

Digestive System

University of Jordan
Faculty of Medicine
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Slide Sheet Handout Other

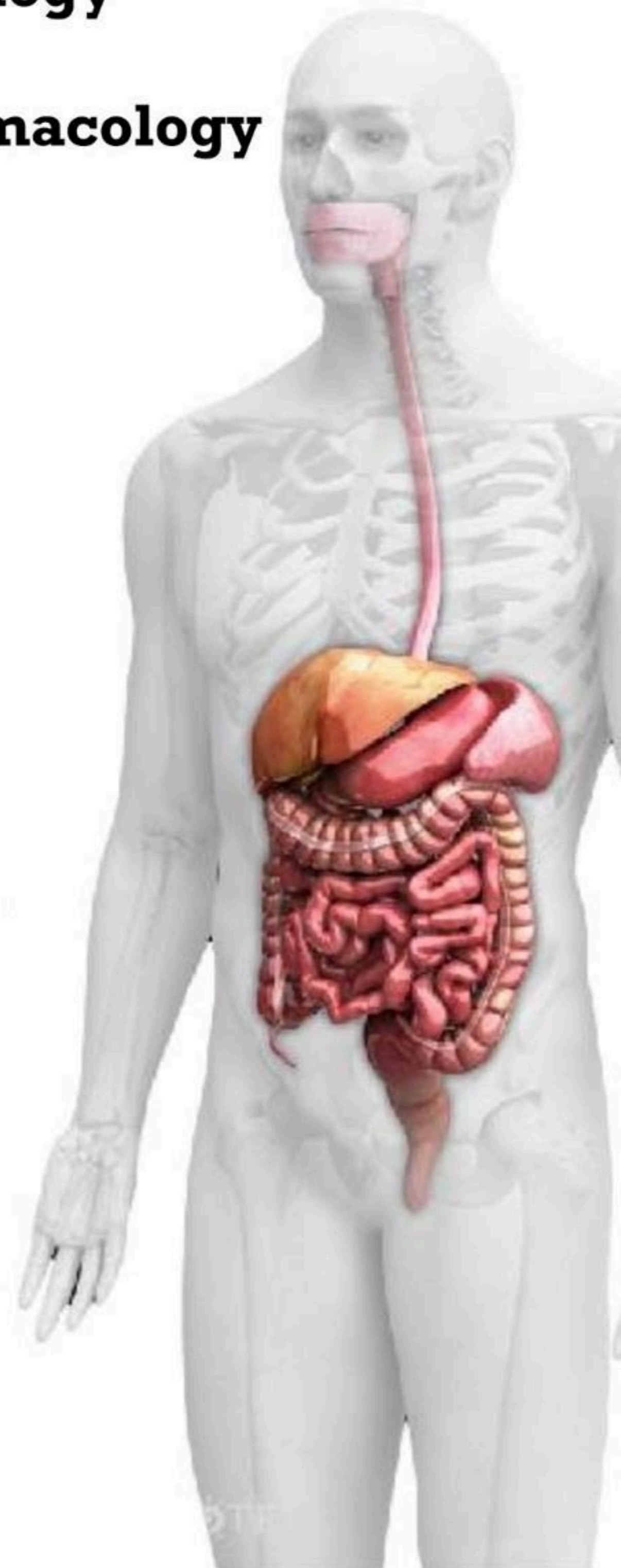
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Sheet #: 9

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Price:





Metabolic rate & Regulation Of Food Intake

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Recap:

We talked about body energetics and that we eat food to use it as a fuel to generate energy needed by the body to perform different functions. Different types of food are oxidized and chemically burned to generate ATP. ATP is the energy currency in the body. Our body performs chemical, mechanical and electrical works, so it needs a lot of energy. Chemical reactions and transformations performed by the body are called **Metabolism**. We can measure the metabolic activity of the body by measuring the **Metabolic Rate**.

What is metabolic rate?

metabolic rate is **the rate of heat liberation**, or simply, it is the **amount of heat released by the body per unit time**, so the unit is Calories/ unit time, the common unit used is (Calories/hour). (we will take it in the lab in the first week after midterm exam).

****Note:** Calories is the same as kilocalories (here it is a capital C, so it is kilocalorie)

*We have different ways of producing energy (different energetics):

**anaerobic energetic & aerobic energetic (not our topic here as we took it in biochemistry)

Respiratory quotient (RQ):

$$\text{Respiratory quotient (RQ)} = \frac{\text{amount of CO}_2 \text{ produced}}{\text{Amount of O}_2 \text{ utilized}}$$



We can know the main type of food being consumed by the body at a certain time by measuring the Respiratory quotient (RQ); **for example**: if the RQ = 1, this means that the body is utilizing Glucose.

Why does the "RQ for glucose "equal one?"

Because for each molecule of glucose oxidized, 6 CO₂ are generated and 6O₂ molecules are consumed, calculating the RQ for glucose, it will equal 1.

Note:

RQ for glucose =1

RQ for fats =0.7

Why the RQ for fats is 0.7 and less than that of glucose?

Because fats have more hydrogen atoms , so more oxygen is consumed when they are oxidized , so the ratio of CO₂ produced to O₂ consumed will be less than 1.

Ways of measuring metabolic rate (MR):

1-direct methods

2- Indirect methods

These two methods will be discussed in the lab, so don't miss it ☺ , there will be questions in the exam to calculate the metabolic rate .

Regarding the unit used to measure the metabolic rate:

We said that the unit is Calorie /hour, but to be more accurate, as the metabolic rate differs from person to person according to the body size , we add a third parameter to that unit , which is the body's surface area , so the unit becomes Calorie /hour/m²surface area.

***** So the final unit that we have to use is Calorie /hour/m²

Let's take some small details regarding the indirect method of measuring MR:



Indirect method:

Here we depend on the fact that the body uses **oxygen** to burn nutrients to generate energy. So we measure the amount of heat generated when **one liter of oxygen** is consumed by the body. *The average amount of energy produced by the body when utilizing one liter of oxygen to oxidize different nutrients is called: Energy Equivalent Of Oxygen, which equals 4.8 Calories.*

So if we know the amount of O₂ consumed by the body, we can calculate the MR. Details will be discussed in the lab.

For more standardization, we measure what is called: **Basal Metabolic Rate**, which is the metabolic rate measured under basal conditions (actually it is the minimal amount of energy expenditure for the body to exist, Guyton☺)

And the basal conditions are:

- 1-the person must not have eaten for at least 12 hours
- 2-the BMR is determined after a night of restful sleep
- 3-No exercise in the hour prior to the test.
- 4- Elimination of all factors that may cause excitement.
- 5- Comfortable temperature during measurement.

So as you notice the person in this test is really comfortable and doing nothing that makes him consumes a lot of energy, what I am trying to tell you that these conditions enable us to measure the basal metabolic rate, which is the minimal amount of energy needed by the body to exist.

Metabolic rate changes according to the situation, for example it differs according to the daily activities .we will mention the different situations that changes the MR later on.

People differ In their metabolic rates, some people live a sedentary life style, while others are very active and perform many physical activities, so of course the ones that



are active will have a higher metabolic rate. So each person has its own metabolic rate that depends on his daily activities, also the food consumption is different from person to the other. Moreover, the food that is consumed differ in its energy content (i.e. for example, 1 gram of fats has 9 Cal, 1 gram of proteins has 4 Cal and 1 gram of carbohydrates has 4 Cal).

Body weight and metabolic rate :

Now we have three cases:

1-**neutral balance**: when your body weight remains constant, and this happens when the metabolic rate is equal to the energy stored in the food you eat.

So neutral balance: Energy intake = energy expenditure.

2-**positive balance**: here there will be weight gain, because you are eating more than your body needs, so excess energy will be stored in form of fat in your adipose tissue.

So positive balance: energy intake > energy expenditure.

3-**negative balance**: results in weight loss, as energy intake is less than the amount needed by the body.

So negative balance: energy intake < energy expenditure.

Usually, the energy intake is equal to the energy expenditure, meaning that usually most normal people maintain neutral balance and keep a constant body weight by eating the adequate amount of food that meets their energy expenditure needs. So the question is **how the body regulates the food intake, how the body knows how much you eat and stops you when you eat a lot , and makes you feel hungry when it needs more energy ?**

Actually, there is a very powerful system that regulates the *quantity of food* eaten daily. So your body knows how much food you must eat; the body wants you to eat an amount of food that contains an amount of energy that can provide the body with enough energy that enables it to perform the chemical, mechanical and



electrical works, and doesn't want you to eat a lot and increase the burden of digesting and storing the huge amount of food you have ingested.

***Regulatory centers in the hypothalamus:**

There are two regulatory centers in the hypothalamus (CNS) that regulate the feeding behavior: (don't memorize the names of the nuclei, just know the function)

1-Feeding centers: it is in the lateral nuclei of the hypothalamus

*When it is stimulated, it makes you eat.

*When it is destroyed for a certain reason, you will lose the desire to eat, leading to inanition, weight loss and muscle weakness

2-Satiety centers: it is in the ventromedial nuclei of the hypothalamus.

*stimulating it makes you stop eating as you feel you are replete شبعان

*Destroying it makes you always eating (polyphagia) .

>>To eat, the activity of feeding centers is increased and the satiety centers activity is decreased.

There are other centers that play a role in the feeding behavior, but those **regulate appetite**, meaning the quality of food you eat, not the quantity. (Appetite is defined as the desire for food) .

Examples on these centers are :

1-prefrontal cortex.

2-Amygdala : it is located at the base of the CNS .(actually it is located deep medially within the temporal lobes of the brain , not important ! 😊 , and another extra note that you may like , I hope so , portions of amygdala are part of your olfactory



nervous system , so when you smell a certain delicious food , your desire to eat (appetite) will increase)

Important note: destruction of Amygdala leads to **Psychic blindness**, meaning that the person lose the control on the type & quality of food he eats, he may eat soil!!!

Returning back to the major centers that control your feeding behavior (i.e. feeding and satiety center in the hypothalamus), we want to discuss the **factors** that work on these centers and regulate how much you eat .

Think ! As we said before, GI tract releases many hormones that go to the blood stream, so of course when you eat and fill your stomach and intestine, some of these hormones will travel to those centers, signaling a state of satiety and preventing you from overeating.

So, we can divide the process of regulation into:

1-long term regulation.

2-short term regulation.

Let's start with the **long term regulation:**

First

glucostatic theory :

This theory is talking about the glucose levels in your body fluids, when it is decreased, feeding centers will be stimulated, and so you will eat to return the levels back to normal and vice versa. But this theory is not right, as diabetic patients always have high levels of glucose in the blood , but at the same time they have polyphagia (meaning that they eat a lot) , so if the theory was right , these patients must be always in the satiety state and eat too little . So, the theory was MODIFIED, now glucostatic theory says: **the Availability of glucose to cells is the factor that affects feeding and satiety centers in the hypothalamus.** Now things are clearer!! Diabetic



patients have high levels of glucose, but this glucose is not available to a cell, that's why they have polyphagia.

Lipostatic theory:

We know that our body stores excess energy in the form of fats, most of these fats are stored in Adipose tissue. The Adipocytes of adipose tissue are endocrine cells and they release a hormone called: Leptin.

When do adipocytes release leptin?

When the fat content in adipocytes increases, they will release **leptin** (so increased fat content is the stimulus for releasing leptin), this leptin will go through the blood and then cross the blood brain barrier and inhibits the feeding centers. Note that leptin signals a message to the **brain that there is enough energy stores in the body,** and there is no need for more energy intake(eating).

Sometimes Adipocytes produce defective leptin when there is a mutation in the gene coding for it, this gene is called the Ob Gene (obesity gene). **Why is it called obesity gene?** Because cells with these genes will produce defective leptin **that is not able to reduce the activity of feeding centers**, so here we see a relationship between obesity and genetic factors, people with defective leptin will have tendency to eat more than normal people.

Aminostatic theory:

The availability of amino acids for the cells affects our feeding behavior.

Second:

Temperature regulation and food intake:

There is a relation between the thermoregulatory centers and food intake regulatory centers in the hypothalamus.



To prove that, ask yourself why do you eat more in winter?

Because in winter, the weather is cold and thermoregulatory **centers** in hypothalamus are activated to maintain the body temperate around 37°C , also these centers can stimulate the **feeding centers** to increase feeding behavior and energy intake , so the metabolic rate increases and heat generated by burning food will increase in an attempt to maintain a constant body temperature .

Third:

Psychosocial factors:

Some people are accustomed to eat three meals a day , others eat two and others eat just one meal .for a person who is accustomed to eat three times a day , when he misses a meal (lunch for example) ,he will feel hungry , because he is used to this . On the other hand, a person who is used to eat one meal a day, this meal will keep him replete the whole day, missing dinner will not be a problem to him.

Short term regulation:

1-gastrointestinal filling:

When the GI tract is filled with food, it will be distended; this stretch is signaled to the brain by the vagus nerve to reduce feeding behavior and the desire to eat.

2-GI secretions:

As we thought before ☺ , GIT releases hormones that act on the feeding and satiety centers , such as :

1-CCK (cholecystokinin) , which also affect sensory nerves that sends signals to the brain by the vagus nerve to reduce feeding behavior .

2-pYY (peptide yy).



3-Insulin is released from beta cells of the pancreas, and insulin reduces the feeding behavior because it is secreted when we have high blood glucose, so insulin increases availability of glucose for cells, so this will decrease the feeding behavior.

3-Oral receptors:

These oral receptors meter the number of swallowing (they are like a counter, counting the number of swallowing / number of bolus), so after **a certain number of swallowing, the satiety center will be activated and you will stop eating.**

Smart thinking!!

If this theory was correct, one can decrease his feeding behavior and lose weight by eating small amount of food but with large number of small bites, so this large number of bites (larger # of swallowing also) will be sufficient to make the oral receptors decrease the feeding behavior, so you will be replete by small amount of food.

Obesity

Obesity occurs when the **energy intake exceeds the energy expenditure**. The excess energy is stored in the form of **fats in adipose tissue**. So obesity is when the body weight becomes more than the ideal weight by at least 10%, and that increase must be **in the form of fat deposits in adipose tissues**.

****So what is the ideal body weight?**

Ideal weight = actual body height-100. If a person is 170 cm, so his ideal weight is 70 Kg. (There are other ways to determine the ideal weight like BMI (body mass index), but this is just an example)



Why are we saying that the increase in body weight must result from deposition of fats to consider it obesity?

Because some athlete people may have a body weight that is more than the ideal one, but the excess weight is due to **increased muscle mass not excess fat deposition** and increased muscle mass is not considered as obesity, but considered as overweight.

So obese people have had a **positive balance** at a certain period of time, they have eaten more than their actual energy needs, and the excess was stored as fats. So if they continue their life by making sure that the energy intake is equal to the expenditure, they will maintain their weight. If they want to lose weight, they have to increase the expenditure or reduce food intake or both.

What are the causes of obesity?

1-Neurogenic abnormalities:

We talked about the *satiety and feeding centers* in the hypothalamus, these centers have a certain "set point or threshold" to be excited by certain stimuli and to be able to suppress or stimulate feeding behavior, respectively. These set points differ from person to person, so we expect an *obese person* to have **higher set points or threshold in satiety centers**, so stronger stimulus is needed to activate these centers, as a result the person eats larger amount of food for these centers to be stimulated and prevent him from eating more, or it could be **a lower threshold in feeding center**, so a weak stimulus activates his feeding center, stimulating him to eat more.

Note: we can determine the level of response (higher or lower threshold) in these centers (satiety centers/feeding centers) by the number of the receptors on each one of them

- more receptors >>> lower threshold / needing a weak stimulus
- less receptors >>> higher threshold / needing a strong stimulus



2-psychosocial factors:

If the life style of a certain person includes a lot of social activities; he visits people and people visit him, of course he will be generous with his guests, preparing the most delicious and fatty food for them, and his friends will be generous with him also, he will be eating food that contain high amount of calories all the time, of course he will be obese at the end of the day.

Also, sedentary life style and little physical activities can cause obesity.

Moreover, some people when they are depressed eat more and more to relieve their stress.

3-childhood over- nutrition:

Usually parents love to give their children everything they want , especially food , and in large quantities , so they give them a lot of money to buy a lot of things that have no significant nutritional value and just make them obese (like chocolate ,chips , ...etc) , it is not just the case of giving them money to buy food , also mothers *force* their children to eat more , so most of them are fat and mkalba6'een ;p . This is really bad as when the child eats more than he needs, he will have **hyperplastic obesity, meaning** that the number of their fat cells increases.

The Best thing to do is to introduce healthy food to them and let them eat according to their needs; the child will feel satiety and will not eat more than his needs. And of course children's' needs differ according to their activity; hyper active child will eat more than the lazy one to satisfy the increased energy needs of his body.

4-hypothyroidism:

Thyroid gland is very important in the regulation of metabolism. If its activity was reduced (hypothyroidism) , metabolism and energy expenditure will decrease and even if the person's food intake is normal , he will gain weight due to **low metabolic rate.**



5- Genetic factors:

As we mentioned earlier, *ob gene* causes adipocytes to release defective leptin that is unable to inhibit feeding centers. Or the problem could be **mutations in the receptors found in the food intake regulation centers** that results in failure of inhibition of feeding center, or failure of activating the satiety center.

Treatment of obesity:

Easy and simple -__- , we can either reduce energy input (reduce food intake) or increase energy expenditure (by increasing the physical activities for example)

Inanition:

It is the opposite of obesity; it happens when the food intake is *less than* normal and can't satisfy the body's needs of energy, so there will be weight loss (negative balance).

Causes:

1-neurogenic abnormalities:

As we mentioned in obesity, same concept but opposite situation, the set points or thresholds in the food intake regulatory centers are not normal. Maybe the threshold in satiety centers are lower than normal (i.e. activated by weak stimuli) or that of feeding center are higher than normal (i.e. activated by stronger stimuli)

2-psychogenic factors:

The status of the psych affects appetite , some people when they are depressed refuse to eat for a long period of time so they lose weight .when a person is not eating enough food for his body to work due to psychogenic factors , we name it : **Anorexia nervosa** : not taking adequate amount of food due psych problems.



Starvation:

Starvation is reduced food intake, not due to neurogenic abnormalities or psych issues, it's because people don't have enough food to eat and supply the body with the food it needs. So there is no food available for these people, this usually occurs in poor countries ☹ .

So, what happens to those people , how their body tries to survive before they die ☹ ?

At the first 2-3 days , the main nutrient to be used is carbohydrates , the body starts to degrade the stored glycogen to supply the body with the energy it needs , as the body is using carbohydrates , so the **RQ = 1** as we mentioned previously .

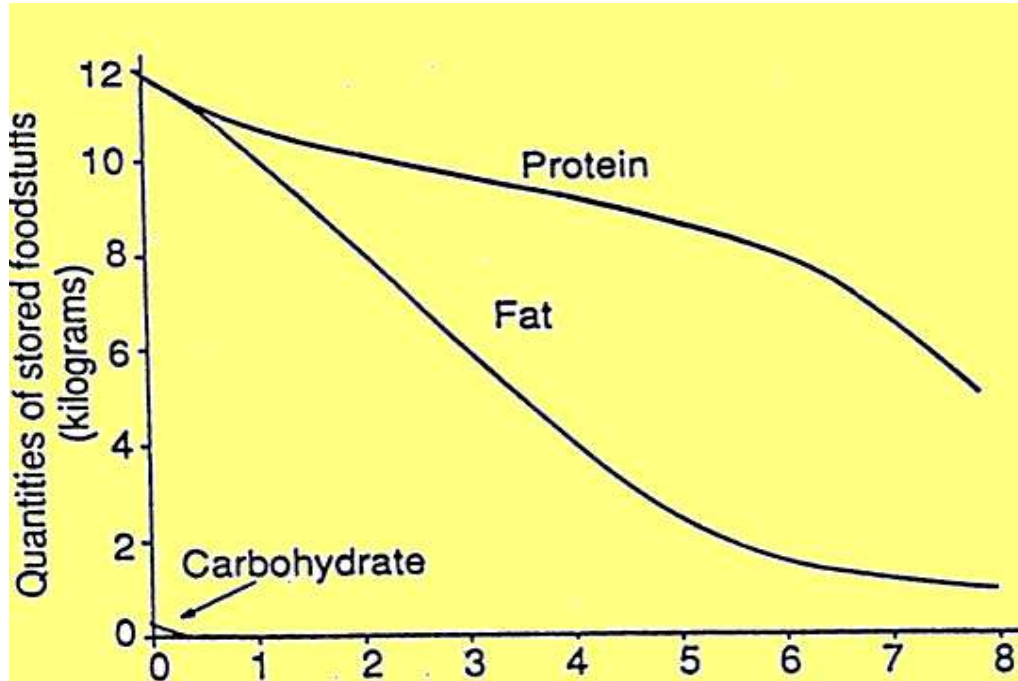
After 2-3 days or less, glycogen stores will be depleted, and the body starts to use *fats and proteins* at the same rate at the beginning, in the first week of starvation but after depletion of carbohydrate stores .But then the body uses only fats in an attempt to conserve its proteins the perform critical functions required for survival, so it starts to degrade fats for 2 to 3 weeks, so during this period if you measured the **RQ, it will be 0.7**. After depletion of fat stores, the body returns to use proteins, and the person dies in the 7th or 8th week as he is losing the functional proteins needed for his survival.

So degradation of proteins has three phases:

*fast degradation

*lower depletion

*higher depletion



The end

لا تنسوني من صالح دعائكم ☺

إهداء إلى الرباعي المرح الجميل : ندى الشريف، إيمان العموش، تقى الغزاوي، فرح زيادة ☺☺