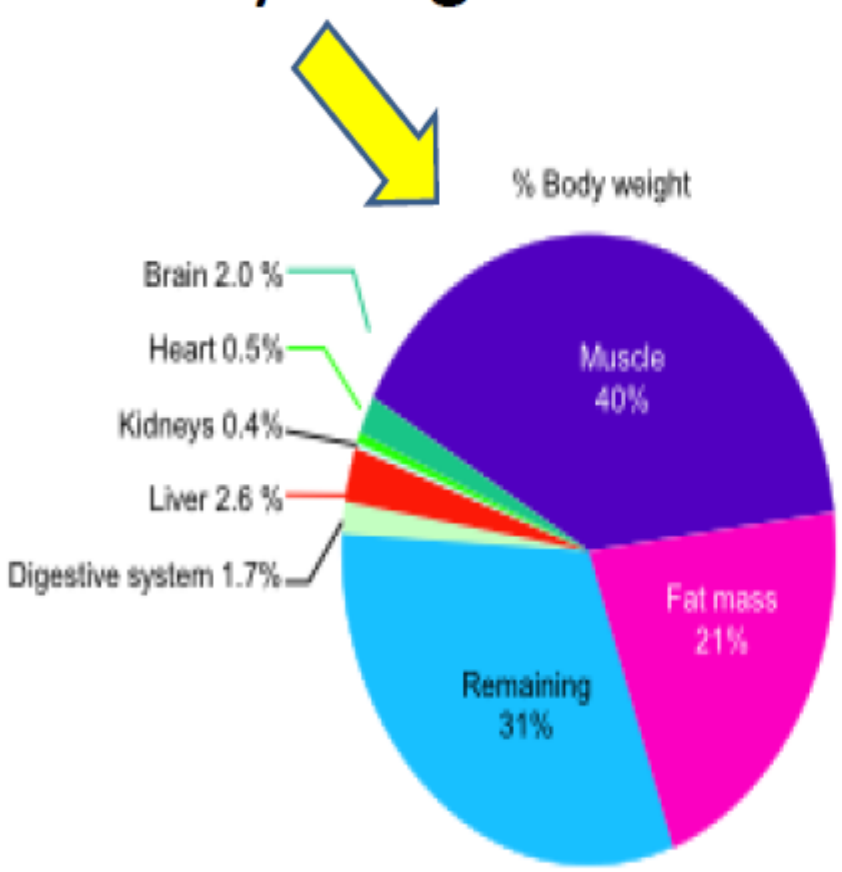
The BEE contributes for 50% to 70% of daily energy requirement.

The measurement of BEE requires the subject to sleep overnight in the metabolic unit. Thus the resting energy expenditure (REE) is usually measured.

Organ contribution

- The body's major organs —the brain, liver, kidneys, and heart —account for about half of the energy burned at rest, while fat, the digestive system, and especially the body's muscles account for the rest.

Contribution of organs and tissues to bodyweight and basal metabolic rate



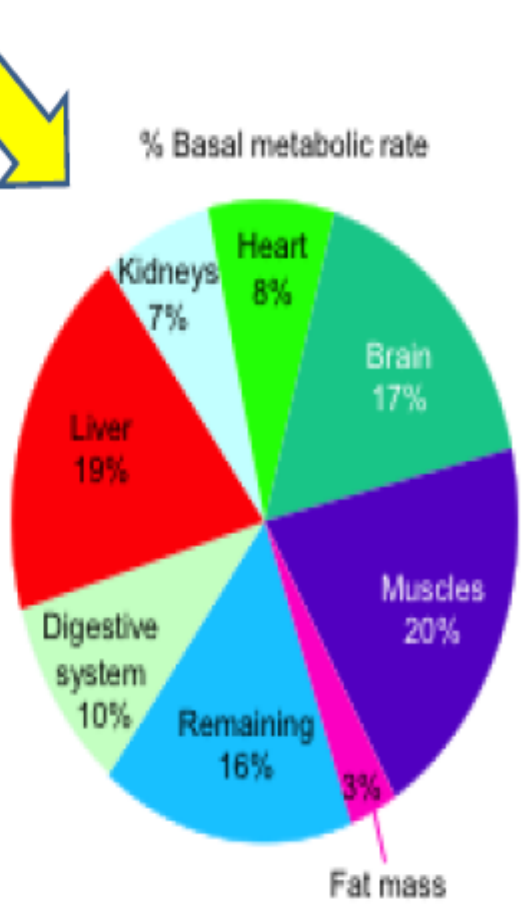


TABLE 8-1 Factors That Affect the BMR

Factor	Effect on BMR
Age	Lean body mass diminishes with age, slowing the BMR.[a]
Height	In tall, thin people, the BMR is higher.[b]
Growth	In children and pregnant women, the BMR is higher.
Body composition (gender)	The more lean tissue, the higher the BMR (which is why males usually have a higher BMR than females). The more fat tissue, the lower the BMR.
Fever	Fever raises the BMR.[c]
Stresses	Stresses (including many diseases and certain drugs) raise the BMR.
Environmental temperature	Both heat and cold raise the BMR.
Fasting/starvation	Fasting/starvation lowers the BMR.[d]
Malnutrition	Malnutrition lowers the BMR.
Hormones (gender)	The thyroid hormone thyroxin, for example, can speed up or slow down the BMR.[e] Premenstrual hormones slightly raise the BMR.
Smoking	Nicotine increases energy expenditure.
Caffeine	Caffeine increases energy expenditure.
Sleep	BMR is lowest when sleeping.

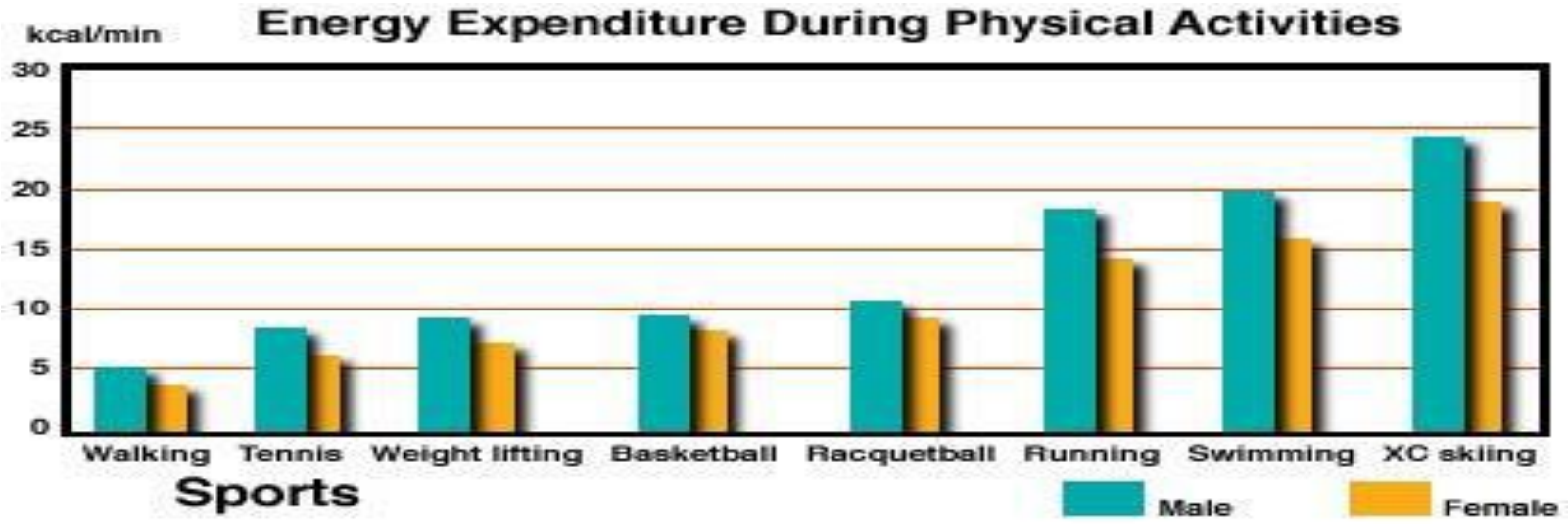
Resting Energy expenditure

- Is the rate of energy expenditure by humans and other animals at rest.
- Influenced by many factor

- REE is 3-10% higher than BEE due to diet induced thermogenesis (DIT) and recent PA.

Physical activity

- Physical activity is defined as any body movement resulting in energy expenditure higher than resting
- Represents the thermic effect of any movement that exceeds BEE.
- Great variability inter and intra individual: from two times the BEE to less than half of the BEE.



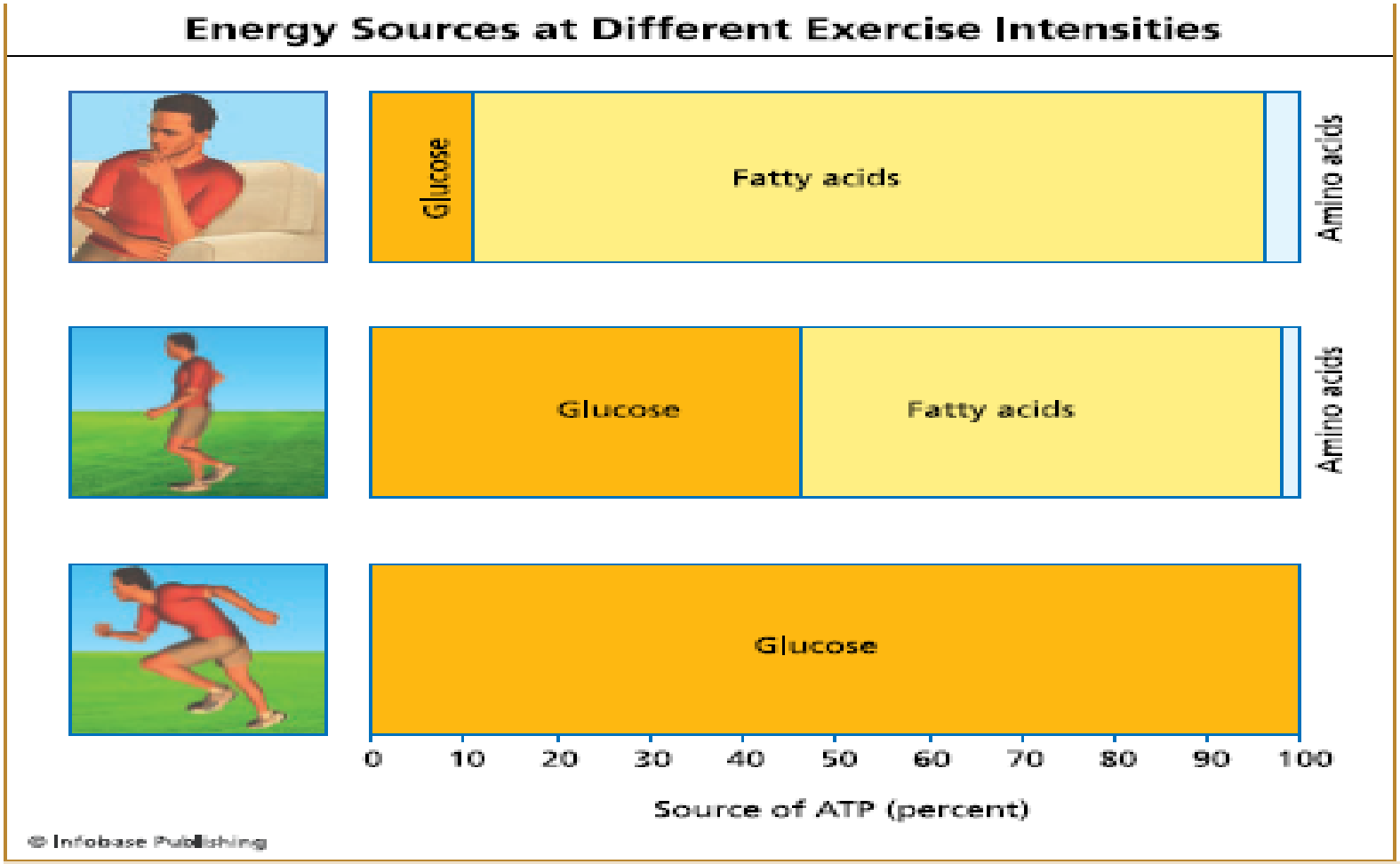


FIGURE 4.3 Blood flow to muscles increases dramatically during strenuous exercises, as shown by the yellow area on this graph. At rest, the muscles primarily use fatty acids as a fuel. Fatty acids are also an important fuel during moderate-intensity exercise. However, when exercise intensity is high, almost all of the energy for muscle contraction comes from glucose.

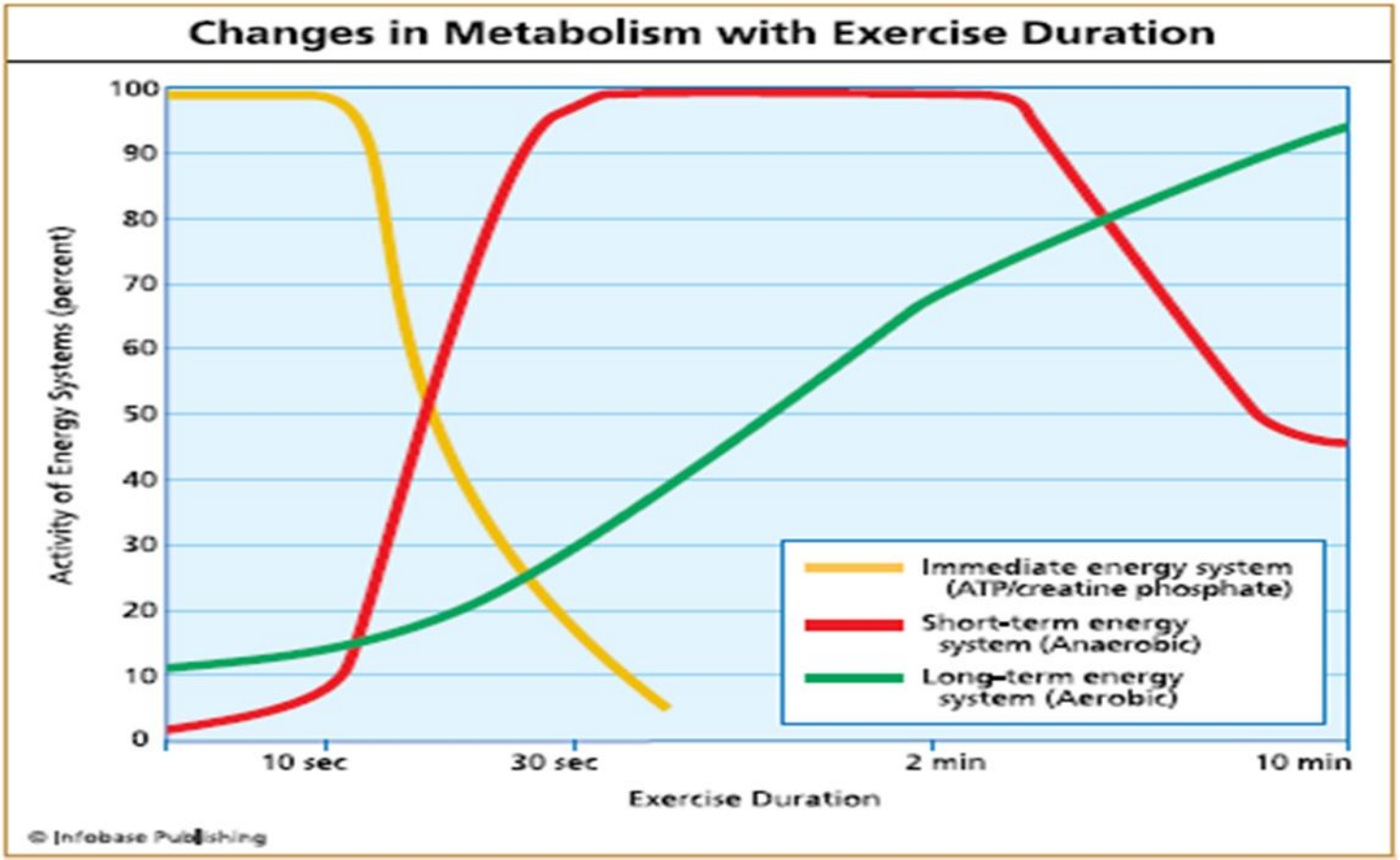


FIGURE 4.1 When exercise first begins, the muscles obtain energy from stored ATP and creatine phosphate. By 30 seconds into the activity, anaerobic pathways are operating at full capacity. Aerobic metabolism begins to make a significant energy contribution by about two minutes after the exercise has begun, and it is responsible for producing the energy needed for longer-term activity.

MET: metabolic equivalence

The **metabolic equivalent of task (MET)** is the objective measure of the ratio of the rate at which a person expends energy, relative to the mass of that person, while performing some specific physical activity compared to a reference (resting).

Measured according to O2 utilization and body mass.

MET affected by Duration (min) and Intensity (VO2& kCal)

Guidelines have recommended using metabolic equivalent of task (METs) as reference thresholds of absolute intensities (light < 3, moderate 3- 5.9, high >6)

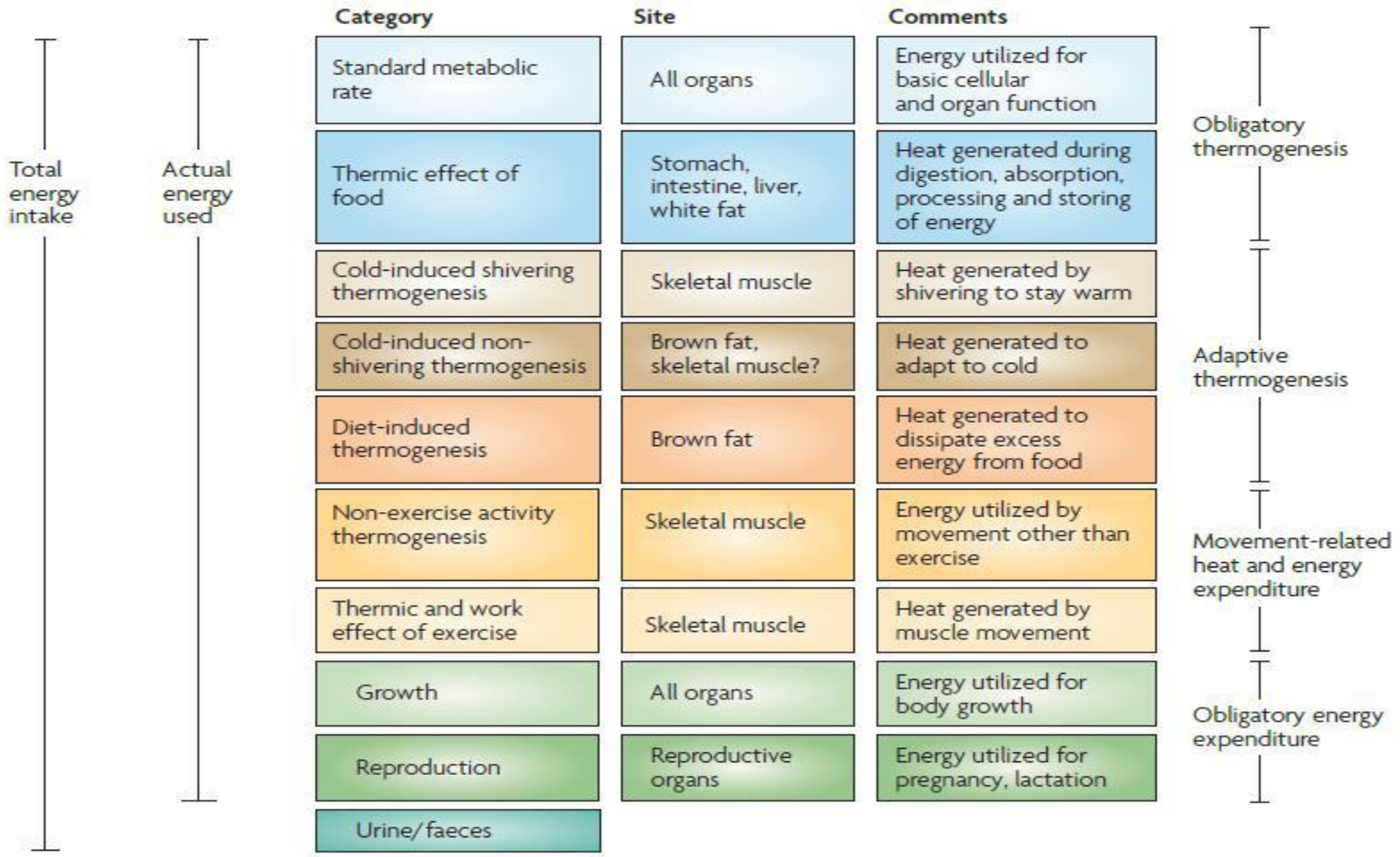
- **V02** max. **V02** max is defined as the maximal volume of oxygen that the body can deliver to the working muscles per minute. This is an excellent measure of physical fitness because it provides a metric of efficiency.

Table 8•3 Five-Level Classification of Physical Activity Based on Exercise Intensity

	ENERGY EXPENDITURE[a]			
	MEN			
LEVEL	kCal·min^{-1}	L·min^{-1}	mL·kg^{-1}·min^{-1}	METs
Light	2.0–4.9	0.40–0.99	6.1–15.2	1.6–3.9
Moderate	5.0–7.4	1.00–1.49	15.3–22.9	4.0–5.9
Heavy	7.5–9.9	1.50–1.99	23.0–30.6	6.0–7.9
Very heavy	10.0–12.4	2.00–2.49	30.7–38.3	8.0–9.9
Unduly heavy	12.5–	2.50–	38.4–	10.0–
	WOMEN			
	kCal·min^{-1}	L·min^{-1}	mL·kg^{-1}·min^{-1}	METs
Light	1.5–3.4	0.30–0.69	5.4–12.5	1.2–2.7
Moderate	3.5–5.4	0.70–1.09	12.6–19.8	2.8–4.3
Heavy	5.5–7.4	1.10–1.49	19.9–27.1	4.4–5.9
Very heavy	7.5–9.4	1.50–1.89	27.2–34.4	6.0–7.5
Unduly heavy	9.5–	1.90–	34.5–	7.6–

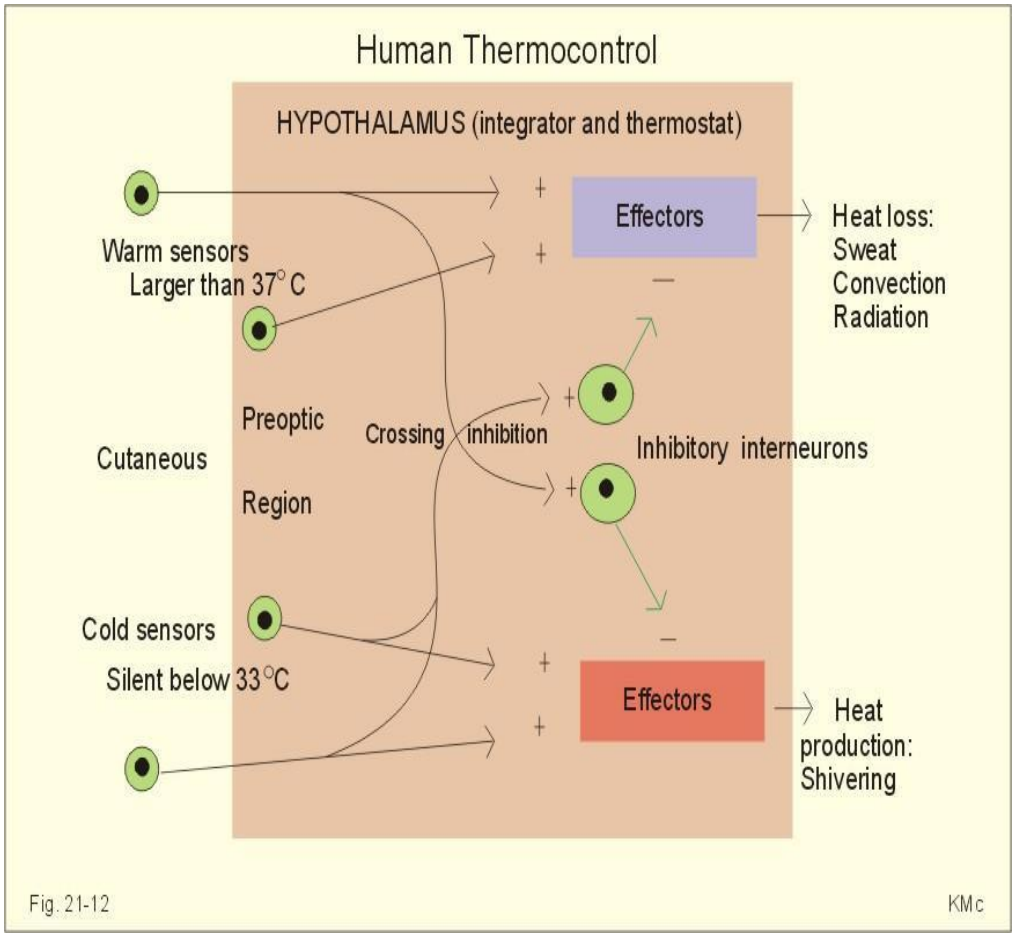
[a] L·min^{-1} based on 5 kCal per liter of oxygen; ml·kg^{-1}·min^{-1} based on 65-kg man and 55-kg woman; one MET equals average resting oxygen uptake of 3.5 mL·kg^{-1}·min^{-1}.

Adaptive thermogenesis



1- shivering thermogenesis

- Function of the skeletal muscle induced by cold **exposure**.



- fall in hypothalamic temperature
- a sympathetic activation with secretion of catecholamines, oxidation of fatty acids and glucose, and increased secretion of the thyroid and adrenal gland.

- The muscle tone is increased, and shivering is triggered reflexlyas asynchronous muscle contractions without external work (movements), so all the metabolic energy is released as heat.

- The capacity for muscular thermogenesis by shivering is high.
- Up to five folds basal metabolic rate is observed, which corresponds to heavy industrial work.

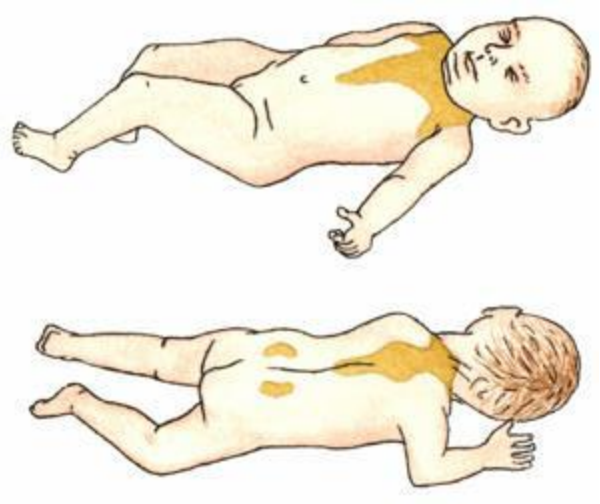
2- non shivering thermogensis

- It is any rise in metabolism, which is not related to shivering.

•Thermogenesis process which appear after prolonged cold exposure

Newborn human infants do not shiver, and thus maintenance of body temperature depends entirely on non-shivering thermogenesis by brown adipose tissue (BAT).

- around vital organs
- in neck and mediastinum between scapulae
- in the armpits

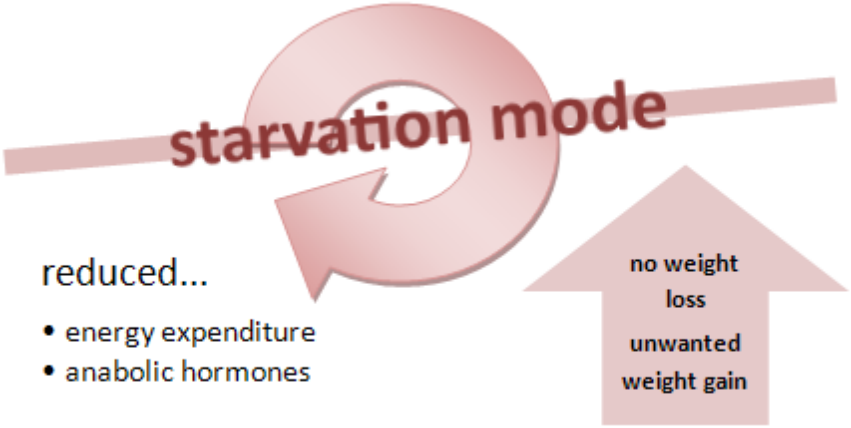


	White fat	Brown fat
Function	Energy storage	Heat production
Morphology	Single lipid droplet Variable amount of mitochondria	Multiple small vacuolae Abundant mitochondria
Characteristic proteins	Leptin	UCP1
Development	From Myf5-negative progenitor cells	From Myf5-positive progenitor cells (but there are also Myf5-negative brown fat cells which are derived from other lineages)
Human data	Large amounts are associated with increased risk of obesity-related disorders	Large amounts are associated with decreased risk of obesity-related disorders
Impact of aging	Increases with age relative to total body weight	Decreases with age

- The brown color of BAT is attributable to its high mitochondrial density and high vascularization

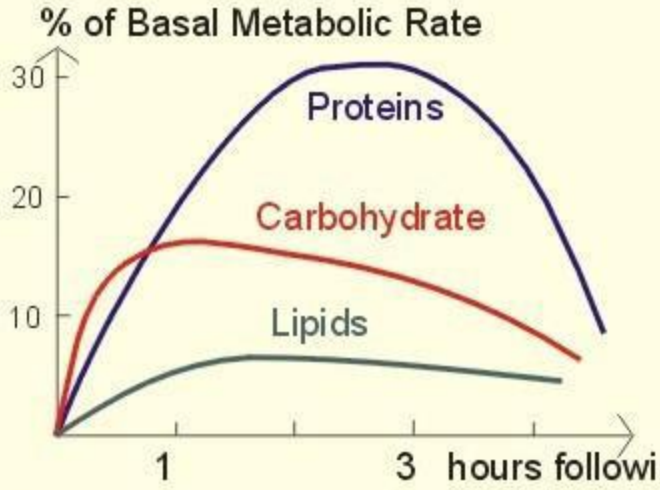
Thermic effect of food (DIT)

- Physiological mechanism that permits excessive calories intake to be dissipated as heat, allowing individuals to eat without gaining weigh.



Dietary Thermogenesis

Specific Dynamic Activity (SDA): Intake of food increases metabolism



1. General causes of SDA:
   Mass balance
   Rise in temperature increases enzyme activity (Q_{10} = 2-3)

2. Glucose - SDA:
   Obligate formation of glycogen and fatty acids.
   Muscular activation by adrenaline via β_2-receptors.
   Non-myogenic activation by noradrenaline via β_1- receptors.

3. Protein-SDA (30%):
   Hepatic intermediary processes (amino acid degradation, urea formation)

Fig. 20-6

KMc

DIT and NST (non shivering thermogenesis)

They share common features:

both occur in brown fat

both are regulated by the sympathetic nervous system (SNS)

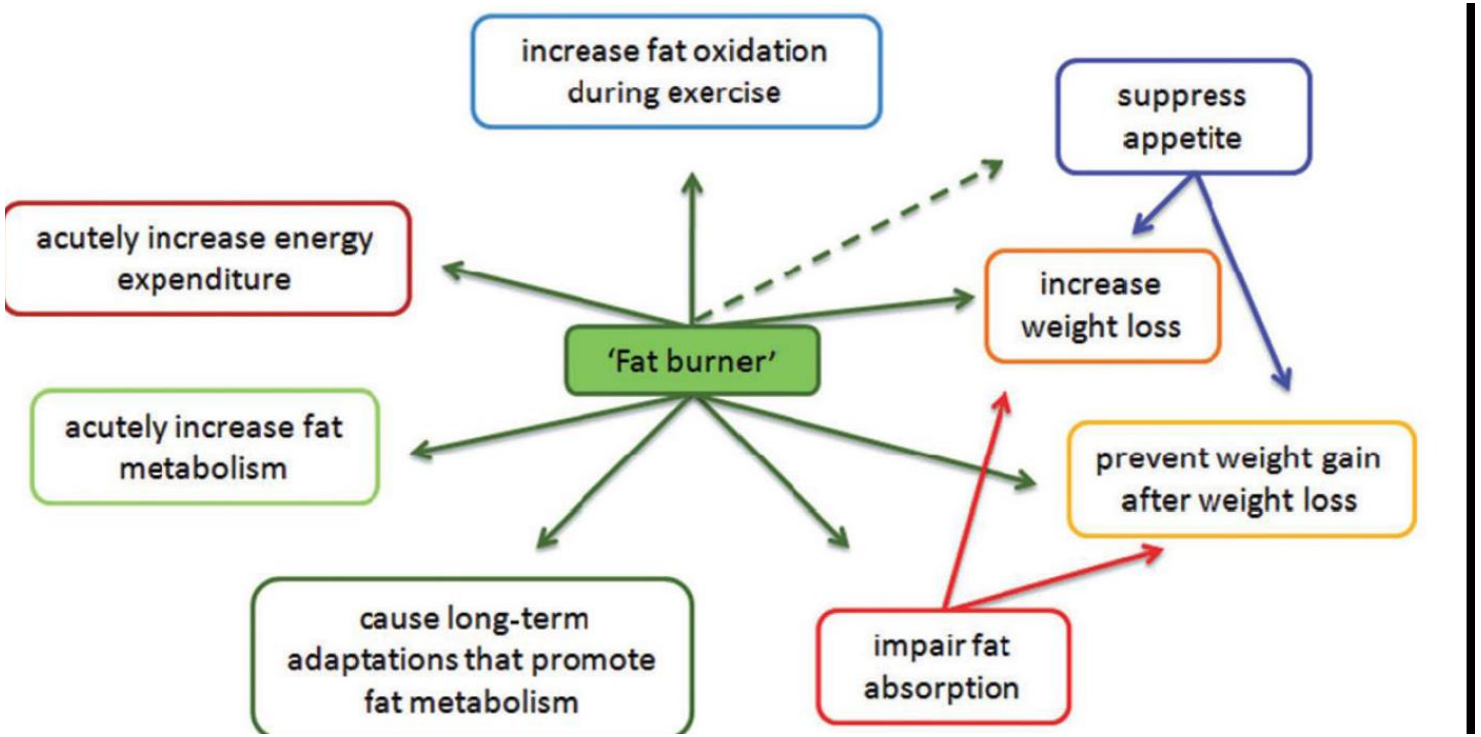
they correlates closely with increased plasma noradrenaline concentrations.

However in NST, heat produced is used to maintain body temperature while in DIT is quickly dissipated to the environment to prevent body temperature from rising.

Factors affect the energy expenditure

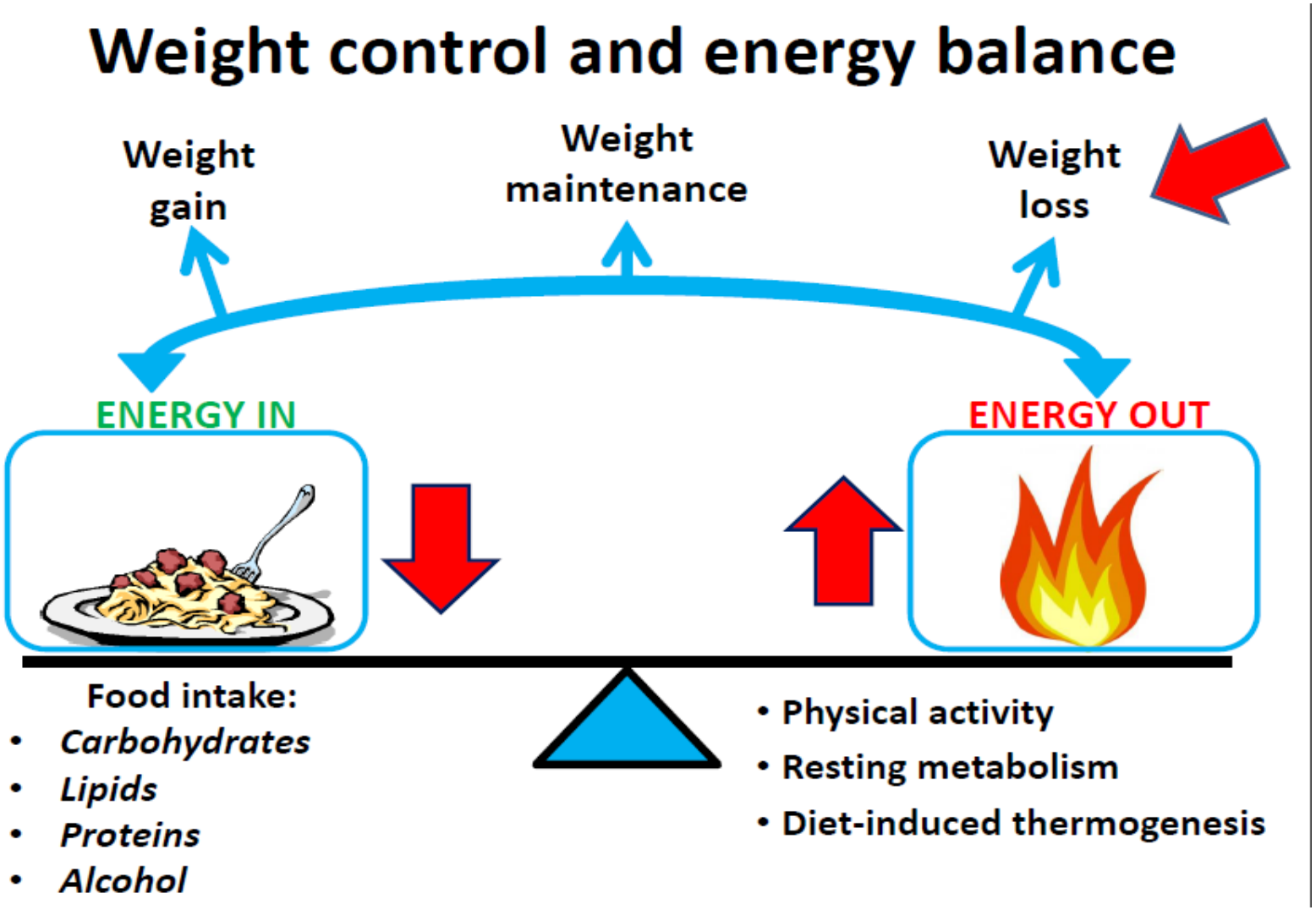
- Supplements used in Weight management

(Fat burner)



Caffeine	Dihydroxyacetone	**Conjugated linoleic acid (CLA)**
Carnitine	Ephedra	Psyllium
Calcium	**Green tea extracts**	Pyruvate
Choline	Hydroxycitrate (HCA)	Leucine
Chromium	Lipase	**Forskolin**
Lecithin	Ma huang	Beta-sitosterol
Fucoxanthin	**Kelp**	Cayenne pepper (Capsaicin)
Garcinia cambogia	Inositol	**Epigallocatechin-3-gallate (EGCG)**

Weight management



To obtain weight loss by diet/food

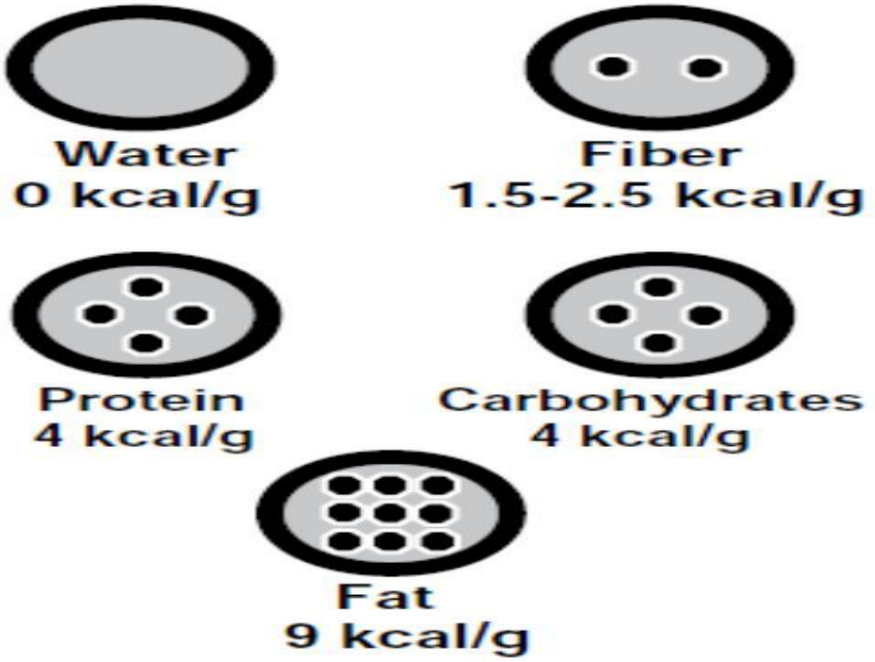
Decrease calorie intake

- **Decrease product energy density and/or portion size**
- **Increase satiety/satiation**

Stimulate energy utilization rather than storage in fat tissue

- **Increase resting metabolism (**body composition**)**
- **Increase thermogenesis by diet (**calorie/fat burning ingredient**)**

- Decreasingcalorie intake*(energydensityof diet)*



- Low-energy-dense diets help people lower their caloric intake while maintaining feelings of satiety and controlling feelings of hunger.

• But do reductions in energy density can be successfully employed to manage body weight?

• A benefit of this type of eating plan is that it allows people to eat satisfying amounts of food while restricting their energy intake. Furthermore, this type of eating plan uses positive messages (i.e. eat satisfying portions of low-energy-dense foods), which has been shown to result in greater dietary changes than restrictive messages (i.e. eat small portions of all foods)

Satiety and hunger


I'M
HUNGRY®

she may have it

... or not!

- Psychological approach to eating : attention to calories? Mood? Pleasure ?

- Hunger:
- construct or intervening variable that connotes the drive to eat. Not directly measurable but can be inferred from objective conditions

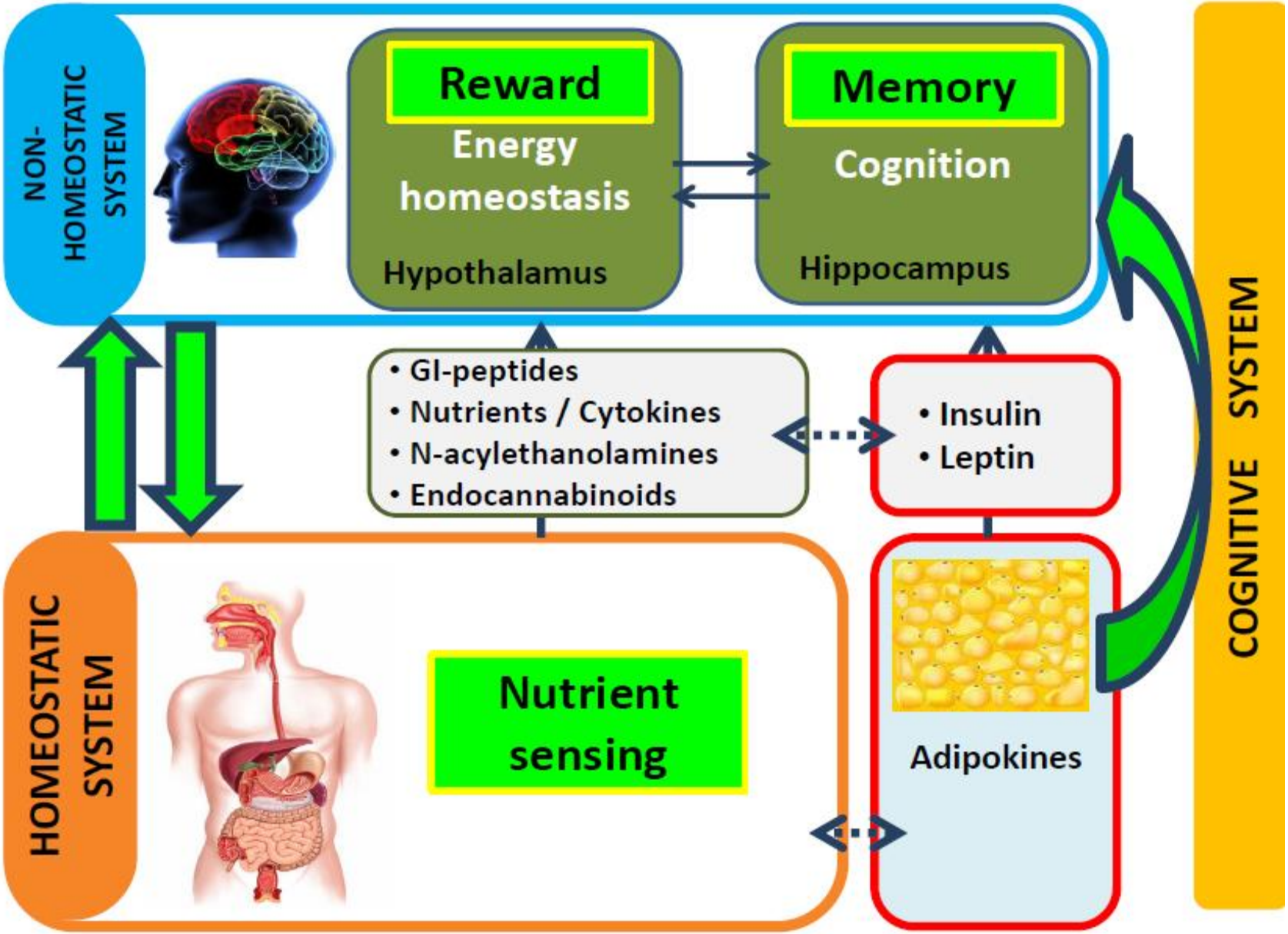
- conscious sensation reflecting a mental urge to eat. Can be traced to changes in physical sensations in parts of the body – stomach, limbs or head.

- In its strong form may include feelings of light-headedness, weakness or emptiness in stomach.

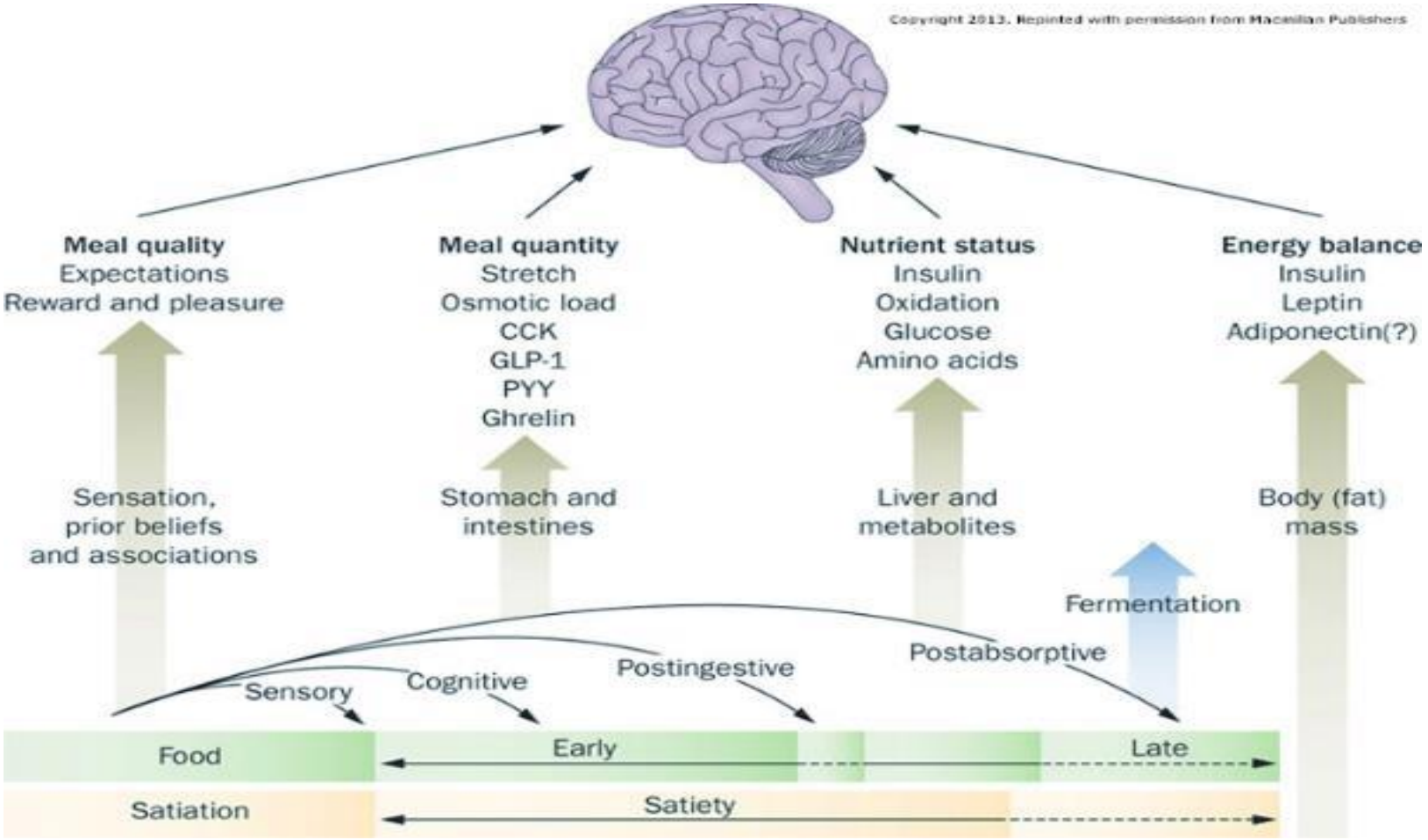
- Satiation:
- process that leads to the termination of eating; therefore controls meal size. Also known as intra-meal satiety.
- Satiety:
- process that leads to inhibition of further eating, decline in hunger, increase in fullness after a meal has finished. Also known as post-ingestive satiety or inter-meal satiety.

Factors affect the food choices

- Hedonic factors
- Cognitive factors
- Metabolic factors
- Social
- Environmental
- Emotional
- Self regulation


NON-HOMEOSTATIC SYSTEM
Reward
Energy homeostasis
Hypothalamus
Memory
Cognition
Hippocampus
COGNITIVE SYSTEM
• GI-peptides
• Nutrients / Cytokines
• N-acylethanolamines
• Endocannabinoids
• Insulin
• Leptin
HOMEOSTATIC SYSTEM
Nutrient sensing
Adipokines

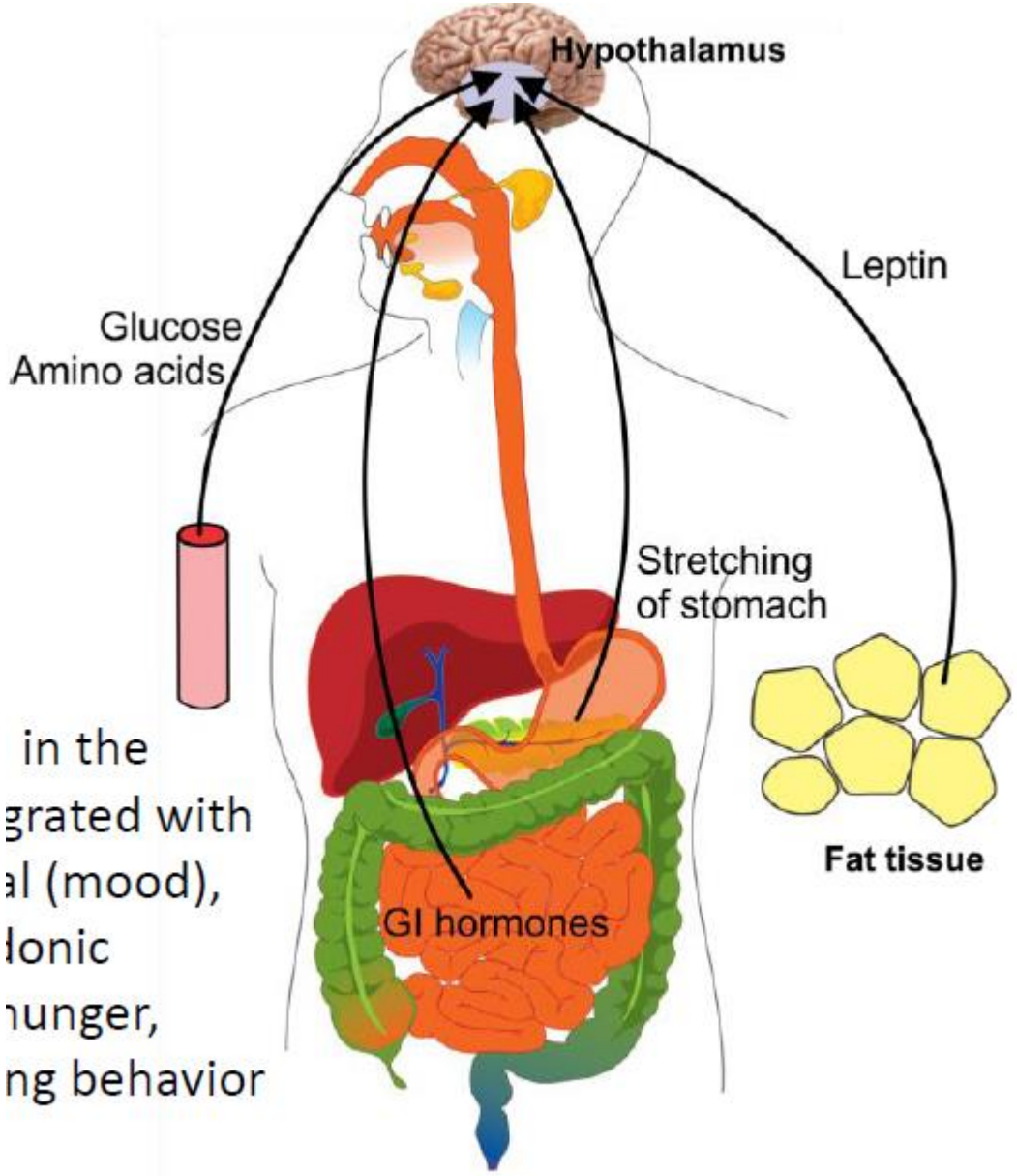
Hedonic and metabolic cause



Feedback regulation of food intake

- **short term** and **long term** feedback signals
- The signals are received in the **hypothalamus** and integrated with other stimuli -emotional (mood), cognitive (thinking), hedonic (liking) -that influence hunger, appetite and food seeking behavior

- SatiationThe process that leads to the termination of eating, which may be accompanied by a feeling of satisfaction**(intra-meal satiety)**
- •SatietyThe feeling of fullness that persists after eating, potentiallysuppressingfurtherenergy intake until hunger returns**(inter-meal satiety)**



in the
grated with
al (mood),
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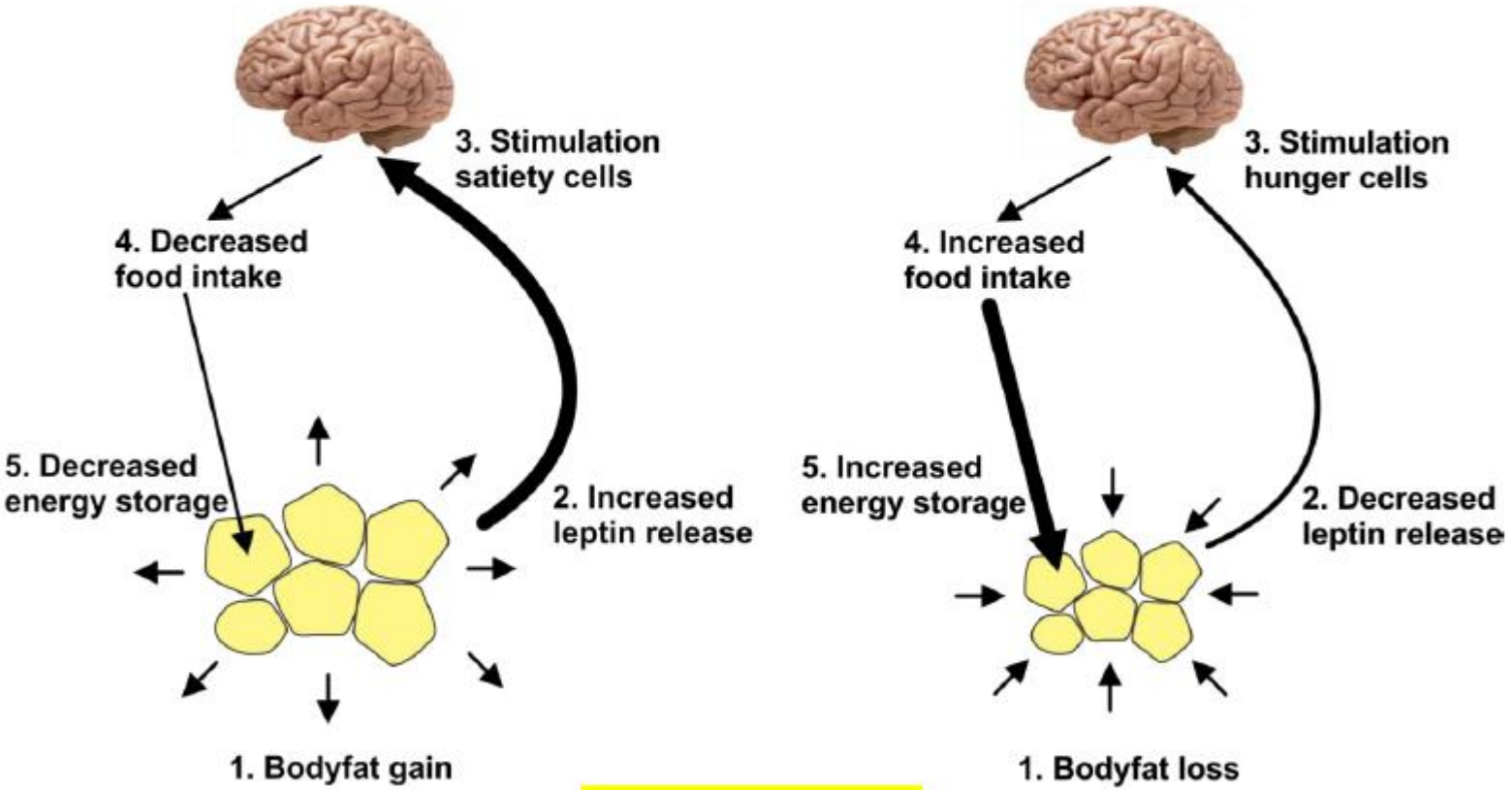
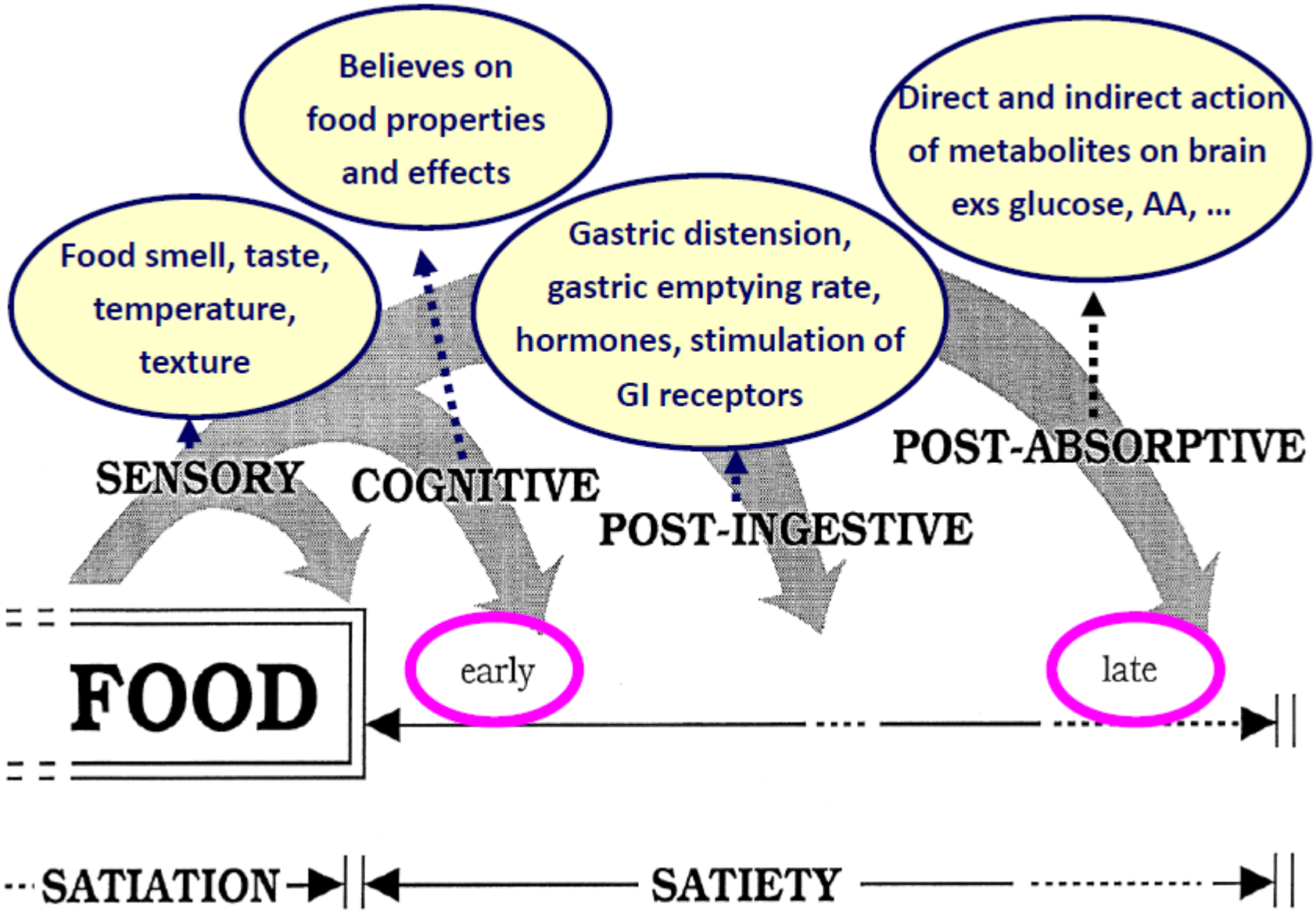
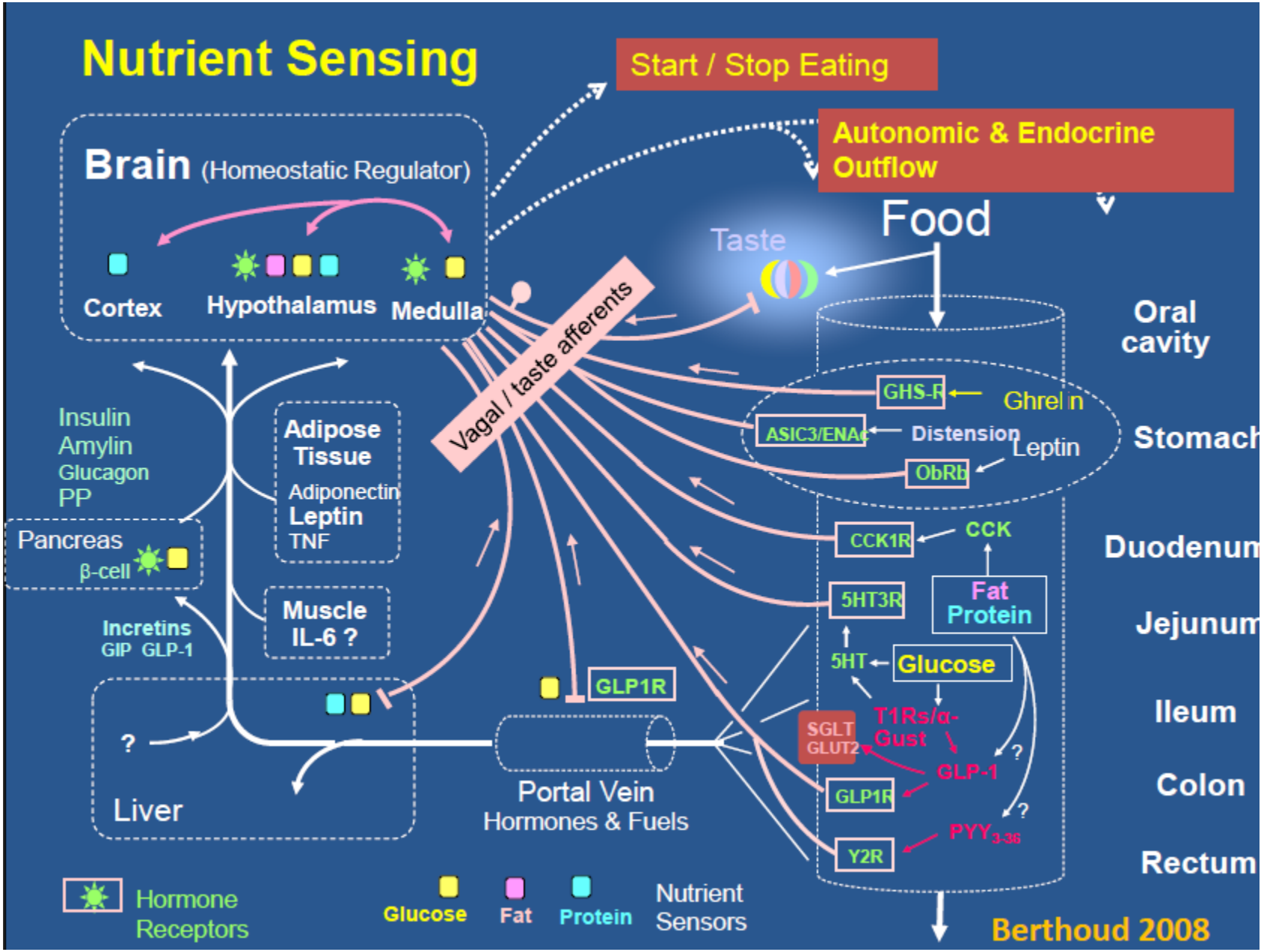
Feedback regulation from adipose tissue



Leptin

Satiety cascade (Blundell, 1987)




Nutrient Sensing
Start / Stop Eating
Autonomic & Endocrine Outflow
Brain (Homeostatic Regulator)
Cortex
Hypothalamus
Medulla
Food
Taste
Oral cavity
Vagal / taste afferents
GHS-R
Ghrelin
ASIC3/ENAc
Distension
Leptin
ObRb
Stomach
Insulin
Amylin
Glucagon
PP
Pancreas
β-cell
Adipose Tissue
Adiponectin
Leptin
TNF
CCK1R
CCK
Duodenum
5HT3R
Fat
Protein
Jejunum
Incretins
GIP GLP-1
Muscle
IL-6 ?
5HT
Glucose
GLP1R
T1Rs/α-Gust
SGLT
GLUT2
Ileum
?
GLP-1
Colon
Liver
Portal Vein
Hormones & Fuels
GLP1R
PYY3-36
Y2R
Rectum
Hormone Receptors
Glucose
Fat
Protein
Nutrient Sensors
Berthoud 2008

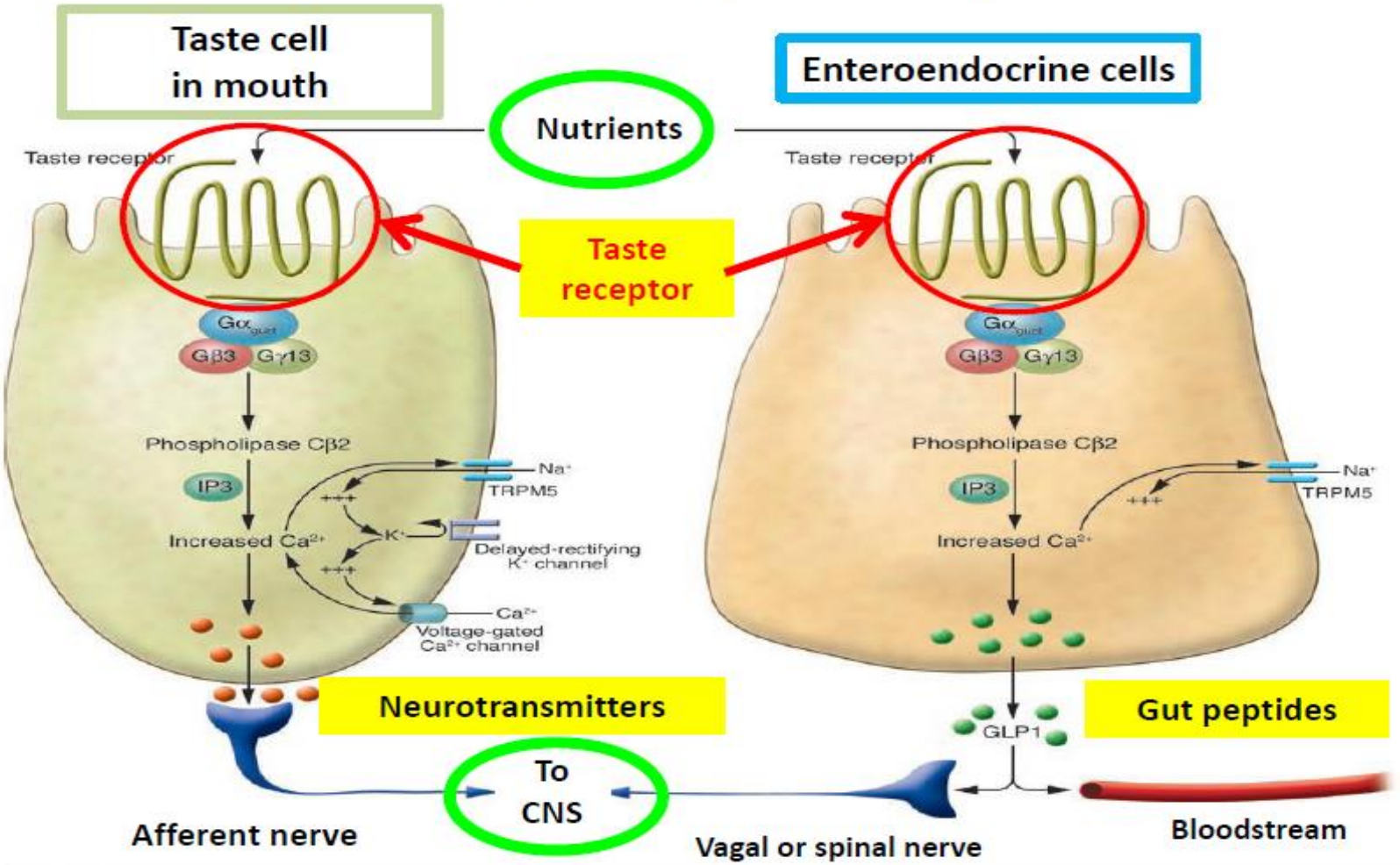
In the stomach… mechanoreceptors

- Food presence is detected by the vagal afferent fibres that are sensible to the mechanic touch
- The volume off foods is detected by the vagal afferent fibres of muscle external layers that are sensible to the stretching and distension:
- Intraganglionic Laminar vagal Afferent Endings (IGLEs)
- Intramuscolar Arrays(IMAs) :they generate the first negative feed back from a full stomach (influence on satiation)

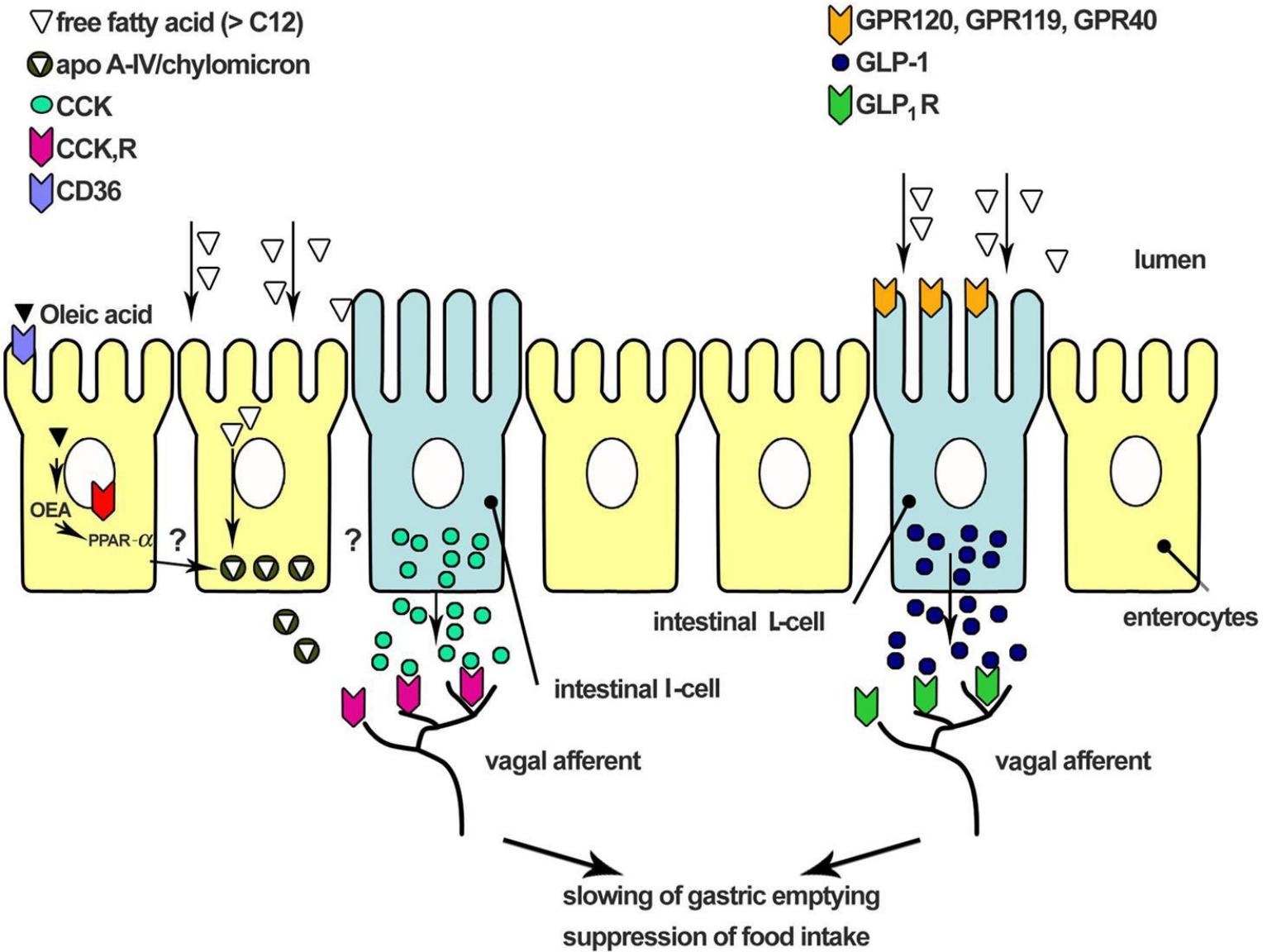
- In the enter endocrine cells, there are receptors (T1R e T2Rs) are involved in the taste signaling in the taste buds

- Cells with taste receptors are widely distributed in several tissues (tong, nasal epithelium , trachea. Stomach, intestine

Nutrient sensing in the gut ➔ The gut taste!



Little and Feinle-Bisset, Frontiers in Neuroscience 2010 doi: 10.3389/fnins.2010.00178



Physiological mechanism of satiation

- Gastric mechanism : distention (independently of nutrients)
- Intestinal mechanisms: infusion of nutrients directly into the intestine promote satiation.
- CCK: rapidly released into the circulation in response to the presence of nutrients in the gut (Fats and proteins) leads to:

1-Delays gastric emptying

2- Stimulate pancreatic enzyme secretion and gall bladder contraction

3- in the brain work as neurotransmitter, for many feelings include satiety

4- synergism with leptin that signals fat tores

Physiologic mechanism of satiety

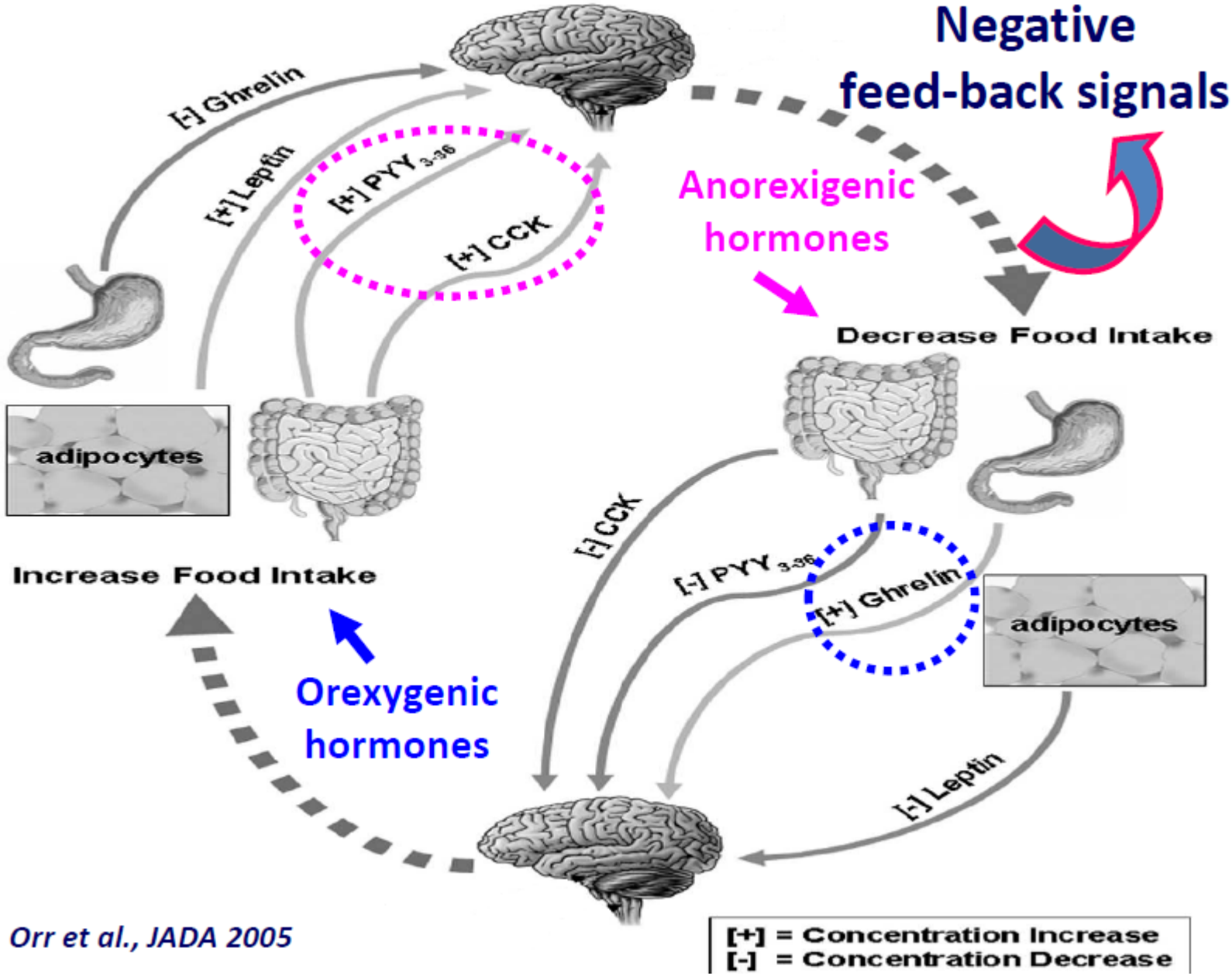
- Episodic signals : response to food consumption
- Tonic signals : infuenced by the levels of energy stores (leptin, insulin)
- The interaction between the two types lead tot the effect

‘Episodic’ signals

Name	Site of production	Effect on appetite	Mechanism	Additional effects
Ghrelin	Stomach	↑ hunger	• Ghrelin R (brain)	Long term effect on energy balance (inversely correlated with body fat)
CCK	Duodenum Jejunum	↑ satiation	• Vagus nerve	• Delays gastric emptying • Stimulates pancreatic enzyme secretion • Stimulates gallbladder contraction • Neurotransmitters
GLP-1	Intestine Brain	↑ satiety	• GLP-1R (brain)	• Incretin (insulin production) • Slows gastric emptying and modulates gastric acid secretion (ileal brake)
Oxynto modulin (OXM)	Intestine Brain	↑ satiety	• GLP-1R (brain) • ↓ ghrelin	• Slows gastric emptying • ↑ *weight loss* • ↑ *energy expenditure*
PYY	Ileum Colon Rectum	↑ satiety	• Y2 R (brain)	• Slows gastric emptying • Slows itestinal transport • Reduces gastric secretions
PP	Pancreas	↑ satiety	• Y2 R (brain) • Vagus nerve	----

Hormone	Predominant site of secretion	Impact on energy intake	Influence of dietary macronutrient composition
Leptin	Adipocytes	↓	↑ with high-carbohydrate low-fat meals relative to high-fat low-carbohydrate meals (references 26,27,29) No apparent effect of dietary protein or fiber (references 38-40)
Ghrelin	Stomach	↑	↓ with dietary carbohydrate ingestion (references 33,47,62,63) Conflicting evidence about the effect of dietary protein (references 38,39,62,63) ↓ with psyllium fiber supplement (reference 54)
PYY_{3-36}[a]	Distal GI[b] tract	↓	Conflicting evidence on the effect of macronutrients; both ↑ with dietary fat and ↑ with dietary protein relative to other macronutrients have been reported (references 72,77)
CCK[c]	Upper GI tract	↓	↑ with dietary fat and protein more than carbohydrates (reference 79) Habitual high-fat low-carbohydrate diet consumption may reduce CCK-induced satiety (references 87,88,91) ↑ with dietary fiber consumption (references 40,92-94)

Orr et al., JADA 2005


Negative
feed-back signals
[-] Ghrelin
[+] Leptin
[+] PYY 3-36
[+] CCK
Anorexigenic
hormones
Decrease Food Intake
adipocytes
Increase Food Intake
[-] CCK
[-] PYY 3-36
[+] Ghrelin
adipocytes
Orexygenic
hormones
[-] Leptin
Orr et al., JADA 2005
[+] = Concentration Increase
[-] = Concentration Decrease

Dietary factors affect satiety

- Energy value
- Palatability
- Volume
- Form
- Macronutrient composition
- Dietary fiber content

- Increase energy density -→ decrease satiety
- In can be related to low volume of high energy dense foods compared to low energy dense
- (evidenced by loading studies)
- Energy dense foods are palatable but not satiating and viceversa
- Palatability directly correlates with hunger and with satiation but not with satiety

Satiety and macronutrients

- Proteins correlates with better than the other macronutrients with the sensation of fullness an satiety after meals. Then carbohydrate then fat.

- The relative satiety power of carbohydrates and fats in the different studies vary if macronutrients are studied alone or inside the foods.

Protein and satiety

- **"Fast" and "slow" proteins ➔** speed of absorption of dietary amino acids depends from dietary protein (Ex whey proteins vs casein)
- **In the short-term postprandial ➔ aminoacidemia** (AA are modulators of protein synthesis, breakdown, and oxidation)

In the short term:

Meals higher in proteins tend to increase satiety when compared to meals lower in proteins.

Solid foods more effective than beverage (role of gustatory system)

- **In the long term ➔ thermogenesis** (Animal vs vegetable protein)
- However there is not a general consensus on higher satiety from proteins

➔ Methodological issue!

In the long term:

The satiating effect of proteins is more evident in studies applying free living condition

- The mechanisms involved are:

✓ elevated amino acid concentrations,

✓ responses of anorexigenic hormones

✓ protein-induced energy expenditure

- **Different proteins cause different nutrient related responses of (an)orexigenic hormones.**
- Protein-induced satiety coincides with

✓ **a relatively high glucagon-like peptide-1 (GLP-1)** release (stimulated by the carbohydrate content and depending from that)

✓ **peptide YY (PYY) release**,

✓ ghrelin does not seem to be especially affected

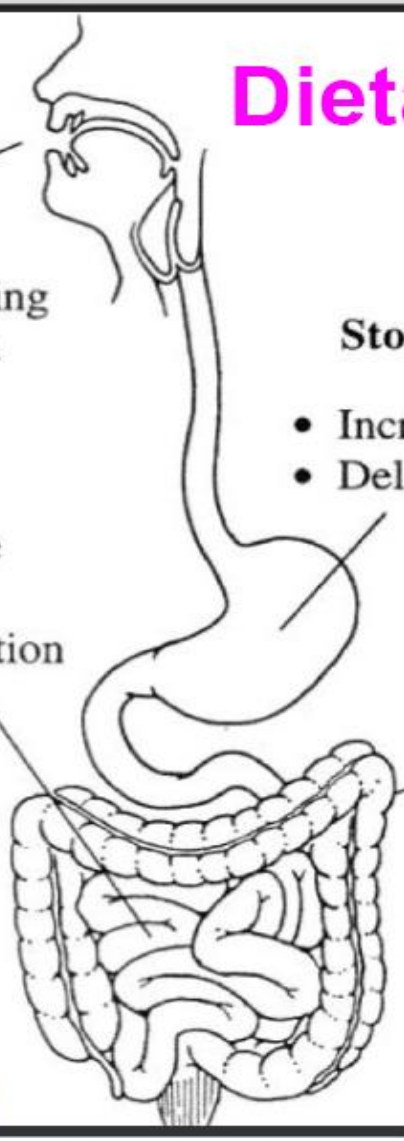
✓ cholecystokinin (CCK) few information

- **Energy expenditure and glucose are probably involved as metabolic signals in protein-induced satiety.**

Carbohydrate and satiety

- Glucostatic theory : low level of glucose triggers appetite
- GI theory: Glycemic index of food, high GI food lead to sudden increase and rebound of blood glucose → hunger
- Dietary fiber theory: DF content of a food make difference in GI and affect appetite
- Low GI : reduce the ghrelin concentration (decrease hunger)
- Energy density theory: increase density ,,, increase the appetite

Dietary fibre and satiety



Mouth

- Increased chewing
- Increased saliva

Stomach

- Increased distention
- Delayed emptying

Small Intestine

- Delayed absorption of nutrients; blunted insulin and glycemic responses
- Alterations in gut hormones
- Ileal brake

Large Intestine

- Fermentation to short-chain fatty acids
- Increased fecal energy excretion

Howarth et al., 2001

- Ileal brake: presence of CHO in the ileum trigger satiety
- Slow vs fast CHO: slow post prandial blood glucose suppress appetite (not always)

- Glucose versus fructose: consider (energy ,,,other side effect), high fructose corn syrup

- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4429636/

Fat and Satiety

TG saturation

Tg with MUFA or PUFA are more satiating than Tg with saturated fatty acid (research – introduodenal infusion))

By meal replacement : no effect

Chain length:

For short chain FA …. Mixed results

MCT: effect on body weight

LCFA: in creased CCK production,, still need research?

- Emulsion and stability effect
- Stable emulsion in the stomach,,,, fat reach the duodenum faster, -→ faster increase of CCK, unstable emulsion (water and lipid phase separate in stomach) may have effect??? Not defined yet????
- Ileal brake mechanism: Fat in ileum increase satiety (Olestra)

Satiety and food form

- Solids vs liquids
- Mastication has effect to promote satiety and reduce food intake (eat slowly)
- Consumption of fruits and vegetables instead of juice increase satiety (fiber)

- Increase volume
- Big volume compared to little volume
- Direct effect: at intestinal level , increase the contact of foods with the receptors along the GI tract
- Indirect effect: potential at cognitive level (different findings among males and females)

Eating cues

- May be positive or negative
- Social influence (parties, fruits on tables)

- Pop corn with movies
- Beach with BBQ
- Mamoul and Eid time
- Qatayef and Ramadan

- Eating cues influenced by:
- Behavioural/ psychological factors (eat in hospital???)
- Physiological factors (chocolate and menstrual cycle)

- Mood ???

Experimental design for appetite and satiety

- Subjective
- Objective (PYY, ghrelin, Leptin) postprandial