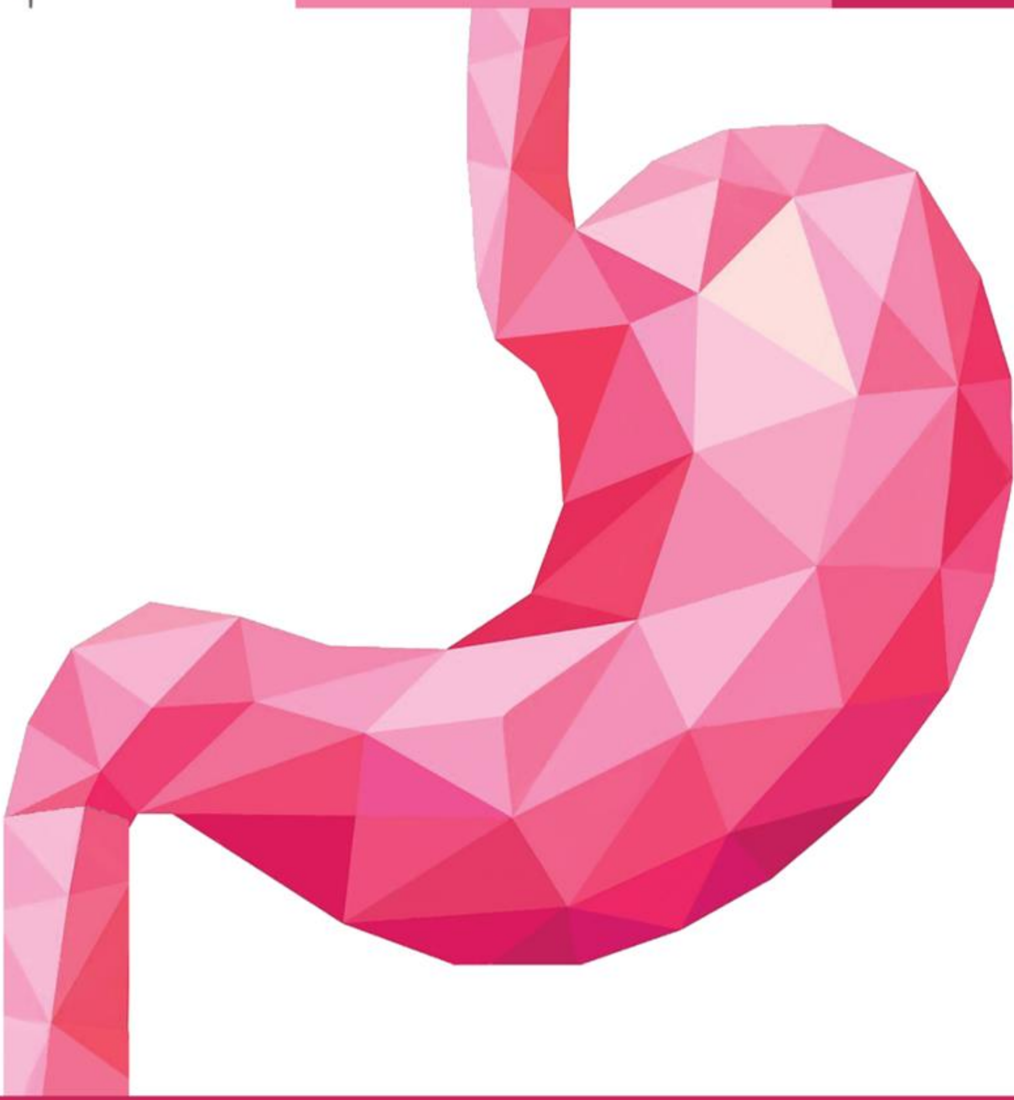
GIS PHYSIOLOGY 8



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Energetics

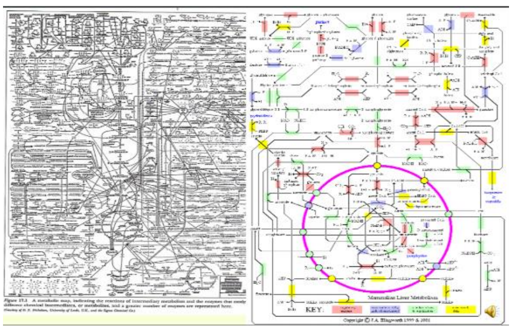
After the chemical transformation of food into smaller foodstuffs and their absorption, foodstuff will undergo many processes by the cells of human body to produce energy for their activities. The energy produced by these reactions is stored in highly energetic phosphate bonds in a compound known as ATP. The formed ATP then is used for body works, which could be as external or internal works. These include:

1) **Chemical works**: ATP energizes the synthesis of cellular components and other substances like enzymes. It also induces glandular secretion.
2) **Mechanical works**: This is where ATP is consumed for muscle contractions to occur, heart pumping, & bowel (intestinal) movements.
3) **Electrical works**: After nerve conduction, ATP is utilized to maintain a concentration gradient for K+ and Na+ across membrane (by the activity of Na+/K+ pumps and other pumps).

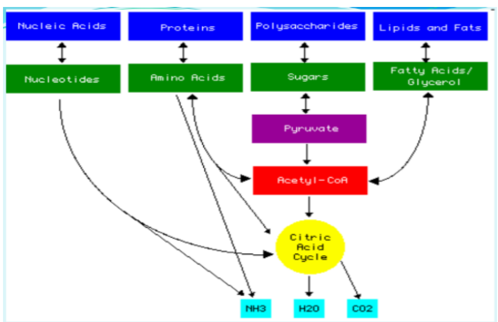
> **Remember**:
>
> The main function of the **Na+/k+ pump** is to maintain resting potential so that the cells will be kept in a state of a low concentration of sodium ions and high levels of potassium ions within the cell.

We have a lot of metabolic activities that take place in our bodies to generate micro-energetic molecules which are used for body works. The question is: Can we measure all the metabolic activities that take place in our bodies?

- The answer, surprisingly, is **yes**, as we can estimate these activities through measuring the "**metabolic rate**" (which will be discussed later in this sheet).



- ATP Is generated by combustion of **Carbohydrates**, **Fats**, and **Proteins**.
- The catabolism of these molecules yields H_20 and CO_2.
- NH_3 might also be produced from the breakdown of amino acids & nucleotides.



In our bodies, we have 2 systems that are responsible for the generation of ATP. These are:

1) Aerobic System

Oxygen is present

Large amount of energy is released

Foodstuff is completely oxidised/broken down & **Water+CO_2** are formed.

Takes place in the mitochondria

Involves the breakdown of carbohydrates, fat & branched chain amino acids

2) Anaerobic System

Oxygen is absent

Small amount of energy is released

Foodstuff is partially oxidised **& intermediate molecules (pyruvate/lactate)** are formed

Takes place in the cytoplasm

Involves the breakdown of carbohydrates

Respiratory Quotient (RQ)

The ratio of the volume of carbon dioxide evolved to that of oxygen consumed in a given time.

In the case of chemical burning of **glucose**, we have the following reaction:

$$C_6H_{12}O_6 + \mathbf{6}O_2 \rightarrow 6H_2O + \mathbf{6}CO_2$$

From this reaction we can calculate "**Respiratory Quotient**" (RQ) (CO_2 produced/O_2 consumed) when glucose is used as a source of energy. In this reaction (RQ) = CO_2/O_2 = **1.0** in the case of **glucose** break down. When **fat** is used as source of energy, RQ = **0.7**. When **protein** is used, RQ = **0.82.**

From the respiratory exchange ratio by the lung over a period of time, we can estimate the respiratory quotient for all body to indicate the main type of foodstuffs used for metabolism in the body.
(I.e. RQ value indicates which nutrients (carbohydrates, fats, and proteins) are being metabolized; if metabolism consists solely of lipids, the RQ is 0.7, for proteins it is 0.8, and for carbohydrates it is 1.0).

Metabolic Rate

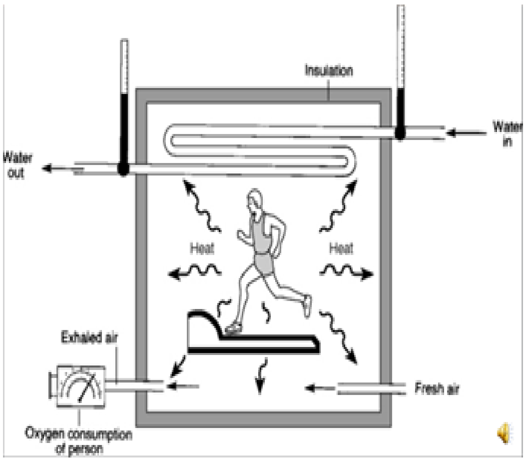
The energy produced and consumed in chemical reactions and body works will finally generate ***heat*** (appears by the **interconversion** between the forms of energy). **The rate of heat production** is known as the **metabolic rate**. The heat produced can be measured to reflect the metabolic activities in the human body.

Why?

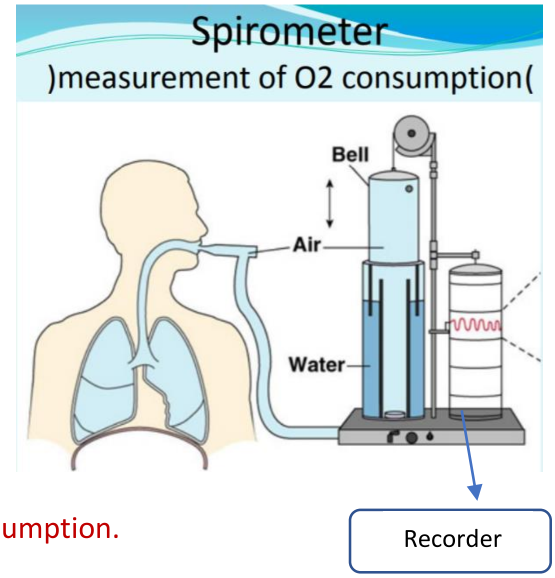
Not all energy in nutrient molecules can be harnessed to perform biological work. The energy that is <u>not</u> used to energize work is transformed into thermal energy (heat).

Measurements of Metabolic Rate:

1. **Direct calorimetry**: Measuring the heat produced with direct methods by calorimeter (an insulated chamber constructed with a constant rate of water flow (in and out) to measure the heat taken by the flow of water) The concept here lies behind the fact that we have already known the **temperature** of water flowing in & out, and the **rate** of **water flow**. Based on this, we can calculate the amount of heat that has been accepted by the water flow, which exactly equals the amount of heat that was irradiated (liberated) from the body.



2. **Indirect calorimetry:**
   a. Closed circuit method



More than 95% of the energy is produced by oxygen consuming chemical reactions. The rate of heat production can be calculated from the amount of oxygen consumed. The heat produced by our body is about **4.8** Calories per one litre of oxygen consumption **(energy equivalent of oxygen).** This method can be applied in the lab with the help of a device, known as a spirometer**.**

Spirometer: an instrument that is used to measure O_2 consumption.

The spirometer that we see has an inverted bell/drum that is partially submerged in water. An air tube extends from the person's mouth through the water and emerges at the bell. When the person exhales, air is passed through the tube entering the bell and lifts it. Once lifted, certain recordings are taken.

Let's take an example to make things clearer:

First, let's say that we add **10** litres of **air** to the bell (keep in mind that **air comprises** almost 20% oxygen, so we initially have around 2 litres of oxygen within the bell). Next, we add an extra **2** litres of **pure oxygen to the bell and we insert certain chemicals, such as soda lime,** to adsorb CO_2 from the expired air and to prevent CO_2 retention & carbon dioxide poisoning. Now, with time, to say after 10 mins, you will not find 12 litres of air in that device, but instead you will find 10 litres, which means that the person has already consumed around 2 litres of O_2. Based on that, we can measure the metabolic rate as following:

❖ **If we measure in 10 minutes**:

oxygen consumption of 2 litres of pure oxygen/10 minutes → **Rate of oxygen consumption** in **minutes**

So, the person is consuming 1 litre of pure oxygen every 5 minutes.

❖ **Per hour the Oxygen consumed would be**:

(1 litre of pure oxygen/5 minutes) *60 minutes =**12** → **Rate of oxygen consumption** per **hour**

For that amount of oxygen consumed, the **energy** produced is:

12 litres/hour X 4.8 Cal./litre = **57 Cal./hour.**

> The **Calorie** is the used unit for measuring heat produced by the body. Calorie spelled with **C** capital to mean 1kilocarie (1000 calories).

1. Indirect calorimetry:

a. **Closed circuit method ✓**
b. **Opened circuit method ……**

Other indirect methods are used for measuring metabolic rate during certain activities is by using opened circuit methods: In these methods a **bag** is used for collection of expired air during the physical activity. By knowing the concentration of oxygen in the atmosphere and in collected air, we can know how much oxygen was consumed and then we can calculate oxygen consumption and the metabolic rate in the same way as above.

- The difference between the closed and the opened circuit system is that in the opened system the person inhales air from the surrounding atmosphere (environment), and then exhales into a container, so we should take into consideration both the atmospheric air and the exhaled air. On the other hand, in the closed circuit system, the person inhales from and exhales into the same container, so we only have to consider the air limited to the container

Clarification

A person inhales air with a constant composition of around 20% oxygen. The changes in oxygen and carbon dioxide percentage in expired air compared with percentages in inspired air indirectly reflect the ongoing process of energy metabolism. So, let's say that after 15 minutes of exercising, we have collected 100 litres of expired air in that bag. We then measure the concentration of oxygen in the expired air. Unsurprisingly, the concentration of oxygen *collected* in the bag is ***reduced*** from 20% to 17%.

Inspired air => 20 litres of oxygen	Expired air => 17 litres of oxygen	Rate of oxygen consumption is 3 litres/15 mins => 12 litres/hour

Standardization of Measurement

1) To **standardize** our calculations, we relate the Metabolic Rate to 1 Meter square Surface area of the body. But how can we calculate the surface area of the body?

We can have the surface area of the body from tables designed to have the surface area by knowing the weight and height of a person.

If we have it as 1.6 m^2.

Then the amount of heat produced is: 57.6 Cal. hour-1 /1.6 m^2 = 36 (Cal. Hour^-1) /m^2.

2) For **further** standardization, we can measure the **metabolic rate** under **basal conditions**.

Basal Metabolic Rate (BMR).

Basal conditions: The person to whom we intend to measure the metabolic rate is not **asleep** and the following basal conditions must be met:

1**. No eaten food for at least 12 hours** to avoid the increase in the gastrointestinal activity, which may affect the oxygen consumption and the metabolic rate.
2. **Measurement after a night of restful sleep**.
3. **No exercise and physical activities in at least one hour prior to and during the test** to ensure that oxygen is at its normal levels & not consumed after the physical activity.
4**. Elimination of all factors that may cause excitement**. The person undergoing the test must be calm & unstressed.
5. **comfortable temperature during measurement**. Since at Low temperatures, for example, the metabolic rate will be higher to regulate the body temperature according to the ambient temperature

Factors affecting metabolic rate

Exercise: increases metabolic rate. This increase is well related with the strength of the exercise.

Daily activities: the metabolic rate depends on the daily activities. If a person lies in bed all day, the metabolic rate will be about 1600 Cal/day. Eating process would increase the rate by 200 Cal.

Age: the metabolic rate calculated for the surface area of the body decreases with age. It is higher in children and less in old people.

Sleep: decreases the metabolic rate.

Climate: the metabolic rate for people living in tropical regions is less.

Fever: during infection there is an increase in metabolic rate.

Malnutrition: Decreases metabolic rate.

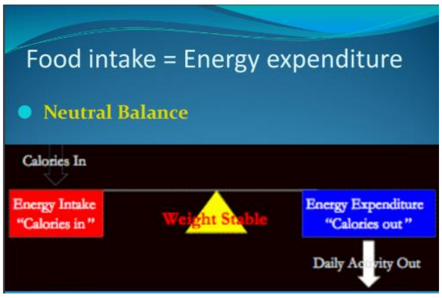
Effect of hormones:1) Thyroid hormones: increase the metabolic rate.
2) Male sex hormones: increase the basal metabolic rate by 10-15%.
3) Growth hormones: Increase metabolic rate by 15-20%.

sympathetic stimulation: increases metabolic rate.

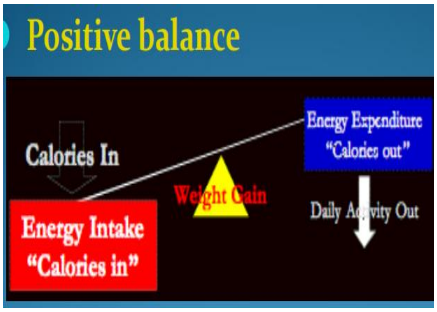
Specific dynamic action: *if a person is placed on a protein diet, he will have a higher metabolic rate due to the presence of certain amino acids that increase the metabolic activities in the body.*

Dietary Balance

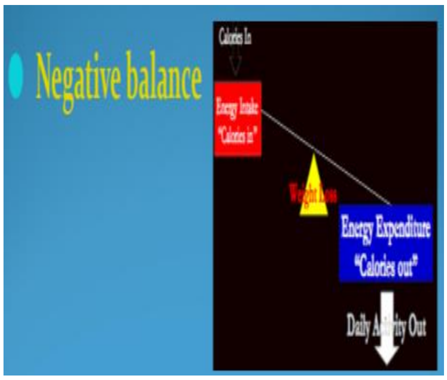
- Food has energetic values that must be sufficient to supply the metabolic needs of our body. The mixed food contains different proportions of proteins, carbohydrate, fat, minerals, vitamins, etc. An appropriate balance must be maintained between these materials to satisfy the needs of our body for its activities.
- The energetic value of food depends on its constituents of carbohydrates, proteins, and fat. The available energy in foodstuff generated by oxidation is about 4Cal/g **carbohydrate**, 9Cal/g **fat** and 4Cal/g **proteins.**
- According to thermodynamics laws, the energy can neither be created nor destroyed. For a healthy living, we must maintain a balance between the input (energetic value of eaten food) and the expenditure, which can be represented by the internal and external works of the body (output).



- To create a **neutral balance**, we must have food (input) with energetic values that balance the expenditure (output).



- If there is an increase in energy input over the output, this will result in a **positive energy balance**. This can be induced when there is an intake of food with energetic values greater than expenditures. In this case, the unneeded amounts are stored in our body.



- If the input is less than the body energetic requirements, this will result in a **negative balance**, and the body begins to use its stores, and this will result in a decrease in body weight.

Normal adults usually maintain a constant body weight. This appears by maintaining a long-term balance between the input and the output. This balance is taking place by control systems that regulate the magnitude of the input according to the expenditures (output)

Regulation of food intake

Hypothalamic control of food intake: (hunger, appetite, and satiety)

- In the hypothalamus, there are centres that control food intake. These centres are known as **feeding centre** & **satiety centre**.

  The feeding centres are represented by lateral nuclei, & by stimulating these centres there will be an increase in feeding behaviours.

  The satiety centres are represented by ventromedial nuclei, & by stimulating these centres there will be a decrease in feeding behaviours.

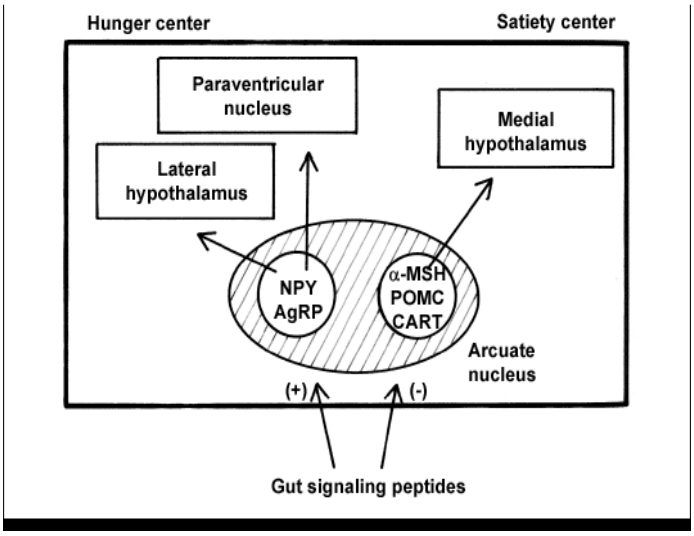
  The destruction of these centres will induce an opposite effect of their stimulation.

- In addition to these neural structures, there are other areas & other higher centres in the brain that contribute in the regulation of feeding (such as **amygdala** & **prefrontal cortex**), but their contribution isn't fully understood.

  The destruction of amygdala results in what we call "psychic blindness" in the **choice of food**. This may appear by losing the appetite control to the **type** & the **quality** of eaten food.

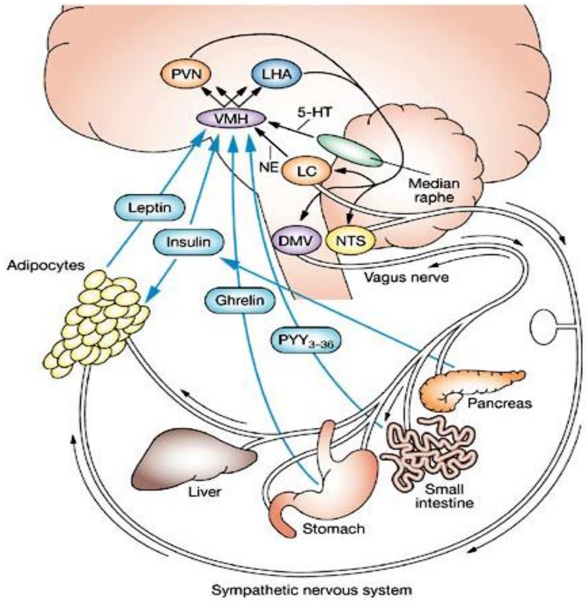
  The prefrontal cortex is involved mainly in the stimulation of appetite for certain types of food.

- The feeding centres receive signals from the body about the status of food storage and the needs for energy by the cells. At these centres there is an integration of these signals. This integration will govern the feeding behaviours of the body.



- We have a lot of **neural** signals which can change the activity of feeding or satiety centres. These signals come from the body through the **vagus nerve**.

- We also have a lot of **hormones** which are involved in changing the activity of feeding & satiety centres such as leptin, insulin, ghrelin, PYY (polypeptide YY). These hormones can be produced from the GIT, the adipose tissue, the adrenal glands, etc.



Theories of food intake regulation

We can divide the regulatory mechanisms for the activity of feeding & satiety centres into:

1. Long-term regulatory mechanisms
2. Short-term regulatory mechanisms

1. **Long-term regulation:** There are many theories that explain the process of regulation of the activity of these centres:

   i. **Glucostatic theory:** which states that the level of glucose in body fluids determines the feeding behaviours. This theory is wrong in this way, since diabetic patients have plenty of glucose in their body fluids, yet their feeding centre is stimulated, so they develop what we call **polyphagia** or **hyperphagia** (they want to eat more although their blood glucose level is high).

   The theory was corrected, so it's now related to an increase in glucose **utilization** by the effect of insulin rather than the concentration of glucose in blood. Insulin is released when there is an increase in the glucose level of blood. The increase in this hormone will cause an increase in glucose utilization and production of ATP by cells which in turn initiate neural signals that act on the hypothalamus to stop feeding.

ii. **Lipostatic theory:** According to this theory, the presence of some fat products in the blood such as keto acids & fatty acids acts to inhibit feeding.

Other studies have related the Lipostatic theory to the fat storage in adipose (fat) cells. The presence of high storage of fat in these cells results in the secretion of **leptin** hormone (hormone produced by adipose cells) that acts on specific receptors in the hypothalamic centres to reduce feeding behaviours. Leptin hormone is important in long-term regulation of the body weight.

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*The leptin hormone is produced by a gene called **OB gene** which refers to obesity gene. Any defect in this gene may result in a non-functional leptin that doesn't have its optimal activity, so it doesn't have a strong effect over the feeding centres*

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iii. **Aminostatic theory:** The concentration of amino acids in the blood has an effect in the feeding behaviours.

iv. **Body temperature:** In cold conditions there is tendency for overeating & in warm conditions the tendency is to eat less. This process appears by the regulatory mechanisms that depend on the metabolic rate of the body.

there is an interaction between temperature regulatory centres (thermoregulatory centre) & the feeding centres in the hypothalamus. The result is an increase in feeding in cold which provides more stores of nutrients and cover the needs of the body for the increase in metabolic rate.

v. **Psychosocial factors:** Eating is influenced also by psychological and social factors. some people are accustomed to eat 3 meals a day. If they miss one of these 3 meals, they will feel hungry no matter of their hunger or satiety status.

Also food plays an important role in our leisure & entertainment because of our social customs. The pleasure by eating food with an enjoyable smell & taste will increase appetite & consequently food intake.

2. **Short-term regulation:** These are **rapid** signals that affect feeding, they include:

i. **Gastrointestinal filling:** Eating will cause distension of the stomach and duodenum and activation of signals that are transmitted by the **vagus nerve** to suppress the activities of feeding centres and thereby stopping food intake.

ii. **Hormonal factors:** The presence of food in the in the gastro-intestinal tract will result in the release of hormones that affect feeding behaviours such as insulin, cholecystokinin & GIP (these 3 hormones decrease feeding behaviour).

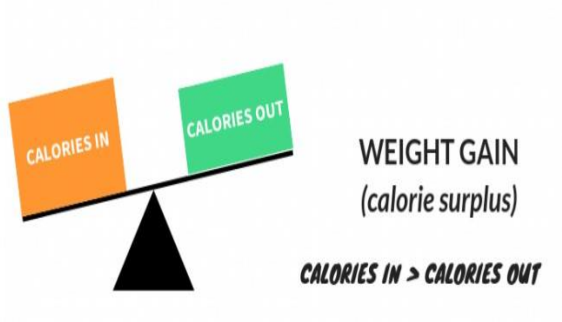
- **Cholecystokinin** is released in response to fat in the duodenum.
- **Insulin** is increased by the presence of food in duodenum & the high level of glucose in the blood.
- **GIP (gastric inhibitory peptide or glucose-dependent insulinotropic polypeptide)** is increased by the presence of fat & carbohydrates in chyme. This hormone acts also to increase insulin release from pancreatic islets.

iii. **Suppression by oral receptors:** These are receptors in the upper part of the GIT (can be found in the mouth & on the tongue) that interfere with feeding behaviour. These receptors are related to swallowing, salivation, chewing & tasting. They meter the amount of taken food, so after a certain amount of food pass through the oral cavity, they send signals towards the hypothalamic centres to reduce feeding.

The long-term & short-term factors of regulation are probably sending signals to the hypothalamus. Some neurotransmitters that are released in that area have been known to affect the feeding behaviours. Such as neuropeptide Y, dopamine & serotonin.

Obesity

- Obesity results from maintained and continued imbalance between the intake and the expenditure **(positive energy balance)** for a long time, which results in the deposition of fat in the adipose tissue stores.



*The increase in body weight must be due to the deposition of **fat**. Athletic people for example have an increase in their body weight, but this increase is because of their muscle mass, so they aren't considered obese.*

- Obesity is defined as an increase in the amount of adipose tissue by **more than 20%** of the ideal body weight. This term is different from "overweight" which represents an increase in the body weight which **can be related to the increase in the muscle** mass rather than an increase in the adipose tissue in the body.

Causes of obesity: As we said, we have long & short-term regulatory mechanisms that regulate food intake. The abnormalities in these mechanisms will result in decreased responses of the hypothalamic centres to the signals that induce the stop in feeding, which will result in **continuation** of feeding and this will result in the development of obesity.

i. **Neurogenic abnormalities:** Lesions in the **satiety centre** (ventromedial nuclei) of the hypothalamus will cause **excessive eating** & as a result obesity will develop.

   The absence of response in these centres may appear in some conditions such as genetic absence of leptin receptors or the presence of a receptor that is not responsive to leptin.

   Other abnormalities could be related to feeding centres.

   All these abnormalities are considered as abnormal functional organization of hypothalamic nuclei that may result in changing of the 'set point' of the regulatory mechanisms & **inducing an excess in food intake** & consequently obesity.

ii. **Genetic factors:** It is known that obesity runs in families. Recent studies have linked the genetic abnormalities to **OB gene (leptin producing gene in adipocytes)**.

Leptin inhibits feeding and increases the metabolic rate. If there is a defect in OB gene, those people will express a non-functional or a defective leptin, which can't act over the hypothalamic centres, so they are subject to have an increase in feeding behaviour & more deposition of fat in their body.

Other studies have related the genetic abnormalities to **leptin receptor** producing gene.

iii. **Psychosocial factors:** Obesity can be determined by our eating **habits**.

These habits indicate that healthy person must eat 3 meals a day and these meals must be filling meals.

- Some people are eating **to release their tension**. This happens during or after stress
- Some develop obesity after **emotional disturbances** or **mental depression**

iv. **Childhood overnutrition:** The overnutrition of a child will result in **<u>new</u> formation of fat cells**. This will increase the capacity of adipose cells to store more fat (overnutrition of the adult will result in the **hypertrophy (increase in cell size) of the existing fat cells** rather than the formation of new fat cells).

So those children will have to fill these fat cells to start releasing good amount of leptin hormone to reduce feeding behaviour (they will have to eat more in order to start releasing leptin).

Overnutrition of the child will result in a **lifetime obesity** by increasing the number of fat cells in the body.

v. **Other causes include:**

- **Disorders of the endocrine system:** For example, in hypothyroidism, there is a decrease in the metabolic rate of the body. If those people are consuming the same amount of food as a healthy person, they will be subject to deposit more fat in their body.
- **Lack of exercise:** There will also be a decrease in the metabolic rate of the body.

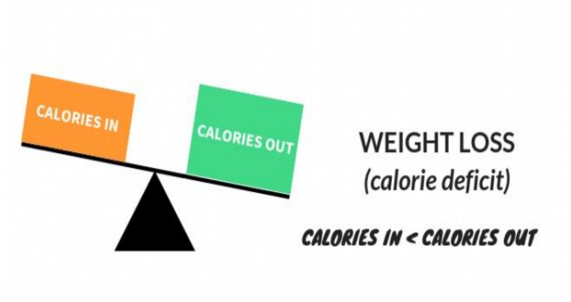
Treatment of obesity:

- ✓ Decreasing the **input** by a diet or other procedures.
- ✓ Increasing **output** by exercise.
- ✓ Using drugs that inhibit feeding centres.

Inanition

- ❖ The opposite of obesity, it's having a body weight less than the ideal body weight by more than 10%. Could be caused by inadequate availability of food. It can also be related to some psychogenic or hypothalamic abnormalities.

- ❖ Those people are in negative balance (the energy value of eaten food is less than what is necessary for energy expenditure).



Causes of inanition:

i. **Psychogenic:** People who are depressed for example are subject to develop what we are calling "anorexia nervosa" (they eat less than what is necessary for their body energetics) & they become in a negative balance.

ii. **Hypothalamic abnormalities:** we said that we have a specific level for the activity of hypothalamic centres to regulate the food intake. For some people, they need weak stimuli to inhibit feeding behaviours. So they are subject to **eat less** than what is necessary for their body energetics & to develop inanition.

-In anorexia nervosa, the person loses all the desire for food and severe inanition may occur (cachexia).
-Destruction of hypothalamic centres by thrombosis may result also in inanition.

Depletion of body stores during starvation

- Starvation is having no food for body energetics. In this condition, there is a depletion of the stores of the body.

- The first stores which are depleted are carbohydrates stores. Within 1~2 days, there is consumption of all carbohydrates stores from the body.

- Then there is a decrease in fat & protein stores. We have consumption of these stores which is taking place for about 1 week. After the first week, we are continuing with the consumption of fat stores & trying to conserve protein stores (since most of these proteins are functional proteins, the body will try to stop using them as a source of energy, so the body consumes fat instead).

- Burning of fat continues for about 6 weeks. After that, there will be a high depletion of fat stores, so the body now returns for protein stores to use them for body energetics. Now there is an increase in the depletion of protein stores.

- Consumption of protein stores takes place in 3 phases:

    1. In the first week there is a high depletion.
    2. Followed by lower depletion until week 6.
    3. After week 6, there will be an increase in depletion.

Try to relate the period at which there is high consumption of fat for body energetics with the respiratory quotient. As you see, during the week 2, 3, 4… there is high consumption of fat, so the respiratory quotient during this period will be closer to the respiratory quotient when we have fat as the major source of energy, which is around 0.7.

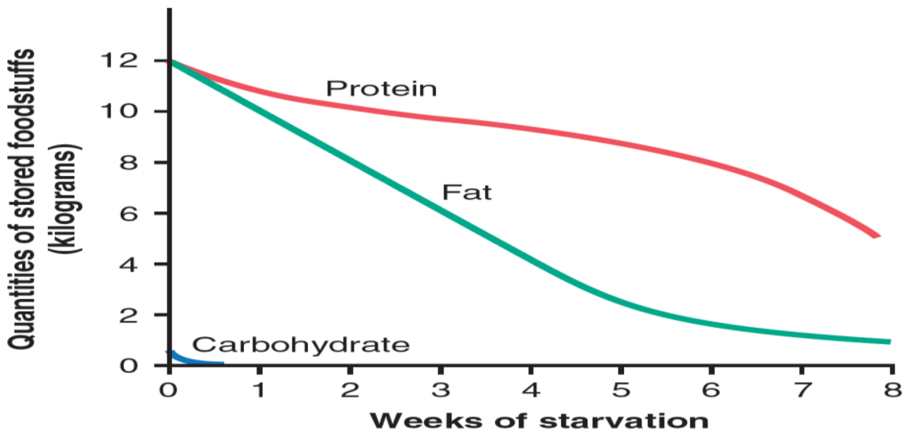


Figure 72-3. Effect of starvation on the food stores of the body.

The following meme was made by Omar Ismail c:

لما تصيبك سخونة والكل
خايف من الكورونا: